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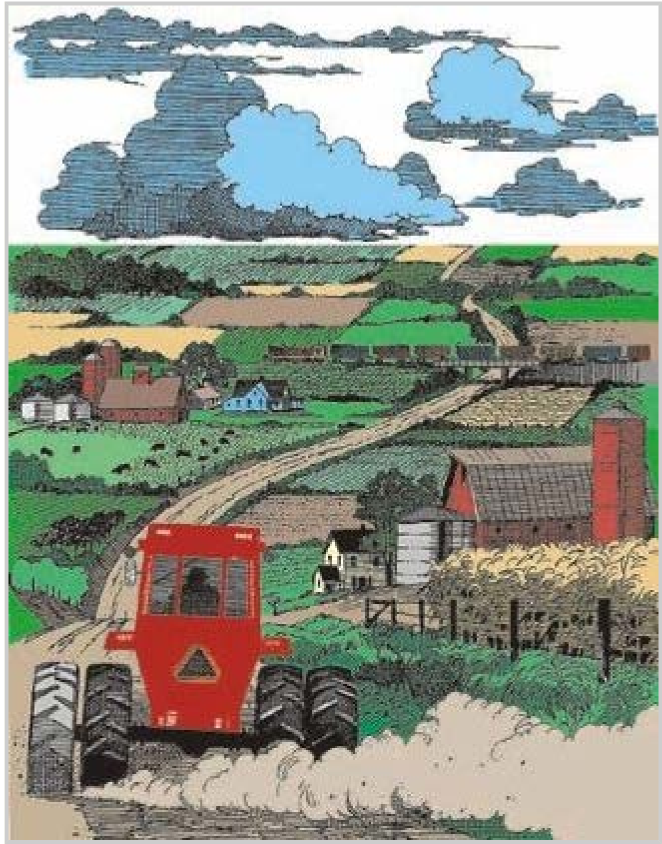
Technological improvements have allowed the productivity of the American farmer to increase dramatically. During colonial times one farmer fed four others. Today, one farmer produces food for 130 others. This dramatic increase in productivity has freed up most of our population to pursue other vocations and has been the foundation for the lifestyle we enjoy today. With this growth however comes added responsibility to ensure that the environment is protected and that the production is sustainable.



Ag 101 provides a brief overview of American agriculture. It covers the primary commodities produced today and the methods of doing so.

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Demographics

There are over 313,000,000 people living in the United States. Of that population, less than 1% claim farming as an occupation (and about 2% actually live on farms). In 2007, only 45% of farmers claimed farming as their principal occupation and a similar number of farmers claiming some other principal occupation. The number of farms in the U.S. stands at about 2.2 million.

What is a farm?

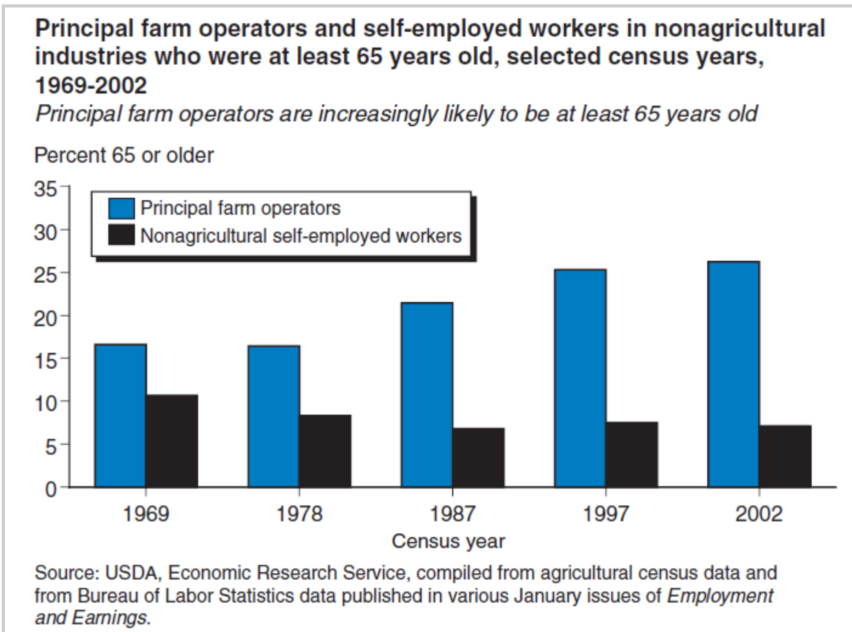
For the purposes of the U.S. Census, a farm is any establishment which produced and sold, or normally would have produced and sold, $1,000 or more of agricultural products during the year. (Government subsidies are included in sales.) By that definition, there are just over 2.2 million farms in the United States.

Farm production expenses average $109,359 per year per farm. Clearly, many farms that meet the U.S. Census' definition would not produce sufficient income to meet farm family living expenses. In fact, fewer than 1 in 4 of the farms in this country produce gross revenues in excess of $50,000.

According to the 2007 Census of Agriculture, the vast majority of farms in this country (87%) are owned and operated by individuals or families. The next largest category of ownership is partnerships (8%). The "Corporate" farms account for only 4% of U.S. farms and 1 percent are owned by other-cooperative, estates or trusts etc. However, the term "family farm" does not necessarily equate with "small farm"; nor does a "corporate farm" necessarily mean a large-scale operation owned and operated by a multi-national corporation. Many of the country's largest agricultural enterprises are family owned. Likewise, many farm families have formed modest-sized corporations to take advantage of legal and accounting benefits of that type of business enterprise.

In spite of the predominance of family farms, there is strong evidence of a trend toward concentration in agricultural production. By 2007, a mere 187,816 of the 2.2 million farms in this country accounted for 63% of sales of agricultural products (USDA, 2007 Census of Agriculture).

In 1935, the number of farms in the United States peaked at 6.8 million as the population edged over 127 million citizens. As the number of farmers has declined, the demand for agricultural products has increased. This increased demand has been met (and exceeded) with the aid of large-scale mechanization (the use of large, productive pieces of farm equipment), improved crop varieties, commercial fertilizers, and pesticides. The need for human labor has also declined as evidenced by the increase in agricultural labor efficiency over the past century – from 27.5 acres/worker in 1890 to 740 acres/worker in 1990 (Illinois data; Hunt, 2001).

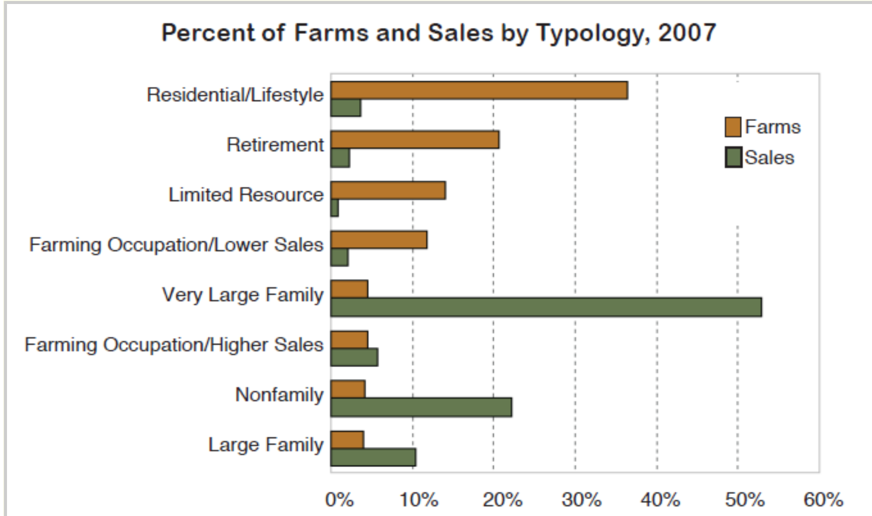


Source: USDA-Economic Research Service

As the U.S. farm population has dwindled, the average age of farmers continues to rise. In fact, about sixty percent of the farmers in this country are 55 years old or older (Bureau of Labor Statistics). The average age of a principal operator of a farm has increased from 54 years old in 1997 to 57 years old in 2007. (USDA, 2007 Census of Agriculture). The percentage of principle farm operators 65 years or older has increased almost 10 percent since 1969, as shown in the graphic to the right. The graying of the farm population has led to concerns about the long-term health of family farms as an American institution.

So, back to the question of what is a farm. According to Ross Korves, Deputy Chief Economist for the American Farm Bureau Federation, there are eight types of farms in the United States that can be grouped into two categories:

Small Family Farms (sales less than $250,000)



Source: USDA-Economic Research Service

1. Retirement farms - Small farms whose operators report they are retired (excludes limited-resource farms operated by retired farmers).
2. Residential/lifestyle farms - Small farms whose operators report a major occupation other than farming (excludes limited resource farms).
3. Limited-resource farms - Any small farm with: gross sales less than $100,000, total farm assets less than $150,000, and total operator household income less than $20,000.
4. Farming occupation/lower-sales farms - Small farms with sales less than $100,000 whose operators report farming as their major occupation (excludes limited-resource farms whose operators report farming as their major occupation).
5. Farming occupation/higher-sales farms - Small farms with sales between $100,000 and $249,000 whose operators report farming as their major occupation.

Other Farms

1. Large family farms – Farms with sales between $250,000 and $499,999.
2. Very large family farms – Farms with sales of $500,000 or more.
3. Non-family farms – Farms organized as non-family corporations or cooperatives, as well as farms operated by hired managers.

Based on these definitions of farm types, the number of farms within each type is shown in the following table:

Farm Type	Number of Farms	Percent of Farms
Non-Family Farms	91,177	4.1
Very Large Family Farms	101,265	4.6
Large Family Farms	86,551	4.0
Limited Resource	308,837	14.0
Farming Occupation/Higher Sales	100,126	4.5
Retirement	456,093	20.7
Farming Occupation/Lower Sales	258,899	11.7
Residential/Lifestyle	801,844	36.4
TOTAL	2,204,792	100.0

Given the different types of farms described above, it is easy to see that there is a wide variation in what constitutes a farm in the United States. Any criterion for declaring a farm small or large, viable or otherwise is open to debate. When asked the question, "How large would a crop and livestock operation have to be to be considered economically viable for the long term?" a group of Purdue University agricultural economists offered the following response in 2002:

An economically viable crop/livestock operation in the Corn Belt would have between 2,000 and 3,000 acres of row crops and between 500 and 600 sows.

Sources:

U.S. USDA. NASS. 2007 Census of Agriculture. N.p., 10 Dec. 2009. Web. <*http://www.agcensus.usda.gov/Publications/2007/Full_Report/usv1.pdf*>. EXIT Disclaimer

U.S. USDA. NASS. 2007 Census of Agriculture Farm Numbers. N.p., n.d. Web. <*http://www.agcensus.usda.gov/Publications/2007/Online_Highlights/Fact_Sheets/Farm_Numbers/farm_numbers.pdf*>. EXIT Disclaimer

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Economic Overview

U.S. agriculture is a complex system that simultaneously produces unprecedented bounty and unparalleled social concerns. Can the unique institution of the American family farm survive the economic realities of the 21st century? Can the United States continue to have the most abundant and the safest food system in the world? These questions and the unfolding answers will have impacts that will be felt for generations to come. What we know for certain is that:

- The U.S. farmer is the most productive in the history of the world.
- Food is more affordable in the United States than in any other developed country in the world.
- There is a definite trend toward fewer farms producing an increasing share of agricultural products in this country.
- In spite of many challenges, U.S. agriculture is uniquely positioned to provide for the food and fiber needs of a growing world community.

Agricultural production in the United States is a business that requires very high capital investments in land, facilities, and machines and most often produces undifferentiated products (commodities) of generally low unit value. Thin profit margins have forced producers to seek efficiencies in all aspects of production. There are efficiencies of scale that favor large producers who can make the most effective use of large, expensive machines. In crops such as corn and soybeans, and in poultry and animal production commercially viability is usually based on producing "in volume."

- Revenues
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Land Use Overview

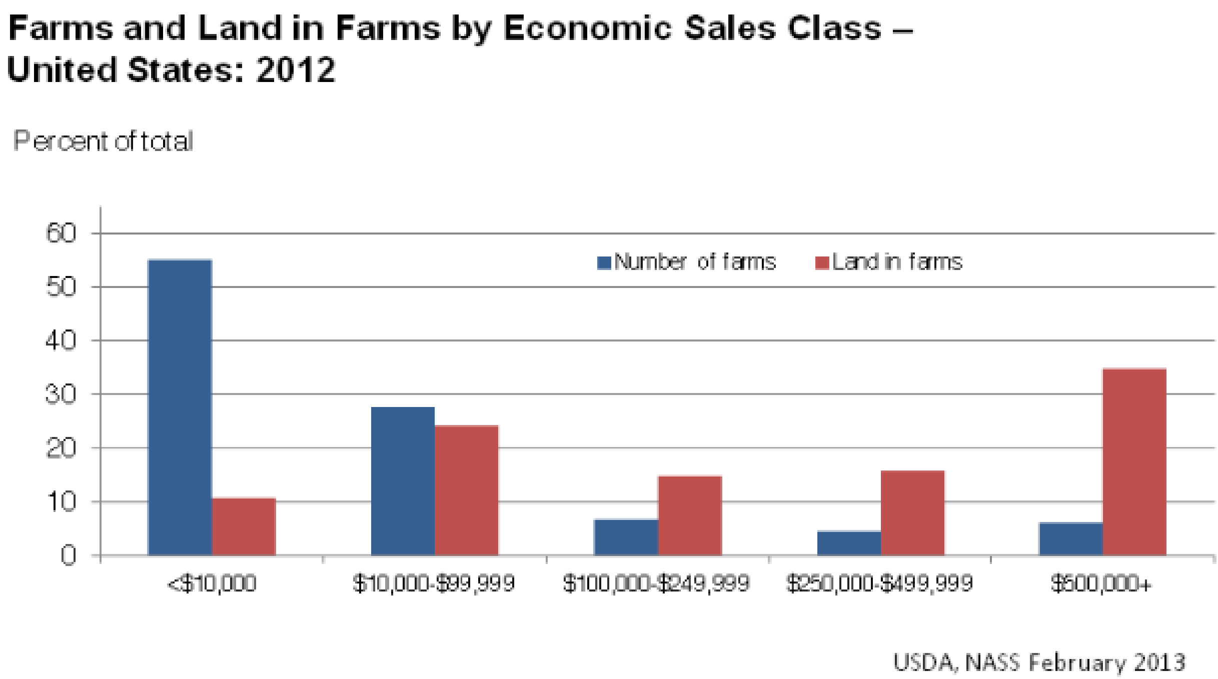
The United States is blessed with more arable land than any other nation on earth. Still, only about one-fifth of our land area (408 million acres (2007))(*2)is used for crop production. Grazing land for livestock accounts for about one-fourth of the privately held land in the U.S. (613 million acres (2007)(*2). In spite of a growing population and increased demand for agricultural products, the land area under cultivation in this country has not increased. While advanced farming techniques, including irrigation and genetic manipulation of crops, has permitted an expansion of crop production in some areas of the country, there has been a decrease in other areas. In fact, some 3,000 acres of productive farmland are lost to development each day in this country. There was an 8% decline in the number of acres in farms over the last twenty years. In 1990, there were almost 987 million acres in farms in the U.S., that number was reduced to just under 943 million acres by 2000, and then reduced to 914 million acres in 2012 (*1).

Development pressure on farmland at the rural-urban interface is posing long-term challenges for production agriculture and for the country as a whole. This is especially significant since about two-thirds of the total value of U.S. agricultural production takes place in, or adjacent to, metropolitan counties (NRCS). About 1/3 of all U.S. farms are actually within metropolitan areas, representing 18% of the total farmland in this country (1992 – 1997 NRCS Report) (*3).

Two significant trends occurring in the agricultural sector during the past century involved the increased use of machines and government price supports. These factors combined to allow operators to increase the size of their farms and gain efficiencies.

While small farms still account for the majority of farms, economies of scale are driving the trend toward larger farm operations. The table below illustrates that the smallest farms, while high in numbers, comprise a very small percentage of overall farm land. The table also shows that farms in the highest economic sales class, are much smaller in number, yet those large farms use the highest percentage of farm land.

Table 1. Farms and Land in Farms by Economic Sales Class - U.S. 2012



Adapted in part from USDA NASS

Sources:

1. US. USDA. National Agricultural Statistics Service. Farms, Land in Farms, and Livestock Operations 2012 Summary. N.p., 19 Feb. 2013. Web. <http://usda01.library.cornell.edu/usda/current/FarmLandIn/FarmLandIn-02-19-2013.pdf>.
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2. "Major Land Uses Overview." USDA, Economic Research Service, n.d. Web. 03 Apr. 2013. <http://www.ers.usda.gov/data-products/major-land-uses.aspx#25962>. EXIT Disclaimer

3. "New Acres of Developed Land in Metropolitan Areas, 1992-1997." USDA, NRCS. Web. 13 Dec. 2000. <http://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/home/?cid=nrcs143_013807>.
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Crop Production

Crop production is a complex business, requiring many skills (such as biology, agronomy, mechanics, and marketing) and covering a variety of operations throughout the year. In this module, the practice of crop production will be described by discussing eight components in the crop production cycle:

Source: USDA - Natural Resources Conservation Service

For each component, the operations and when they need to be carried out, the machinery or equipment farmers use, potential environmental concerns related to that component, and best management practices recommended to minimize environmental problems will be described.

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Pork Production

Pork production is an important component of American agriculture and an important part of the American diet and way of life. 74,789 farms had pig sales in 2007 with production concentrated in the Corn Belt states and in North Carolina. (2007 USDA Census of Agriculture). In 2012 there were 60,200 hog and pig operations. (USDA Farms, Land in Farms, and Livestock Operations 2012 Summary).

Modern pork production is mostly done in enclosed buildings to protect animals from the weather, from predators and from the spread of diseases. While larger operations enabled farmers to significantly increase the efficiency of production using less labor, it resulted in environmental challenges with larger amounts of manure concentrated in a small area.

This module will look at pork production as it has evolved over the past 300 years in the U.S., at the economic value of pork to the U.S. and American agriculture and at typical production and manure handling systems in use today.

Additional Information

Livestock and Poultry Environmental Stewardship (LPES) Curriculum EXIT Disclaimer (joint EPA/USDA project)
A national curriculum and supporting educational tools for livestock and poultry industry advisors to help producers achieve environmentally sustainable production systems.

Concentrated Animal Feeding Operations (CAFO) Fact Sheets EXIT Disclaimer (joint EPA/USDA project)
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Poultry Production

Poultry production is an important and diverse component of American agriculture. Poultry products including eggs, chicken and turkey meat are a healthy part of the diets of most Americans. In 2007, nearly 145,615 farms were producing poultry and poultry products (egg, broiler, and turkey; NASS/USDA). While broiler chicken production is concentrated primarily in the southern and southeastern U.S., turkey production occurs primarily in the Corn Belt and in North Carolina. Egg production is distributed throughout the U.S.

Modern poultry production occurs primarily in enclosed buildings to protect the birds from weather, predators, and the spread of diseases from wild birds. This has allowed farmers to greatly increase production efficiency while significantly reducing the amount of labor required. As with pork production, this has resulted in environmental challenges with production of larger volumes of manure in much smaller areas.

This module will cover the modernization of poultry production over the past 60 years, different phases of production and the production systems in which they occur.

- Background of Poultry Production in U.S.
- Products from Poultry
- Poultry Production Phases
- Production Systems
- Nutrition
- Common Manure Handling Systems
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Dairy Production

Dairy production is an important part of American agriculture. Milk and other dairy products remain a staple in the diets of most Americans. In 2000, there were about 90,000 dairy farms in the United States. During the 1980s and 1990s, dairy production markedly shifted from the Midwest and Great Lakes regions to the West.

Modern dairy production is diverse with systems ranging from cows housed indoors year-round to cows maintained on pasture nearly year-round. Expansion to larger herd sizes has allowed producers to increase the efficiency of production and capitalize on economies of scale, but it has resulted in environmental challenges with larger numbers of cattle and more manure concentrated in smaller areas.

This module will look at dairy production as it has evolved in the U.S., the array of dairy products available, dairy production systems, milking systems, and typical manure handling systems in use today.

All photos are from M. Schutz, Purdue University unless otherwise noted.

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Beef Production

Beef cattle production is a strong animal industry within the United States and throughout the world. Since beef cattle can graze forages in the open range and pasturelands, they serve a unique role in providing high quality protein for human consumption from byproducts and forage sources that humans and non-ruminant animals do not consume. Considerable land in the U.S. and the world that will not support intensive crop production, can often times sustain grasses and forages that provide conservation of the land, and produce feeds that cattle can utilize. Beef cattle production is dispersed throughout the U.S., but a significant amount of beef is produced on the rangelands of the Western U.S. About 720,000 farms had beef cows in 2007 and almost 12 million cattle on feed annually. (USDA, 2007 Census of Agriculture)

Beef cattle production ranges from the beef cow herds that typically graze on pastureland or graze the remaining residue on the land after grain harvest to growing and finishing young cattle in feedlots. The feedlot-housing systems used in beef cattle production typically varies by climate and can range from open earthen lots with very little shelter to open shed and lot or an enclosed confinement building. Manure handling and storage ranges from solid manure with bedding included, and runoff water from open lots to liquid slurry and treatment lagoon systems. Due to the increasing size of beef operations, the large volume of manure production, collection, storage and application to the land has presented challenges.

This module will look at beef cattle production from a historical perspective, economic impact of the beef industry in the U.S., typical production practices and manure management systems used today.

Additional Information

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A national curriculum and supporting educational tools for livestock and poultry industry advisors to help producers achieve environmentally sustainable production systems.

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Related Links

This information is provided for reference. Over time, links to the items may become unavailable, in these cases the item will remain listed, but no link will be provided.

Beef

- National Agricultural Statistics Service
- National Cattlemen's Beef Association EXIT Disclaimer

Crops EXIT Disclaimer

- A History of American Agriculture 1776-1990, USDA Economic Research Service
- Agricultural Science, CAST – Council for Agricultural Science and Technology
- AgriMarketing
- American Farm Bureau
- American Farmland Trust (AFT)
- Bt Corn, "Bt Corn and European Corn Borer"
- Conservation Tillage, Conservation Technology Information Center
- Corn, KingCorn.org, "The Corn Growers' Guidebook"
- Corn, The National Corn Growers Association
- Cotton, The National Cotton Council of America
- Cotton, "The Cotton Pickin' Web"
- Glossary, "A Glossary of Agricultural Terms, Programs and Laws," Congressional Research Service, Library of Congress
- Glossary, "Glossary of Agricultural Terms," Pennsylvania Farm Bureau
- Glossary of Forage Terms: Forage Information System, Oregon State University
- Grain Crops, U.S. Grains Council
- Grain Sorghum, National Grain Sorghum Producers
- Hay, The National Hay Association
- Rice, U.S. Rice Producers Association
- Rice, International Rice Research Institute (IRRI)
- Small Grains – The Internet Source for Small Grain Growers
- Soybeans, The United Soybean Board
- Tractors, The Small Tractor FAQ
- Terminology for Grazing Lands and Grazing Animals
- USDA Economic Research Service (ERS)
- USDA National Agricultural Statistics Service (NASS), 2007 Census of Agriculture
- Value Enhanced Grains
- "What is a Farm?"
- Wheat, International Grains Council
- Wheat, National Association of Wheat Growers

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- Dairy @ Purdue
- National Biosecurity Resource Center For Animal Health Emergencies
- Moo Milk
- National Dairy Shrine
- World Dairy Expo

- Oklahoma State University Cattle Breeds
- American Dairy Science Association
- National Milk Producers Federation
- Understanding Dairy Markets
- Dairy Management Inc.
- Dairy Quality Assurance Center
- Hoards Dairyman
- Dairy Herd Management

Pork EXIT Disclaimer

- The Pig Page - Australia
- National Pork Producers Council, Industry site on pork production
- The Joy of Pigs – Nature Magazine Web site
- Purdue Porkpage
- The Columbia Electronic, Encyclopedia, Sixth Edition, Copyright © 2008, Columbia, University Press.
- USDA Agricultural Marketing Service - How to Buy Meat (PDF) (24 pp, 745K, About PDF)
- USDA Foreign Agricultural Service - FASonline
- Pork Industry Handbook, select Publications at the bottom of the left sidebar, then select Pork Industry Handbook Summaries from the list of publications at the top of the page

Poultry EXIT Disclaimer

- U.S. Poultry and Egg Association
- U.S. Poultry and Egg Export Council
- American Egg Board
- National Chicken Council
- National Turkey Federation
- United Egg Producers
- Purdue Avian Sciences Extension Publications
- The Columbia Electronic, Encyclopedia, Sixth Edition, Copyright © 2008, Columbia, University Press.
- USDA - How to Buy Eggs (PDF) (12 pp, 358K, About PDF)
- USDA - How to Buy Poultry (PDF) (12 pp, 262K, About PDF)
- USDA Foreign Agricultural Service - FASonline

Links to Primary Turkey Breeders EXIT Disclaimer

- Aviagen
- Hybrid Turkeys
- Nicholas Turkeys (See Aviagen)

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Media Resources

Crops

- John Deere Photo Library, Vols. 1, 2, and 3 (available on CD-ROM, (309) 765-9833).

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Acid Rinse - Part of the equipment cleaning process for stainless steel and rubber parts, removes fat, protein and minerals and also reduces bacteria.

Acre - The unit of measure most typically used to describe land area in the United States. An acre is equivalent to 43,560 square feet and is about 9/10 the size of a football field.

Acre-Inch - A volume measurement typically associated with irrigation operations on cropland. An acre-inch is equivalent to 27,154 gallons. When an inch of water is applied to cropland via irrigation, each acre receives 27,154 gallons. (Alternatively, a measure of the volume of water applied to the soil/growing crop using irrigation - approximately equivalent to 27,154 gallons.)

Acute - Used to describe disease where symptoms are readily evident. Treatment is generally required.

Aerobic - Microorganisms that require free oxygen to biodegrade organic matter.

Agribusiness - An enterprise that derives a significant portion of its revenues from sales of agricultural products or sales to agricultural producers.

Alley - A walking area for cattle within a barn such as a loafing alley, feeding alley or cross alley (walkway) from a barn to the milking parlor.

Alley Scraper - A "V" shaped mechanical blade that is dragged over an alley by chain or cable to pull manure to collection channel at the end of the alley (or possibly the center of the barn). The blade then collapses and is drawn back to the opposite end of the alley.

All-in, All-out production - A production system whereby animals are moved into and out of facilities in distinct groups. By preventing the commingling of groups, the hope is to reduce the spread of disease. Facilities are normally cleaned and disinfected thoroughly between groups of animals

Anaerobic - Microorganisms that biodegrade organic matter without free oxygen.

Anhydrous Ammonia - A fertilizer used to provide nitrogen for crop production. The product, stored under high pressure as a liquid, changes state during application and is injected into soil as a gas. It is popular due to the fact that it is composed of 82 percent nitrogen compared to other nitrogen fertilizers such as urea that contain only 46% nitrogen and ammonium nitrate with 30-33% nitrogen content.

Antibiotic - A metabolic product of one microorganism or a chemical that in low concentrations is detrimental to activities of specific other microorganisms. Examples include penicillin, tetracycline, and streptomycin. Not effective against viruses. A drug that kills microorganisms that cause mastitis or other infectious disease.

Antibiotic Residues - The presence of traces of antibiotics or their derivatives in milk or meat.

Antibiotic Test Kit - Test kit for use on the farm to detect residues of antibiotics in milk before the milk is picked up for delivery to the plant.

Artificial Insemination (AI) - Placing semen into the female reproductive tract (usually the cervix or uterus) by means other than natural service.

Automatic Detacher or Automatic Take-off - A device for sensing the end of milk flow in the milking machine which shuts of the milking vacuum and releases the milking machine from the cow's udder.

Average Daily Gain - Pounds of liveweight gained per day.

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Backgrounding - Growing program for feeder cattle from the time calves are weaned until they are on a finishing ration in the feedlot. Backgrounding is the management process of feeding the stocker animal.

Barn Cleaner - Usually a chain linked system of paddles that moved manure from gutters, up a chute, into a waiting manure spreader. Most often seen in tie-stall or stanchion barns.

Barrow-A neutered male is a barrow and the adult male is a boar.

Bedded Pack - Open housing in a barn that is commonly used in conjunction with an outside feeding area.

Bedding - Material used to absorb moisture and provide cushion. It is easily cleaned to provide a clean, dry surface and reduce the incidence of mastitis. Possible bedding materials include: straw, sawdust, wood chips, sand, ground limestone, separated manure solids, shredded newspaper, corn stalks, bark, peanut hulls, sunflower hulls and rice hulls.

Beef - Meat from cattle (bovine species) other than calves. Meat from calves is called veal.

Biosecurity - Any of a broad range of practices enforced at a dairy farm to prevent transmittal of pathogens from other sources by feed, cattle, people, or other animals. System of procedures and other means to reduce or eliminate exposure of poultry flocks to any type of infectious agent, whether it be viral, bacterial, fungal, or parasitic in nature.

For more information on specifics of biosecurity systems, please visit the following links.
EXIT Disclaimer

- Biosecurity for Poultry
- Poultry Facility Biosecurity (PDF) (5 pp, 96K)

Black-out House - Houses that do not allow any natural light into the building.

Blind Quarter - A quarter of an udder that does not secrete milk or one that has an obstruction in the teat that prevents the removal of milk. A nonfunctional mammary gland.

Boar - A term for a male domestic swine suitable for breeding.

Boot - The time when the head is enclosed by the sheath of the uppermost leaf.

Bovine - Refers to a general family grouping of cattle.

Breed - Cattle of common origin and having characteristics that distinguish them from other groups within the same species.

Breeder - A bird that is utilized to produce offspring.

Brisket Board - A raised part of the freestall platform about 6.5 feet in front of rear of the stall to keep cows positioned properly while lying. Usually made of wood or plastic, but occasionally concrete.

Broken Udder - Term used to describe an udder that is loosely attached or pendulous.

Broiler - Chicken, sometimes called fryers, reared primarily for meat production. Age to market weight is typically 6 to 8 weeks (5 to 8 pounds), and are the epitome of efficient meat production.

Brooding - Early period of growth when supplemental heat must be provided, due to the birds inability to generate enough body heat.

Bt Corn - Field corn that has received a gene transferred from a naturally-occurring soil bacterium called *Bacillus thuringiensis*. The gene causes the corn plant to produce one of several insecticidal compounds commonly called Bt toxins. The toxins affect the midgut of particular groups of insects such as European corn borer that can be harmful to corn.

Bucket Milking System - A system in which the milk coming from the cow is drawn into a bucket or pail and manually transferred to a collection area or the milk house.

Bull - A sexually mature, uncastrated bovine male.

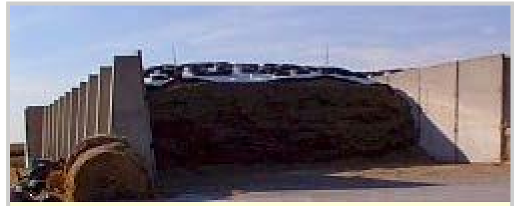
Bullock - Young bull, typically less than 20 months of age.

Bulk Tank - A refrigerated, stainless steel vessel in which milk is cooled quickly to 2 to 4 C (35 - 39 F) and stored until collected by a bulk tank truck for shipping to the milk plant.

Bunk - A feed trough or feeding station for cattle.


Feed Bunk

Bunker - (Sometimes called Bunker Silo) A flat rectangular structure with concrete floors and walls used to ensile and store forages.


Bunker Silo


Bunker Silo

Bushel - A unit of dry volume typically used to quantify crop yields. One bushel is equivalent to 32 quarts or 2,150.42 cubic inches. A bushel is often used to represent the weight of a particular crop; for example, one bushel of No. 2 yellow shelled corn at 15.5% moisture content weighs 56 lb.

Byproduct - Product of considerably less value than the major product. For example, the hide and offal are by-products while beef is the major product.

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Calf - A young male or female bovine under 1 year of age. Usually referred to as calves until reaching sexual maturity.

Calve - Giving birth to a calf. Same as parturition.

Cake Manure - Surface manure on top of litter, typically only a few inches deep.

Cannula - A special tube designed for placing drugs into the udder through the teat end and streak canal.

Cash Crop - An agricultural crop grown to provide revenue from an off-farm source.

Center Pivot - A type of irrigation system that consists of a wheel-driven frame that supports a series of sprinkler nozzles. The frame rotates about a central point to distribute water over a large circular area.

Chalk Sticks - Used to mark treated, fresh, or special-needs cows.

Channel Erosion - Erosion in channels is mostly caused by downward scour due to flow shear stress. Side wall sluffing can also occur during widening of the channel caused by large flows.

Cheese Curd - The clumps of casein and other milk components that are formed during the cheese making process. These curds are then pressed into blocks or barrels for proper aging and curing of the cheese.

Churning - The process of stirring and agitating cream in the process of making butter. Churning causes the fat globules in cream to clump together and separate from the liquid.

Chronic - Used to describe recurring symptoms or disease.

Clinical - Symptoms are present, supportive therapy or treatment is necessary.

Colostrum - First milk following calving. High in fat, protein, and immunoglobulins that may be directly absorbed by the newborn calf in its first 24 hours of life.

Commodity Storage - Usually a steel framed shed that provides storage for commodity feeds, such as cottonseed, brewers grains, chopped hay, etc.

Commodity Barn

Composting Pad - A concrete or hard packed surface that provides an area on which manure and discarded feed may be composted with ready access to aerate the composting materials.

Concentrates - High energy or high protein feeds consisting primarily of the seed of the plant, but with out stems and leaves.

Conformation - The body form or physical traits of an animal or parts of the animal in the case of udder conformation.

Conservation Tillage - Any tillage and planting system that covers 30 percent or more of the soil surface with crop residue, after planting, to reduce soil erosion by water. Where soil erosion by wind is the primary concern, any system that maintains at least 1,000 pounds per acre of flat, small grain residue equivalent on the surface throughout the critical wind erosion period.

Contagious - Disease that can be passed from one bird or animal to another through a number of possible ways.

Conventional Tillage - Full width tillage that disturbs the entire soil surface and is performed prior to and/or during planting. There is less than 15 percent residue cover after planting, or less than 500 pounds per acre of small grain residue equivalent throughout the critical wind erosion period. Generally involves plowing or intensive (numerous) tillage trips. Weed control is accomplished with crop protection products and/or row cultivation.

Cooling - Using ventilation to prevent birds or animals from becoming too hot.

Corn Belt - The area of the United States where corn is a principal cash crop, including Iowa, Indiana, most of Illinois, and parts of Kansas, Missouri, Nebraska, South Dakota, Minnesota, Ohio, and Wisconsin.

Cow - A mature female bovine. Usually referring to any dairy females that have born a calf. Some may consider females having given birth only once as "first-calf heifers" until they have a second calf.

Cow-Calf Operation - Management unit that maintains a breeding herd and produces weaned calves.

Cow Trainer - A tin or wire structure supported a few inches above a cow to prevent her from soiling the platform of her stall by administering a gentle electric shock if she arches her back to urinate or defecate while too far forward in the stall.

Coverall - A brand name, but commonly referring to any of a group of hoop type barns with opaque or mylar fabric covers over a tubular steel frame.

Crate - An elevated stall for a calf in an indoor facility.

Crowd Gate - A motorized or manual gate at the end of the holding pen that may be moved forward to guide cows toward the entrance to the milking parlor.

Cull - To remove a cow from the herd. Culling reasons in clued voluntary culling of cows for low milk production, or involuntary culling of cows for reasons of health or injury.

Cull Cow - A cow having been identified to be removed from the herd or having recently left.

Culture - In microbiology, a population of microorganisms in a growth medium or the act of growing bacteria in media for identification. A pure culture contains only organisms that initially arose from a single cell. Cultures are used in manufacturing cultured dairy products and most cheeses.

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Dairy Cow - A bovine from which milk production is intended for human consumption, or is kept for raising replacement dairy heifers.

Dairy Herd Improvement (DHI) - A specific testing plan which requires supervision and compliance with all official DHI rules.

Dairy Herd Improvement Association (DHIA) - An organization with programs and objectives intended to improve the production and profitability of dairy farming. Aids farmers in keeping milk production and management records.

Dairy Herd Improvement Registry (DHIR) - A modification of the DHIA program to make milk production records acceptable by the specific dairy breed associations.

DHI Records - Generic term used to refer to records computed by the Dairy Record Processing Centers.

DHI Supervisor - An officially trained and DHIA-certified employee qualified to collect milk samples and record milk weights on the farm for all official types of testing plans.

Dairy Steer - A neutered male of any of the dairy cattle breeds. The "dairy steers" are raised for meat production and usually managed like beef cattle.

Dam - Mother or female parent in a pedigree, normally applies to cattle.

Denitrification - The biochemical reduction of nitrate or nitrite to gaseous nitrogen, either as molecular nitrogen or as an oxide of nitrogen.

Depression - A low area in a field where surface drainage away from the area does not occur.

Direct Microscopic Somatic Cell Count (DMSCC) - Microscopic count of the actual number of somatic cells in milk. This system is used to check and verify electronic cell count machines used in DHI laboratories.

Dock - To remove a cow's tail. This practice may keep cows udders cleaner, but may also result in cows being less content, especially in fly season.

Downer Cow - A cow unable to arise due to disease or injury.

Drawbar - A tractor component typically located at the rear and near the ground that permits attachment of implements for pulling or towing.

Drawbar Work - Any operation performed by a tractor that requires force to be exerted by wheels/tracks to propel an implement through or over the soil.

Drilled - Planted with a grain drill. Grain drills differ from row crop planters in that they do not meter individual seeds, but drop small groups of seed in a process referred to as bulk metering. Drills plant crops in closely spaced rows (typically seven to 10 inches on center) that will not be mechanically cultivated.

Dry Cow - A cow that is not lactating or secreting milk after it has completed a lactation period following calving.

Dry Lot - An open lot that may be covered with concrete, but that has no vegetative cover. Generally used as exercise areas in most of US, but may be used as primary cow housing in the more arid climates.

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Edema - The presence of abnormally large amounts of fluid in the intercellular tissue spaces of the body, as in a swelling of mammary glands commonly accompanying the initiation of the birthing process in many farm animals.

Electronic Feeders - Stations in which cows are fed specified amounts of feed by a computer that recognizes their unique electronic identification transponders.

Ensiling - The process of creating silage via anaerobic fermentation.

Environmental - Derived from the animal's environment, bedding, housing, etc.

Environmental Control - Temperature and humidity control in poultry and animal production barns.

Equipment Sanitization - The removal of microorganisms and fat, protein, and mineral residues in milking equipment through use of water, heat, and chemicals.

Estrous - See Heat

Eutrophication - The process by which lakes and streams are enriched by nutrients (usually phosphorus and nitrogen) which leads to excessive plant growth.

Extra-Label Drug Use - An antibiotic or other chemical used on the advice of a veterinarian in a dosage, route of administration, for a different disease or in some other manner not included on the approved printed package label.

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Fallow - Plowed, but left unseeded.

Farrowing - The period from birth to weaning.

Farrow to Finish Operation - A production system that contains all production phases, from breeding to gestation to farrowing to nursery to grow-finishing to market.

Fed Cattle - Steers and heifers that have been fed concentrates, usually for 90-120 days in a feedlot.

Federal, Food, Drug, and Cosmetic Act (FFDCA) - It specifies the levels of pesticides, chemicals, and naturally occurring poisonous substances in food products. It also regulates the safety of cosmetic products. (Federal Regulations of Chemicals in the Environment) EXIT Disclaimer

Federal Insecticide, Fungicide, and Rodenticide Act - The objective of FIFRA is to provide federal control of pesticide distribution, sale, and use. All pesticides used in the United States must be registered (licensed) by EPA. Registration assures that pesticides will be properly labeled and that, if used in accordance with specifications, they will not cause unreasonable harm to the environment. Use of each registered pesticide must be consistent with use directions contained on the label or labeling. (More information from EPA's Agriculture Web site)

Feeder

1. Cattle that need further feeding prior to slaughter.
2. Producer who feeds cattle.

Feeder Pig Operation - Breeder sells pigs out of the nursery phase to a finishing operation to grow them out to market weight.

Feedlot - Enterprise in which cattle are fed grain and other concentrates for usually 90-120 days. Feedlots range in size from less than 100-head capacity to many thousands.

Feed Grain - Any of a number of grains used for livestock or poultry feed. Corn and sorghum are feed grains.

Fibrosis (fibrotic) - Of a condition marked by the presence of interstitial fibrous tissue, especially in the mammary gland resulting from mastitis.

Finished Cattle - Fed cattle whose time in the feedlot is completed and are now ready for slaughter.

Finisher Pig - Production phase between the nursery and market.

Finishing Operation - The operation purchases feeder pigs from a feeder pig operation and feeds them to market weight at 240 to 260 lbs. Historically, producers purchased feeder pigs at auctions, but because of disease transmission concerns, most operations now bypass auctions and buy all of their animals from the same supplier.

Flat Barn - An area for milking cattle where the person milking is on the same level as the cow. May be used with a pipeline or bucket milking system. Generally the same area is used for cow housing.

Flowering - This is the stage when the crop starts flowering. In corn, tassel emergence and pollen shedding takes place at this stage. Two to three days after pollen shedding, silk emergence takes place. At this stage, typically occurs 51-56 days after planting the corn seed, pollination between silks (female) and tassels (male) takes place.

Flush System - A manure removal system in which an area is cleaned by high volumes of fresh water, or gray water that is recycled from a manure pit or lagoon.

Food and Drug Administration (FDA) - An agency of the U.S. Government responsible for the safety of the human food supply.

Footbath - A long shallow tub or depression in the concrete where cows walk through a mild solution (usually including copper sulfate or formalin) to promote foot health. Usually located along an alley where cows return from the milking parlor.

Forage - Feedstuffs composed primarily of the whole plant, including stems and leaves that are utilized by cattle.

Forage Crop - Annual or perennial crops grown primarily to provide feed for livestock. During harvesting operations, most of the aboveground portion of the plant is removed from the field and processed for later feeding.

Forestripping - Expressing streams of milk from the teat prior to machine milking to determine visual quality and to stimulate "milk letdown."

Forequarters - The two front quarters of a cow. Also called the fore udder.

Freestalls - Resting cubicles or "beds" in which dairy cows are free to enter and leave, as opposed to being confined in stanchions or pens.

Drive-through Freestall Barn
Source: Stacy Nichols, Land O'Lakes

Fresh Cow - A cow that has recently given birth to a calf.

Fresh Milk - Dairy products having original qualities unimpaired and those recently produced or processed.

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Garget - A common term for an inflammation of the udder of the cow or the resulting abnormal milk. More accurately referred to as mastitis.

Genetically-Modified Organism (GMO) - A term that refers to plants that have had genes implanted to improve their performance by making them resistant to certain pesticides, diseases, or insects.

Germicidal - A substance that has the ability to kill germs.

Gestation - The period in a female's life from conception to birth.

Gilt -In swine, a female is called a gilt until she has borne a litter, after which she is called a sow.

Gray Water - Water that is considered waste and not to be used for cleaning milking systems. Usually including recycled water from a lagoon or milk house waste. Even water only used to cool milk in a plate cooler is considered gray water, though it is often fed to cows to reduce total usage.

Grazing - Any vegetated land that is grazed or that has the potential to be grazed by animals. (More information from the Forage Information System) EXIT Disclaimer

Greenhouse Barn - Commonly referring to any of a group of hoop type barns with translucent or plastic covers over a tubular steel frame.

Ground Water - The water under the surface of the earth that is found within the pore spaces and cracks between the particles of soil, sand, gravel and bedrock.

Grooved Concrete - Floor surfaces with grooved patterns cut or depressed into concrete to provide better traction for cattle.

Grow-Finish - The last phase of production before the animals go to market.

Gully Erosion - They are formed when channel development has progressed to the point where the gully is too wide and too deep to be tilled across. These channels carry large amounts of water after rains and deposit eroded material at the foot of the gully. They disfigure landscape and make land unfit for growing crops.

Gutter - A shallow to deep channel located behind cows in tiestall barns capture manure and urine.

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Handlers - Processors or dealers of milk who commonly purchase raw milk and sell pasteurized milk and milk products.

Hand Mating - An individual female that is ready to be bred is exposed to an individual boar in a small pen for a few minutes, under the supervision of the producer.

Hand Milking - The manual milking of an animal as opposed to the use of mechanical milking devices.

Source: Genex, CRI

Harvestore Silo - A brand of oxygen limiting (air tight) upright silos with bottom unloading.

Hay - Dried feed consisting of the entire plant that can be used a feed for ruminant animals. Alfalfa, clover, grass, and oat hay are used in dairy rations.

Heading - The stage in which the head pushes its way through the flag leaf collar.

Headlocks - Self-locking stanchions along a feed alley in which cows voluntarily enter the head slot when going to eat. All cows may be held until herd health work is completed, and then all cows may be simultaneously released. Headlocks may be adjusted to remain open, allowing cows to come an go at will, when restraining the cows is not necessary.

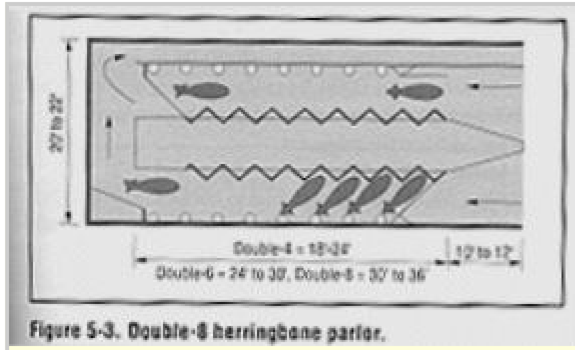
Heat - Refers to the estrous period for a female of breeding age. In swine, the first estrous normally occurs 3 to 5 days after the pigs are weaned.

Heifer - A bovine female less than three years of age who has not borne a calf. Young cows with their first calves are often called first-calf heifers.

Herd - A group of animals (especially cattle), collectively considered as a unit.

Herringbone Parlor - A milking parlor in which cows stand side-by-side, angled towards the pit. This allows milking from the side of the udder.

Herringbone Parlor
Source: Midwest Plan Service



Herringbone Parlor
Source: Midwest Plan Service

Hide - Skins from cattle.

Hog - Generic term, usually applied to growing swine.

Holding Pen - An area in which cows congregate prior to entering a milking parlor to be milked.

Hoop Structure - A low cost, uninsulated and naturally ventilated building used for older swine. The floor is mostly earthen and typically bedded with straw.

Hot Quarter - A quarter of the udder that is infected and may actually feel hard or hot to the touch due to elevated temperatures.

Hutch - An individual housing unit for young calves. Often made of white fiberglass or polyvinyl.

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Immunity - The power an animal has to resist and/or overcome an infection to which most of its species are susceptible. Active immunity is due to the presence of antibodies formed by an animal in response to previous exposure to the disease or through live or modified-live vaccines. Passive immunity is produced by giving the animal preformed or synthetic antibodies as with killed vaccines.

Inflammation - Swelling caused by the accumulation of lymph and blood cells at the site of infection or injury.

Inorganic - Not capable of sustaining life. Often refers to dirt or soil.

Integration - Bringing together of two or more segments of beef productions and processing under one centrally organized unit.

Intramuscular - Injections given in the muscle.

IPM - An integrated approach to controlling plant pests using careful monitoring of pests and weeds. It may include use of natural predators, chemical agents and crop rotations.

Source: Pennsylvania Farm Bureau Glossary of Terms

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Lactate - To secrete or produce milk.

Lagoon - Earthen storage structure with sufficient dilution water added to allow microorganisms to biodegrade and treat organic matter.

Leach - The downward transport of dissolved or suspended minerals, fertilizers, pesticides and other substances by water percolating through the soil.

Leg Bands - Cloth or plastic strips of a bright color used for marking treated cows, fresh cows, or cows needing special handling.

Legume - Any of thousands of plant species that have seed pods that split along both sides when ripe. Some of the more common legumes used for human consumption are beans, lentils, peanuts, peas, and soybeans. Others, such as clover and alfalfa, are used as animal feed. Legumes have a unique ability to obtain much or all of their nitrogen requirements from symbiotic nitrogen fixation.

Letdown - The process in a cow where physical stimulation causes a release of oxytocin and the contraction of smooth muscles surrounding milk alveoli resulting in fluid pressure within the udder and milk flow.

Limit Feeding - Feeding strategy in which pigs are fed a specific amount of food in a specific time period Vs free access to feed. Limit feeding is common in Europe, but normally only used for gestation animals in the U.S.

Liner - A flexible sleeve in the milking teat cup or rigid-walled liner holder. Responsible for massaging the teat end and intermittently cutting vacuum at the teat end during milking. Also called an inflation.

Liner Slips or Squawks - Slippage of the liner and teat cup during milking. Caused by a sharp change of milking vacuum within the unit or cluster by drawing in air alongside the teat. Generally creates a "squawking" sound.

Liquid Egg - Contents of egg (white, yolk, or both) that have been removed and shipped as a product in bulk.

Litter - The pigs that are born at one time to one sow - normally 8-12 pigs.

Litter - Substance applied to dirt or concrete flooring systems that is absorbent in nature, including: wood shavings, rice hulls, chopped straw, sand, sawdust, oat hulls, and several other materials.

Loose Housing - Facilities that allow cattle access to a large, open bedded area for resting (also known as free housing). Loose housing should provide at least 200 square feet per animal for feeding and resting (freestall housing uses only 90 square feet per animal).

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Karst - Areas with shallow ground water, caverns, and sinkholes.

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Marketing - Increasing awareness of a product by advertising.

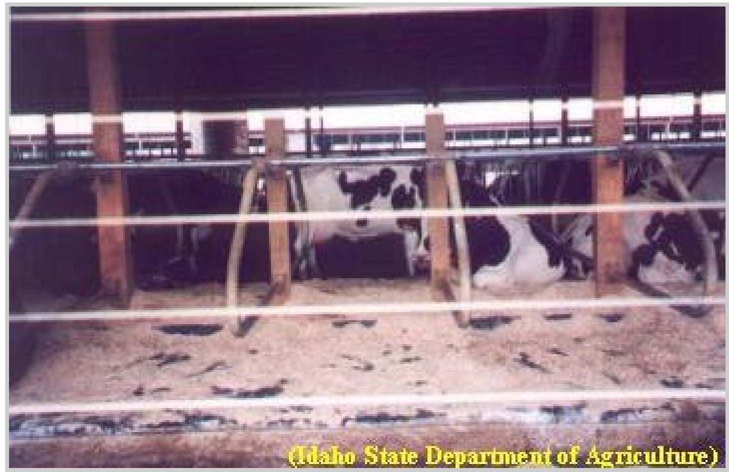
Market Weight (Pork) - 240 to 260 lbs.

Mastitis - An inflammation of the mammary gland (or glands), usually caused by bacteria.

Maternity Barn - A special needs facility where cows can be closely monitored during the period immediately before and after they give birth.

Mating - Breeding a sow or gilt after the onset of estrus and before ovulation, may include at least two services by different boars to ensure successful mating.

Mattress - Bedding material compacted to 3 to 4 inches and sandwiched in a heavyweight polypropolene or other fabric. Possible fillers include: long or chopped straw, poor quality hay, sawdust, shavings, rice hulls and, most commonly, shredded rubber.



Meat - Tissue of the animal body that are used for food.

Mechanical Ventilation - The use of fans, either electric or pneumatic, to ventilate houses.

Milk Handlers - Processors or dealers of milk who commonly purchase raw milk and sell pasteurized milk and milk products.

Milk House - The area near a milking parlor where the bulk milk tank, cleaning units, and equipment are located.

Milk House Waste - Water having been used in cleaning the milking equipment and washing the parlor.

Milking Pit - A sunken area that houses both the milker and some milking equipment during milking. This places the milker at shoulder level with udders and reduces physical demands.

Molting - The process of shedding and then regrowing feathers in laying hens. It corresponds with a period of no egg laying.

Mulch Tillage - Full-width tillage involving one or more tillage trips which disturbs all of the soil surface and is done prior to and/or during planting. Tillage tools such as chisels, field cultivators, disks, sweeps or blades are used. Weed control is accomplished with crop protection products and/or cultivation.

Source: Conservation Technology Information Center (CTIC) EXIT Disclaimer

Mutualism - A symbiotic relationship in which both partners benefit.

Mycoplasma - An organism capable of causing mastitis.

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Natural Ventilation - Air circulation is provided by opening barn doors or windows and allowing the wind to draw through the barn.

Nitrification - The biochemical oxidation of ammonium to nitrate, predominantly by autotrophic bacteria.

Non-Point Source Management Program - Under the Non-point Source Management Program, states can receive funding to control non-point sources of pollution to protect surface and ground water, including programs to control pesticide contamination of the ground and surface water.

Non-Productive Sow Days - Days a sow is neither lactating or gestating.

Non-Return Dip Cup - A dip cup that does not allow the liquid to reenter and potentially contaminate the storage container.

No-Tillage - Crop production system in which the soil is left undisturbed from harvest to planting. At the time of planting, a narrow strip up to 1/3 as wide as the space between planted rows (strips may involve only residue disturbance or may include soil disturbance) is engaged by a specially equipped planter. Planting or drilling is accomplished using disc openers, coulter(s), row cleaners, in-row chisels, or roto-tillers. Weed control is accomplished primarily with crop protection products. Other common terms used to describe No-till include direct seeding, slot planting, zero-till, row-till, and slot-till.

Nursery - The growth phase immediately after weaning until pigs enter the grow-finish building. Many larger operations are eliminating the nursery phase and placing newly weaned pigs in a growing building where they stay till marketed.

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Open Barns/Tromp Sheds/Loose Housing) - Open spaced shelter in which cattle are free to move about or rest wherever they might prefer, usually on a pack of bedding and manure. Organic - A substance that contains carbon and capable of sustaining life.

Organic Material - Substances containing plant or animal substance. In the context of milking equipment this usually refers to manure.

Over the Counter Drugs - Medications available without prescription.

Oxytocin - A naturally secreted hormone that is important in milk letdown and the contraction of the smooth uterine muscles during the birthing process.

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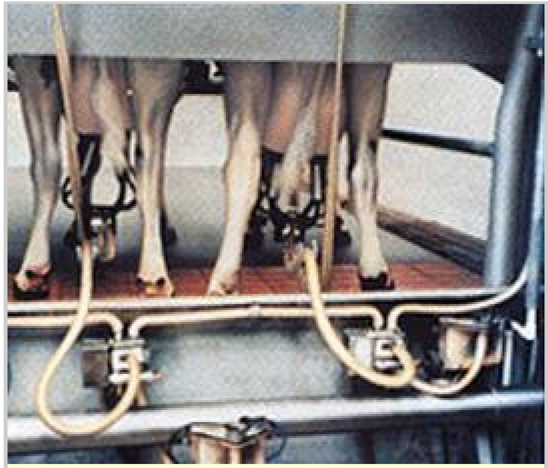
Paddocks - Subdivision of a pasture designed to provide short-duration grazing followed by an appropriate (related to species, soil type and weather conditions) rest period for re-growth and stand maintenance.

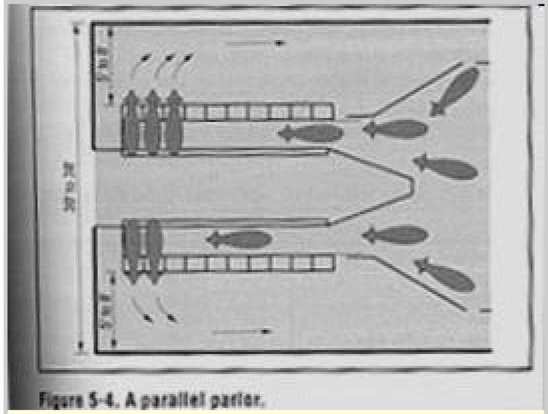
Paint Sticks - Contain liquid or chalky paint used for marking treated cows.

Parakeratosis - Any abnormality of the horny layer of the outer skin which prevents the formation of keratin.

Parallel Parlor- A raised milking area or platform where the cow stands perpendicular to the operator and milking units are attached between the rear legs. This may also be referred to as a side-by-side.



Parallel Parlors
Source: Midwest Plan Service



Parallel Parlors
Source: Midwest Plan Service

Parlor - The specialized area on the dairy farm where milking is performed. Parlors come in many types:

- Flat Barn,
- Walk-through,
- Herringbone,
- Parallel,
- Swing and
- Rotary.

Pasture (or Pastureland) - Land used primarily for the production of domesticated forage plants for livestock (in contrast to rangeland, where vegetation is naturally-occurring and is dominated by grasses and perhaps shrubs).

Pathogen - Any microorganism that produces disease (bacteria, viruses, yeasts, molds and parasites).

Peak Egg Production - The point in a hen's laying cycle where she will lay the highest percentage of eggs.

Pendulous Udder - A loosely attached udder.

Pen - Most swine are grouped together in pens, whether kept in a shelter or in a fenced open lot. The number of animals penned together may be less than 10 to several hundred, but is normally between 15 and 30.

Pen Mating - Boar is placed in a pen with group of sows to allow for breeding.

Pesticide - A general name for agricultural chemicals that include:

- Herbicide - for the control of weeds and other plants
- Insecticide - for the control of insects
- Fungicide - for the control of fungi
- Nematocide - for the control of parasitic worms
- Rodenticide - for the control of rodents

Pesticide Handlers - Refers to individuals who mix, load, apply, or otherwise handle pesticides.

Pig - Term usually applied to young, immature swine.

Piglet - The offspring of a male boar and a female sow are called piglets, or just pigs.

Pipeline - A stainless steel or glass pipe used for transporting milk.

Pit - A contained unit usually with concrete walls in which liquid or semi-liquid manure is stored.

Plate Cooler - A heat exchanger in which water at ground temperature or chilled water is used to cool milk prior to its movement to the bulk milk tank.

Point Source Contamination - The Clean Water Act's National Pollutant Discharge Elimination System (NPDES) program controls direct discharges into navigable waters. Direct discharges or "point source" discharges are from sources such as pipes and sewers.

Postemergence - Refers to the timing of pest control operations. Postemergence operations are accomplished during the period subsequent to the emergence of a crop from the soil and must be completed prior to point at which crop growth stage prohibits in-field travel (unless alternative application means – aerial or irrigation-based – are used).

Post-Milking Teat Dip - A product applied after milking to protect the teat from contagious pathogens that may have come into contact with the teat during the milking process.

Poult - A baby turkey.

Power Takeoff (PTO) - A splined shaft that extends from a tractor drive train and is designed to couple with the splined drive shaft of an implement. The connection permits mechanical power to be transmitted from tractor to implement.

Preemergence - Refers to the timing of pest control operations. Preemergence operations are accomplished during the period subsequent to the planting of a crop and prior to the emergence of that crop from the soil.

Pre-Milking Teat Dip - A product applied in preparation for milking to clean the teat and reduce the spread of disease and maintain healthy teats.

Preplant - Refers to the timing of pest control operations. Preplant operations are accomplished during the period subsequent to the harvest of one season’s crop and prior to the planting of the next season’s crop.

Prescription Drugs - Drugs that the FDA has determined must be used only under the direction and supervision of a licensed veterinarian.

Primary Tillage - The mechanical manipulation of soil that displaces and shatters soil to reduce soil strength and to bury or mix plant materials and crop chemicals in the tillage layer. Tends to leave a rough soil surface that is smoothed by secondary tillage.

Puberty - Time of first estrus in sows, usually occurring at 6 mo. of age.

Pullet - A laying hen before it lays its first egg.

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Rapid Exit - Panels or rails that raise to release all cows on one side of the milking parlor at once.

Ration - Feed fed to an animal during a 24-hour period.

Replacement Heifers - Often ones being raised to replace the cows currently in the herd.

Return Alley - The alley through which cows must pass when moving from the milking parlor back to the cow housing area after milking.

Ridge Tillage - The soil is left undisturbed from harvest to planting except for strips up to 1/3 of the row width. Planting is completed on the ridge and usually involves the removal of the top of the ridge. Planting is completed with sweeps, disk openers, coulters, or row cleaners. Residue is left on the surface between ridges. Weed control is accomplished with crop protection products (frequently banded) and/or cultivation. Ridges are rebuilt during row cultivation.

Source: Conservation Technology Information Center (CTIC) EXIT Disclaimer

Rill Erosion - The removal of soil by concentrated water running through little streamlets, or headcuts. Detachment in a rill occurs if the sediment in the flow is below the amount the load can transport and if the flow exceeds the soil's resistance to detachment. As detachment continues or flow increases, rills will become wider and deeper.

Ring Feeder - A steel hoop with individual head gates that may be placed over a large round bale of hay when feeding it.

Robotic Parlor - A completely automated system for milking cows that requires limited human contact.

Rotary Parlor - A raised, round rotating platform or carousel on which cows ride while being milked.


Rotary Parlor

Roughage - Feed that is high in fiber, low in digestible nutrients, and low in energy (e.g., hay, straw, silage, and pasture).

Row Crop - Agricultural crop planted, usually with mechanical planting devices, in individual rows that are spaced to permit machine traffic during the early parts of the growing season

Ruminant - Mammal whose stomach has four parts-rumen, reticulum, omasum, and abomasum. These animals chew their cud or regurgitate partially digested food for further breakdown in the mouth. Ruminant animals include cattle, sheep, goats, deer and camels.

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Safe Drinking Water Act - The objective of the Safe Drinking Water Act is to protect public health by establishing safe limits (based on the quality of water at the tap) for contaminants that may have an adverse effect on human health, and to prevent contamination of surface and ground sources of drinking water.

Sand Separator - A mechanical device or series of course ways used to settle sand from sand-laden manure.

Scrape-and-Haul - Manure handling system in which manure is scrape manually or with a skidloader, placed in a solid manure spreader and directly applied to appropriate crop land.

Secondary Tillage - The mechanical manipulation of soil that follows primary tillage. Performed at shallower depths than primary tillage, secondary tillage can provide additional soil pulverization, crop chemical mixing, soil surface leveling, and firming, and weed control. In conventional tillage systems, the final secondary tillage pass is used to prepare a seedbed.

Seeded - Generic term for introducing seed into the soil-air-water matrix, typically via a mechanized process that will maximize the likelihood of subsequent seed germination and plant growth.

Segregated Early Weaning - Removal of pigs from mother at 10 - 14 days of age in order to reduce transmission of disease from the mother to her offspring. The milk produced immediately after birth helps to protect the pigs from disease, but this protection decrease over time.

Self-Propelled - A term that is typically applied to farm machines with integral power units that are capable of moving about as well as performing some other simultaneous operation such as harvesting or spraying a crop.

Sensitivity Tests - Tests used to determine the most effective method of treatment of disease by testing the resistance of the microorganism to classes of antibiotics.

Separator -

1. Formerly a centrifuge device used to remove the fat from milk on the farm, but now used primarily at processing plants.
2. A device used to separate manure into solids and effluent and accomplish by trickling manure over a sloped screen or mechanically forcing through a screen.

Service - Breeding, the deposition of boar semen into the female. Breeding may be by done naturally by a boar or artificially by the manager, using semen obtained from a local boar or purchased from a supplier. Producers often use artificial insemination as a way to bring new genetics into their herd, without the biosecurity concerns involved with bringing new animals onto their farm.

Settling Pond - A manure pit where the flow rate of liquid manure is slowed to allow suspended materials to collect at the bottom where they can later be removed.

Shoat - A young pig, just after weaning.

Sidedress - When a readily available form of nitrogen, normally urea, is injected beside the growing row of plants, usually corn.

Silage - A feed prepared by chopping green forage (e.g. grass, legumes, field corn) and placing the material in a structure or container designed to exclude air. The material then undergoes fermentation, retarding spoilage. Silage has a water content of between 60 and 80%.

Silage Bags - Large plastic tubes in which forages are fermented. Plastic is removed and discarded as the ensiled feed is fed.

Silo - A storage facility for silage. Usually referring to upright concrete or fiberglass silos.

Silking - It is considered the first reproductive stage

Sinkhole - A surface depression caused by a collapse of soil or overlying formation above fractured or cavernous bedrock.

Sire - Father or male parent in a pedigree.

Slotted Floor - A concrete floor design in which slats are positioned in the floor so that animal traffic can work manure through the narrow openings (slots) between the slats and into a collection pit located beneath the floor of the barn.

Soil Test - A soil test indicates the availability of nutrients present in the soil and the availability of those nutrients to crops grown there.

Somatic cell count (SCC) - The number of white blood cells per milliliter of milk or measurement of the number of somatic cells present in a sample of milk. A high concentration of more than 500,000 somatic cells per milliliter of milk indicates abnormal condition in the udder. This serves as an indicator of mastitis infection when elevated above 200,000.

Somatic Cell Score - A logarithmic representation of the SCC, often referred to as linear scores because they are linearly related to milk production loss.

Somatic Cells - The combination of the leukocytes (white blood cells) from blood and the epithelial cells from the secretory tissue of the udder which indicate the presence of infection or injury in the animal.

Sow - In swine, the term sow refers to a female after she has borne a litter.

Sown - Planted using a broadcast seeding machine that distributes seed upon the soil surface. The seed may then be incorporated into the soil to ensure adequate seed-soil contact for germination.

Sphincter - A ring-shaped muscle that allows an opening to close tightly, such as the sphincter muscle in the lower end of a cow's teat.

Stall - A cow housing cubicle.

Stanchion - A device with two rails that was closed around a cows neck after she entered a stall and to keep her restrained in the stall.

Standing Heat - A sow or gilt will assume a rigid stance and maintain it during servicing if she is ready to be bred.

Steer - Bovine male castrated prior to puberty.

Step-Up Parlor - Cows step onto raised platforms for milking. The milking units are attached from the side.

Sterile - Clean, free of any living organisms. Also means unable to reproduce.

Streak canal - Small canal located in the end of each teat, through which the milk passes immediately prior to expulsion. Also called the teat meatus.

Strip Cup - A small cup or device to collect forestrippings and which makes abnormal milk easier to observe.

Strip Tillage - The process in which only a narrow strip of land needed for the crop row is tilled.

Stocker - Weaned cattle that are fed high-roughage diets (including grazing) before going into the feedlot.

Subclinical - A disease condition without symptoms but often resulting in decreased production or impaired milk quality.

Subcutaneous - Under the skin.

Subway - An area beneath the milking pit that houses milk meters, pipelines, vacuum lines and transfer tanks to reduce noise and improve the milker's ability to move around in the pit.

Superhutches - Calf housing structures, often open on one side, designed for a small number of calves when first grouped immediately after weaning.

Supplemental Heat - Furnace or radiant heat provided to maintain a comfortable temperature for the animals

Swing Parlor - Parlor characterized by having the milking units positioned in the middle of the parlor for use by cows on both sides.

Symbiotic Nitrogen Fixation - Symbiotic nitrogen fixation occurs in plants that harbor nitrogen-fixing bacteria within their tissues. The best-studied example is the association between legumes and **bacteria** in the genus ***Rhizobium*.** Each of these is able to survive independently (soil nitrates much then be available to the legume), but life together is clearly beneficial to both. Only together can nitrogen fixation take place. A symbiotic relationship in which both partners benefit is called mutualism.

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Tail Bands - Used for marking treated cows. Rubber bands are sometimes used to dock cow's tails.

Tandem Parlor - Parlor design where cows line up head to tail in individually opening stalls.

Tasseling - A condition when the tassel-like male flowers emerge.

Teat - The appendage on the udder through which milk from the udder flows.

Teat Dip - Pre and Post-milking - Substance that kills bacteria and helps to seal the teat end to prevent entry of bacteria into the udder between milkings. May contain emollients to improve teat end condition for use in cold, winter conditions.

Teat Sealant - A product that forms a mechanical barrier on the teat end to protect the teat. Generally used at dry-off after antibiotic infusion.

10 Point Milk and Dairy Beef Residue Prevention Protocol - Designed by veterinarians and milk producer organizations to avoid contamination of milk with antibiotics. It identifies the 10 points in milk production where milk is at greatest risk for antibiotic contamination of milk.

Throughput - The number of cows that can be milked in a parlor in a given period of time.

Tie Stall Parlor - Facility is frequently used for both housing and milking. Cows are tied and milked with the cow and operator on the same level.

Tillage - The mechanical manipulation of soil performed to nurture crops. Tillage can be performed to accomplish a number of tasks including: seedbed preparation, weed control, and crop chemical incorporation.

Total Mixed Ration (TMR) - Ration formulated to meet requirements of the cow in which all of the ingredients are blended together in a mixer.

Toxic - Harmful.

Transgenic Crop - Contains a gene or genes which have been artificially inserted instead of the plant acquiring the gene(s) through pollination. The inserted gene(s) may come from an unrelated plant or from a completely different species.

Transition Cow - The time in a cow's life from 2 months before, to 1 month after, her expected calving date.

Transition Housing - Barns designed especially for transition cows, often including a maternity area.

Tunnel Ventilation - Placement of large fans at end of building to draw air from one end to the other.

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Udder - The encased group of mammary glands provided with teats or nipples as in a cow, ewe, mare or sow. Also referred to as a bag.

Urea - A form of nitrogen that converts readily to ammonium.

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Value-Added Products - A general term that refers to agricultural products that have increased in value due to processing. Examples include corn oil and soybean meal.

Veal - A calf (usually male) that is raised on milk and is intended to be used for meat at a young age. Veal meat is served at many restaurants and is very popular in cultural cuisine.

Ventilation - The circulation of air through a building in order to expel noxious air and admit clean, fresh air.

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Walk Through Parlor - Upon completion of milking, cows walk through the front of the stall to exit.

Weaning - The process of removing the pigs from the sow and moving them to the nursery.

Wild boar - These wild hogs are still found in parts of the United States. Pigs used in modern pork production are thought to be descendants of the European wild boar. Wild boars are considered to be descendants of European wild boars introduced into the U.S. for sport hunting, or the hybrid offspring of escaped domestic hogs.

Withdrawal Time - Time required after the last drug treatment to lower drug residues to acceptable levels. These times are established using healthy animals according to label directions. An amount of time required following use of a medication in an animal before milk or meat can be entered into the human food supply. Ensures residues are maintained at levels approved by the USDA.

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Yeast - An organism that can grow and develop in the udder, causing mastitis.

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Revenues

Gross farm income includes cash receipts from the sale of farm products, government payments arising from farm program participation, the value of fuel, feed, fertilizer, see and other inputs consumed on the farm, and the rental value of farmland and dwellings. Farmers often are able to enhance their income by using futures and/or production contracts to achieve a higher selling price than would be available if a crop was sold at the time it was harvested. Often, production contracts require the seller (the farmer) to achieve certain levels of quality and/or quantity in order to qualify for a premium selling price. Many farms participate in U.S. government farm programs in which income support payments are made to farmers who raise program commodity crops and participate in applicable conservation plans to reduce soil erosion and adhere to wetland protection requirements currently in law.

The following table provides an estimate of the per-acre value of major crops grown in the United States in the year 2012. Crop yields vary widely across the country and overall production has an impact on market prices.

Table 1. Typical value of major agricultural crops grown in the United States in 2012.

Crop	Typical Yield (-/ acre)	Typical Farm Price ($/-)	Crop Value ($/acre)
Cotton	866 lb.	0.731/pound	633.05
Rice	7,449 lb.	14.90/hundredweight	110.99
Corn (grain)	123.4 bu.	7.20/bu.	888.48
Soybeans	39.6 bu.	14.30/bu.	566.28
Sorghum (grain)	2,788.8 lb.	12.80/hundredweight	35.70
Wheat	46.3 bu.	7.90/bu.	365.77

Agricultural commodity prices have not kept pace with rising prices in other segments of the economy, which has decimated the number of small farms. Even though the per-acre value of most major crops is low, the volume and value of crop production in the United States is staggering. The 2007 Census of Agriculture found that U.S. farms sold $297 billion in agricultural products. This was a 48 percent change from 2002 where the U.S. farm receipts totaled $201 billion (Statistical Abstract of the United States: 2012; Section 17: Agriculture). Of the 2007 total, approximately 3% ($8 billion) comes to the farm in the form of government payments. The U.S. exports about ¼ of the total U.S. farm receipts, (Frequently Asked Questions About Agricultural Trade) helping to offset trade deficits in other sectors of the economy. Of the total crop production in the U.S., about 30 percent is exported.

The agribusiness sector, which provides production agriculture with necessary inputs and which adds value to farm products, continues to thrive. In 2010, agriculture and related industries had about 5% percent value-added share of nominal GDP (USDA FAQs) ($9.95 trillion in 2010). Agriculture employed about 2% of the U.S. civilian labor force (2.63 million hired workers).

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Production Expenses

The major agricultural commodities produced in the U.S. have a relatively low per-acre value. In the past, crop prices often failed to keep pace with inflation. For example, the average price paid to farmers for soybeans in 2000 was $4.40 per bushel, the lowest average price since 1972, and a 40 percent decline since 1996. Over the past couple of years, this has been changing. For instance, in 2012 the cost of soybeans increased to $14.30 per bushel.

USDA tracks both prices received for farm products and prices paid for production inputs. Using the 1910-1914 period as a base, the prices received by today's farmer have increased by at least a factor of six. However, prices paid by farmers for production inputs have increased by at least a factor of sixteen! For statistics on crop totals (prices), visit USDA's National Agriculture Statistics Service here: http://www.nass.usda.gov/Statistics_by_Subject/index.php?sector=CROPS. EXIT Disclaimer

Thin profit margins have forced producers to seek efficiencies in all aspects of production. Efficiencies of scale favor large producers who can make the most effective use of large, expensive machines. For crops such as corn and soybeans, commercial viability is based on producing "in volume." These forces have dramatically changed the size and numbers of farms.

In addition to efficiencies in machinery and crop production volume, crop inflation costs and crop production expenses are linked to various other factors including gas prices, weather conditions, environmental events, and consumer demand related to crops.

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Expense Categories

Land: The average price of an acre of U.S. farmland is over $2,000. Prime farm real estate (including farm land and buildings used for agriculture) in the Corn Belt can sell for over $ 5,560 per acre (2012). Contrary to the high prices of the Corn Belt is the average price in the Mountain states, where farm real estate sells for $974 per acre (2012). The average value of cropland (land used for field crops, vegetables or land harvested for hay) per acre in the US sold for $3,550 in 2012.

Harvest scene in the Corn Belt - a large combine quickly unloads grain to a high-capacity grain cart Source: Daniel R. Ess, Purdue University

Cash rental prices for land vary by state and quality of the land. Prices range from $ 30 per acre per year for pasture to over $261 for highly productive cropland.

Machinery: The variety of machines for producing crops is as great as the variety of crops produced. However, there are certain "staple" technologies such as tractors and combines that serve to illustrate the magnitude of investment that modern farmers must make in machinery.

It is often puzzling to non-farmers to see expensive equipment stored in sheds and/or sitting idle for months at a time. Why would a farmer invest $300,000 in a large combine only to use it for four weeks out of the year? How could a farmer possibly justify spending upwards of $200,000 for a tractor that is used for little else but tillage? The simple, but important, answer is TIMELINESS. Crops are biological “products” that produce optimum yields only when planting and harvest operations can be performed within relatively small windows of time. For instance, the optimum harvest window for corn in Eastern Illinois is only 30 days long and for wheat in Kansas the harvest window is only 10 to 14 days. This requires the use of large equipment that is used very intensively for relatively short periods of time.

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Production Inputs

The per-unit costs of agricultural production inputs such as feed, fertilizers, crop chemicals, and seed also vary widely due to production systems. For instance, a corn farmer might have nitrogen fertilizer costs of $50 per acre while a soybean farmer down the road might have no nitrogen fertilizer costs due to a legume's ability to fix nitrogen. Crop chemicals such as herbicides, insecticides, and fungicides are applied on an "as-needed" basis and applications vary widely from farm-to-farm, and from crop-to-crop. Seed costs tend to vary based on conventional or biotech varieties. For instance, farmers may pay an average of $200 per bag of seed corn for a non-GMO seed and around $300 per bag of GMO seed. (*1) While seed costs vary by the type of seed, per-unit costs vary somewhat less across types of crops. For instance, a more expensive bag of seed corn would plant about 2½ acres, while a less expensive bag of soybeans would plant about an acre.

In addition to land, machinery, fertilizer, crop chemicals, and seed, farmers face costs for buildings, grain handling facilities, hired labor, fuel for vehicles, heating, and conditioning crops, livestock, feed and veterinary care for the livestock, taxes, crop insurance, property insurance, and the list goes on. All of the expenses add to the challenge of remaining profitable and economically viable for the long term.

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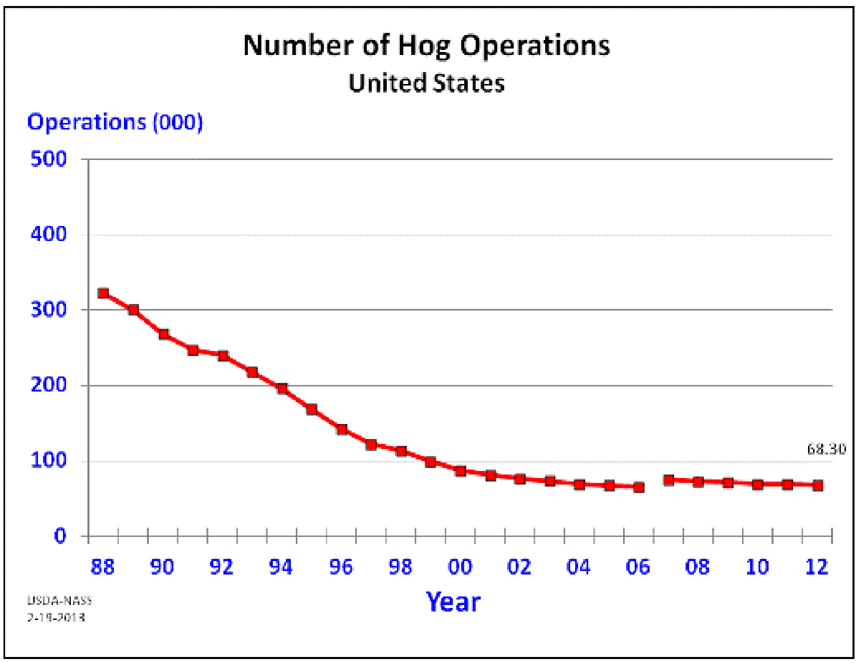
Social and Economic Interactions and the Structure of U.S. Agriculture

"Consolidation" and "concentration" are perhaps the most apt words to characterize the structural change in American agricultural production over the past three decades. This change continues today. In 2012 the total number of farms in the US decreased by 11,630 from 2011 and the total land in farms, at 914 million acres, decreased 3 million acres from 2011 (USDA Farms, Land in Farms, and Livestock Operations 2012 Summary).

The number of farms with hogs in the United States declined from almost 700,000 in 1980 to approximately 68,300 in 2012. At the same time, the percentage of hogs produced by the largest sized farms (greater than 5,000 head inventory) rose from 20 percent of total U.S. production in 1992 to approximately 62 percent in 2012. Similar statistics also exist for poultry and crop production in the U.S.



This shift toward larger production units and the substitution of chemical and mechanical inputs for labor have raised a variety of social and economic issues. For example, there are questions concerning the environmental sustainability of modern agricultural production systems. Low product prices, larger government payments to farmers, and increased use of alternative business arrangements such as contracting also have brought into question the economic and social sustainability of the current agricultural industry structure.

State governments have traditionally promulgated and enforced environmental policies with respect to farm level production. However, varying political forces across state lines have led to different degrees of regulation and enforcement. There is anecdotal evidence suggesting that such differences are responsible for shifts in livestock production to non-traditional areas (and less regulated) with less stringent regulation and often where there is little or no crop base to utilize the manure nutrients. Such shifts in economic activity may have social and environmental consequences that are not always in society's best interest.

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Economics Study Questions

Identify the definition that best fits the following terms:

1. **Food is most affordable in this country:**

   - Japan
   - Netherlands
   - United States
   - Australia

   Feedback

2. **U.S. farm receipts exceed $297 billion per year. The following percentage is exported, on the average:**

   - 5%
   - 10%
   - 30%
   - 50%

   Feedback

3. **Farms and agriculture-related business account for the following portion of the U.S. gross domestic product:**

   - 1/50 (2%)
   - 1/20 (5%)
   - 1/4 (25%)
   - 1/2 (50%)

   Feedback

4. **Farms and agribusinesses employ the following portion of the U.S. civilian work force:**

   - 1/9 (11%)
   - 1/6 (13%)
   - 1/4 (25%)
   - 1/2 (50%)

   Feedback

5. **About this much of the United State's land area is used for crop production:**

   - 1/2
   - 1/12
   - 1/5
   - 1/8

   Feedback

6. **The primary reason that many crop farmers pay several hundred thousand dollars for large harvesting equipment is:**

   - To impress the bankers
   - To impress their neighbors
   - End of year equipment sales
   - The very short time period when they are able to harvest crops

   Feedback

7. **Farmers in the Midwest typically have this yield (in bushels) per acre for corn (2012 data):**

   - 123.4 bu.
   - 155.6 bu.
   - 331.3 bu.
   - 403 bu.

   Feedback

8. **The number of swine farms dropped by approximately this amount over the last twenty years:**

   - 10 % (500,000 => 450,000)
   - 25 % (400,000 => 300,000)
   - 60 % (1,000,000 =>400,000)
   - 90 % (700,000 => 70,000)

   Feedback

See Results RESET

Score in Percentage:	

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Economic Overview

U.S. agriculture is a complex system that simultaneously produces unprecedented bounty and unparalleled social concerns. Can the unique institution of the American family farm survive the economic realities of the 21st century? Can the United States continue to have the most abundant and the safest food system in the world? These questions and the unfolding answers will have impacts that will be felt for generations to come. What we know for certain is that:

- The U.S. farmer is the most productive in the history of the world.
- Food is more affordable in the United States than in any other developed country in the world.
- There is a definite trend toward fewer farms producing an increasing share of agricultural products in this country.
- In spite of many challenges, U.S. agriculture is uniquely positioned to provide for the food and fiber needs of a growing world community.

Agricultural production in the United States is a business that requires very high capital investments in land, facilities, and machines and most often produces undifferentiated products (commodities) of generally low unit value. Thin profit margins have forced producers to seek efficiencies in all aspects of production. There are efficiencies of scale that favor large producers who can make the most effective use of large, expensive machines. In crops such as corn and soybeans, and in poultry and animal production commercially viability is usually based on producing "in volume."

Revenues

Gross farm income includes cash receipts from the sale of farm products, government payments arising from farm program participation, the value of fuel, feed, fertilizer, see and other inputs consumed on the farm, and the rental value of farmland and dwellings. Farmers often are able to enhance their income by using futures and/or production contracts to achieve a higher selling price than would be available if a crop was sold at the time it was harvested. Often, production contracts require the seller (the farmer) to achieve certain levels of quality and/or quantity in order to qualify for a premium selling price. Many farms participate in U.S. government farm programs in which income support payments are made to farmers who raise program commodity crops and participate in applicable conservation plans to reduce soil erosion and adhere to wetland protection requirements currently in law.

The following table provides an estimate of the per-acre value of major crops grown in the United States in the year 2012. Crop yields vary widely across the country and overall production has an impact on market prices.

Table 1. Typical value of major agricultural crops grown in the United States in 2012.

Crop	Typical Yield (-/ acre)	Typical Farm Price ($/-)	Crop Value ($/acre)
Cotton	866 lb.	0.731/pound	633.05
Rice	7,449 lb.	14.90/hundredweight	110.99
Corn (grain)	123.4 bu.	7.20/bu.	888.48
Soybeans	39.6 bu.	14.30/bu.	566.28
Sorghum (grain)	2,788.8 lb.	12.80/hundredweight	35.70
Wheat	46.3 bu.	7.90/bu.	365.77

Agricultural commodity prices have not kept pace with rising prices in other segments of the economy, which has decimated the number of small farms. Even though the per-acre value of most major crops is low, the volume and value of crop production in the United States is staggering. The 2007 Census of Agriculture found that U.S. farms sold $297 billion in agricultural products. This was a 48 percent change from 2002 where the U.S. farm receipts totaled $201 billion (*4). Of the 2007 total, approximately 3% ($8 billion) comes to the farm in the form of government payments. The U.S. exports about ¼ of the total U.S. farm receipts, (*5) helping to offset trade deficits in other sectors of the economy. Of the total crop production in the U.S., about 30 percent is exported.

The agribusiness sector, which provides production agriculture with necessary inputs and which adds value to farm products, continues to thrive. The economic impact of agribusiness is huge. In 2010, agriculture and related industries had about 5% percent value-added share of nominal GDP (*6) ($9.95 trillion in 2010) and employs just over one-sixth of the U.S. civilian labor force (2.63 million workers; 2007 Agricultural Census)(*3).

Sources:

(1) US. USDA. National Agricultural Statistics Service. Crop Values 2012 Summary. N.p., 15 Feb. 2013. Web. <http://usda01.library.cornell.edu/usda/current/CropValuSu/CropValuSu-02-15-2013.pdf>.
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(2) U.S. USDA. National Agricultural Statistics Service. 2007 Census of Agriculture: Economics. N.p., 3 Feb. 2009. Web. <http://www.agcensus.usda.gov/Publications/2007/Online_Highlights/Fact_Sheets/Economics/economics.pdf>.
EXIT Disclaimer

(3) U.S. USDA. National Agricultural Statistics Service. 2007 Census of Agriculture. N.p., 15 Mar. 2011. Web. <http://www.agcensus.usda.gov/Publications/2007/Online_Highlights/Fact_Sheets/Economics/farm_labor.pdf>
EXIT Disclaimer

(4) U.S. U.S. Census Bureau. Statistical Abstract of the United States: 2012; Section 17: Agriculture. N.p., 27 Sept. 2011. Web. <http://www.census.gov/prod/2011pubs/12statab/agricult.pdf>.
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(5) U.S. USDA. Foreign Agricultural Service. Frequently Asked Questions About Agricultural Trade. N.p., n.d. Web. <http://www.fas.usda.gov/itp/Policy/tradeFAQ.asp>. EXIT Disclaimer

(6) U.S. USDA. Economic Research Service. FAQs. N.p., n.d. Web. <http://www.ers.usda.gov/faqs.aspx#.UVxs2pMX-5R>. EXIT Disclaimer

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Production Expenses

The major agricultural commodities produced in the U.S. have a relatively low per-acre value. In the past, crop prices often failed to keep pace with inflation. For example, the average price paid to farmers for soybeans in 2000 was $4.40 per bushel, the lowest average price since 1972, and a 40 percent decline since 1996. Over the past couple of years, this has been changing. For instance, in 2012 the cost of soybeans increased to $14.30 per bushel.

USDA tracks both prices received for farm products and prices paid for production inputs. Using the 1910-1914 period as a base, the prices received by today's farmer have increased by at least a factor of six. However, prices paid by farmers for production inputs have increased by at least a factor of sixteen! For statistics on crop totals (prices), visit USDA's National Agriculture Statistics Service here: http://www.nass.usda.gov/Statistics_by_Subject/index.php?sector=CROPS. EXIT Disclaimer

Thin profit margins have forced producers to seek efficiencies in all aspects of production. Efficiencies of scale favor large producers who can make the most effective use of large, expensive machines. For crops such as corn and soybeans, commercial viability is based on producing "in volume." These forces have dramatically changed the size and numbers of farms.

In addition to efficiencies in machinery and crop production volume, crop inflation costs and crop production expenses are linked to various other factors including gas prices, weather conditions, environmental events, and consumer demand related to crops.

Sources:

1. U.S. USDA. Economic Research Service. Food Price Outlook: Summary Findings. N.p., n.d. Web. 09 Apr. 2013. <http://www.ers.usda.gov/data-products/food-price-outlook/summary-findings.aspx>. EXIT Disclaimer

2. "World Food Prices Rise to Near-Record High as Inflation Speeds Up, UN Says." Bloomberg. N.p., 5 May 2011. Web. 09 Apr. 2013. <http://www.bloomberg.com/news/2011-05-05/food-prices-approach-record-high-as-grain-prices-fuel-inflation-worldwide.html>. EXIT Disclaimer

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Expense Categories

Land: The average price of an acre of U.S. farmland is over $1,000. Prime farmland in the Corn Belt can sell for over $3,000 per acre (2000). In the Midwest, cash rental prices for land range from $10 per acre per year for pasture to over $100 for highly productive cropland.

Harvest scene in the Corn Belt - a large combine quickly unloads grain to a high-capacity grain cart Source: Daniel R. Ess, Purdue University

Machinery: The variety of machines for producing crops is as great as the variety of crops produced. However, there are certain "staple" technologies such as tractors and combines that serve to illustrate the magnitude of investment that modern farmers must make in machinery.

It is often puzzling to non-farmers to see expensive equipment stored in sheds and/or sitting idle for months at a time. Why would a farmer invest $300,000 in a large combine only to use it for four weeks out of the year? How could a farmer possibly justify spending upwards of $200,000 for a tractor that is used for little else but tillage? The simple, but important, answer is TIMELINESS. Crops are biological “products” that produce optimum yields only when planting and harvest operations can be performed within relatively small windows of time. For instance, the optimum harvest window for corn in Eastern Illinois is only 30 days long and for wheat in Kansas the harvest window is only 10 to 14 days. This requires the use of large equipment that is used very intensively for relatively short periods of time.

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Production Inputs

The per-unit costs of agricultural production inputs such as feed, fertilizers, crop chemicals, and seed also vary widely due to production systems. For instance, a corn farmer might have nitrogen fertilizer costs of $50 per acre while a soybean farmer down the road might have no nitrogen fertilizer costs due to a legume's ability to fix nitrogen. Crop chemicals such as herbicides, insecticides, and fungicides are applied on an "as-needed" basis and applications vary widely from farm-to-farm, and from crop-to-crop. Seed costs tend to vary based on conventional or biotech varieties. For instance, farmers may pay an average of $200 per bag of seed corn for a non-GMO seed and around $300 per bag of GMO seed. (*1) While seed costs vary by the type of seed, per-unit costs vary somewhat less across types of crops. For instance, a more expensive bag of seed corn would plant about 2½ acres, while a less expensive bag of soybeans would plant about an acre.

In addition to land, machinery, fertilizer, crop chemicals, and seed, farmers face costs for buildings, grain handling facilities, hired labor, fuel for vehicles, heating, and conditioning crops, livestock, feed and veterinary care for the livestock, taxes, crop insurance, property insurance, and the list goes on. All of the expenses add to the challenge of remaining profitable and economically viable for the long term.

Sources:

1. "Purdue Agriculture News." Ag Economist: Seed Prices Going Up, but so Will Revenues. N.p., n.d. Web. 01 Nov. 2012. <http://www.purdue.edu/newsroom/releases/2012/Q4/ag-economist-seed-prices-going-up,-but-so-will-revenues.html> EXIT Disclaimer

2. US. USDA. National Agricultural Statistics Service. Farm Production Expenditures 2011 Summary. N.p., 8. Aug. 2012. Web. <http://usda01.library.cornell.edu/usda/current/FarmProdEx/FarmProdEx-08-02-

2012.pdf>. EXIT Disclaimer

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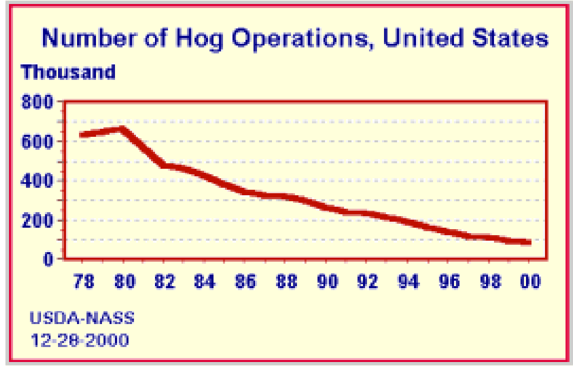
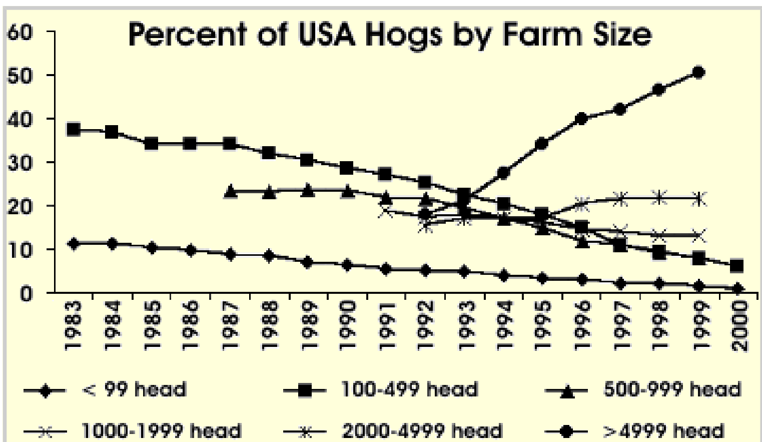
Social and Economic Interactions and the Structure of U.S. Agriculture



"Consolidation" and "concentration" are perhaps the most apt words to characterize the structural change in American agricultural production over the past two decades. The number of farms with hogs in the United States declined from almost 700,000 in 1980 to approximately 70,000 in 2000. At the same time, the percentage of hogs produced by the largest sized farms (greater than 5,000 head inventory) rose from 20 percent of total U.S. production in 1992 to approximately 50 percent in 2000. Similar statistics also exist for poultry and crop production in the U.S.



This shift toward larger production units and the substitution of chemical and mechanical inputs for labor have raised a variety of social and economic issues. For example, there are questions concerning the environmental sustainability of modern agricultural production systems. More recently, low product prices, larger government payments to farmers, and increased use of alternative business arrangements such as contracting have also brought into question the economic and social sustainability of the current agricultural industry structure.

State governments have traditionally promulgated and enforced environmental policies with respect to farm level production. However, varying political forces across state lines have led to different degrees of regulation and enforcement. There is anecdotal evidence suggesting that such differences are responsible for shifts in livestock production to non-traditional areas (and less regulated) with less stringent regulation and often where there is little or no crop base to utilize the manure nutrients. Such shifts in economic activity may have social and environmental consequences that are not always in society's best interest.

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Economics Study Questions

Identify the definition that best fits the following terms:

1. **Food is most affordable in this country:**

   - Japan
   - Netherlands
   - United States
   - Australia

   Feedback

2. **U.S. farm receipts exceed $200 billion per year. The following percentage is exported, on the average:**
   - 5 %
   - 10 %
   - 30%
   - 50%

   Feedback

3. **Farms and agriculture-related business account for the following portion of the U.S. gross domestic product:**
   - 1/50 (2%)
   - 1/20 (5%)
   - 1/4 (25%)
   - 1/2 (50%)

   Feedback

4. **Farms and agribusinesses employ the following portion of the U.S. civilian work force:**
   - 1/9 (11%)
   - 1/6 (13%)
   - 1/4 (25%)
   - 1/2 (50%)

   Feedback

5. **About this much of the United State's land area is used for crop production:**
   - 1/2
   - 1/12
   - 1/5
   - 1/8

   Feedback

6. **The primary reason that many crop farmers pay several hundred thousand dollars for large harvesting equipment is:**
   - To impress the bankers
   - To impress their neighbors
   - End of year equipment sales
   - The very short time period when they are able to harvest crops

   Feedback

7. **Farmers in the Midwest typically have this yield (in bushels) per acre for corn (2012**

data):

- 123.4
- 155.6 bu.
- 331.3 bu.
- 403 bu.

Feedback

8. **The number of swine farms dropped by this amount over the last twenty years:**

- 10 % (500,000 => 450,000)
- 25 % (400,000 => 300,000)
- 60 % (1,000,000 =>400,000)
- 90 % (700,000 => 70,000)

Feedback

See Results RESET

Score in Percentage:	

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U.S. ENVIRONMENTAL PROTECTION AGENCY

Ag 101

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Background

Growing crops for food was one of the first priorities of the earliest settlers arriving in North America. With shipboard supplies depleted, and having little familiarity with the land and native vegetation, groups arriving from Europe were quickly forced to learn to produce crops to ensure their survival. The stories of Native Americans teaching the settlers to plant and fertilize a corn crop are part of this country’s lore.

In the era of Thomas Jefferson (arguably the most illustrious farmer that this nation has produced), farmers made up about 90% of the work force. As late as 1900, almost 40% of the labor force was engaged in producing crops and livestock for food, feed, and fiber. Now, with less than one percent of our population claiming farming as a principal occupation, most U.S. citizens have little or no crop production experience. This section provides an overview of the principles and practices associated with production of the major crops grown in the United States.

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Last updated on July 29, 47489

Major Crops Grown in the United States

In round numbers, U.S. farmers produce about $ 143 billion worth of crops and about $153 billion worth of livestock each year. Production data from the year 2011 for major agricultural crops grown in this country are highlighted in the following table:

Major agricultural crops produced in the United States in 2011 (excluding root crops, citrus, vegetable, etc).

Crop	Harvested Area (million acres)	Cash Receipts from Sales ($ billion)
Corn (grain)	84	63.9
Soybeans	73.8	37.6
Hay	55.7	6.7
Wheat	45.7	14.6
Cotton	9.5	8.3
Sorghum (grain)	3.9	1.3
Rice	2.6	2.9

Source:
U.S. USDA. National Agricultural Statistics Service. Crop Production. March 8, 2013.

Corn: The United States is, by far, the largest producer of corn in the world, producing 32 percent of the world's corn crop in the early 2010s. Corn is grown on over 400,000 U.S. farms. The U.S. exports about 20 percent of the U.S. farmer's corn production. Corn grown for grain accounts for almost one quarter of the harvested crop acres in this country. Corn grown for silage accounts for about two percent of the total harvested cropland or about 6 million acres. The amount of land dedicated to corn silage production varies based on growing conditions. In years that produce weather unfavorable to high corn grain yields, corn can be "salvaged" by harvesting the entire plant as silage. Additionally, corn farming has become exponentially more efficient. If U.S. farmers in 1931 wanted to equivalently yield the same amount of corn as farmers in 2008, the 1931 farmers would need an additional 490 million acres!

According to the National Corn Growers Association, about eighty percent of all corn grown in the U.S. is consumed by domestic and overseas livestock, poultry, and fish production. The National Corn Growers Association also reports that each American consumes 25 pounds of corn annually. The crop is fed as ground grain, silage, high-moisture, and high-oil corn. About 12% of the U.S. corn crop ends up in foods that are either consumed directly (e.g. corn chips) or indirectly (e.g. high fructose corn syrup). Cornhas a wide array of industrial uses including ethanol, a popular oxygenate in cleaner burning auto fuels. In addition many household products contain corn, including paints, candles, fireworks, drywall, sandpaper, dyes, crayons, shoe polish, antibiotics, and adhesives.

Sources:

National Corn Grower's Association 2013 Report. N.p., 11 Feb. 2013. Web. <http://www.ncga.com/upload/files/documents/pdf/WOC%202013.pdf>. EXIT Disclaimer

U.S. USDA. Economic Research Service. Corn: Trade. N.p. Web. <http://www.ers.usda.gov/topics/crops/corn/trade.aspx#.UWbCQ7UX-w5>. EXIT Disclaimer

Soybeans: Approximately 3.06 billion bushels of soybeans were harvested from 73.6 million acres of cropland in the U.S. in 2011. This acreage is roughly equivalent to that of corn grown for grain (84 million acres in 2011).Soybeans rank second, after corn, among the most-planted field crops in the U.S. Over 279,110 (2007 Census of Agriculture) farms in the U.S. produce soybeans making the

U.S. the largest producer and exporter of soybeans. , accounting for over 50% of the world's soybean production and $3-4 billion in soybean and product exports in the late 2000s. Soybeans represent 50 percent of world oilseed production.

Soybeans are used to create a variety of products, the most basic of which are soybean oil, meal, and hulls. According to the United Soybean Board, soybean oil, used in both food manufacturing and frying and sautéing, is the number one edible oil in the U.S. Currently, soybean oil represents approximately 65 percent of all edible oil consumed in the United States, down from about 79 percent in 2000 due to controversy over trans-fat. Soybean oil also makes its way into products ranging from anti-corrosion agents to Soy Diesel fuel to waterproof cement. Over 30 million tons of soybean meal is consumed as livestock feed in a year. Even the hulls are used as a component of cattle feed rations.

Sources:

U.S. USDA. ERS. Characteristics and Production Costs of U.S. Soybean Farms. N.p., Mar. 2002. Web. < http://www.ers.usda.gov/media/761260/sb974-4_1_.pdf>. EXIT Disclaimer

U.S. USDA. ERS. Soybeans and Oil Crops: Background. Web. Accessed 4 Apr. 2013. < http://www.ers.usda.gov/topics/crops/soybeans-oil-crops/background.aspx#.UV3SYZMX-5Q>. EXIT Disclaimer

U.S. USDA. ERS. Soybeans and Oil Crops: Trade. Web. Accessed 4 Apr. 2013. < http://www.ers.usda.gov/topics/crops/soybeans-oil-crops/trade.aspx#US>. EXIT Disclaimer

United Soybean Board. New QUALISOY Efforts Reach out to Educate Soybean Value Chain. March 2013. Web. < http://www.unitedsoybean.org/issue_entry/march/>. EXIT Disclaimer

Hay: Hay production in the United States exceeds 119 million tons per year. Alfalfa is the primary hay crop grown in this country. U.S. hay is produced mainly for domestic consumption although there is a growing export market. Hay can be packaged in bales or made into cubes or pellets. Hay crops also produce seeds that can be used for planting or as specialized grains.

Wheat: Over 160,810 (2007 Census of Agriculture)farms in the United States produce wheat and wheat production exceeds 2.27 billion bushels a year. The U.S. produces about 10% of the world's wheat and supplies about 25% of the world's wheat export market. About two-thirds of total U.S. wheat production comes from the Great Plains (from Texas to Montana).

Wheat is classified by time of year planted, hardness, and color (e.g. Hard Red Winter (HRW)). The characteristics of each class of wheat affect milling and baking when used in food products. Of the wheat consumed in the United States, over 70% is used for food products, about 22% is used for animal feed and residuals, and the remainder is used for seed.

Cotton: Fewer than 18,605 (2007 Census of Agriculture) farms in the United States produce cotton (2007 Census of Agriculture). Cotton is grown from coast-to-coast, but in only 17 southern states, concentrated in California, Texas, and the Southeast. According to the National Cotton Council of America, farms in those states produce over 30% of the world's cotton with annual exports of more than $7 billion. The nation's cotton farmers harvest about 15 million bales or 7.3 billion pounds of cotton each year.

Cotton is used in a number of consumer and industrial products and is also a feed and food ingredient. Most of the crop (75 percent) goes into apparel, 18 percent into home furnishings and 7 percent into industrial products each year. Cottonseed and cottonseed meal are used in feed for livestock, dairy cattle, and poultry. Cottonseed oil is also used for food products such as margarine and salad dressing.

Sources:

"World of Cotton." National Cotton Council. N.p., n.d. Web. 04 Apr. 2013. <http://www.cotton.org/econ/world/>. EXIT Disclaimer

U.S. USDA. NASS. 2007 Census of Agriculture, Cotton Industry. Web. 27 Jan. 2010. <http://www.agcensus.usda.gov/Publications/2007/Online_Highlights/Fact_Sheets/Production/cotton.pdf>. EXIT Disclaimer

Grain sorghum: In the United States, 26,242 farms grow grain sorghum. Grain Sorghumis used primarily as an animal feed, but also is used in food products and as an industrial feedstock.

Industrial products that utilize sorghum include wallboard and biodegradable packaging materials. Worldwide, over half of the sorghum grown is for human consumption.

Some farmers grow sorghum as a hedge against drought. This water-efficient crop is more drought tolerant and requires fewer inputs than corn. Kansas, Texas, Nebraska, Oklahoma, and Missouri produce most of the grain sorghum grown in this country. The U.S. exports almost half of the sorghum it produces and controls 70% to 80% of world sorghum exports.

As much as one-third of domestic sorghum production goes to produce biofuels like ethanol and its various co-products. With demand for renewable fuel sources increasing, demand for co-products like sorghum-DDG (dry distillers grain) will increase as well due the sorghum's favorable nutrition profile.

Sources:
"Biofuels." Sorghum Checkoff. N.p., Apr. 2012. Web. 04 Apr. 2013. <http://sorghumcheckoff.com/sorghum-markets/biofuels/>. EXIT Disclaimer

U.S. USDA. ERS. Feed Grains: Yearbook Tables; Overview: Web. Accessed 10 Apr. 2013. < http://www.ers.usda.gov/data-products/feed-grains-database/feed-grains-yearbook-tables.aspx#26773> EXIT Disclaimer

Rice: Just over 6,084 (2007 Census of Agriculture)farms produce rice in the United States. Those farms are concentrated in four regions including the Arkansas Grand Prairie, the Mississippi Delta (parts of Arkansas, Mississippi, Missouri, and Louisiana), the Gulf Coast (Texas and Southwest Louisiana), and the Sacramento Valley of California. There are three types of rice grain; long, medium, and short, and each growing region harvests the type of rice best suited for the land. U.S. rice production accounts for just under 2% of the world's total, but this country is the second leading rice exporter with 10% of the world market.

About 50 - 60% of the rice consumed in the U.S. is for direct food use; another 18% goes into processed foods, 10-12 percent goes into pet food, and most of the rest (about 10 percent) goes into beer production.

Source:
U.S. USDA. ERS. Rice: Trade. Web. Accessed 4 Apr. 2013. < http://www.ers.usda.gov/topics/crops/rice/trade.aspx#.UV3eZpMX-5Q>. EXIT Disclaimer

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Crop Production Systems

Major agricultural crops produced in the United States in 2011.		
Crop	**Harvested Area (million acres)**	**Cash Receipts from Sales ($ billion)**
Corn (grain)	84	63.9
Soybeans	73.8	37.6
Hay	55.7	6.7
Wheat	53.0	14.6
Cotton	9.5	8.3
Sorghum (grain)	3.9	1.3
Rice	2.6	2.9

Of the seven crops listed, six are annual crops that must be replanted each year (only hay crops would be left in place from year to year). The process of cultivating crops typically begins with tillage of the soil. Although tillage can serve a number of functions within a crop production system, the most fundamental function is to create conditions that will ensure good contact between seed and soil at the time of seed planting and the ready availability of water to the seed during germination. The degree to which the soil is disturbed by tillage prior to seed planting provides a means of categorizing crop production within a range of tillage systems. These systems range from ***no-tillage*** in which there is not soil disturbance in a field except during the process of planting a crop to ***conventional tillage*** in which multiple tillage operations can extend over many months and take place before, during, and after planting. Crop production systems that involve pre-plant tillage but maintain residues from a previous crop on the soil surface are referred to as ***conservation tillage*** practices.

For the major row crops produced in the United States, farmers use a range of production practices. Conventional tillage (also known as ***intensive tillage***) usually involves a series of field operations that result in a residue-free soil surface at the time a crop is planted. Conventional tillage systems developed in this country to take advantages of the following benefits:

- Creation of a seedbed or root bed
- Control of weeds or the removal of unwanted crop plants
- Incorporation of plant residues into the soil profile
- Incorporation of fertilizers and/or soil-applied pesticides
- Establishment of specific soil surface configurations for planting, irrigating, drainage, and/or harvesting operations

The major disadvantage of conventional tillage is the susceptibility of "unprotected" soil to erosion by water or by wind. Tillage is also energy-intensive, requiring large inputs of machine work and numerous trips across a field during a single growing season. Conventional tillage was "standard operating procedure" in the era before effective chemical weed and pest control strategies were available to farmers.

Concerns about soil erosion led to the development of crop production strategies that retained crop residues on the soil surface. Conservation tillage requires more sophisticated implements that are capable of producing a seedbed while leaving a portion of surface residues undisturbed. Reduced tillage usually leaves 15% to 30% residue coverage on the soil surface. True conservation tillage is any tillage method that leaves at least 30% residue coverage on the soil after a crop has been planted. It can be accomplished through no-till, strip-till, ridge-till, or mulch till practices.

Organic Farming

Organic farming is a small, but growing, segment of U.S. agriculture. USDA estimated the value of retail sales of organic foods at $6 billion in 1999 with about 12,200 organic farmers nationwide, most with small-scale operations. Almost a decade later, USDA's 2008 Organic Production Survey counted 14,540 organic farms. In 2008, the certified and exempt organic farms totaled $3.16 billion in sales. Organic farming encompasses both crop and animal production and is defined as "ecological production management system that promotes and enhances biodiversity, biological cycles and soil biological activity."'Organic' is a labeling term that denotes products produced under the authority of the U.S. Organic Foods Production Act. "The principal guidelines are to use materials and practices that enhance the ecological balance of natural systems. Organic agriculture practices do not ensure that products are completely free of residues; however, methods must be used to minimize contamination." Organic food handlers, processors and retailers must adhere to standards that maintain the integrity of organic agricultural products. This includes practices such as minimizing or eliminating the use of herbicides in crop production and antibiotics in animal production.

Source:

U.S. USDA. NASS. 2007 Census of Agriculture, 2008 Organic Production Survey. Web. 27 Jan. 2010. <*http://www.agcensus.usda.gov/Publications/2007/Online_Highlights/Fact_Sheets/Practices/organics.pdf*>.
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U.S. USDA. National Agricultural Statistics Service. Crop Production. March 8, 2013.

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Soil Preparation

Source: USDA - Natural Resources Conservation Service

Prior to planting, the soil needs to be prepared, usually by some form of tillage or chemical "burn-down" to kill the weeds in the seedbed that would crowd out the crop or compete with it for water and nutrients. Tillage methods can be divided into three major categories, depending on the amount of crop residue they leave on the surface. Residue slows the flow of runoff that can displace and carry away soil particles.

- **Conventional tillage** - Up until about 20 years ago, the standard tillage practice for corn was use of the moldboard plow for primary tillage followed by several secondary tillages and mechanical cultivation after the crop was up. Today's farmers have turned away from moldboard tillage because moldboard plows tend to leave minimal crop residue on the soil surface after tillage and in turn, decreases valuable organic matter. By reducing moldboard plow use, and increasing organic matter in the soil, the soil becomes less erodible soil, looser, and holds more water. Today, a very low percentage of row crops are planted with the moldboard plowand mechanical cultivation is often limited to one, or no operations.
- **Reduced tillage** is usually done with a chisel plow and leaves 15% to 30% residue coverage on the soil.
- **Conservation tillage** leaves at least 30% residue coverage on the soil. Conservation tillage methods include no-till, where no tillage is done at all and seeds are placed directly into the previous season's crop residue; strip-till, in which only the narrow strip of land needed for the crop row is tilled; ridge till; and mulch till.

Herbicides might be used in all these methods to kill weeds. In no-till systems, the herbicide is applied directly on last season's crop residue. In the other methods, some soil preparation takes place before the herbicide is applied. A common myth is that more herbicide is used with conservation tillage methods, but in fact farmers rely on herbicides for weed control under all tillage systems, and the amount used is more or less independent of tillage method.

Source:

U.S. USDA. Economic Research Service.Farmers Now Part of the Global Warming Solution as U.S. Agriculture Becomes Net Carbon Sink. N.p., 17 May 1999. Web. <http://www.ars.usda.gov/is/pr/1999/990517.htm?pf=1>. EXIT Disclaimer

Revegetation Equipment Catalog. N.p., n.d. Web. <http://reveg-catalog.tamu.edu/07-Site%20Preparation.htm>. EXIT Disclaimer

Soil Preparation Operations and Timing

Tillage can occur anytime between harvest of the previous year's crop and spring planting. In the eastern Corn Belt, most tillage is usually done between March and May for corn, and can be as

Source: USDA - Natural Resources Conservation Service

late as early June for soybeans. In some cases, tillage is done in the fall, after harvest. In southern states, planting can be considerably earlier or later because of their longer growing season. The optimum time for tillage (to prevent soil erosion) is just before planting. However, wet spring weather can often make it difficult to get equipment into the field as early as needed to optimize yield. Late planting can seriously reduce yields. For example, in the eastern corn belt, corn yields are reduced by 1 bu/acre for each day after May 1 that planting is delayed.

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Equipment Used for Soil Preparation

Farm tractor and tillage implementation
Source: Daniel R. Ess, Purdue University

Tractor - a traction machine that provides mechanical, hydraulic, and/or electrical power to implements to perform a wide range of crop production and handling operations. Tractors are most often used to perform drawbar work (pulling equipment through the field) and PTO (power take-off) (power to rotate equipment components) work. Tractors can be equipped with rubber tires, rubber belts, or steel tracks. A modern farm tractor is almost always equipped with a diesel engine and tractor size is measured by the amount of power that the tractor can produce at the PTO. Tractor sizes range from those with less than 40 PTO horsepower to ones that produce more than 500 horsepower. The cost of a large modern tractor can is between $200,000 and $300,000.

Plow - an implement used to perform primary tillage. A number of types of plows are in common use including the *moldboard plow*, the *chisel plow*, and the *disk plow*.

> The **moldboard plow** has a large frame that is equipped with a series of "bottoms," each of which consists of a steel coulter to slice through residue followed closely by a steel share that cuts the soil and an attached moldboard that is used to raise and turn over the cut "slice" of soil.
>
> **Disk plows** work in a similar manner to laterally displace and invert soil through the use of concave steel disk blades.
>
> **Chisel plows** use curved shanks to penetrate and "stir" the soil without inverting a soil layer. Chisel plows cause less residue disturbance than moldboard plows and are often used in conservation tillage systems.

Disk Harrows (or Disk) - are implements that uses steel blades to slice through crop residues and soil. Disk blades are mounted in groups or gangs that rotate as they move forward through the soil. Front gangs move soil toward the outside of the disk while rear gangs move soil back toward the center of the disk. A disk can be used for primary or secondary tillage.

Field Cultivator -an implement used to perform secondary tillage operations such as seedbed preparation and weed eradication. Field cultivators are equipped with steel shanks that are typically spring mounted to permit the shank to move within the soil and shatter clods. Field cultivators are constructed similarly to chisel plows, but are more lightly built. Large chisel plows can exceed 50 feet in width in the field.

Source:
Machinery Cost Estimates: Tractors. Farmdoc, 2008. Web. 11 Apr. 2013. <*http://www.farmdoc.illinois.edu/manage/machinery/machinery_tractors.html*>. EXIT Disclaimer

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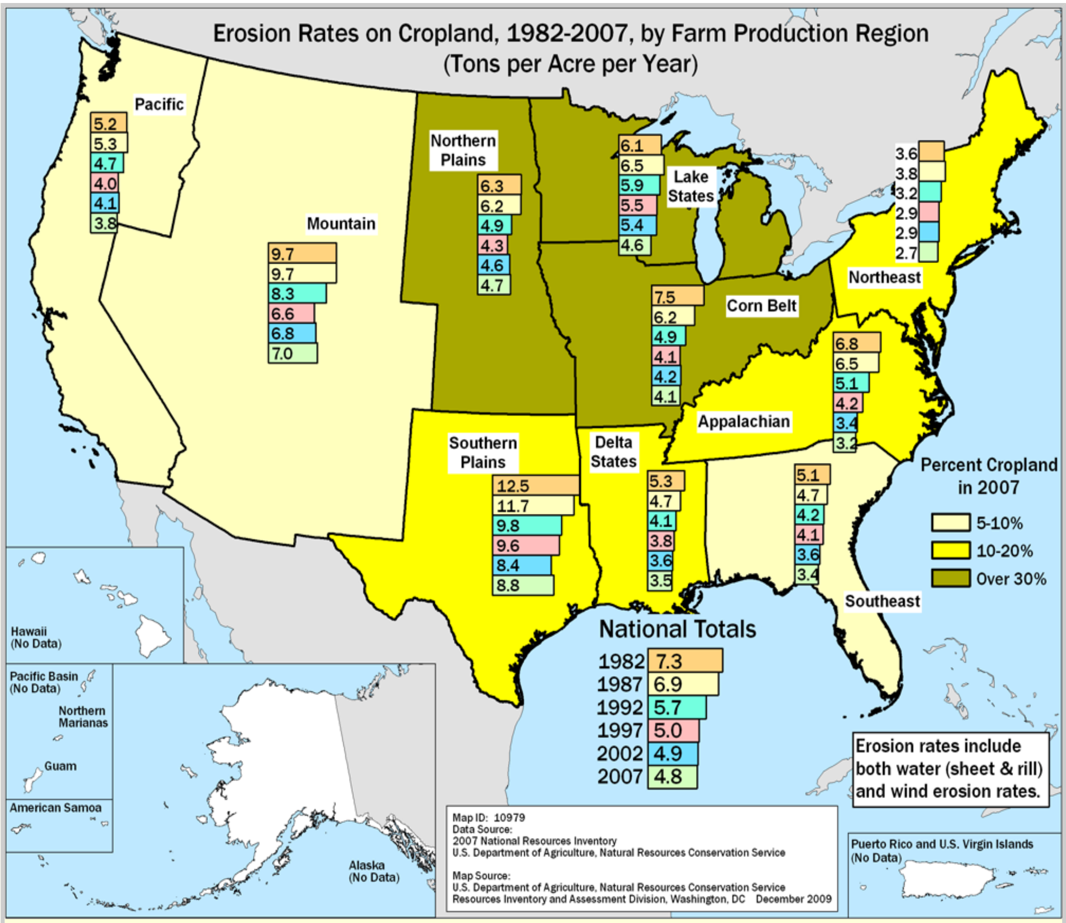
Environmental Concerns Related to Soil Preparation: Soil Erosion

Source: USDA - Natural Resources Conservation Service

The major environmental concern related to soil preparation is erosion. Soil erosion is a natural process that occurs when the actions of water and/or wind cause topsoil to be removed and carried elsewhere.

Soil erosion can be caused by either water or wind. In many

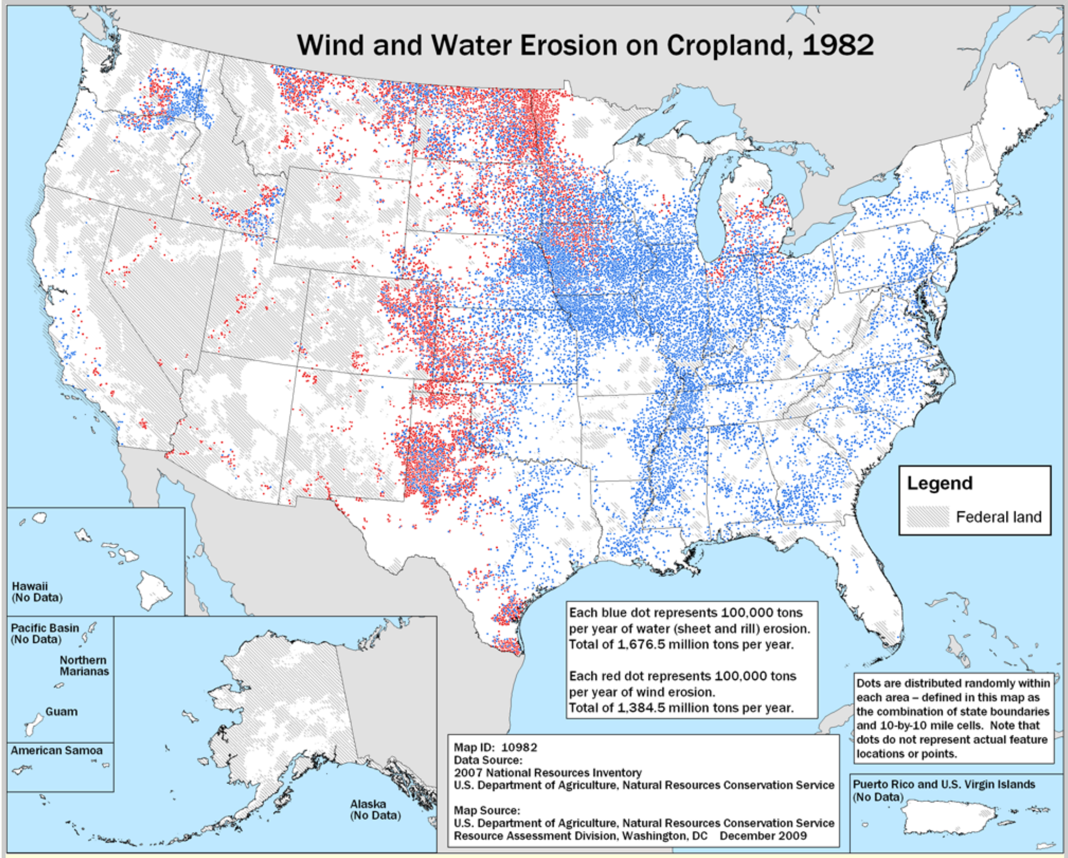


Source: USDA-NRCS

agricultural areas, soil is eroding at a rate of several tons of soil per acre per year or higher. The map shows erosion rates on cropland from 1982 through 2007 by farm production regions. . This map only includes erosion rates on cropland.

The good news is that soil erosion in the U.S. is decreasing. From 1982-2007, soil erosion declined about 40% in the U.S., due to government conservation programs, technological advances, and extension education efforts.

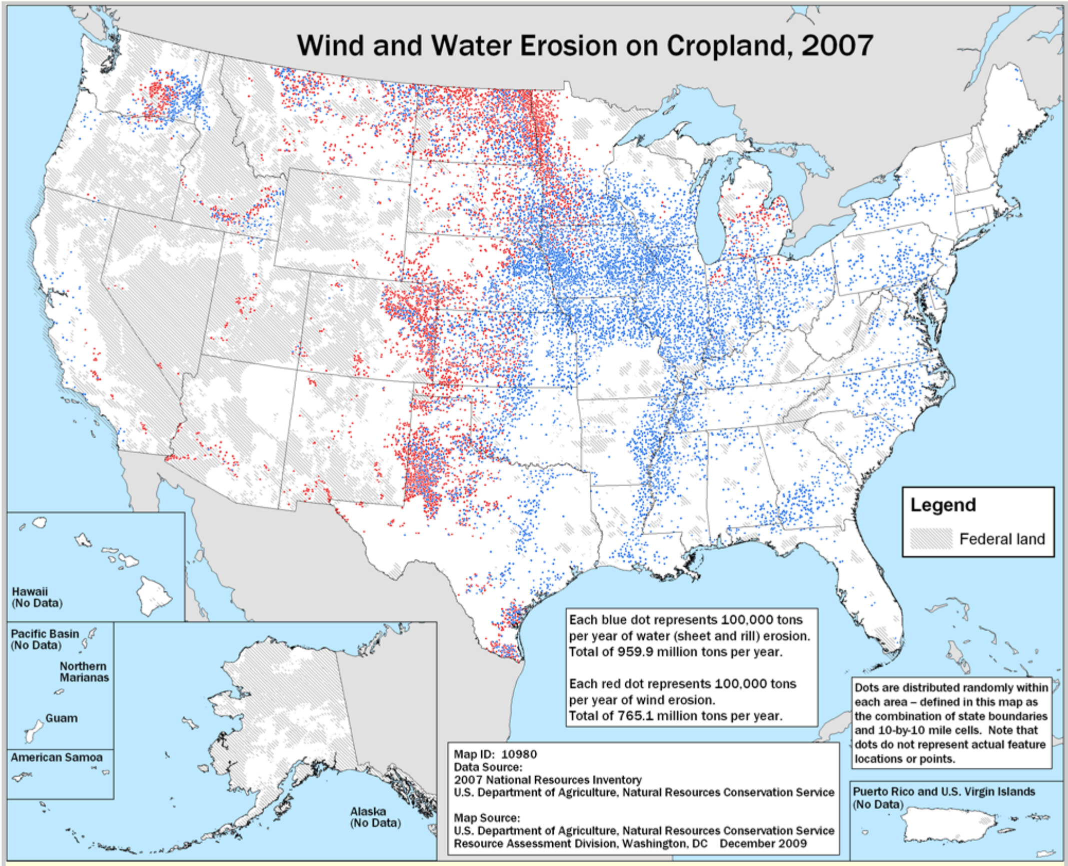
The following maps show the contrast of wind and water erosion in 1982 and 2007.There is a significant decrease in wind and water erosion on cropland in 2007.



Source: USDA-NRCS

Water erosion is caused by the erosive power of raindrops falling on the soil (particularly if the soil is not covered by vegetation or residue) or by surface runoff. Raindrops cause the less severe forms of erosion (know as sheet and interrill erosion). Severe erosion problems such as rill erosion, channel erosion, and gully erosion can result from concentrated overland flow of water.

Wind erosion is



Source: USDA-NRCS

particularly a problem in windy areas when the soil is not protected by residue cover. Wind erosion in the United States is most widespread in the Great Plains states, as can be seen in the map at right. Wind erosion is a serious problem on cultivated organic soils, sandy coastal areas, alluvial soils along river bottoms, and other areas in the United States.

Impacts of soil erosion

Soil erosion has both on-farm impacts (reduction in yield and farm income) and off-farm impacts (contaminated water due to the sediment and associated contamination from nutrients and pesticides carried on the soil particle).

On-farm impacts due to the loss of soil and nutrients include:

- lower fertility levels
- development of rills and gullies in the field
- poorer crop yields
- less water infiltration into the soil
- more soil crusting
- more runoff in the spring and after storms

When fertile topsoil is lost, nutrients and organic matter needed by crops often are removed along with it. Erosion tends to remove the less dense soil constituents such as organic matter, clays, and silts, which are often the most fertile part of the soil. However, the loss in productivity caused by erosion has not been so evident in many parts of the U.S., since it has been compensated for over the years by improved crop varieties and increased fertilization.

Soils can tolerate a certain amount of erosion without adverse effects on soil quality or long-term productivity, because new soil is constantly formed to replace lost soil. This tolerable level is known as "T" and generally ranges from 3 to 5 tons per acre per year. Goals for reducing soil erosion often use the "T" value as a target, because erosion rates below T should maintain long-term productivity of the soil.

Off-farm impacts occur when the eroded soil is deposited elsewhere, along with nutrients, pesticides or pathogens that may be attached to the soil. The tolerable"T" value described above does not take into consideration the off-farm or downstream impacts. Soil eroded by water has effects such as:

- eroded soil deposited in depressions and adjacent fields
- decreased water quality downstream
- decline of downstream aquatic ecosystems because of sedimentation and the addition of nutrients, pesticides, and bacteria associated with the soil
- clogged drainage ditches and other costly problems

Off-farm impacts of wind erosion are due to the blowing soil, which can reduce seedling survival and growth (seed cover), increase the susceptibility of plants to certain types of stress, contribute to transmission of some plant pathogens, and reduce crop yields. Dust affects air quality, obscures visibility which can cause automobile accidents, clogs machinery, and deposits in road ditches, where it can impact water quality.

Source:
U.S. USDA. National Resources Conservation Service.Soil Erosion on Cropland 2007. N.p., 2007. Web. <http://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/technical/nra/nri/?cid=stelprdb1041887>. EXIT Disclaimer

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Best Management Practices to Reduce Erosion

Source: USDA-Natural Resources Conservation Service

Conservation tillage leaves at least 30% residue cover on the ground. This simple, low-cost practice can have a huge impact on the amount of soil eroded. Because of energy savings and obvious improvements in soil quality that can result from conservation tillage, it has been widely adopted across the Midwest. In Indiana, for example, the use of conservation tillage since 1990 has resulted in the accomplishment of 75 percent of the state losing soil at or below "T" (the tolerable level of soil loss) (Indiana State Department of Agriculture).There is still room for improvement, however. This map shows the percent of U.S. crop land currently in conservation tillage. Percentages are generally higher for soybeans than for corn or other crops.

Source:
Indiana State Department of Agriculture; Soil Conservation District. Indiana Government, n.d. Web. <http://www.in.gov/isda/2383.htm>. EXIT Disclaimer

Source: USDA - Natural Resources Conservation Service

Contour farming and strip cropping is the practice of planting along the slope instead of up-and-down slopes, and planting strips of grass between row crops.

Cover crops are crops such as rye that grow in late fall and provide soil cover during winter. By

Source: USDA - Natural Resources Conservation Service

providing a cover to the soil, winter soil erosion from both air and water can be greatly reduced.

Source: USDA - Natural Resources Conservation Service

Grassed waterways protect soil against the erosive forces of concentrated runoff from sloping lands. By collecting and concentrating overland flow, waterways absorb the destructive energy that would otherwise cause channel erosion and gully formation.

Source: USDA - Natural Resources Conservation Service

Terraces are structural practices that can reduce erosion by holding back the water and routing it along a channel at a lower velocity to where it can be safely discharged, usually into a grassed waterway.

Source: USDA - Natural Resources Conservation Service

Windbreaks are the best way to protect soil from wind erosion. They can be in the form of rows of shrubs or trees.

Source: USDA - Natural Resources Conservation Service

Windbreaks

Source: USDA - Natural Resources Conservation Service

Grass barriers can prevent wind erosion by slowing the wind.

Source: USDA - Natural Resources Conservation Service

"**Living snow fences**" prevent wind erosion by slowing the wind.

Photos courtesy of USDA-Natural Resources Conservation Service, except for the four pictures for practices controlling wind erosion, from the ARS Wind Erosion Unit. EXIT Disclaimer

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National Agriculture Compliance Assistance Center (Ag Center)

Planting

Operations and Timing

Most crops in the U.S. are planted in the spring. The exception is winter wheat, which is planted across the U.S. but concentrated in the central and southern Great Plains and the Pacific Northwest. Winter wheat is planted in the fall, goes into dormancy during the winter, and is harvested for grain the following spring.

The table below shows the "usual planting dates" for six major crops. Planting dates vary by region, following the weather. For simplification, the usual range of planting dates for the top-producing states are shown; if planting dates vary widely, more than one is given. The actual planting dates may begin earlier and extend later, but these are considered the most common. Over the past ten years, planting dates have typically shifted a couple days backward.

Source: USDA NASS Field Crops Usual Planting and Harvesting Dates (October 2010) (PDF) (51 pp, 1.96 MB, About PDF) EXIT Disclaimer

Crop	Usual Planting Dates (most active period) in Top-Producing States	Top Producing States	Total Acreage (million acres)
Barley	Apr 7 - May 11 (ID, MT); Apr 26 - May 25 (ND)	ND, ID, MT	3.11
Corn (grain)	Apr 25 - May 18 (IA); May 5 - May 26 (ID)	IA, ID	79.6
Hay, alfalfa	NA	CA	21
Wheat (spring)	Apr 24 - May 25	ND	13
Soybeans	May 8 - June 12	IA, IL, MN	77.5
Wheat (winter)	Sep 1 - Oct 20	KS, CO, WA	43

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Equipment Used

Drills - are implements used to plant crops in closely spaced rows (typically four to ten inches); drills are commonly used for cereal crops such as wheat and can be used to plant soybeans. Grain drills are typically equipped with disks to open a small trench in the soil, a metering system to deliver a measured, controlled amount of seed to drop tubes which guide the seed to the seed trench. There must

A grain drill on display at a farm machinery show
Source: Daniel R. Ess, Purdue University

be some means (wheels or drag chains) of gently closing the seed trench with soil to cover the seeds.

Tractors - are traction machines that provide mechanical, hydraulic, and/or electrical power to implements to perform a wide range of crop production and handling operations. Tractors are most often used to perform drawbar work and PTO (power take-off) work. Tractors can be equipped with rubber tires, rubber belts, or steel tracks. A modern farm tractor is almost always equipped with a diesel engine and tractor size is measured by the amount of power that the tractor can produce at the PTO. Tractor sizes range for those with less than 40 PTO horsepower to ones that produce more than 500 horsepower. The cost of a large tractor is between $200,000 and $300,000.

Farm tractor and tillage implementation
Source: Daniel R. Ess, Purdue University

A twelve-row planter working in a conventionally-tilled field

Source: Source: Daniel R. Ess, Purdue University

Planters - are implements used to plant row crops (typically in row spacings ranging from 10 to 40 inches). Planters open a seed trench, meter seeds one-at-a-time, drop seeds into the seed trench, and gently cover the seed. Some planters can cut through residues and till a small strip of soil in each row at the time of planting. Planters can also be equipped to apply fertilizer, pesticides, and herbicides during planting. Planters come in sizes as large as sixty feet wide - that is twenty-four rows with a typical 30-inch row spacing, or thirty-six rows with a narrower 20-inch row spacing. Such large planters can cost in excess of $140,000.

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Potential Environmental Concerns

One current controversy related to planting is the choice of seeds. More and more of the seeds planted in the U.S. are genetically modified (GMOs) to make crop production more efficient, to better withstand environmental stresses such as drought, flood, frost, or extreme temperatures, to protect crops against pests such as weeds, insects, or diseases, and to be resistant to herbicides.

Environmental concerns related to GMOs include increased pest resistance, development of weed tolerance, and decreased genetic diversity. For example, insects exposed to a genetically engineered crop with the Bt gene (Bt is a natural toxin taken from the *Bacillus* *thuringiensis* bacteria, which is toxic to a number of insects) may become more resistant to pesticides. This is a serious concern for organic farmers who use Bt on their crops as an alternative to chemical insecticides. Another environmental concern is that, over time, some weed species could develop a tolerance to herbicides that are applied repeatedly to a crop tolerant to that herbicide. A transgenic crop might cross with another crop or weed, resulting in an undesirable crop or weed species. Others are concerned that reliance on a few genetically modified crops may reduce biological diversity. Also, a lack of genetic diversity in the food supply could increase the risk of catastrophic crop failure and threaten our food security.

Source:
Crops; Wheat. GMO Compass, 4 Dec. 2008. Web. <*http://www.gmocompass.org/eng/grocery_shopping/crops/22.genetically_modified_wheat.html*>.
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Best Management Practices

To reduce the risk of insect resistance to Bt, a certain percentage of crop acreage on every farm is normally devoted to non-genetically modified variety.

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Nutrient Management

Source: USDA - Natural Resources Conservation Service

Plant nutrients, which come primarily from chemical fertilizers, manure, and in some cases sewage sludge, are essential for crop production. When applied in proper quantities and at appropriate times, nutrients (especially nitrogen, phosphorus, and potassium) help achieve optimum crop yields. However, improper application of nutrients can cause water quality problems both locally and downstream. **Nutrient management** is the practice of using nutrients wisely for optimum economic benefit, while minimizing impact on the environment.

Operations and Timing

Source: USDA - Natural Resources Conservation Service

Farmers sometimes apply fertilizer soon after the previous year's harvest, since equipment and labor are usually available then. Fertilizer can also be applied in the spring, near the time it is needed by the plant, usually at planting, or as side-dress after the crop has started to grow. In general, the greatest efficiency results when fertilizer is applied at planting time or during the early part of growing season.

Proper timing is most important with nitrogen fertilizer. In some locations, a large part of the nitrogen may be lost if it is applied too long before the crop is planted, particularly if applied the previous fall before soil temperature drops to below 50° F. Phosphorus application is also most efficient when made at or near planting time, especially with soils low in phosphorus. Time of application is less critical with potassium than with nitrogen or phosphorus.

Knowing how much fertilizer to apply can be difficult. Soil tests are used to determine soil deficiencies for nutrients such as phosphorus and potassium. It is more difficult to determine nitrogen needs in advance, however, and most farmers simply use standard nitrogen recommendations based on crop yield goals. Recommendations are provided by Cooperative Extension services in most states. Other farmers get recommendations from fertilizer dealers and crop consultants.

Common nitrogen fertilizers are anhydrous ammonia (82% nitrogen), urea (45% nitrogen), urea and ammonium nitrate solutions (28% nitrogen), and ammonium nitrate (33.5% nitrogen). Manure can be an excellent source of Nitrogen (N), Phosphorous (P), and Potassium (K) plant nutrients. Every load of manure is different, however, so manure testing is necessary to accurately estimate nutrient contents.

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Equipment Used

Tractors - are traction machines that provide mechanical, hydraulic, and/or electrical power to implements to perform a wide range of crop production and handling operations. Tractors are most often used to perform drawbar work and PTO (power take-off) work. Tractors can be equipped with rubber tires, rubber belts, or steel tracks. A modern farm tractor is almost always equipped with a diesel engine and tractor size is measured by the amount of power that the tractor can produce at the PTO. Tractor sizes range for those with less than 40 PTO horsepower to ones that produce more than 400 horsepower. The cost of a large tractor can exceed $200,000.

Farm tractor and tillage implementation
Source: Daniel R. Ess, Purdue University

Sprayers - are implements or vehicles used to apply liquid crop chemicals, most often herbicides, and increasingly, fertilizers. Sprayers typically include a tank, pump, plumbing, valves, a boom, and nozzles. Sprayers can be mounted on a tractor or other implement, pulled by a tractor, self-propelled, or mounted on airplanes or helicopters. Large self-propelled sprayers that incorporate technologies to vary application rates within a field can cost more than $250,000.

Planters - are implements used to plant row crops (typically in row spacing ranging from 10 to 40 inches). Planters open a seed trench, meter seeds one-at-a-time, drop seeds into the seed trench, and gently cover the seed. Some planters can cut through residues and till a small strip of soil in each row at the time of planting. Planters can also be equipped to apply liquid fertilizer, pesticides, and herbicides during planting. Planters come in sizes as large as sixty feet wide - that is twenty-four rows with a typical 30-inch row spacing, or thirty-six rows with a narrower 20-inch row spacing. Such large planters can cost in excess of $100,000.

A twelve-row planter working in a conventionally-tilled field
Source: Daniel R. Ess, Purdue University

Spreaders - are implements or vehicles used to apply dry crop chemicals, most often fertilizers. Spreaders typically include a bed, conveyor, and either a set of spinning disks to distribute material over a wide area or a pneumatic system to push material through openings in a boom for distribution on the ground. Spreaders can be mounted on a tractor, pulled by a tractor, self-propelled, or mounted on airplanes. Large self-propelled spreaders that incorporate technologies to vary application rates of multiple dry chemicals within a field can cost more than $250,000.

Toolbars - are implements that can use a range of soil-engaging tools typically mounted to a long steel bar of rectangular cross-section. A toolbar equipped with a set of uniformly spaced steel discs can be used to create trenches in the soil into which liquid fertilizers can be applied or gaseous fertilizers (such as anhydrous ammonia) can be injected. Toolbar fertilizer applicators lend themselves to sidedress application in standing crops.

A tractor-drawn toolbar being used to inject anhydrous ammonia into the soil. The wagon mounted tank attached to the toolbar supplied ammonia.
Source: Daniel R. Ess, Purdue University

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Potential Environmental Concerns

Water quality problems can occur when nutrients are added to the soil at a time when they could be removed in surface runoff from rainfall or snow melt at rates exceeding that removed by the crop, or if applied at times that they cannot be utilized by the crop.

When nitrogen or phosphorus are present in lakes or rivers at a high concentration, a condition called "eutrophication" or biological enrichment can occur. High nitrogen from the Mississippi River has been blamed for a hypoxic or "dead" zone in the Gulf of Mexico, where excess algae grow in response to the enriched nutrient solution and few fish can be found. When the algae die, their decomposition consumes enough dissolved oxygen to suffocate fish and other animal life. Sources of nitrogen contributing to the problem include agricultural runoff, sewage treatment plants, atmospheric nitrogen, and other sources.

Excessive nitrate in ground water can present a direct health hazard to very young infants. Ingestion of nitrate (NO_3) can bind with hemoglobin in the infant's bloodstream and cause a condition called methemoglobinemia or "blue baby" syndrome. Nitrate does not bind to soil particles and is quite soluble, making it susceptible to leaching into groundwater if not used by the crop.

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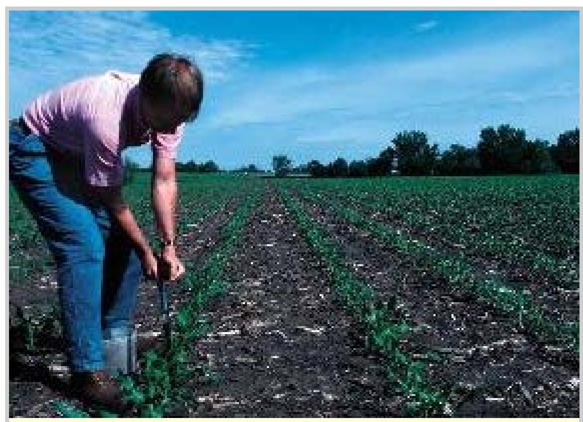
Source: USDA - Natural Resources Conservation Service

- Use **regular soil tests** to determine nutrient needs, and apply only the amount of nutrients needed by the crop to be grown. Site-specific nutrient application varies the amount of nutrients within fields based on a series of soil tests and global positioning equipment.
- Use **manure tests** to determine nutrient content, and take credit for the nutrient content of manure.
- Use **conservation tillage and other erosion-control practices** to minimize loss of phosphorus that is attached to the soil. (See Best Management Practices for Soil Erosion).
- **Improve timing** of fertilizer application, applying nutrients just before they are needed by the crop. Most of the nitrogen is needed by corn after the plant is three to four weeks old. The most efficient method of applying N fertilizer is as sidedress after planting.
- Look for a low soil test to decide which field to apply manure on and base manure application rate on the manure test for N.

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Pest Management

Source: USDA - Natural Resources Conservation Service

Pesticides are used to control pests, which include insects, mice and other animals, unwanted plants (weeds), fungi, or microorganisms like bacteria and viruses. Though often misunderstood to refer only to insecticides, the term pesticide also applies to herbicides (that control weeds), fungicides (that control fungi), and substances used to control other pests.

Pesticides are used on the vast majority of U.S. cropland. According to agricultural chemical usage statistics from USDA, herbicides were applied to 98% of corn acreage and 96% of soybean acreage in 2001.

Operations and Timing

Source: USDA - Natural Resources Conservation Service

Pesticides are either applied prior to planting ("preplant"), before the crop emerges ("preemergence") or after the plant has emerged ("postemergence").

The label includes information on when the product should be applied. Labels often list the minimum number of days which must pass between the last pesticide application and harvest of crops or grazing by livestock. These are intervals set by EPA to allow time for the pesticide to break down in the environment, preventing residues on food, feed, or animal products.

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Application Practices

More and more producers have their pesticides applied by commercial applicators. This practice has many advantages, such as not having to store pesticides on-farm, avoiding having to be certified as pest control applicators, and benefiting from the dealer's record keeping.

Sprayers - are implements or vehicles used to apply liquid crop chemicals, most often herbicides, and increasingly,

A tractor-sprayer-field cultivator combo that performs tillage and crop chemical application operations simultaneously
Source: Ag-Chem, a division of AGCO Corporation

fertilizers. Sprayers typically include a tank, pump, plumbing, valves, a boom, and nozzles. Sprayers can be mounted on a tractor or other implement, pulled by a tractor, self-propelled, or mounted on airplanes or helicopters. Large self-propelled sprayers that incorporate technologies to vary application rates within a field can cost more than $250,000.

A self-propelled sprayer broadcasting crop chemicals in the field
Source: Ag-Chem, a division of AGCO Corporation

A pull-type sprayer and tractor
Source: Ag-Chem, a division of AGCO Corporation

- **Aerial Application**

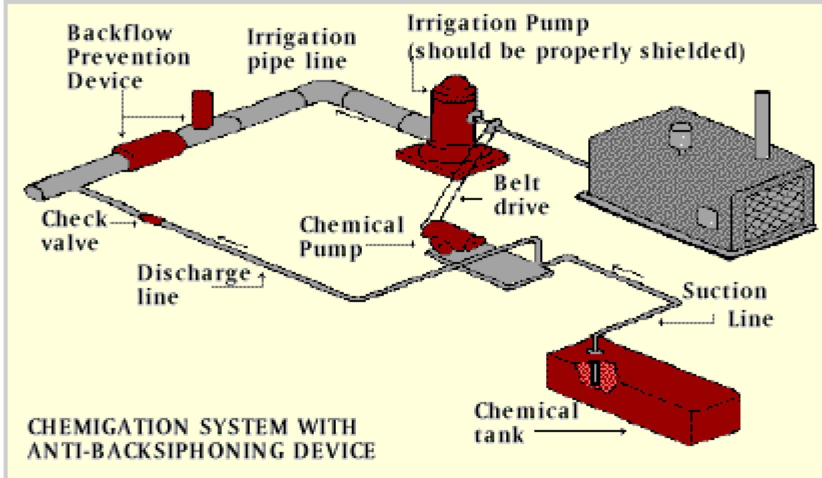
Aerial application of pesticides has several advantages for the modern agricultural producer. When properly managed, aerial application offers speed of dispersal, accessibility to crops on areas where ground equipment cannot operate, and reasonable cost. In many cases, aerial application also allows more timely applications and, therefore, better utilization of pesticides.

Aerial application programs require good cooperation between the pilot and grower. It must also recognize the potential dangers to people, other crops and the environment.

Limitations on aerial application include weather hazards, fixed obstacles such as radius towers, field size and shape, the distance from the point of application to the landing area, and the danger of contamination of nearby areas due to drift or misapplication. Careless applications can be harmful to the crop, the grower and the applicator.

Source: University of Kentucky - Applicator Training Manual for Aerial Application of Pesticides EXIT Disclaimer

- **Chemigation**



A growing practice in many areas of the country is the application of pesticides through irrigation systems, often termed "chemigation." Although there are systems specifically designed for chemigation, in most cases an existing irrigation system is modified to mix the chemical with irrigation water. Fertilizers are generally stored in large tanks located near wells drawing ground water for irrigation. Fertilizers flow from the storage tanks into the irrigation water. Concerns about groundwater contamination from this practice arise from the fact that accidental backflow or siphoning of chemicals into the well can occur when the irrigation pumping system shuts down unexpectedly.

Source: EPA - Software for Environmental Awareness, Pesticide Storage and Handling Practices on the Farm, Chemigation

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Potential Environmental Concerns

The likelihood of pesticide contamination of groundwater and water wells depends partly on the geologic and hydrologic characteristics that vary from location to location as well as on pesticide characteristics.

Contamination of drinking water wells by pesticides is usually the result of one or more of the following:

- Improper application of pesticides on the fields
- Careless handling of the pesticides
- Careless storage of pesticides
- Careless disposal of unused pesticides and pesticide containers.

Ideally, pesticides should be applied at just the right time to control pests, then degrade into harmless compounds in the soil, air, or water without contaminating the environment. However, this is difficult to attain. Pesticides have the potential to harm the environment by injuring nontarget plants and animals, leaving harmful residues, or moving from the application site into the surrounding environment.

Some pesticides (called accumulative pesticides) can build up in the bodies of animals over time, including humans. These persistent pesticides stay in the environment without change for long periods of time. Pesticides which break down quickly in the environment to form harmless materials area called non-persistent. Most agricultural pesticides used in the U.S. are broken down easily by microorganisms or sunlight.

Pesticides come into contact with nontarget insects and plants through drift, runoff, or spills. Drift to nearby areas may injure fish, birds, other wildlife, and sensitive plants. It can also damage nearby crops, forests, or landscape plantings. Poorly timed applications can kill bees and other pollinators which are working in the area, or beneficial parasites and predators that help control pests naturally .

Pesticides have the potential to contaminate both surface waters (lakes, streams, ponds, rivers) and ground water.

Pesticides can move into surface water through **surface runoff**, attached to eroding soil particles, or from tile drainage systems. Concerns about pesticide movement in surface runoff include pesticide persistence, time between application and a runoff event, and any management practices in place that reduce surface runoff from the field.

Pesticides can also leach into **ground water.** The soil type plays an important role in determining the extent to which pesticides leach to ground water. Sandy soils greatly increase the risk of pesticide loss, because they have very limited capacities to adsorb pesticides. In karst areas, pesticides can easily reach ground water through sinkholes. Pesticides may also enter ground water via improperly constructed wells or by back-siphoning into wells while mixing and filling the applicator chemicals. Cases of ground water contamination have also been traced to spills and improper handling of pesticides (such as improper disposal of excess spray and rinsate from cleaning equipment).

The EPA has labeled some commonly used pesticides as having a high probability of moving into ground water when applied to very porous soils. Some pesticides are required to have a statement on their label such as "This product is a chemical that can travel through the soil and contaminate ground water, which may be used as drinking water. This product has been found in ground water because of agricultural use. Users are advised not to apply this product where the water table is close to the surface or where soils are very permeable. Your local Cooperative Extension Service Office can provide further information on the type of soil in your area and the location of ground water".

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Best Management Practices

1. **Integrated pest management (IPM)**: IPM programs use a range of methods and disciplines to assure stable and economical crop production while minimizing risks to humans, animals, plants and the environment. IPM weighs costs, benefits, and impacts on health and the environment and thus identifies the most suitable ways to control pests. Options include prevention, monitoring, mechanical trapping devices, natural predators, biological pesticides, and, if appropriate, chemical pesticides.
2. **Pesticide selection:** Select a pesticide that will have the least impact on the environment. Environmental impacts of pesticides depend on sorption (how tightly pesticide is held by the soil surfaces), water solubility (the amount of pesticide that will dissolve in a given amount of water), and persistence (the amount of time a pesticide remains in the environment. Pesticides with high sorption and low solubility are much less likely to leach into groundwater, or be transported by runoff. Pesticides with low persistence (short half-life) are likely to break down into less harmful compounds before they have a chance to harm the environment.
3. **Timing:** Apply pesticides only when they are needed for pest control, and when conditions are least likely for the pesticide to move to ground or surface water. Contamination events often happen when pesticides are applied just before a high-intensity rainfall, when runoff can move the newly-applied pesticide into lakes and streams. The window of highest vulnerability for pesticide runoff is typically within 10 to 15 days after application.
4. **Sprayer calibration:** Apply the correct amount, which can only be done if sprayers are calibrated regularly.

   Spray nozzles are an important part of pesticide application equipment. Quality nozzles can reduce pesticide use and reduce environmental pollution.

   In row crops, nozzle patterns are directed downward. In citrus and other tree crop applications, it is a common practice to

Source: USDA - Natural Resources Conservation Service

direct half the spray volume laterally toward the upper half of the tree and the rest to the lower half.

Sprayer calibration: Application errors can originate from either incorrect pesticide concentration in the tank, (mixing error) or incorrect sprayer output per unit area (calibration error). The latter may be due to travel speed, nozzle pressure, or the use of improper, defective and worn nozzles. By properly matching sprayer discharge rate, swath width and travel speed, calibration errors can be minimized. Sprayer calibration can be carried out by:

a) determining the amount of the tank mix used to spray a known area;
b) operating the sprayer in a fixed place and measuring the amount of discharged liquid (water) for a specified time;
or c) collecting the nozzle discharge and determining the output for a time period.

The use of high capacity nozzles at low pressures to achieve low-volume application rates, one-sided calibration of the sprayer for two-sided operations and vice versa, calibration at closed pressure settings and intermittent operation of the nozzles can introduce errors in application rates. Sprayers using positive displacement pumps (diaphragm, piston, etc.) have more potential for application error compared to sprayers using centrifugal pumps, particularly at high volume rates.
Source: Florida Cooperative Extension Service/Institute of Food and Agricultural Sciences/University of Florida EXIT Disclaimer

5. **Consider alternatives:** Alternatives to chemical pesticides include:
   - Biological pesticides, which target specific pests. Because of this targeting, these methods are generally considered to pose less risk to human beings, other species and the environment.
   - Microbial pesticides, which are naturally occurring or genetically altered microorganisms including fungi, viruses, and bacteria.
   - Pheromones, which disrupt normal mating behavior by stimulating breeding pests and luring them into traps.
   - Cultural practices such as different tillage practices and not growing the same crop every year (crop rotation)

Source: USDA - Natural Resources Conservation Service

6. **Avoid sensitive areas**: Know the location of sensitive areas such as sinkholes, depressions, wells, surface water, public institutions. For example, buffer zone should be in effect when applying pesticides around these sites. A buffer is **required** between the application of atrazine, one of the most common herbicides, and wells or surface water.

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National Agriculture Compliance Assistance Center (Ag Center)

Irrigation

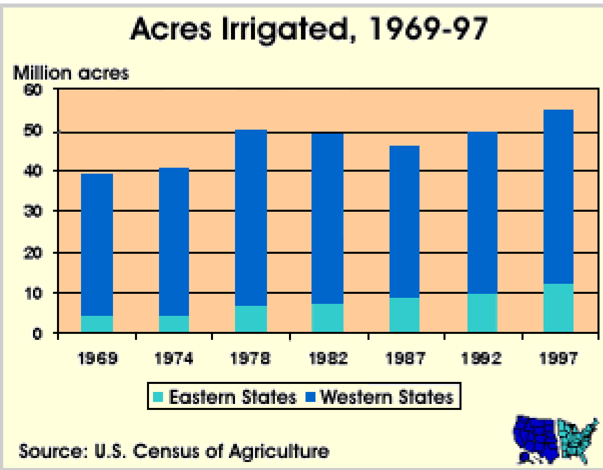
Source: USDA - Natural Resources Conservation Service

Irrigation makes agriculture possible in areas previously unsuitable for intensive crop production. Irrigation transports water to crops to increase yield, keep crops cool under excessive heat conditions and prevent freezing.

Less than 15% of U.S. cropland is irrigated, although irrigation is essential for crop production in some of the most productive areas of the country. For instance, in Arizona, home to some the highest corn yields in the country (208 bushel per acre state average in 2001 compared to 152 for Illinois), much of the crop is under continuous irrigation from planting until harvest.

The need to irrigate is usually driven by the necessity to meet the water needs of the crop from year to year (some areas of the country simply receive too little rainfall during the growing season to support economical crop growth). In other situations, irrigation is viewed as insurance against occasional drought. In areas where rainfall is plentiful in most years, irrigation can bring benefits by reducing risk, meaning that a farmer is better able to control income fluctuation. Other benefits include:

- Improving crop quality (most noticeable for vegetable crops)
- Significantly increasing crop yields, particularly on sandy soils which have low moisture-holding capacities
- Increasing opportunities for double cropping (planting soybeans after wheat in the same year)
- Providing a means of liquid fertilizer application



In 1997 there were about 55 million irrigated crop acres in the U.S. Irrigation is concentrated in certain areas like central California, Nebraska and the Great Plains, and the lower Mississippi valley.

Although irrigation has always been most common in the West, U.S. irrigated acreage in the East has also grown from 11 percent of acres in 1969 to 22 percent of acres in 1997.

Irrigation water is obtained from either ground water or surface water. Wells drilled on the farm are a common source of water in many areas, and are usually the only source used in the Great Plains. Offsite sources such as rivers, pipelines, canals operated by irrigation districts and private water companies, are also used, mainly in western states. The percentage of water source used for irrigation varies across the U.S.

Operations and Timing

Irrigation water is applied throughout the growing season to meet crop needs. Moisture needs depend on the type of crop and its stage of development. In the Eastern Corn Belt, for example, it takes 20-22 inches to produce an optimal corn crop, 18-20 inches for a soybean crop, 12-13 inches for small grain, and 24-26 inches for alfalfa. Irrigation can reduce crop stress if rainfall does not provide this amount of moisture during the growing season.

It is not only total moisture, but also the timing of moisture application (or rain) that is necessary for optimum crop yields. Crops have critical periods during the growing season when soil moisture must be maintained to ensure optimal yields. For corn, the most critical period is from just before tasseling through silking. For small grain, it is from boot to heading stage, for alfalfa, the start of flowering and after cutting, and for pasture, after grazing.

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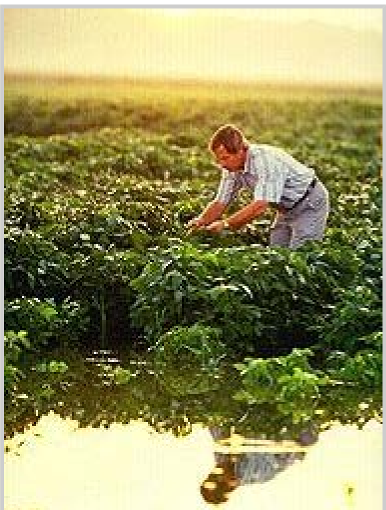
Equipment Used

There are four primary types of irrigation:

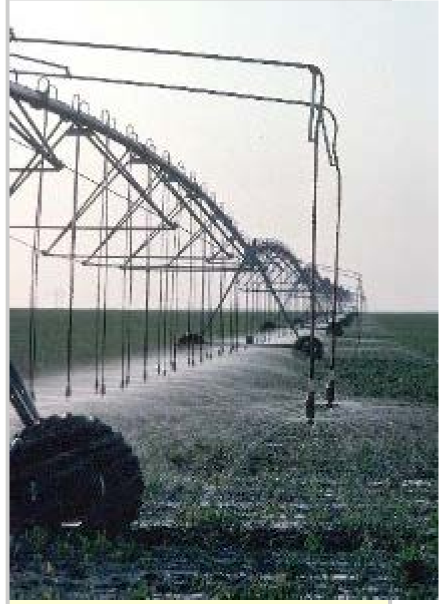
- Surface irrigation,
- Sprinkler irrigation,
- Drip or trickle irrigation, and
- Subsurface irrigation (or "subirrigation").



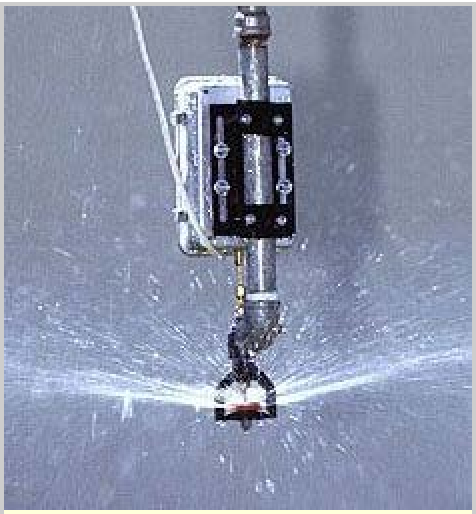
Source: USDA - Natural Resources Conservation Service

Surface Irrigation - With surface irrigation, water flows directly over the surface of the soil. The entire surface can be flooded (most often used for crops that are sown, drilled, or seeded) or the water can be applied through furrows between the rows (for row crops).

Sprinkler Irrigation - With sprinkler irrigation, water is sprayed through the air from pressurized nozzles, and falls like rain on the crop.



Center Pivot Irrigation
Source: USDA - Natural Resources Conservation Service



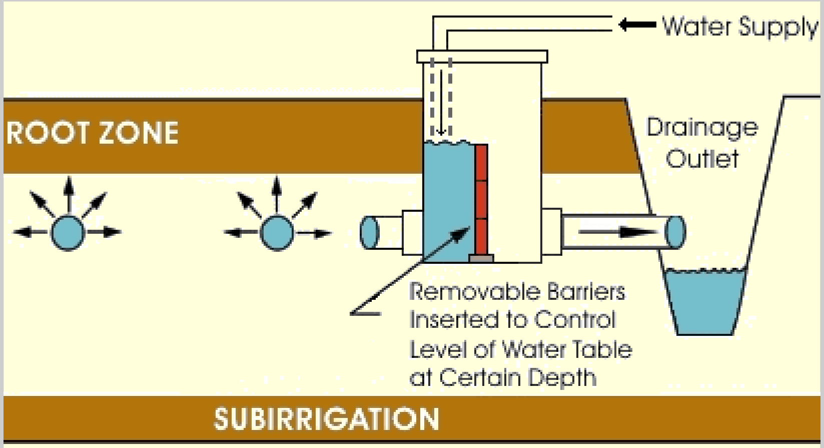
Source: USDA - Natural Resources Conservation Service

Variable-Flow Irrigation - Variable-flow irrigation sprinkler head improves the precision of water and farm chemical applications.

Trickle or Drip Irrigation - Trickle or drip irrigation supplies water directly onto or below the soil surface through "emitters' that control water flow.

Source: USDA - Natural Resources Conservation Service

Subirrigation - With subirrigation, the water table is artificially raised either through blocking ditches or by supplying water through the perforated pipes also used for



Source: Modified from graphic by Leslie Zucker, Ohio State University Extension

subsurface drainage.

Irrigation types can be further distinguished by whether the equipment is permanently installed in one place (stationary system) or whether it is used until the necessary amount of water is applied, then moved to a different area (traveling system). Stationary systems such as permanent spray installations or trickle systems require less labor, but usually cost much more to install. Traveling systems such as center pivot sprinkler irrigation, linear-move, or cable-tow require more labor but less capital expense.

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Potential Environmental Concerns

Environmental concerns related to irrigation include depletion of the water source (falling water tables or reduced water levels in streams or reservoirs), soil erosion due to over-application, runoff and leaching of chemicals, and salinization of the soil (salt-buildup) and minerals and nutrients in the irrigation return flow that drains from the irrigated area.

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Best Management Practices

1. **Minimize water use**. Apply only enough water to meet crop needs. This can be determined through regular soil moisture monitoring or through a "checkbook" system to monitor water applied and crop needs.
2. **Irrigation efficiency**. Use efficient irrigation systems such as drip irrigation to minimize evaporation.
3. **Apply at rate the soil can absorb**. Runoff due to excess irrigation can cause soil erosion.
4. **Uniform Irrigation**. Make sure water is applied uniformly. This makes the water more efficient, and reduces the chance of runoff and leaching in certain areas where water may be overapplied.
5. **Provide good drainage**. Salinization in areas of low rainfall can be minimized by providing good drainage along with the irrigation, to leach salts down through the soil profile.

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Drainage

Impacts of poor drainage -- stunted, yellow plants
Source: Purdue University

The purpose of agricultural drainage is to remove excess water from the soil in order to enhance crop production. In some soils, the natural drainage processes are sufficient for growth and production of agricultural crops, but in many other soils, artificial drainage is needed for efficient agricultural production.

Surface drainage is the removal of water that collects on the land surface. Many fields have low spots or depressions where water ponds. Surface drainage techniques such as land leveling, constructing surface inlets to subsurface drains, and the construction of shallow ditches or waterways can allow the water to leave the field rather than causing prolonged wet areas.

Subsurface drainage removes excess water from the soil profile, usually through a network of perforated tubes installed 2 to 4 feet below the soil surface. These tubes are commonly called "tiles" because they were originally made from short lengths of clay pipes known as tiles. Water would seep into the small spaces between the tiles and drains away.

Poorly drained area in crop field will damage yields
Source: Purdue University

The most common type of "tile" is corrugated plastic tubing with small perforations to allow water entry. When the water table in the soil is higher than the tile, water flows into the tubing, either through holes in the plastic tube or through the small cracks between adjacent clay tiles. This lowers the water table to the depth of the tile over the course of several days. Drain tiles allow excess water to leave the field, but once the water table has been lowered to the elevation of the tiles, no more water flows through the tiles. In most years, drain tiles are not flowing between June and October.

Drain tile outlet to a drainage ditch
Source: Purdue University

Operations and Timing

On average, about two-thirds of annual precipitation is used by crops in the eastern Corn Belt. The rest falls at a time when it does not meet crop needs. Monthly precipitation remains fairly constant throughout the year, while evapotranspiration (a combination of evaporation from soil and transpiration from the crop), is much higher from June to September. From January to May, and from October to December, precipitation is greater than evapotranspiration, creating a water surplus. The surplus results in excess water in the crop root zone and the need for drainage. Drainage is primarily a concern in the periods prior to the growing season (January to April) so that crops can be planted at the optimum time.

(Note: Even in humid areas, crop water needs often exceed precipitation in July, August, and September. Although some of the moisture deficiency is met by stored soil moisture, irrigation can often increase yields.)

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Equipment Used

Trenching machine used by drainage contractors to install subsurface drainage tile (shown in white)
Source: Purdue University

Designing and installing a drainage system is a complex process. Every field is unique and usually requires an individual design. Drainage depends on topography, crops that will be grown on the field, and soil type. Every soil type has different properties that affect its drainage. Agronomists and engineers have developed recommendations for drainage depth and spacing in specific soil types based on years of experience and knowledge of soil properties. Drainage contractors use these recommendations to design drainage systems that economically and effectively drain a particular field.

Drainage plow being pulled by farm tractor installing a tileline

Source: Purdue University

Drainage plows that can be pulled by farm tractors are becoming more popular. But most farmers hire contractors to design and install their tile drainage systems because of the knowledge, skills, and experience needed to install a successful system.

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Potential Environmental Concerns

The major concerns related to drainage are:

- Loss of wetlands, and
- Increased loss of nitrate through tile drains.

Wetlands

Much of the Midwest landscape consisted of wetlands before large-scale drainage began in the 19th century. Although enormous public health and economic benefits have resulted from the draining of these wetlands over the last 150 years, there have also been negative impacts on the environment. Wetlands have an important hydrologic function in regulating water flow and maintaining water quality, as well as providing habitat for water-based wildlife. Recognition of their value has changed the way our society thinks about and protects wetlands.

Drainage improvements today are rarely for the purpose of converting existing wetlands to agricultural production. Improved drainage is usually aimed at making existing agricultural land more productive. Some fields have drain tiles that were installed 100 or more years ago, and are broken or plugged. In many fields, only a few of the wettest spots were originally drained, while the entire field would benefit from improved drainage. More tiles are often added to improve drainage efficiency, with the goal of increasing production.

Water quality

Drainage has both positive and negative effects on water quality.

Poor Drainage
Source: Purdue University

In general, less surface runoff, erosion, and phosphorus is lost from land that has good subsurface drainage than from land without drainage improvements or with only surface drainage.

Nitrate loss can be quite high from drained land. Because nitrate is very soluble, it flows easily through the soil and into tile lines. Nitrate flow from subsurface drains is one of the main sources of nitrate in streams and rivers in the Midwest. Concern about hypoxia, or low oxygen levels, in the Gulf of Mexico has increased concern about this nitrate source. Concentrations of nitrate in tile drains are usually quite high (10-40 mg/l).

Pesticides can also flow into subsurface drains, but usually only in very low concentrations. Pesticides move more easily in flow over the soil surface than through the soil, so the highest concentrations of pesticides in tiles are often in fields that have surface inlets into the drains. In fact, subsurface drainage may actually reduce pesticide loss to rivers and streams because it reduces surface runoff.

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Best Management Practices

Traditionally, the goals of drainage were to:

1. Maximize crop yield and

2. Minimize costs of drainage installation.

Reducing water quality effects of drainage is becoming a third objective in drainage design.

Source: Purdue University

Nitrate loss is the biggest water quality concern related to tile drainage. Several new technologies can reduce nitrate loss. **Controlled drainage** keeps the water table high during the off-season when crops are not growing. The high water table increases the rate of denitrification (a process that converts nitrate to harmless nitrogen gas (N_2) as soon as the saturated soil warms up in the spring) and reduces nitrate loss to the environment.

Controlled drainage can be combined with **subirrigation** to improve yields while protecting water quality. Subirrigation is irrigation back through the subsurface drain tiles. Subirrigation may be economical when fields are relatively level and need to be drained anyway, since additional infrastructure consists mainly of increased numbers of tiles the pumping system. One system being developed in Ohio combines a wetland for water treatment and a pond serving as a reservoir for subirrigation with a drainage system. This system has been shown to increase yields and reduce water quality impacts of drainage, although it is costly.

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Harvest

Source: USDA - Natural Resources Conservation Service

Harvesting crops involves getting the crop out of the field and transported to market. Most crops are harvested in the fall, except for hay which is cut several times over the course of the summer.

Field crops are harvested by machine, while small fruits and other food crops are typically harvested by hand, although in certain cases, they may be harvested by machine.

Operations and Timing

Source: USDA - Natural Resources Conservation Service

Crop	Typical harvest period (in eastern corn belt)
Corn - grain	October 7 to November 3
Corn - silage	September 1 to October 15
Soybeans	October 1 to October 20
Wheat (spring)	August 14 to September 1
Wheat (winter)	June 15 to July 15
Hay	Usually 3 cuttings from May 15 to Sept. 30

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Equipment Used

Farm tractor and tillage implement
Source: Daniel R. Ess, Purdue University

Tractors - are traction machines that provide mechanical, hydraulic, and/or electrical power to implements to perform a wide range of crop production and handling operations. Tractors are most often used to perform drawbar work and PTO (power take-off) work. Tractors can be equipped with rubber tires, rubber belts, or steel tracks. A modern farm tractor is almost always equipped with a diesel engine and tractor size is measured by the amount of power that the tractor can produce at the PTO. Tractor sizes range for those with less than 40 PTO horsepower to ones that produce more than 400 horsepower. The cost of a large tractor can exceed $200,000.

Forage Harvesters - are tractor-drawn implements or self-propelled machines that are used to gather, chop, and discharge forage crops as it moves through the field. The crops are typically harvested at a very high moisture content to permit ensiling (preservation through anaerobic fermentation). Forage harvesters require a great deal of power to perform the required functions. The largest self-propelled forage harvesters currently available have diesel engines that produce in excess of 600 horsepower.

A self-propelled forage harvester loading chopped corn into a truck on-the-go.
Source: Class of America

Tractor and pull-type combine operating in a small grain crop

Combines - are farm machines used to harvest grain and seed crops. The major functions performed by a combine include cutting and/or gathering, feeding, threshing, separating, cleaning, and grain handling operations on-the-go in the field. The vast majority are self-propelled, receiving power to perform all of the previously listed operations and traction from a diesel engine. The combine is often the most expensive farm machine used in grain or row crop production with list prices for the largest models exceeding $350,000. Some machines can harvest a thirty-foot swath of crop in a single pass through the field.

Self-propelled combine equipped with a grain header
Source: Daniel R. Ess, Purdue University

Self-propelled combine equipped with a corn head preparing to harvest corn
Source: Daniel R. Ess, Purdue University

Cotton Harvesters - are self-propelled machines specifically designed to pick (or strip), accumulate, and off-load large quantities of cotton in the field.

Cotton harvesters at work in the field
Source: Deere Photo Library, Vol. 3

Grain Carts - are tractor-drawn implements used to shuttle grain from combines to hauling vehicles or to grain receiving facilities. Grain carts are usually equipped with "high-flotation" tires or rubber tracks to attempt to minimize soil compaction in the field. The capacity of such carts can exceed 1,000 bushels (equivalent to 56,000 lb of shelled corn or 60,000 lb of soybeans).

A large-capacity grain cart unloading into a waiting truck
Source: Daniel R. Ess, Purdue University

Large round baler discharging a newly-formed bale of hay
Source: Deere Photo Library, Vol. 3

Balers - are implements used for packaging hay, or straw to permit mechanized handling and transport. The two most common bale formats are large round bales (> 4 feet in diameter) and large rectangular bales (up to 8 feet in length). Large bales can weigh more than 2,000 pounds.

Large rectangular baler discharging a newly-formed bale of straw
Source: Class of America

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Storage of Fertilizer and Chemicals

- Fertilizer and Pesticide Storage
- Petroleum Product Storage

For more information, visit Software for Environmental Awareness. This site offers free interactive software to download.

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Agricultural Pesticides

(University of Florida - IFAS)

The federal government has regulated pesticides since the early 1900s.

The use of synthetic pesticides in agriculture is the most widespread method for pest control. "...Farmers spend approximately $4.1 billion on pesticides annually. They justify this high cost by a direct dollar return of from $3 to $5 for every $1 spent on pesticides." (1991 edition of the *Handbook of Pest Management in Agriculture.*)

Environmental and human health problems related to the use of synthetic pesticides have created an increasing pressure against their use. In recent years, non-chemical alternatives for pest control have been developed and modern pesticides have become safer and more specific. Technical developments of the application equipment have also improved to enable their proper application. However, their proper professional use has not always been transferred satisfactorily to field practice.

Alternative approaches to pest control are used more and more and the concept of integrated pest management where synthetic pesticides are only applied as a last resort is now considered common practice in professional agriculture. The non-chemical alternatives include cultural practices, choice of resistant varieties, creation of an environment favorable for natural enemies of pests, and use of biological products and agents, including beneficial insects.

Likewise, synthetic pesticides have undergone a development process to match today's requirements. They have become less toxic for humans, though not necessarily for the environment, they have become more specific to act as a useful contribution within an IPM concept and they have become more powerful. While 40 years ago pesticides were applied in kilograms or liters of active ingredient per hectare, modern pesticides only require grams or milliliters to achieve the same or better result.

On the other hand, the new pesticides require a more sophisticated technology for a safe, even and efficient application. Modern application equipment (including backpack sprayers) allow a fairly safe and efficient application of pesticides of all kinds. "The design of equipment has impact mostly on the operator and environmental safety preventing unnecessary contamination, accidents, loss and spills and allowing an even distribution of the product." Modern electronics have improved the accuracy of dosing, distribution, and application. The use of global positioning systems (GPS) allows precise tracking of the application. Spray nozzle technology greatly affects spray coverage, which is second in importance only to the selection of the pesticide in determining the success of an application.

Originally, the purpose of pesticide laws and regulations was to protect consumers from fraudulent claims about product performance. The focus now has shifted to the protection of health and the environment, including:

- Providing for the proper and beneficial use of pesticides to protect public health and safety.
- Protecting the environment by controlling the uses and disposal of potentially harmful pesticides.
- Assuring safe working conditions for farm workers, commercial pest control personnel, and consumers.
- Assuring users that pesticides are labeled properly and are appropriate for their intended use, and contain all instructions and precautions necessary.
- Encouraging the use of integrated pest management (IPM) systems that emphasize biological and cultural pest control techniques with selective use of pesticides.

More information on Agricultural Pesticides

- Benefits of Pesticide Use
- Risks of Pesticide Use
- Lethal Dosage (LD50) Values
- Ever-Changing Laws and Regulations
- Formulation Selection Considerations
- Integrated Pest Management
- Water Quality
- Soil/Water Adsorption Coefficient (Kd)
- Water Solubility
- Half-Life
- Movement Off Target

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Crop Production Study Questions

Identify the definition that best fits the following terms:

1. **U.S. farmers produce about $____________________ worth of crops each year.**

   - 1,000,000
   - 1,000,000,000
   - 10,000,000,000
   - 100,000,000,000

   Feedback

2. **Soybeans produced in the United States account for about ________% of world soybean trade.**

   - 1
   - 10
   - 25
   - 50

   Feedback

3. **Most corn grown in the United States is used for ___________________________ production.**

   - animal feed
   - corn chip
   - high fructose corn syrup
   - ethanol

   Feedback

4. **Which of the following is the number one cash crop grown by U.S. farmers?**

   - Wheat
   - Corn
   - Soybeans
   - Rice

   Feedback

5. **There are approximately how many farms in the United States?**

- 10,000
- 1,000,000
- 2,000,000
- 20,000,000

Feedback

6. **Which of the following is an off-farm impact of soil erosion?**

- Lower soil fertility levels
- Development of rills and gullies in the field
- Less water infiltration into the soil
- Decreased water quality downstream

Feedback

7. **The practice of planting along the slope instead of up-and-down slopes is called:**

- Contour farming
- Cover cropping
- Strip cropping
- Terracing

Feedback

8. **Nitrogen fertilizer is most efficient when applied**

- In the fall
- In late winter
- At or after planting
- In late summer

Feedback

9. **Sources of nutrients that can cause eutrophication and hypoxia in the Gulf of Mexico include:**

- Sewage treatment plant discharge
- The atmosphere
- Fertilizer or manure application
- All of the above

Feedback

10. **Restricted-use pesticides**

- Cannot be applied on agricultural fields
- Can only be applied by Certified Applicators
- Should only be applied in the fall
- Are illegal on most crops

Feedback

11. **Which of the following is not a reason that irrigation is used?**

- To facilitate pesticide application
- Insurance against possible drought
- Moisture may not be available at the optimum time for crop growth
- To improve crop quality

Feedback

12. **Since 1987, irrigated acres in the U.S. have been**

- Steadily decreasing
- Steadily increasing
- Staying about the same
- Increasing in the West but decreasing in the East

Feedback

13. **Positive effects of drainage on water quality include:**

- Decreased loss of nitrogen to streams
- Decreased soil erosion
- Increased health of aquatic and wetland vegetation
- All of the above

Feedback

14. **Perforated subsurface drains are often called "tiles" because**

- They are square like tiles
- They are placed in a grid like a tiled floor
- An early plastic tubing manufacturer called them “tiles” as part of its brand name
- They used to be made of clay pipe called tiles

Feedback

15. **Drainage systems are usually designed to:**

- ○ Lower the water table within a few hours after a rain
- ○ Lower the water table within a few days after a rain
- ○ Flow throughout the year
- ○ Prevent excessive loss of nitrogen from the field

Feedback

See Results | RESET

Score in Percentage:	

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Crop Glossary

Acre - The unit of measure most typically used to describe land area in the United States. An acre is equivalent to 43,560 square feet and is about 9/10 the size of a football field.

Acre-Inch - A volume measurement typically associated with irrigation operations on cropland. An acre-inch is equivalent to 27,154 gallons. When an inch of water is applied to cropland via irrigation, each acre receives 27,154 gallons. (Alternatively, a measure of the volume of water applied to the soil/growing crop using irrigation - approximately equivalent to 27,154 gallons.)

Agribusiness - An enterprise that derives a significant portion of its revenues from sales of agricultural products or sales to agricultural producers.

Anhydrous Ammonia - A fertilizer used to provide nitrogen for crop production. The product, stored under high pressure as a liquid, changes state during application and is injected into soil as a gas. It is popular due to the fact that it is composed of 82 percent nitrogen compared to other nitrogen fertilizers such as urea that contain only 46% nitrogen and ammonium nitrate with 30-33% nitrogen content.

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Boot - The time when the head is enclosed by the sheath of the uppermost leaf.

Bt Corn - Field corn that has received a gene transferred from a naturally-occurring soil bacterium called *Bacillus thuringiensis*. The gene causes the corn plant to produce one of several insecticidal compounds commonly called Bt toxins. The toxins affect the midgut of particular groups of insects such as European corn borer that can be harmful to corn.

Bushel - A unit of dry volume typically used to quantify crop yields. One bushel is equivalent to 32 quarts or 2,150.42 cubic inches. A bushel is often used to represent the weight of a particular crop; for example, one bushel of No. 2 yellow shelled corn at 15.5% moisture content weighs 56 lb.

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Cash Crop - An agricultural crop grown to provide revenue from an off-farm source.

Center Pivot - A type of irrigation system that consists of a wheel-driven frame that supports a series of sprinkler nozzles. The frame rotates about a central point to distribute water over a large circular area.

Channel Erosion - Erosion in channels is mostly caused by downward scour due to flow shear stress. Side wall sluffing can also occur during widening of the channel caused by large flows.

Conservation Tillage - Any tillage and planting system that covers 30 percent or more of the soil surface with crop residue, after planting, to reduce soil erosion by water. Where soil erosion by wind is the primary concern, any system that maintains at least 1,000 pounds per acre of flat, small grain residue equivalent on the surface throughout the critical wind erosion period.

Conventional Tillage - Full width tillage that disturbs the entire soil surface and is performed prior to and/or during planting. There is less than 15 percent residue cover after planting, or less than 500 pounds per acre of small grain residue equivalent throughout the critical wind erosion period. Generally involves plowing or intensive (numerous) tillage trips. Weed control is accomplished with crop protection products and/or row cultivation.

Corn Belt - The area of the United States where corn is a principal cash crop, including Iowa, Indiana, most of Illinois, and parts of Kansas, Missouri, Nebraska, South Dakota, Minnesota, Ohio, and Wisconsin.

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Depression - A low area in a field where surface drainage away from the area does not occur.

Drawbar - A tractor component typically located at the rear and near the ground that permits attachment of implements for pulling or towing.

Drawbar Work - Any operation performed by a tractor that requires force to be exerted by wheels/tracks to propel an implement through or over the soil.

Drilled - Planted with a grain drill. Grain drills differ from row crop planters in that they do not meter individual seeds, but drop small groups of seed in a process referred to as bulk metering. Drills plant crops in closely spaced rows (typically seven to 10 inches on center) that will not be mechanically cultivated.

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Ensiling - The process of creating silage via anaerobic fermentation.

Eutrophication - The process by which lakes and streams are enriched by nutrients (usually phosphorus and nitrogen) which leads to excessive plant growth.

Federal, Food, Drug, and Cosmetic Act (FFDCA) - It specifies the levels of pesticides, chemicals, and naturally occurring poisonous substances in food products. It also regulates the safety of cosmetic products.

Source: University of Vermont Environmental Safety Facility EXIT Disclaimer

Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) - The objective of FIFRA is to provide federal control of pesticide distribution, sale, and use. All pesticides used in the United States must be registered (licensed) by EPA. Registration assures that pesticides will be properly labeled and that, if used in accordance with specifications, they will not cause unreasonable harm to the environment. Use of each registered pesticide must be consistent with use directions contained on the label or labeling.

Source: EPA's Agriculture Web site

Feed Grain - Any of a number of grains used for livestock or poultry feed. Corn and sorghum are feed grains.

Flowering - This is the stage when the crop starts flowering. In corn, tassel emergence and pollen shedding takes place at this stage. Two to three days after pollen shedding, silk emergence takes place. At this stage, typically occurs 51-56 days after planting the corn seed, pollination between silks (female) and tassels (male) takes place.

Forage Crop - Annual or perennial crops grown primarily to provide feed for livestock. During harvesting operations, most of the aboveground portion of the plant is removed from the field and processed for later feeding.

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Genetically-Modified Organism (GMO) - A term that refers to plants that have had genes implanted to improve their performance by making them resistant to certain pesticides, diseases, or insects.

Grazing - Any vegetated land that is grazed or that has the potential to be grazed by animals.

Source: Forage Information System EXIT Disclaimer

Ground Water - The water under the surface of the earth that is found within the pore spaces and cracks between the particles of soil, sand, gravel and bedrock.

Gully Erosion - They are formed when channel development has progressed to the point where the gully is too wide and too deep to be tilled across. These channels carry large amounts of water after rains and deposit eroded material at the foot of the gully. They disfigure landscape and make land unfit for growing crops.

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Hay - The product of any of a variety of perennial crops, typically grasses or legumes, that can be used a feed for ruminant animals.

Heading - The stage in which the head pushes its way through the flag leaf collar.

IPM - An integrated approach to controlling plant pests using careful monitoring of pests and weeds. It may include use of natural predators, chemical agents and crop rotations.

Source: Pennsylvania Farm Bureau Glossary of Terms EXIT Disclaimer

Leach - The downward transport of dissolved or suspended minerals, fertilizers, pesticides and other substances by water percolating through the soil.

Karst - Areas with shallow ground water, caverns, and sinkholes.

Mulch Tillage - Full-width tillage involving one or more tillage trips which disturbs all of the soil surface and is done prior to and/or during planting. Tillage tools such as chisels, field cultivators, disks, sweeps or blades are used. Weed control is accomplished with crop protection products and/or cultivation.

Source: Conservation Technology Information Center (CTIC) EXIT Disclaimer

Non-Point Source Management Program - Under the Non-point Source Management Program, states can receive funding to control non-point sources of pollution to protect surface and ground water, including programs to control pesticide contamination of the ground and surface water.

No-Tillage - Crop production system in which the soil is left undisturbed from harvest to planting. At the time of planting, a narrow strip up to 1/3 as wide as the space between planted rows (strips may involve only residue disturbance or may include soil disturbance) is engaged by a specially equipped planter. Planting or drilling is accomplished using disc openers, coulter(s), row cleaners, in-row chisels, or roto-tillers. Weed control is accomplished primarily with crop protection products. Other common terms used to describe No-till include direct seeding, slot planting, zero-till, row-till, and slot-till.

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Pasture (or Pastureland) - Land used primarily for the production of domesticated forage plants for livestock (in contrast to rangeland, where vegetation is naturally-occurring and is dominated by grasses and perhaps shrubs).

Pesticide - A general name for agricultural chemicals that include:

- Herbicide - for the control of weeds and other plants
- Insecticide - for the control of insects
- Fungicide - for the control of fungi
- Nematocide - for the control of parasitic worms
- Rodenticide - for the control of rodents

Postemergence - Refers to the timing of pest control operations. Postemergence operations are accomplished during the period subsequent to the emergence of a crop from the soil and must be completed prior to point at which crop growth stage prohibits in-field travel (unless alternative application means – aerial or irrigation-based – are used).

Power Take-Off (PTO) - A splined shaft that extends from a tractor drive train and is designed to couple with the splined drive shaft of an implement. The connection permits mechanical power to be transmitted from tractor to implement.

Preemergence - Refers to the timing of pest control operations. Preemergence operations are accomplished during the period subsequent to the planting of a crop and prior to the emergence of that crop from the soil.

Preplant - Refers to the timing of pest control operations. Preplant operations are accomplished during the period subsequent to the harvest of one season's crop and prior to the planting of the next season's crop.

Primary Tillage - The mechanical manipulation of soil that displaces and shatters soil to reduce soil strength and to bury or mix plant materials and crop chemicals in the tillage layer. Tends to leave a rough soil surface that is smoothed by secondary tillage.

Ridge Tillage - The soil is left undisturbed from harvest to planting except for strips up to 1/3 of the row width. Planting is completed on the ridge and usually involves the removal of the top of the ridge. Planting is completed with sweeps, disk openers, coulters, or row cleaners. Residue is left on the surface between ridges. Weed control is accomplished with crop protection products (frequently banded) and/or cultivation. Ridges are rebuilt during row cultivation.

Source: Conservation Technology Information Center (CTIC) EXIT Disclaimer

Rill Erosion - The removal of soil by concentrated water running through little streamlets, or headcuts. Detachment in a rill occurs if the sediment in the flow is below the amount the load can transport and if the flow exceeds the soil's resistance to detachment. As detachment continues or flow increases, rills will become wider and deeper.

Row Crop - Agricultural crop planted, usually with mechanical planting devices, in individual rows that are spaced to permit machine traffic during the early parts of the growing season

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Safe Drinking Water Act - The objective of the Safe Drinking Water Act is to protect public health by establishing safe limits (based on the quality of water at the tap) for contaminants that may have an adverse effect on human health, and to prevent contamination of surface and ground sources of drinking water.

Secondary Tillage - The mechanical manipulation of soil that follows primary tillage. Performed at shallower depths than primary tillage, secondary tillage can provide additional soil pulverization, crop chemical mixing, soil surface leveling, and firming, and weed control. In conventional tillage systems, the final secondary tillage pass is used to prepare a seedbed.

Seeded - Generic term for introducing seed into the soil-air-water matrix, typically via a mechanized process that will maximize the likelihood of subsequent seed germination and plant growth.

Self-Propelled - A term that is typically applied to farm machines with integral power units that are capable of moving about as well as performing some other simultaneous operation such as harvesting or spraying a crop.

Sidedress - To apply fertilizer to a standing crop, usually by surface application of liquid fertilizer products or subsurface application of liquid or gaseous fertilizers placed near crop rows.

Silage - A feed prepared by chopping green forage (e.g. grass, legumes, field corn) and placing the material in a structure or container designed to exclude air. The material then undergoes fermentation, retarding spoilage. Silage has a water content of between 60 and 80%.

Silking - It is considered the first reproductive stage

Sinkhole - A surface depression caused by a collapse of soil or overlying formation above fractured or cavernous bedrock.

Soil Test - A soil test indicates the availability of nutrients present in the soil and the availability of those nutrients to crops grown there.

Sown - Planted using a broadcast seeding machine that distributes seed upon the soil surface. The seed may then be incorporated into the soil to ensure adequate seed-soil contact for germination.

Strip Tillage - The process in which only a narrow strip of land needed for the crop row is tilled.

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Tasseling - A condition when the tassel-like male flowers emerge.

Tillage - The mechanical manipulation of soil performed to nurture crops. Tillage can be performed to accomplish a number of tasks including: seedbed preparation, weed control, and crop chemical incorporation.

Transgenic Crop - Contains a gene or genes which have been artificially inserted instead of the plant acquiring the gene(s) through pollination. The inserted gene(s) may come from an unrelated plant or from a completely different species.

Urea - A form of nitrogen that converts readily to ammonium.

Value-Added Products - A general term that refers to agricultural products that have increased in value due to processing. Examples include corn oil and soybean meal.

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- John Deere Photo Library, Vols. 1, 2, and 3 (available on CD-ROM, (309) 765-9833).

Links EXIT Disclaimer

This information is provided for reference. Over time, links to the items may become unavailable, in these cases the item will remain listed, but no link will be provided.

- A History of American Agriculture 1776-1990, USDA Economic Research Service (PDF) (1 pp, 188K)
- Agricultural Science, CAST – Council for Agricultural Science and Technology
- AgriMarketing
- American Farm Bureau
- American Farmland Trust (AFT)
- Bt Corn, “Bt Corn and European Corn Borer”
- Conservation Tillage, Conservation Technology Information Center
- Corn, KingCorn.org, “The Corn Growers’ Guidebook”
- Corn, The National Corn Growers Association
- Cotton, The National Cotton Council of America
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- Glossary, “A Glossary of Agricultural Terms, Programs and Laws,” Congressional Research Service, Library of Congress
- Glossary, “Glossary of Agricultural Terms,” Pennsylvania Farm Bureau
- Glossary of Forage Terms: Forage Information System, Oregon State University
- Grain Crops, U.S. Grains Council
- Grain Sorghum, National Grain Sorghum Producers
- Hay, The National Hay Association
- Rice, U.S. Rice Producers Association
- Rice, International Rice Research Institute (IRRI)
- Small Grains – The Internet Source for Small Grain Growers
- Soybeans, The United Soybean Board

- Tractors, The Small Tractor FAQ
- Terminology for Grazing Lands and Grazing Animals
- USDA Economic Research Service (ERS)
- USDA National Agricultural Statistics Service (NASS), Census of Agriculture
- Value Enhanced Grains
- “What is a Farm?”
- Wheat, International Grains Council
- Wheat, National Association of Wheat Growers

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Crop Production

Crop production is a complex business, requiring many skills (such as biology, agronomy, mechanics, and marketing) and covering a variety of operations throughout the year. In this module, the practice of crop production will be described by discussing eight components in the crop production cycle:

Source: USDA - Natural Resources Conservation Service

For each component, the operations and when they need to be carried out, the machinery or equipment farmers use, potential environmental concerns related to that component, and best management practices recommended to minimize environmental problems will be described.

Background

Growing crops for food was one of the first priorities of the earliest settlers arriving in North America. With shipboard supplies depleted, and having little familiarity with the land and native vegetation, groups arriving from Europe were quickly forced to learn to produce crops to ensure their survival. The stories of Native Americans teaching the settlers to plant and fertilize a corn crop are part of this country's lore.

In the era of Thomas Jefferson (arguably the most illustrious farmer that this nation has produced), farmers made up about 90% of the work force. As late as 1900, almost 40% of the labor force was engaged in producing crops and livestock for food, feed, and fiber. Now, with less than one percent of our population claiming farming as a principal occupation, most U.S. citizens have little or no crop production experience. This section provides an overview of the principles and practices associated with production of the major crops grown in the United States.

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Major Crops Grown in the United States

In round numbers, U.S. farmers produce about $100 billion worth of crops and about $100 billion worth of livestock each year. Production data from the year 2000 for major agricultural crops grown in this country are highlighted in the following table:

Major agricultural crops produced in the United States in 2000 (excluding root crops, citrus, vegetable, etc).		
Crop	**Harvested Area (million acres)**	**Cash Receipts from Sales ($ billion)**
Corn (grain)	72.7	15.1
Soybeans	72.7	12.5
Hay	59.9	3.4
Wheat	53.0	5.5
Cotton	13.1	4.6
Sorghum (grain)	7.7	0.82
Rice	3.0	1.2

Corn: The United States is, by far, the largest producer of corn in the world. Corn is grown on over 400,000 U.S. farms. In 2000, the U.S. produced almost ten billion bushels of the world's total 23 billion bushel crop. Corn grown for grain accounts for almost one quarter of the harvested crop acres in this country. Corn grown for silage accounts for about two percent of the total harvested cropland or about 6 million acres. The amount of land dedicated to corn silage production varies based on growing conditions. In years that produce weather unfavorable to high corn grain yields, corn can be "salvaged" by harvesting the entire plant as silage.

According to the National Corn Growers Association, about eighty percent of all corn grown in the U.S. is consumed by domestic and overseas livestock, poultry, and fish production. The crop is fed as ground grain, silage, high-moisture, and high-oil corn. About 12% of the U.S. corn crop ends up in foods that are either consumed directly (e.g. corn chips) or indirectly (e.g. high fructose corn syrup). It also has a wide array of industrial uses including ethanol, a popular oxygenate in cleaner burning auto fuels.

Soybeans: Approximately 2.8 billion bushels of soybeans were harvested from almost 73 million acres of cropland in the U.S. in 2000. This acreage is roughly equivalent to that of corn grown for grain. Over 350,000 farms in the United States produce soybeans, accounting for over 50% of the world's soybean production and $6.66 billion in soybean and product exports in 2000. Soybeans represented 56 percent of world oilseed production in 2000.

Soybeans are used to create a variety of products, the most basic of which are soybean oil, meal, and hulls. According to the United Soybean Board, soybean oil, used in both food manufacturing and frying and sautéing, represents approximately 79 percent of all edible oil consumed in the United States. Soybean oil also makes its way into products ranging from anti-corrosion agents to Soy Diesel fuel to waterproof cement. Over 30 million tons of soybean meal are consumed as livestock feed in a year. Even the hulls are used as a component of cattle feed rations.

Hay: Hay production in the United States exceeds 150 million tons per year. Alfalfa is the primary hay crop grown in this country. U.S. hay is produced mainly for domestic consumption although there is a growing export market. According to the National Hay Association, the most common exports are timothy, some alfalfa, sudangrass, and bermudagrass hay. Hay can be packaged in bales or made into cubes or pellets. Hay crops also produce seeds that can be used for planting or as specialized grains.

Wheat: Over 240,000 farms in the United States produce wheat. The U.S. produces about 13% of the world's wheat and supplies about 25% of the world's wheat export market. About two-thirds of total U.S. wheat production comes from the Great Plains (from Texas to Montana).

Wheat is classified by time of year planted, hardness, and color (e.g. Hard Red Winter (HRW)). The characteristics of each class of wheat affect milling and baking when used in food products. Of the wheat consumed in the United States, over 70% is used for food products, about 22% is used for animal feed and residuals, and the remainder is used for seed.

Cotton: Fewer than 32,000 farms in the United States produce cotton. Cotton is grown from coast-to-coast, but in only 17 southern states. Farms in those states produce over 20% of the world's cotton with annual exports of more than $3 billion. The nation's cotton farmers harvest about 17 million bales or 7.2 billion pounds of cotton each year.

Cotton is used in a number of consumer and industrial products and is also a feed and food ingredient. Over 60% of the annual cotton crop goes into apparel, 28 percent into home furnishings, and 8 percent into industrial products each year. Cottonseed and cottonseed meal are used in feed for livestock, dairy cattle, and poultry. Cottonseed oil is also used for food products such as margarine and salad dressing.

Grain sorghum: In the United States, grain sorghum is used primarily as an animal feed, but is also used in food products and as an industrial feedstock. Industrial products that utilize sorghum include wallboard and biodegradable packaging materials. Worldwide, over half of the sorghum grown is for human consumption.

Some farmers grow sorghum as a hedge against drought. This water-efficient crop is more drought tolerant and requires fewer inputs than corn. Kansas, Texas, Nebraska, Oklahoma, and Missouri produce most of the grain sorghum grown in this country. The U.S. exports almost half of the sorghum it produces and controls 70% to 80% of world sorghum exports.

As much as 12% of domestic sorghum production goes to produce ethanol and its various co-products. With demand for renewable fuel sources increasing, demand for co-products like sorghum-DDG (dry distillers grain) will increase as well due the sorghum's favorable nutrition profile.

Rice: Just over 9,000 farms produce rice in the United States. Those farms are concentrated in six states: Arkansas, California, Louisiana, Mississippi, Missouri, and Texas. U.S. rice production accounts for just over 1% of the world's total, but this country is the second leading rice exporter with 18% of the world market.

About 60% of the rice consumed in the U.S. is for direct food use; another 20% goes into processed foods, and most of the rest into beer.

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Crop Production Systems

Major agricultural crops produced in the United States in 2000.		
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Wheat	53.0	5.5
Cotton	13.1	4.6
Sorghum (grain)	7.7	0.82
Rice	3.0	1.2

Of the seven crops listed, six are annual crops that must be replanted each year (only hay crops would be left in place from year to year). The process of cultivating crops typically begins with tillage of the soil. Although tillage can serve a number of functions within a crop production system, the most fundamental function is to create conditions that will ensure good contact between seed and soil at the time of seed planting and the ready availability of water to the seed during germination. The degree to which the soil is disturbed by tillage prior to seed planting provides a means of categorizing crop production within a range of tillage systems. These systems range from ***no-tillage*** in which there is not soil disturbance in a field except during the process of planting a crop to ***conventional tillage*** in which multiple tillage operations can extend over many months and take place before, during, and after planting. Crop production systems that involve pre-plant tillage but maintain residues from a previous crop on the soil surface are referred to as ***conservation tillage*** practices.

For the major row crops produced in the United States, farmers use a range of production practices. Conventional tillage (also known as ***intensive tillage***) usually involves a series of field operations that result in a residue-free soil surface at the time a crop is planted. Conventional tillage systems developed in this country to take advantages of the following benefits:

- Creation of a seedbed or root bed
- Control of weeds or the removal of unwanted crop plants
- Incorporation of plant residues into the soil profile
- Incorporation of fertilizers and/or soil-applied pesticides
- Establishment of specific soil surface configurations for planting, irrigating, drainage, and/or harvesting operations

The major disadvantage of conventional tillage is the susceptibility of "unprotected" soil to erosion by water or by wind. Tillage is also energy-intensive, requiring large inputs of machine work and numerous trips across a field during a single growing season. Conventional tillage was "standard operating procedure" in the era before effective chemical weed and pest control strategies were available to farmers.

Concerns about soil erosion led to the development of crop production strategies that retained crop residues on the soil surface. Conservation tillage requires more sophisticated implements that are capable of producing a seedbed while leaving a portion of surface residues undisturbed. Reduced tillage usually leaves 15% to 30% residue coverage on the soil surface. True conservation tillage is any tillage method that leaves at least 30% residue coverage on the soil after a crop has been planted. It can be accomplished through no-till, strip-till, ridge-till, or mulch till practices.

Organic Farming

Organic farming is a small, but growing, segment of U.S. agriculture. USDA estimates the value of retail sales of organic foods at $6 billion in 1999 with about 12,200 organic farmers nationwide, most with small-scale operations. Organic farming encompasses both crop and animal production and is defined as "ecological production management system that promotes and enhances biodiversity, biological cycles and soil biological activity."'Organic' is a labeling term that denotes products produced under the authority of the U.S. Organic Foods Production Act. "The principal guidelines are to use materials and practices that enhance the ecological balance of natural systems. Organic agriculture practices do not ensure that products are completely free of residues; however, methods must be used to minimize contamination." Organic food handlers, processors and retailers must adhere to standards that maintain the integrity of organic agricultural products. This includes practices such as minimizing or eliminating the use of herbicides in crop production and antibiotics in animal production.

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Soil Preparation

- Operations and Timing
- Equipment Used
- Potential Environmental Problems (Soil Erosion)
- Best Management Practices

Source: USDA - Natural Resources Conservation Service

Prior to planting, the soil needs to be prepared, usually by some form of tillage or chemical "burn-down" to kill the weeds in the seedbed that would crowd out the crop or compete with it for water and nutrients. Tillage methods can be divided into three major categories, depending on the amount of crop residue they leave on the surface. Residue slows the flow of runoff that can displace and carry away soil particles.

- **Conventional tillage** - Until the last decade or so the standard tillage practice for corn was use of the moldboard plow for primary tillage followed by several secondary tillages and mechanical cultivation after the crop was up. Now about two-thirds of row crops are planted without use of the moldboard plow (Allmaras et al., 1997), and mechanical cultivation is often limited to one, or no operations.
- **Reduced tillage** is usually done with a chisel plow and leaves 15% to 30% residue coverage on the soil.
- **Conservation tillage** leaves at least 30% residue coverage on the soil. Conservation tillage methods include no-till, where no tillage is done at all and seeds are placed directly into the previous season's crop residue; strip-till, in which only the narrow strip of land needed for the crop row is tilled; ridge till; and mulch till.

Herbicides are used in all these methods to kill weeds. In no-till systems, the herbicide is applied directly on last season's crop residue. In the other methods, some soil preparation takes place before the herbicide is applied. A common myth is that more herbicide is used with conservation tillage methods, but in fact farmers rely on herbicides for weed control under all tillage systems, and the amount used is more or less independent of tillage method.

Soil Preparation Operations and Timing


Source: USDA - Natural Resources Conservation Service

Tillage can occur anytime between harvest of the previous year's crop and spring planting. In the eastern Corn Belt, most tillage is usually done between March and May for corn, and can be as late as early June for soybeans. In some cases, tillage is done in the fall, after harvest. In southern states, planting can be considerably earlier or later because of their longer growing season. The optimum time for tillage (to prevent soil erosion) is just before planting. However, wet spring weather can often make it difficult to get equipment into the field as early as needed to optimize yield. Late planting can seriously reduce yields. For example, in the eastern corn belt, corn yields are reduced by 1 bu/acre for each day after May 1 that planting is delayed.

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Equipment Used for Soil Preparation


Farm tractor and tillage implementation
Source: Daniel R. Ess, Purdue University

Tractor - a traction machine that provides mechanical, hydraulic, and/or electrical power to implements to perform a wide range of crop production and handling operations. Tractors are most often used to perform drawbar work (pulling equipment through the field) and PTO (power take-off) (power to rotate equipment components) work. Tractors can be equipped with rubber tires, rubber belts, or steel tracks. A modern farm tractor is almost always equipped with a diesel engine and tractor size is measured by the amount of power that the tractor can produce at the PTO. Tractor sizes range from those with less than 40 PTO horsepower to ones that produce more than 400 horsepower. The cost of a large modern tractor can be well over $200,000.

Plow - an implement used to perform primary tillage. A number of types of plows are in common use including the *moldboard plow*, the *chisel plow*, and the *disk plow*.


Rubber-tracked tractor and moldboard plow at work in the field
Source: farmphoto.com

The **moldboard plow** has a large frame that is equipped with a series of "bottoms," each of which consists of a steel coulter to slice through residue followed closely by a steel share that cuts the soil and an attached moldboard that is used to raise and turn over the cut "slice" of soil.

Disk plows work in a similar manner to laterally displace and invert soil through the use of concave steel disk blades.

Chisel plows use curved shanks to penetrate and "stir" the soil without inverting a soil layer. Chisel plows cause less residue disturbance than moldboard plows and are often used in conservation tillage systems.

Disk Harrows (or Disk) - are implements that uses steel blades to slice through crop residues and soil. Disk blades are mounted in groups or gangs that rotate as they move forward through the soil. Front gangs move soil toward the outside of the disk while rear gangs move soil back toward the center of the disk. A disk can be used for primary or secondary tillage.

A close-up view of a disk harrow in the field
Source: Deere Photo Library, Vol. 1

A field shot of a tractor and disk harrow at work
Source: Deere Photo Library, Vol. 1

Field Cultivator -an implement used to perform secondary tillage operations such as seedbed preparation and weed eradication. Field cultivators are equipped with steel shanks that are typically spring mounted to permit the shank to move within the soil and shatter clods. Field cultivators are constructed similarly to chisel plows, but are more lightly built. Large chisel plows can exceed 50 feet in width in the field.

A tractor and row crop cultivator working in soybeans plated with a conservation tillage system
Source: Deere Photo Library, Vol. 1

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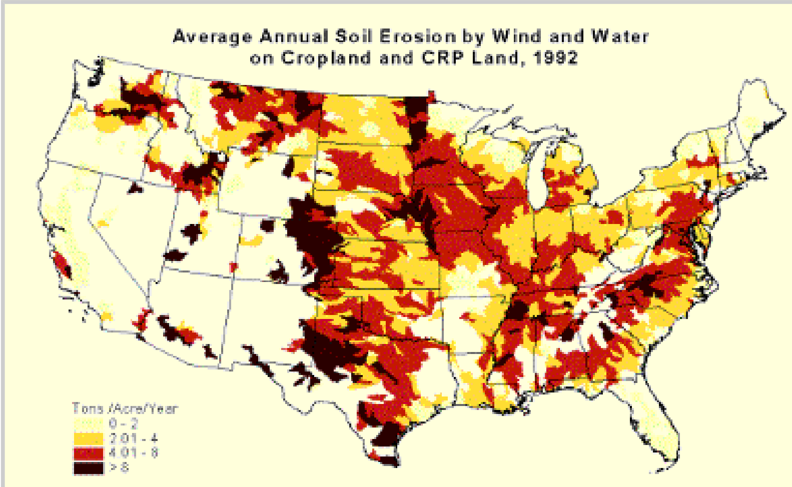
Environmental Concerns Related to Soil Preparation: Soil Erosion

The major environmental concern related to soil preparation is erosion. Soil erosion is a natural process that occurs when the actions of water and/or wind cause topsoil to be removed and carried elsewhere.

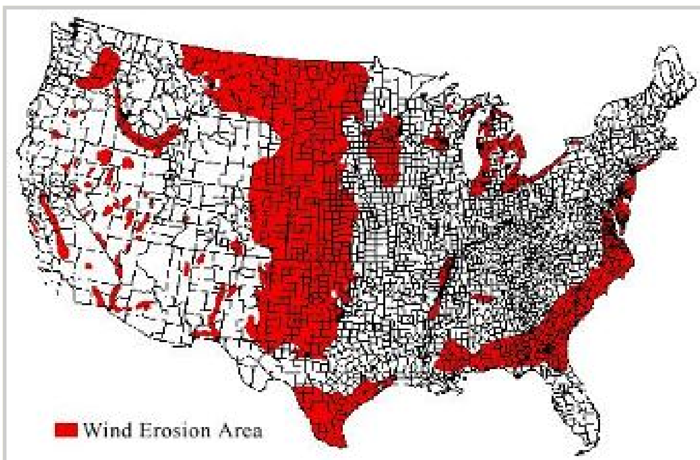
Source: USDA - Natural Resources Conservation Service



Source: USDA-NRCS

Soil erosion can be caused by either water or wind. In many agricultural areas, soil is eroding at a rate of several tons of soil per acre per year or higher. The map shows an estimate of total soil erosion on agricultural areas in 1992. This includes both cropland and set-aside land in the Conservation Reserve Program. Forested and urban land is not included in the map.

The good news is that soil erosion in the U.S. is decreasing. From 1982-1997, soil erosion declined about 40% in the U.S., due to government conservation programs, technological advances, and extension education efforts.



Source: USDA-NRCS

Water erosion is caused by the erosive power of raindrops falling on the soil (particularly if the soil is not covered by vegetation or residue) or by surface runoff. Raindrops cause the less severe forms of erosion (know as sheet and interrill erosion). Severe erosion problems such as rill erosion, channel erosion, and gully erosion can result from concentrated overland flow of water.

Wind erosion is particularly a problem in windy areas when the soil is not protected by residue cover. Wind erosion in the United States is most widespread in the Great Plains states, as can be seen in the map at right. Wind erosion is a serious problem on cultivated organic soils, sandy coastal areas, alluvial soils along river bottoms, and other areas in the United States.

Impacts of soil erosion

Soil erosion has both on-farm impacts (reduction in yield and farm income) and off-farm impacts (contaminated water due to the sediment and associated contamination from nutrients and pesticides carried on the soil particle).

On-farm impacts due to the loss of soil and nutrients include:

- lower fertility levels
- development of rills and gullies in the field
- poorer crop yields
- less water infiltration into the soil
- more soil crusting
- more runoff in the spring and after storms

When fertile topsoil is lost, nutrients and organic matter needed by crops often are removed along with it. Erosion tends to remove the less dense soil constituents such as organic matter, clays, and silts, which are often the most fertile part of the soil. However, the loss in productivity caused by erosion has not been so evident in many parts of the U.S., since it has been compensated for over the years by improved crop varieties and increased fertilization.

Soils can tolerate a certain amount of erosion without adverse effects on soil quality or long-term productivity, because new soil is constantly formed to replace lost soil. This tolerable level is known as "T" and generally ranges from 3 to 5 tons per acre per year. Goals for reducing soil erosion often use the "T" value as a target, because erosion rates below T should maintain long-term productivity of the soil.

Off-farm impacts occur when the eroded soil is deposited elsewhere, along with nutrients, pesticides or pathogens that may be attached to the soil. The tolerable"T" value described above does not take into consideration the off-farm or downstream impacts. Soil eroded by water has effects such as:

- eroded soil deposited in depressions and adjacent fields
- decreased water quality downstream
- decline of downstream aquatic ecosystems because of sedimentation and the addition of nutrients, pesticides, and bacteria associated with the soil
- clogged drainage ditches and other costly problems

Off-farm impacts of wind erosion are due to the blowing soil, which can reduce seedling survival and growth (seed cover), increase the susceptibility of plants to certain types of stress, contribute to transmission of some plant pathogens, and reduce crop yields. Dust affects air quality, obscures visibility which can cause automobile accidents, clogs machinery, and deposits in road ditches, where it can impact water quality.

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Best Management Practices to Reduce Erosion

Conservation tillage leaves at least 30% residue cover on the ground. This simple, low-cost practice can have a huge impact on the amount of soil eroded. Because of energy savings and obvious improvements in soil quality that can result from conservation tillage, it has been widely adopted across the Midwest. In Indiana, for example, conservation tillage was used on 50% of corn and 80% of soybean acres in 2000, a dramatic improvement from 10 years earlier. There is still room for improvement, however. This map shows the percent of U.S. crop land currently in conservation tillage. Percentages are generally higher for soybeans than for corn or other crops.

Source: USDA-Natural Resources Conservation Service

Contour farming and strip cropping is the practice of planting along the slope instead of up-and-down slopes, and planting strips of grass between row crops.

Source: USDA - Natural Resources Conservation Service

Source: USDA - Natural Resources Conservation Service

Cover crops are crops such as rye that grow in late fall and provide soil cover during winter. By providing a cover to the soil, winter soil erosion from both air and water can be greatly reduced.

Source: USDA - Natural Resources Conservation Service

Grassed waterways protect soil against the erosive forces of concentrated runoff from sloping lands. By collecting and concentrating overland flow, waterways absorb the destructive energy that would otherwise cause channel erosion and gully formation.

Source: USDA - Natural Resources Conservation

Terraces are structural practices that can reduce erosion by holding back the water and routing it along a channel at a lower velocity to where it can be safely discharged, usually into a grassed waterway.

Service

Source: USDA - Natural Resources Conservation Service

Windbreaks are the best way to protect soil from wind erosion. They can be in the form of rows of shrubs or trees.

Source: USDA - Natural Resources Conservation Service

Windbreaks

Source: USDA - Natural Resources Conservation Service

Grass barriers can prevent wind erosion by slowing the wind.

Source: USDA - Natural Resources Conservation Service

"**Living snow fences**" prevent wind erosion by slowing the wind.

Photos courtesy of USDA-Natural Resources Conservation Service, except for the four pictures for practices controlling wind erosion, from the ARS Wind Erosion Unit. EXIT Disclaimer

Maps from USDA-NRCS "State of the Land."

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Planting

Operations and Timing

Most crops in the U.S. are planted in the spring. The exception is winter wheat, which is planted across the U.S. but concentrated in the central and southern Great Plains and the Pacific Northwest. Winter wheat is planted in the fall, goes into dormancy during the winter, and is harvested for grain the following spring.

The table below shows the "usual planting dates" for six major crops. Planting dates vary by region, following the weather. For simplification, the usual range of planting dates for the top-producing states are shown; if planting dates vary widely, more than one is given. The actual planting dates may begin earlier and extend later, but these are considered the most common.

Source: USDA NASS Agricultural Handbook 628 "Usual Planting and Harvesting Dates for U.S. Field Crops (PDF) (51 pp, 441K, About PDF)

Crop	Usual Planting Dates (most active period) in Top-Producing States	Top Producing States	Total Acreage (million acres)
Barley	Apr 7- May 5 (ID); May 2-15 (ND)	ND, ID	7
Corn (grain)	April 30-May 18	IA, IL	73
Hay, alfalfa	NA	CA, SD	24
Wheat (spring)	May 1-19	ND	24
Soybeans	May15-June 5	IA, IL, MN	64
Wheat (winter)	Sept. 20-Oct. 10	KS	52

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Equipment Used

A grain drill on display at a farm machinery show
Source: Daniel R. Ess, Purdue University

Drills -are implements used to plant crops in closely spaced rows (typically four to ten inches); drills are commonly used for cereal crops such as wheat and can be used to plant soybeans. Grain drills are typically equipped with disks to open a small trench in the soil, a metering system to deliver a measured, controlled amount of seed to drop tubes which guide the seed to the seed trench. There must be some means (wheels or drag chains) of gently closing the seed trench with soil to cover the seeds.

A grain drill on planting a crop
Source: farmphoto.com

Tractors - are traction machines that provide mechanical, hydraulic, and/or electrical power to implements to perform a wide range of crop production and handling operations. Tractors are most often used to perform drawbar work and PTO (power take-off) work. Tractors can be equipped with rubber tires, rubber belts, or steel tracks. A modern farm tractor is almost always equipped with a diesel engine and tractor size is measured by the amount of power that the tractor can produce at the PTO. Tractor sizes range for those with less than 40 PTO horsepower to ones that produce more than 400 horsepower. The cost of a large tractor can exceed $200,000.

Farm tractor and tillage implementation
Source: Daniel R. Ess, Purdue University

A twelve-row planter working in a conventionally-tilled field

Source: Source: Daniel R. Ess, Purdue University

Planters - are implements used to plant row crops (typically in row spacings ranging from 10 to 40 inches). Planters open a seed trench, meter seeds one-at-a-time, drop seeds into the seed trench, and gently cover the seed. Some planters can cut through residues and till a small strip of soil in each row at the time of planting. Planters can also be equipped to apply fertilizer, pesticides, and herbicides during planting. Planters come in sizes as large as sixty feet wide - that is twenty-four rows with a typical 30-inch row spacing, or thirty-six rows with a narrower 20-inch row spacing. Such large planters can cost in excess of $100,000.

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Potential Environmental Concerns

One current controversy related to planting is the choice of seeds. More and more of the seeds planted in the U.S. are genetically modified (GMOs) to make crop production more efficient, to better withstand environmental stresses such as drought, flood, frost, or extreme temperatures, to protect crops against pests such as weeds, insects, or diseases, and to be resistant to herbicides. In 1999, 25% of corn and 54% of soybeans planted in the U.S. were genetically modified.

Environmental concerns related to GMOs include increased pest resistance, development of weed tolerance, and decreased genetic diversity. For example, insects exposed to a genetically engineered crop with the Bt gene (Bt is a natural toxin taken from the *Bacillus thuringiensis* bacteria, which is toxic to a number of insects) may become more resistant to pesticides. This is a serious concern for organic farmers who use Bt on their crops as an alternative to chemical insecticides. Another environmental concern is that, over time, some weed species could develop a tolerance to herbicides that are applied repeatedly to a crop tolerant to that herbicide. A transgenic crop might cross with another crop or weed, resulting in an undesirable crop or weed species. Others are concerned that reliance on a few genetically modified crops may reduce biological diversity. Also, a lack of genetic diversity in the food supply could increase the risk of catastrophic crop failure and threaten our food security.

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Best Management Practices

To reduce the risk of insect resistance to Bt, a certain percentage of crop acreage on every farm is normally devoted to non-genetically modified variety.

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Nutrient Management

Source: USDA - Natural Resources Conservation Service

Plant nutrients, which come primarily from chemical fertilizers, manure, and in some cases sewage sludge, are essential for crop production. When applied in proper quantities and at appropriate times, nutrients (especially nitrogen, phosphorus, and potassium) help achieve optimum crop yields. However, improper application of nutrients can cause water quality problems both locally and downstream. **Nutrient management** is the practice of using nutrients wisely for optimum economic benefit, while minimizing impact on the environment.

Operations and Timing

Source: USDA - Natural Resources Conservation Service

Farmers sometimes apply fertilizer soon after the previous year's harvest, since equipment and labor are usually available then. Fertilizer can also be applied in the spring, near the time it is needed by the plant, usually at planting, or as side-dress after the crop has started to grow. In general, the greatest efficiency results when fertilizer is applied at planting time or during the early part of growing season.

Proper timing is most important with nitrogen fertilizer. In some locations, a large part of the nitrogen may be lost if it is applied too long before the crop is planted, particularly if applied the previous fall before soil temperature drops to below 50° F. Phosphorus application is also most efficient when made at or near planting time, especially with soils low in phosphorus. Time of application is less critical with potassium than with nitrogen or phosphorus.

Knowing how much fertilizer to apply can be difficult. Soil tests are used to determine soil deficiencies for nutrients such as phosphorus and potassium. It is more difficult to determine nitrogen needs in advance, however, and most farmers simply use standard nitrogen recommendations based on crop yield goals. Recommendations are provided by Cooperative Extension services in most states. Other farmers get recommendations from fertilizer dealers and crop consultants.

Common nitrogen fertilizers are anhydrous ammonia (82% nitrogen), urea (45% nitrogen), urea and ammonium nitrate solutions (28% nitrogen), and ammonium nitrate (33.5% nitrogen). Manure can be an excellent source of Nitrogen (N), Phosphorous (P), and Potassium (K) plant nutrients. Every load of manure is different, however, so manure testing is necessary to accurately estimate nutrient contents.

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Equipment Used

Tractors - are traction machines that provide mechanical, hydraulic, and/or electrical power to implements to perform a wide range of crop production and handling operations. Tractors are most often used to perform drawbar work and PTO (power take-off) work. Tractors can be equipped with rubber tires, rubber belts, or steel tracks. A modern farm tractor is almost always equipped with a diesel engine and tractor size is measured by the amount of power that the tractor can produce at the PTO. Tractor sizes range for those with less than 40 PTO horsepower to ones that produce more than 400 horsepower. The cost of a large tractor can exceed $200,000.

Farm tractor and tillage implementation
Source: Daniel R. Ess, Purdue University

Sprayers - are implements or vehicles used to apply liquid crop chemicals, most often herbicides, and increasingly, fertilizers. Sprayers typically include a tank, pump, plumbing, valves, a boom, and nozzles. Sprayers can be mounted on a tractor or other implement, pulled by a tractor, self-propelled, or mounted on airplanes or helicopters. Large self-propelled sprayers that incorporate technologies to vary application rates within a field can cost more than $250,000.

A tractor-sprayer-field cultivator combo that performs tillage and crop chemical application operations simultaneously
Source: Ag-Chem, a division of AGCO Corporation

A self-propelled sprayer broadcasting crop chemicals in the field
Source: Ag-Chem, a division of AGCO Corporation

A pull-type sprayer and tractor
Source: Ag-Chem, a division of AGCO Corporation

Planters - are implements used to plant row crops (typically in row spacing ranging from 10 to 40 inches). Planters open a seed trench, meter seeds one-at-a-time, drop seeds into the seed trench, and gently cover the seed. Some planters can cut through residues and till a small strip of soil in each row at the time of planting. Planters can also be equipped to apply liquid fertilizer, pesticides, and herbicides during planting. Planters come in sizes as large as sixty feet wide - that is twenty-four rows with a typical 30-inch row spacing, or thirty-six rows with a narrower 20-inch row spacing. Such large planters can cost in excess of $100,000.

A twelve-row planter working in a conventionally-tilled field
Source: Daniel R. Ess, Purdue University

A self-propelled spreader that uses spinning disks to distribute dry crop chemicals
Source: Ag-Chem, a division of AGCO Corporation

Spreaders - are implements or vehicles used to apply dry crop chemicals, most often fertilizers. Spreaders typically include a bed, conveyor, and either a set of spinning disks to distribute material over a wide area or a pneumatic system to push material through openings in a boom for distribution on the ground. Spreaders can be mounted on a tractor, pulled by a tractor, self-propelled, or mounted on airplanes. Large self-propelled spreaders that incorporate technologies to vary application rates of multiple dry chemicals within a field can cost more than $250,000.

A self-propelled spreader that uses a pneumatic system to evenly distribute dry crop chemicals
Source: Ag-Chem, a division of AGCO Corporation

Toolbars - are implements that can use a range of soil-engaging tools typically mounted to a long steel bar of rectangular cross-section. A toolbar equipped with a set of uniformly spaced steel discs can be used to create trenches in the soil into which liquid fertilizers can be applied or gaseous fertilizers (such as anhydrous ammonia) can be injected. Toolbar fertilizer applicators lend themselves to sidedress application in standing crops.

A tractor-drawn toolbar being used to inject anhydrous ammonia into the soil. The wagon mounted tank attached to the toolbar supplied ammonia.
Source: Daniel R. Ess, Purdue University

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Potential Environmental Concerns

Water quality problems can occur when nutrients are added to the soil at a time when they could be removed in surface runoff from rainfall or snow melt at rates exceeding that removed by the crop, or if applied at times that they cannot be utilized by the crop.

When nitrogen or phosphorus are present in lakes or rivers at a high concentration, a condition called "eutrophication" or biological enrichment can occur. High nitrogen from the Mississippi River has been blamed for a hypoxic or "dead" zone in the Gulf of Mexico, where excess algae grow in response to the enriched nutrient solution and few fish can be found. When the algae die, their decomposition consumes enough dissolved oxygen to suffocate fish and other animal life. Sources of nitrogen contributing to the problem include agricultural runoff, sewage treatment plants, atmospheric nitrogen, and other sources.

Excessive nitrate in ground water can present a direct health hazard to very young infants. Ingestion of nitrate (NO_3) can bind with hemoglobin in the infant's bloodstream and cause a condition called methemoglobinemia or "blue baby" syndrome. Nitrate does not bind to soil particles and is quite soluble, making it susceptible to leaching into groundwater if not used by the crop.

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Best Management Practices

Source: USDA - Natural Resources Conservation Service

- Use **regular soil tests** to determine nutrient needs, and apply only the amount of nutrients needed by the crop to be grown. Site-specific nutrient application varies the amount of nutrients within fields based on a series of soil tests and global positioning equipment.
- Use **manure tests** to determine nutrient content, and take credit for the nutrient content of manure.
- Use **conservation tillage and other erosion-control practices** to minimize loss of phosphorus that is attached to the soil. (See Best Management Practices for Soil Erosion).
- **Improve timing** of fertilizer application, applying nutrients just before they are needed by the crop. Most of the nitrogen is needed by corn after the plant is three to four weeks old. The most efficient method of applying N fertilizer is as sidedress after planting.
- Look for a low soil test to decide which field to apply manure on and base manure application rate on the manure test for N.

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Pest Management

- Operations and Timing
- Application Practices
- Potential Environmental Problems
- Best Management Practices

Source: USDA - Natural Resources Conservation Service

Pesticides are used to control pests, which include insects, mice and other animals, unwanted plants (weeds), fungi, or microorganisms like bacteria and viruses. Though often misunderstood to refer only to insecticides, the term pesticide also applies to herbicides (that control weeds), fungicides (that control fungi), and substances used to control other pests.

Pesticides are used on the vast majority of U.S. cropland. According to agricultural chemical usage statistics from USDA, herbicides were applied to 98% of corn acreage and 96% of soybean acreage in 2001.

Operations and Timing

Pesticides are either applied prior to planting ("preplant"), before the crop emerges ("preemergence") or after the plant has emerged ("postemergence").

The label includes information on when the product should be applied. Labels often list the minimum number of days which must pass between the last pesticide application and harvest of crops or grazing by livestock. These are intervals set by EPA to allow time for the pesticide to break down in the environment, preventing residues on food, feed, or animal products.

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Application Practices

More and more producers have their pesticides applied by commercial applicators. This practice has many advantages, such as not having to store pesticides on-farm, avoiding having to be certified as pest control applicators, and benefiting from the dealer's record keeping.

A tractor-sprayer-field cultivator combo that performs tillage and crop chemical application operations simultaneously
Source: Ag-Chem, a division of AGCO Corporation

Sprayers - are implements or vehicles used to apply liquid crop chemicals, most often herbicides, and increasingly, fertilizers. Sprayers typically include a tank, pump, plumbing, valves, a boom, and nozzles. Sprayers can be mounted on a tractor or other implement, pulled by a tractor, self-propelled, or mounted on airplanes or helicopters. Large self-propelled sprayers that incorporate technologies to vary application rates within a field can cost more than $250,000.

A self-propelled sprayer broadcasting crop chemicals in the field
Source: Ag-Chem, a division of AGCO Corporation

A pull-type sprayer and tractor
Source: Ag-Chem, a division of AGCO Corporation

- **Aerial Application**

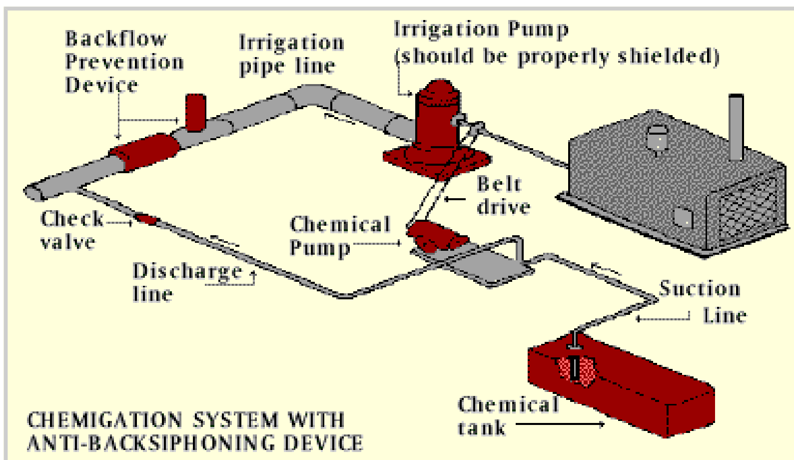
  Aerial application of pesticides has several advantages for the modern agricultural producer. When properly managed, aerial application offers speed of dispersal, accessibility to crops on areas where ground equipment cannot operate, and reasonable cost. In many cases, aerial application also allows more timely applications and, therefore, better utilization of pesticides.

  Aerial application programs require good cooperation between the pilot and grower. It must also recognize the potential dangers to people, other crops and the environment.

  Limitations on aerial application include weather hazards, fixed obstacles such as radius towers, field size and shape, the distance from the point of application to the landing area, and the danger of contamination of nearby areas due to drift or misapplication. Careless applications can be harmful to the crop, the grower and the applicator.

  Source: [University of Kentucky - Applicator Training Manual for Aerial Application of Pesticides] EXIT Disclaimer

- **Chemigation**



  A growing practice in many areas of the country is the application of pesticides through irrigation systems, often termed "chemigation." Although there are systems specifically designed for chemigation, in most cases an existing irrigation system is modified to mix the chemical with irrigation water. Fertilizers are generally stored in large tanks located near wells drawing ground water for irrigation. Fertilizers flow from the storage tanks into the irrigation water. Concerns about groundwater contamination from this practice arise from the fact that accidental backflow or siphoning of chemicals into the well can occur when the irrigation pumping system shuts down unexpectedly.

Source: [EPA - Software for Environmental Awareness, Pesticide Storage and Handling Practices on the Farm, Chemigation]

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Potential Environmental Concerns

The likelihood of pesticide contamination of groundwater and water wells depends partly on the geologic and hydrologic characteristics that vary from location to location as well as on pesticide characteristics.

Contamination of drinking water wells by pesticides is usually the result of one or more of the following:

- Improper application of pesticides on the fields
- Careless handling of the pesticides
- Careless storage of pesticides
- Careless disposal of unused pesticides and pesticide containers.

Ideally, pesticides should be applied at just the right time to control pests, then degrade into harmless compounds in the soil, air, or water without contaminating the environment. However, this is difficult to attain. Pesticides have the potential to harm the environment by injuring nontarget plants and animals, leaving harmful residues, or moving from the application site into the surrounding environment.

Some pesticides (called accumulative pesticides) can build up in the bodies of animals over time, including humans. These persistent pesticides stay in the environment without change for long periods of time. Pesticides which break down quickly in the environment to form harmless materials area called non-persistent. Most agricultural pesticides used in the U.S. are broken down easily by microorganisms or sunlight.

Pesticides come into contact with nontarget insects and plants through drift, runoff, or spills. Drift to nearby areas may injure fish, birds, other wildlife, and sensitive plants. It can also damage nearby crops, forests, or landscape plantings. Poorly timed applications can kill bees and other pollinators which are working in the area, or beneficial parasites and predators that help control pests naturally .

Pesticides have the potential to contaminate both surface waters (lakes, streams, ponds, rivers) and ground water.

Pesticides can move into surface water through **surface runoff**, attached to eroding soil particles, or from tile drainage systems. Concerns about pesticide movement in surface runoff include pesticide persistence, time between application and a runoff event, and any management practices in place that reduce surface runoff from the field.

Pesticides can also leach into **ground water.** The soil type plays an important role in determining the extent to which pesticides leach to ground water. Sandy soils greatly increase the risk of pesticide loss, because they have very limited capacities to adsorb pesticides. In karst areas, pesticides can easily reach ground water through sinkholes. Pesticides may also enter ground water via improperly constructed wells or by back-siphoning into wells while mixing and filling the applicator chemicals. Cases of ground water contamination have also been traced to spills and improper handling of pesticides (such as improper disposal of excess spray and rinsate from cleaning equipment).

The EPA has labeled some commonly used pesticides as having a high probability of moving into ground water when applied to very porous soils. Some pesticides are required to have a statement on their label such as "This product is a chemical that can travel through the soil and contaminate ground water, which may be used as drinking water. This product has been found in ground water because of agricultural use. Users are advised not to apply this product where the water table is close to the surface or where soils are very permeable. Your local Cooperative Extension Service Office can provide further information on the type of soil in your area and the location of ground water".

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Best Management Practices

1. **Integrated pest management (IPM)**: IPM programs use a range of methods and disciplines to assure stable and economical crop production while minimizing risks to

humans, animals, plants and the environment. IPM weighs costs, benefits, and impacts on health and the environment and thus identifies the most suitable ways to control pests. Options include prevention, monitoring, mechanical trapping devices, natural predators, biological pesticides, and, if appropriate, chemical pesticides.

2. **Pesticide selection:** Select a pesticide that will have the least impact on the environment. Environmental impacts of pesticides depend on sorption (how tightly pesticide is held by the soil surfaces), water solubility (the amount of pesticide that will dissolve in a given amount of water), and persistence (the amount of time a pesticide remains in the environment. Pesticides with high sorption and low solubility are much less likely to leach into groundwater, or be transported by runoff. Pesticides with low persistence (short half-life) are likely to break down into less harmful compounds before they have a chance to harm the environment.
3. **Timing:** Apply pesticides only when they are needed for pest control, and when conditions are least likely for the pesticide to move to ground or surface water. Contamination events often happen when pesticides are applied just before a high-intensity rainfall, when runoff can move the newly-applied pesticide into lakes and streams. The window of highest vulnerability for pesticide runoff is typically within 10 to 15 days after application.
4. **Sprayer calibration:** Apply the correct amount, which can only be done if sprayers are calibrated regularly.

   Spray nozzles are an important part of pesticide application equipment. Quality nozzles can reduce pesticide use and reduce environmental pollution.

   In row crops, nozzle patterns are directed downward. In citrus and other tree crop applications, it is a common practice to direct half the spray volume laterally toward the upper half of the tree and the rest to the lower half.

Source: USDA - Natural Resources Conservation Service

   Sprayer calibration: Application errors can originate from either incorrect pesticide concentration in the tank, (mixing error) or incorrect sprayer output per unit area (calibration error). The latter may be due to travel speed, nozzle pressure, or the use of improper, defective and worn nozzles. By properly matching sprayer discharge rate, swath width and travel speed, calibration errors can be minimized. Sprayer calibration can be carried out by:

   a) determining the amount of the tank mix used to spray a known area;
   b) operating the sprayer in a fixed place and measuring the amount of discharged liquid (water) for a specified time;
   or c) collecting the nozzle discharge and determining the output for a time period.

   The use of high capacity nozzles at low pressures to achieve low-volume application rates, one-sided calibration of the sprayer for two-sided operations and vice versa, calibration at closed pressure settings and intermittent operation of the nozzles can introduce errors in application rates. Sprayers using positive displacement pumps (diaphragm, piston, etc.) have more potential for application error compared to sprayers using centrifugal pumps, particularly at high volume rates.
   Source: Florida Cooperative Extension Service/Institute of Food and Agricultural Sciences/University of Florida EXIT Disclaimer
5. **Consider alternatives:** Alternatives to chemical pesticides include:
   - Biological pesticides, which target specific pests. Because of this targeting, these methods are generally considered to pose less risk to human beings, other species and the environment.
   - Microbial pesticides, which are naturally occurring or genetically altered microorganisms including fungi, viruses, and bacteria.
   - Pheromones, which disrupt normal mating behavior by stimulating breeding pests and luring them into traps.
   - Cultural practices such as different tillage practices and not growing the same crop every year (crop

Source: USDA - Natural Resources Conservation Service

rotation)

6. **Avoid sensitive areas**: Know the location of sensitive areas such as sinkholes, depressions, wells, surface water, public institutions. For example, buffer zone should be in effect when applying pesticides around these sites. A buffer is **required** between the application of atrazine, one of the most common herbicides, and wells or surface water.

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Irrigation

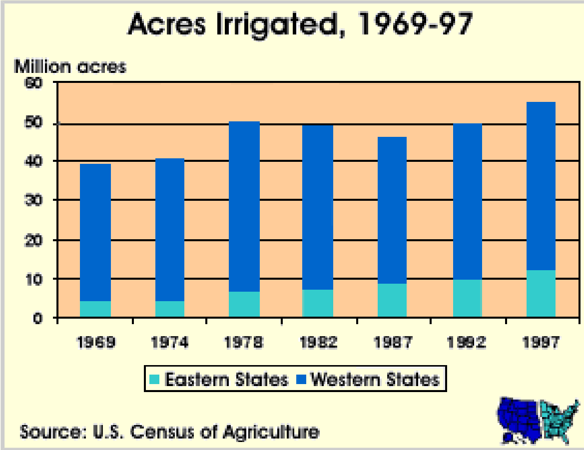
Source: USDA - Natural Resources Conservation Service

Irrigation makes agriculture possible in areas previously unsuitable for intensive crop production. Irrigation transports water to crops to increase yield, keep crops cool under excessive heat conditions and prevent freezing.

Less than 15% of U.S. cropland is irrigated, although irrigation is essential for crop production in some of the most productive areas of the country. For instance, in Arizona, home to some the highest corn yields in the country (208 bushel per acre state average in 2001 compared to 152 for Illinois), much of the crop is under continuous irrigation from planting until harvest.

The need to irrigate is usually driven by the necessity to meet the water needs of the crop from year to year (some areas of the country simply receive too little rainfall during the growing season to support economical crop growth). In other situations, irrigation is viewed as insurance against occasional drought. In areas where rainfall is plentiful in most years, irrigation can bring benefits by reducing risk, meaning that a farmer is better able to control income fluctuation. Other benefits include:

- Improving crop quality (most noticeable for vegetable crops)
- Significantly increasing crop yields, particularly on sandy soils which have low moisture-holding capacities
- Increasing opportunities for double cropping (planting soybeans after wheat in the same year)
- Providing a means of liquid fertilizer application



In 1997 there were about 55 million irrigated crop acres in the U.S. Irrigation is concentrated in certain areas like central California, Nebraska and the Great Plains, and the lower Mississippi valley.

Although irrigation has always been most common in the West, U.S. irrigated acreage in the East has also grown from 11 percent of acres in 1969 to 22 percent of acres in 1997.

Irrigation water is obtained from either ground water or surface water. Wells drilled on the farm are a common source of water in many areas, and are usually the only source used in the Great Plains. Offsite sources such as rivers, pipelines, canals operated by irrigation districts and private water companies, are also used, mainly in western states. The percentage of water source used for irrigation varies across the U.S.

Operations and Timing

Irrigation water is applied throughout the growing season to meet crop needs. Moisture needs depend on the type of crop and its stage of development. In the Eastern Corn Belt, for example, it takes 20-22 inches to produce an optimal corn crop, 18-20 inches for a soybean crop, 12-13 inches for small grain, and 24-26 inches for alfalfa. Irrigation can reduce crop stress if rainfall does not provide this amount of moisture during the growing season.

It is not only total moisture, but also the timing of moisture application (or rain) that is necessary for optimum crop yields. Crops have critical periods during the growing season when soil moisture must be maintained to ensure optimal yields. For corn, the most critical period is from just before tasseling through silking. For small grain, it is from boot to heading stage, for alfalfa, the start of flowering and after cutting, and for pasture, after grazing.

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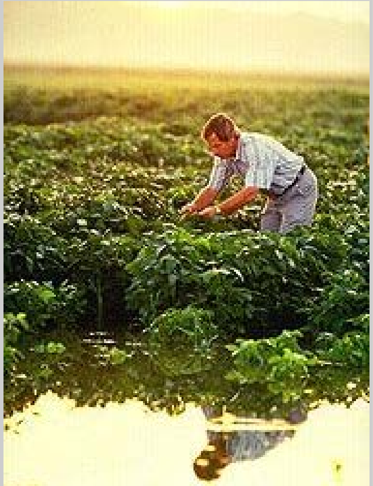
Equipment Used

There are four primary types of irrigation:

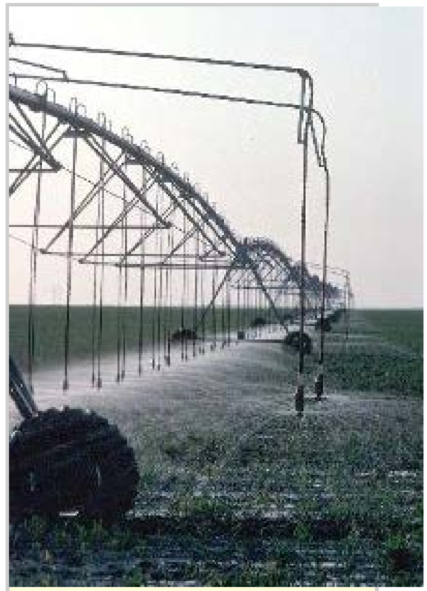
- Surface irrigation,
- Sprinkler irrigation,
- Drip or trickle irrigation, and
- Subsurface irrigation (or "subirrigation").

Surface Irrigation - With surface irrigation, water flows directly over the surface of the soil. The entire surface can be flooded (most often used for crops that are sown, drilled, or seeded) or the water can be applied through furrows between the rows (for row crops).

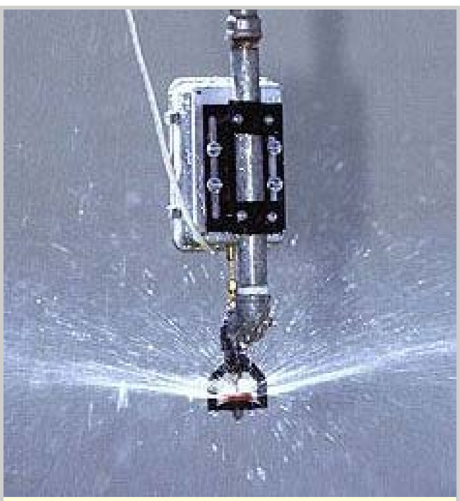


Source: USDA - Natural Resources Conservation Service

Sprinkler Irrigation - With sprinkler irrigation, water is sprayed through the air from pressurized nozzles, and falls like rain on the crop.



Center Pivot Irrigation
Source: USDA - Natural Resources Conservation Service

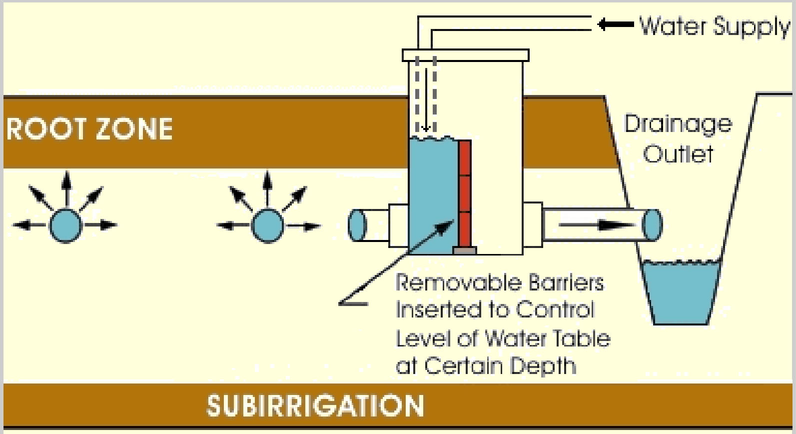


Source: USDA - Natural Resources Conservation Service

Variable-Flow Irrigation - Variable-flow irrigation sprinkler head improves the precision of water and farm chemical applications.

Trickle or Drip Irrigation - Trickle or drip irrigation supplies water directly onto or below the soil surface through "emitters' that control water flow.

Source: USDA - Natural Resources Conservation Service



Source: Modified from graphic by Leslie Zucker, Ohio State University Extension

Subirrigation - With subirrigation, the water table is artificially raised either through blocking ditches or by supplying water through the perforated pipes also used for subsurface drainage.

Irrigation types can be further distinguished by whether the equipment is permanently installed in one place (stationary system) or whether it is used until the necessary amount of water is applied, then moved to a different area (traveling system). Stationary systems such as permanent spray installations or trickle systems require less labor, but usually cost much more to install. Traveling systems such as center pivot sprinkler irrigation, linear-move, or cable-tow require more labor but less capital expense.

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Potential Environmental Concerns

Environmental concerns related to irrigation include depletion of the water source (falling water tables or reduced water levels in streams or reservoirs), soil erosion due to over-application, runoff and leaching of chemicals, and salinization of the soil (salt-buildup) and minerals and nutrients in the irrigation return flow that drains from the irrigated area.

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Best Management Practices

1. **Minimize water use**. Apply only enough water to meet crop needs. This can be determined through regular soil moisture monitoring or through a "checkbook" system to monitor water applied and crop needs.
2. **Irrigation efficiency**. Use efficient irrigation systems such as drip irrigation to minimize evaporation.
3. **Apply at rate the soil can absorb**. Runoff due to excess irrigation can cause soil erosion.
4. **Uniform Irrigation**. Make sure water is applied uniformly. This makes the water more efficient, and reduces the chance of runoff and leaching in certain areas where water may be overapplied.
5. **Provide good drainage**. Salinization in areas of low rainfall can be minimized by providing good drainage along with the irrigation, to leach salts down through the soil profile.

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Drainage

Impacts of poor drainage -- stunted, yellow plants
Source: Purdue University

The purpose of agricultural drainage is to remove excess water from the soil in order to enhance crop production. In some soils, the natural drainage processes are sufficient for growth and production of agricultural crops, but in many other soils, artificial drainage is needed for efficient agricultural production.

Surface drainage is the removal of water that collects on the land surface. Many fields have low spots or depressions where water ponds. Surface drainage techniques such as land leveling, constructing surface inlets to subsurface drains, and the construction of shallow ditches or waterways can allow the water to leave the field rather than causing prolonged wet areas.

Subsurface drainage removes excess water from the soil profile, usually through a network of perforated tubes installed 2 to 4 feet below the soil surface. These tubes are commonly called "tiles" because they were originally made from short lengths of clay pipes known as tiles. Water would seep into the small spaces between the tiles and drains away.

Poorly drained area in crop field will damage yields
Source: Purdue University

Drain tile outlet to a drainage ditch
Source: Purdue University

The most common type of "tile" is corrugated plastic tubing with small perforations to allow water entry. When the water table in the soil is higher than the tile, water flows into the tubing, either through holes in the plastic tube or through the small cracks between adjacent clay tiles. This lowers the water table to the depth of the tile over the course of several days. Drain tiles allow excess water to leave the field, but once the water table has been lowered to the elevation of the tiles, no more water flows through the tiles. In most years, drain tiles are not flowing between June and October.

Operations and Timing

On average, about two-thirds of annual precipitation is used by crops in the eastern Corn Belt. The rest falls at a time when it does not meet crop needs. Monthly precipitation remains fairly constant throughout the year, while evapotranspiration (a combination of evaporation from soil and transpiration from the crop), is much higher from June to September. From January to May, and from October to December, precipitation is greater than evapotranspiration, creating a water surplus. The surplus results in excess water in the crop root zone and the need for drainage. Drainage is primarily a concern in the periods prior to the growing season (January to April) so that crops can be planted at the optimum time.

(Note: Even in humid areas, crop water needs often exceed precipitation in July, August, and September. Although some of the moisture deficiency is met by stored soil moisture, irrigation can often increase yields.)

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Equipment Used

Trenching machine used by drainage contractors to install subsurface drainage tile (shown in white)
Source: Purdue University

Designing and installing a drainage system is a complex process. Every field is unique and usually requires an individual design. Drainage depends on topography, crops that will be grown on the field, and soil type. Every soil type has different properties that affect its drainage. Agronomists and engineers have developed recommendations for drainage depth and spacing in specific soil types based on years of experience and knowledge of soil properties. Drainage contractors use these recommendations to design drainage systems that economically and effectively drain a particular field.

Drainage plow being pulled by farm tractor installing a tileline

Source: Purdue University

Drainage plows that can be pulled by farm tractors are becoming more popular. But most farmers hire contractors to design and install their tile drainage systems because of the knowledge, skills, and experience needed to install a successful system.

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Potential Environmental Concerns

The major concerns related to drainage are:

- Loss of wetlands, and
- Increased loss of nitrate through tile drains.

Wetlands

Much of the Midwest landscape consisted of wetlands before large-scale drainage began in the 19th century. Although enormous public health and economic benefits have resulted from the draining of these wetlands over the last 150 years, there have also been negative impacts on the environment. Wetlands have an important hydrologic function in regulating water flow and maintaining water quality, as well as providing habitat for water-based wildlife. Recognition of their value has changed the way our society thinks about and protects wetlands.

Drainage improvements today are rarely for the purpose of converting existing wetlands to agricultural production. Improved drainage is usually aimed at making existing agricultural land more productive. Some fields have drain tiles that were installed 100 or more years ago, and are broken or plugged. In many fields, only a few of the wettest spots were originally drained, while the entire field would benefit from improved drainage. More tiles are often added to improve drainage efficiency, with the goal of increasing production.

Water quality

Drainage has both positive and negative effects on water quality.

Poor Drainage
Source: Purdue University

In general, less surface runoff, erosion, and phosphorus is lost from land that has good subsurface drainage than from land without drainage improvements or with only surface drainage.

Nitrate loss can be quite high from drained land. Because nitrate is very soluble, it flows easily through the soil and into tile lines. Nitrate flow from subsurface drains is one of the main sources of nitrate in streams and rivers in the Midwest. Concern about hypoxia, or low oxygen levels, in the Gulf of Mexico has increased concern about this nitrate source. Concentrations of nitrate in tile drains are usually quite high (10-40 mg/l).

Pesticides can also flow into subsurface drains, but usually only in very low concentrations. Pesticides move more easily in flow over the soil surface than through the soil, so the highest concentrations of pesticides in tiles are often in fields that have surface inlets into the drains. In fact, subsurface drainage may actually reduce pesticide loss to rivers and streams because it reduces surface runoff.

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Best Management Practices

Traditionally, the goals of drainage were to:

1. Maximize crop yield and
2. Minimize costs of drainage installation.

Source: Purdue University

Reducing water quality effects of drainage is becoming a third objective in drainage design.

Nitrate loss is the biggest water quality concern related to tile drainage. Several new technologies can reduce nitrate loss. **Controlled drainage** keeps the water table high during the off-season when crops are not growing. The high water table increases the rate of denitrification (a process that converts nitrate to harmless nitrogen gas (N_2) as soon as the saturated soil warms up in the spring) and reduces nitrate loss to the environment.

Controlled drainage can be combined with **subirrigation** to improve yields while protecting water quality. Subirrigation is irrigation back through the subsurface drain tiles. Subirrigation may be economical when fields are relatively level and need to be drained anyway, since additional infrastructure consists mainly of increased numbers of tiles the pumping system. One system being developed in Ohio combines a wetland for water treatment and a pond serving as a reservoir for subirrigation with a drainage system. This system has been shown to increase yields and reduce water quality impacts of drainage, although it is costly.

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Harvest

Source: USDA - Natural Resources Conservation Service

Harvesting crops involves getting the crop out of the field and transported to market. Most crops are harvested in the fall, except for hay which is cut several times over the course of the summer.

Field crops are harvested by machine, while small fruits and other food crops are typically harvested by hand, although in certain cases, they may be harvested by machine.

Operations and Timing

Source: USDA - Natural Resources Conservation Service

Crop	Typical harvest period (in eastern corn belt)
Corn - grain	October 7 to November 3
Corn - silage	September 1 to October 15
Soybeans	October 1 to October 20
Wheat (spring)	August 14 to September 1
Wheat (winter)	June 15 to July 15
Hay	Usually 3 cuttings from May 15 to Sept. 30

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Equipment Used

Farm tractor and tillage implement
Source: Daniel R. Ess, Purdue University

Tractors - are traction machines that provide mechanical, hydraulic, and/or electrical power to implements to perform a wide range of crop production and handling operations. Tractors are most often used to perform drawbar work and PTO (power take-off) work. Tractors can be equipped with rubber tires, rubber belts, or steel tracks. A modern farm tractor is almost always equipped with a diesel engine and tractor size is measured by the amount of power that the tractor can produce at the PTO. Tractor sizes range for those with less than 40 PTO horsepower to ones that produce more than 400 horsepower. The cost of a large tractor can exceed $200,000.

Forage Harvesters - are tractor-drawn implements or self-propelled machines that are used to gather, chop, and discharge forage crops as it moves through the field. The crops are typically harvested at a very high moisture content to permit ensiling (preservation through anaerobic fermentation). Forage harvesters require a great deal of power to perform the required functions. The largest self-propelled forage harvesters currently available have diesel engines that produce in excess of 600 horsepower.

A self-propelled forage harvester loading chopped corn into a truck on-the-go.
Source: Class of America

Tractor and pull-type combine operating in a small grain crop

Combines - are farm machines used to harvest grain and seed crops. The major functions performed by a combine include cutting and/or gathering, feeding, threshing, separating, cleaning, and grain handling operations on-the-go in the field. The vast majority are self-propelled, receiving power to perform all of the previously listed operations and traction from a diesel engine. The combine is often the most expensive farm machine used in grain or row crop production with list prices for the largest models exceeding $350,000. Some machines can harvest a thirty-foot swath of crop in a single pass through the field.

Self-propelled combine equipped with a grain header
Source: Daniel R. Ess, Purdue University

Self-propelled combine equipped with a corn head preparing to harvest corn
Source: Daniel R. Ess, Purdue University

Cotton Harvesters - are self-propelled machines specifically designed to pick (or strip), accumulate, and off-load large quantities of cotton in the field.

Cotton harvesters at work in the field
Source: Deere Photo Library, Vol. 3

Grain Carts - are tractor-drawn implements used to shuttle grain from combines to hauling vehicles or to grain receiving facilities. Grain carts are usually equipped with "high-flotation" tires or rubber tracks to attempt to minimize soil compaction in the field. The capacity of such carts can exceed 1,000 bushels (equivalent to 56,000 lb of shelled corn or 60,000 lb of soybeans).

A large-capacity grain cart unloading into a waiting truck
Source: Daniel R. Ess, Purdue University

Balers - are implements used for packaging hay, or straw to permit mechanized handling

Large round baler discharging a newly-formed bale of hay
Source: Deere Photo Library, Vol. 3

and transport. The two most common bale formats are large round bales (> 4 feet in diameter) and large rectangular bales (up to 8 feet in length). Large bales can weigh more than 2,000 pounds.

Large rectangular baler discharging a newly-formed bale of straw
Source: Class of America

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Storage of Fertilizer and Chemicals

- Fertilizer and Pesticide Storage
- Petroleum Product Storage

More information: Software for Environmental Awareness - interactive software to download.

Fertilizer and Pesticide Storage

- Summary of an Ideal Fertilizer and Pesticide Storage Facility
- Building a New Storage Facility
- Modifying an Existing Facility

Summary of an Ideal Fertilizer and Pesticide Storage Facility

Properly designed facilities promote storage, handling and disposal practices that enhance worker safety and minimize the risk of point source contamination. An ideal facility incorporates safety features in all aspects of its design and provides:

- Secure storage of fertilizers away from pesticides.
- Secondary containment of day to day spills resulting from normal mixing/loading operations.
- Secondary containment of large, accidental spills or leaks (separate secondary containment for pesticides and fertilizers)
- Facilities for collecting, storing and recycling excess spray solutions and rinsates.
- A dry, secure, well managed area for storing empty containers and other waste prior to proper disposal.
- Office facilities for effective management and communications.
- Orderly, accessible storage for personal protection equipment (PPE) and emergency supplies.
- Worker convenience facilities: first-aid and training areas, restrooms, shower(s), laundry.

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Building a New Storage Facility

Building a new storage facility just for fertilizer storage may be expensive, but generally it will be safer than trying to modify areas meant for other purposes.

When selecting a site on which to build the facility, two basic criteria should be considered:

1. Human safety
2. Environmental safety

When designing and building a new fertilizer or pesticide storage facility, keep in mind a few simple principles of safe storage:

1. Check with your state Cooperative Extension Service or department of agriculture for design recommendations and requirements of a fertilizer or pesticide storage facility.
2. Check the local and state building codes and local zoning requirements before constructing the facility.
3. Have the site checked for background levels for potential soil and water contaminants.
4. Draw a facility site plan on which you locate and sketch important structures and activity areas using accurate dimensions and distances.
5. Locate the building downslope and away from your well. Separation from the well should be greater if the site has sandy soils or fractured bedrock near the soil surface. If the site must be upslope from the well, be sure to take precautions to have any spill contained to prevent it from moving into the water that supplies your well.
6. Surface water should drain to a retention area in the event of a fire.
7. The mixing and loading area should be close to your storage facility, to minimize the distance that chemicals are carried.
8. Maintain safe separation distances from your fertilizer or pesticide storage facility to other structures and activity areas.
9. The building foundation should be well drained and high above the water table. The finished grade should be 3 inches below the floor and sloped away from the building to prevent frost heave. The subsoil should have a low permeability.
10. Provide pallets to keep large drums or bags off the floor in order to keep them dry. Shelves for smaller containers should have a lip to keep the containers from sliding off easily. Steel shelves are easier to clean than wood if a spill occurs.
11. If you plan to store large tanks, provide a containment area capable of confining 110-125% of the volume of the largest container (check state regulations).
12. The building may need to be insulated and heated if fertilizer is to be stored over the winter. It may need to be air conditioned in the summer, depending on the type of fertilizers or pesticides stored.
13. Keep the building locked and clearly labeled as a fertilizer or pesticide storage area. Provide exterior illumination of the warning signs and of the building to identify it as a fertilizer or pesticide storage facility. Preventing unauthorized use of fertilizers or pesticides reduces the chance of accidental spills or theft. Labels on the windows and doors of the building give firefighters information about fertilizers and other products present during an emergency response to a fire or a spill. It is a good idea to keep a separate list of the chemicals and amounts stored. If a fire should occur, consider where the water used to fight the fire will go and where it might collect. For example, a curb around the floor can help confine contaminated water.
14. Provide adequate road access for deliveries and use, and in making the storage area secure,

also make it accessible, to allow getting fertilizers and other chemicals out in a hurry.

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Modifying an Existing Facility

Some of the principles for safe fertilizer storage:

1. Provide pallets to keep large drums or bags off the floor. Shelves for smaller containers should have a lip to keep the containers from sliding off easily. Steel shelves are easier to clean than wood if a spill occurs.
2. If you plan to store large bulk tanks, provide a containment area large enough to confine 125 percent of the contents of the largest bulk container.
3. Keep the building locked and clearly labeled as a fertilizer storage area. Preventing unauthorized use of fertilizers reduces the chance of accidental spills or theft. Labels on the windows and doors of the building give firefighters information about fertilizers and other products present during an emergency response to a fire or a spill. It is a good idea to keep a separate list of the chemicals and amounts stored. If a fire should occur, consider where the water used to fight the fire will go and where it might collect. For example, a curb around the floor can help confine contaminated water
4. Provide adequate road access for deliveries and use, and in making the storage area secure, also make it accessible, to allow getting fertilizers and other chemicals out in a hurry.
5. Never store fertilizers inside a wellhouse or a facility containing an abandoned well.

If you decide to improve your current storage building, applying the above principles can be expensive. However, compared to the cost of a major accident, fine or lawsuit, storage improvements can be a bargain! If that is not practical, consider how you can protect the fertilizers that you keep on hand.

Sound containers are your first line of defense against a spill or leak. If a container is accidentally ripped open or knocked off a shelf, the spill should be confined to the immediate area and promptly cleaned up. The building should have a solid floor and, for liquid fertilizers, a curb. The containment volume should be large enough to hold the contents of the largest full container.

Ideally, the fertilizer storage area should be separate from other activities. If the building must also serve as a machine shed or as livestock housing, you may find it difficult to meet all the requirements for safe storage.

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Petroleum Product Storage

Aboveground Storage Systems

In most states there are two major sets of regulations which impact the design, installation, use and management of aboveground storage tanks (ASTs) for motor fuel and waste oil:

1. Those related to fire, explosion and human safety; and
2. Those designed to protect the environment.

In addition, ASTs may also be subject to state "spill reporting" laws. For instance, Indiana's Spill Reporting Law requires that surface spills and releases of about 25 gallons or more "that enter or threaten the waters of the state" must be reported to the Emergency Response Section of the Indiana Department of Environmental Management within 24 hours, and appropriate corrective action must be initiated immediately. Check for similar laws in other states.

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Underground Storage Systems

Most states have adopted the federal regulations (or a stricter version of them) for underground storage tanks (USTs) greater than 1100 gallons. They may also have regulations for smaller USTs - check to be sure.

State and local UST Regulatory Web sites

Whether regulated or not, all USTs deserve careful management with attention to preventing water pollution, including:

- Overfilling
- Pipe Leaks
- Tank Corrosion

There are many prudent measures to prevent contamination of water supplies, including:

- Secondary Containment Structures
- Catchment Basins
- Automatic Shutoff Devices
- Automatic Overfill Alarm
- Tank Relining
- Sacrificial Anodes for Corrosion Prevention

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Agricultural Pesticides

(University of Florida - IFAS)

The federal government has regulated pesticides since the early 1900s.

The use of synthetic pesticides in agriculture is the most widespread method for pest control. "...Farmers spend approximately $4.1 billion on pesticides annually. They justify this high cost by a direct dollar return of from $3 to $5 for every $1 spent on pesticides." (1991 edition of the *Handbook of Pest Management in Agriculture.*)

Environmental and human health problems related to the use of synthetic pesticides have created an increasing pressure against their use. In recent years, non-chemical alternatives for pest control have been developed and modern pesticides have become safer and more specific. Technical developments of the application equipment have also improved to enable their proper application. However, their proper professional use has not always been transferred satisfactorily to field practice.

Alternative approaches to pest control are used more and more and the concept of integrated pest management where synthetic pesticides are only applied as a last resort is now considered common practice in professional agriculture. The non-chemical alternatives include cultural practices, choice of resistant varieties, creation of an environment favorable for natural enemies of pests, and use of biological products and agents, including beneficial insects.

Likewise, synthetic pesticides have undergone a development process to match today's requirements. They have become less toxic for humans, though not necessarily for the environment, they have become more specific to act as a useful contribution within an IPM concept and they have become more powerful. While 40 years ago pesticides were applied in kilograms or liters of active ingredient per hectare, modern pesticides only require grams or milliliters to achieve the same or better result.

On the other hand, the new pesticides require a more sophisticated technology for a safe, even and efficient application. Modern application equipment (including backpack sprayers) allow a fairly safe and efficient application of pesticides of all kinds. "The design of equipment has impact mostly on the operator and environmental safety preventing unnecessary contamination, accidents, loss and spills and allowing an even distribution of the product." Modern electronics have improved the accuracy of dosing, distribution, and application. The use of global positioning systems (GPS) allows precise tracking of the application. Spray nozzle technology greatly affects spray coverage, which is second in importance only to the selection of the pesticide in determining the success of an application.

Originally, the purpose of pesticide laws and regulations was to protect consumers from fraudulent claims about product performance. The focus now has shifted to the protection of health and the environment, including:

- Providing for the proper and beneficial use of pesticides to protect public health and safety.
- Protecting the environment by controlling the uses and disposal of potentially harmful pesticides.
- Assuring safe working conditions for farm workers, commercial pest control personnel, and consumers.
- Assuring users that pesticides are labeled properly and are appropriate for their intended use, and contain all instructions and precautions necessary.
- Encouraging the use of integrated pest management (IPM) systems that emphasize biological and cultural pest control techniques with selective use of pesticides.

More information on Agricultural Pesticides

- Benefits of Pesticide Use
- Risks of Pesticide Use
- Lethal Dosage (LD50) Values
- Ever-Changing Laws and Regulations
- Formulation Selection Considerations
- Integrated Pest Management
- Water Quality
- Soil/Water Adsorption Coefficient (Kd)
- Water Solubility
- Half-Life
- Movement Off Target

Benefits of Pesticide Use

For many years, we have enjoyed the benefits of using pesticides to control weed, insect, fungus, parasitic, and rodent pests. Recently, both the public and the press have increasingly focused on the negative impacts of agricultural, urban industrial, and residential chemicals. However, there are also substantial benefits to society, including:

- Pesticides are the only effective means of controlling disease organisms, weeds, or insect pests in many circumstances.
- Consumers receive direct benefits from pesticides through wider selections and lower prices for food and clothing.
- Pesticides protect private, public, and commercial dwellings from structural damage associated with termite infestations.
- Pesticides contribute to enhanced human health by preventing disease outbreaks through the control of rodent and insect populations.
- Pesticides are used to sanitize our drinking and recreational water.
- Pesticides are used to disinfect indoor areas (e.g., kitchens, operating rooms, nursing homes) as well as dental and surgical instruments.
- The pesticide industry also provides benefits to society. For instance, local communities and state governments may be partially dependent upon the jobs and tax base that pesticide manufacturers, distributors, dealers, commercial applicators, and farmers provide.

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Risks of Pesticide Use

Within the last few decades, scientists have learned that some pesticides can leach through the soil and enter the groundwater below. While 50% of the nation depends upon groundwater for drinking water, almost 95% of the households in rural areas use groundwater as their primary source of drinking water. The impact of agricultural chemicals on surface and groundwater quality has become an issue of national importance.

(EPA has responsibility under a variety of statutes to protect the quality of the nation's ground water as well as direct responsibility for regulating the availability and use of pesticide products.

Each pesticide product has inherent risks associated with it. Potentially detrimental impacts of pesticides include:

- Acute poisoning from a single or short-term exposure can result in death.
- Chronic impacts of long-term exposure to pesticides, including pesticide residues in food, could also result in death.
- Natural resources can be degraded when pesticide residues in storm water runoff enter streams or leach into groundwater.
- Pesticides that drift from the site of application can harm or kill nontarget plants, birds, fish, or other wildlife.
- The mishandling of pesticides in storage facilities and in mixing and loading areas can contribute to soil and water contamination.

The risk associated with a given pesticide or pesticide product depends on the toxicity of the compound and the probability of exposure.

Source: University of Florida - IFAS

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Lethal Dosage (LD50) Values

An LD50 is a standard measurement of acute toxicity that is stated in milligrams (mg) of pesticide per kilogram (kg) of body weight. An LD50 represents the individual dose required to kill 50 percent of a population of test animals (e.g., rats, fish, mice, cockroaches). Because LD50 values are standard measurements, it is possible to compare relative toxicities among pesticides. The lower the LD50 dose, the more toxic the pesticide.

A pesticide with an LD50 value of 10 mg/kg is 10 times more toxic than a pesticide with an LD50 of 100 mg/kg.

The toxicity of a pesticide is related to the mode of entry of the chemical into an organism. Oral LD50 values are obtained when test subjects are fed pesticide-treated feed or water. Dermal LD50 values are obtained when the pesticide is applied to the skin of the animal. Inhalation LD50 values are obtained when the animal breathes the pesticide with a mask. Often the inhalation LD50 is lower (more toxic) than the oral LD50, which is in turn lower (more toxic) than the dermal LD50.

LD50 values are not always given on the pesticide label; rather, the relative toxicity of a pesticide product is reflected by one of three signal words: DANGER, WARNING, or CAUTION. The purpose of signal words is to alert the user to the level of toxicity of the product. The signal word is generally assigned based on the pesticide's inhalation, oral or dermal toxicity, whichever is the most toxic.

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Ever-Changing Laws and Regulations

Shortly after the EPA's Groundwater Protection Strategy was issued in August 1984, the Agency initiated an intensive review of existing information and scientific knowledge about the extent of pesticide contamination, its causes and potential health impacts, and statutory authorities and programs available to help address the problem. EPA supports state strategy development through grants under Section 106 of the Clean Water Act as a means for strengthening the capacity of state governments to protect groundwater quality.

Other regulations and programs such as the Safe Drinking Water Act and its amendments, a new Wellhead Protection Program, Clean Water Act, the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), and the new Non-point Source Management Program have all been initiated in an attempt to protect the nation's groundwater from contamination by all types of pollutants including pesticides. Since the early 1970s, the EPA's Office of Pesticide Programs has been evaluating the leaching potential of new and existing pesticides.

Because of potential environmental concerns associated with pesticide application, there are two federal laws that regulate pesticide use: FIFRA and FFDCA. Most of the states have also enacted their own pesticide legislation. All pesticide labels contain certain standard information, including the ingredients, directions for proper use, warning statements to protect users, the public, and nontarget species of plants and animals. All statements on the label must be adhered to by all users and sellers. All pesticides must be registered with the EPA to ensure that they will not cause unreasonable adverse effects on the environment.

Certain pesticides are classified as "Restricted-Use" and can only be used by or under the direct supervision of a trained Certified Applicator. Restricted-Use pesticides are those that have a greater chance of causing adverse impacts to humans and the environment. Certification is a way of ensuring that people who apply these restricted-use pesticides possess the knowledge to do so in a safe manner. It is illegal to make restricted use pesticides available to non-certified personnel.

The benefits and risks are periodically reassessed as new scientific information is discovered and to reflect changes in the views of society. This does not mean that decisions of today eventually will be proven wrong. Rather, the balance of benefits and risks is ever-changing because of improved science and the changing expectations of society.

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Formulation Selection Considerations

The importance of formulation type is generally overlooked. The decision to use a formulation for a given application should include an analysis of the following factors:

- Applicator safety. Different formulations present various degrees of hazard to the applicator. Some products are easily inhaled, while others readily penetrate skin, or cause injury when splashed in the eyes.
- Environmental concerns. Special precautions need to be taken with formulations that are prone to drift in air or move off-target into water. Wildlife can also be affected to varying degrees by different formulations. Birds may be attracted by granules, and fish or aquatic invertebrates can prove especially sensitive to specific pesticide formulations such as 2,4-D esters.
- Pest biology. The growth habits and survival strategies of a pest will often determine what formulation provides optimum contact between the active ingredient and the pest.
- Available application equipment. Some pesticide formulations require specialized application equipment. This includes safety equipment, spill control equipment and, in special cases, containment structures.
- Surfaces to be protected. Applicators should must be aware that certain formulations can stain fabrics, discolor linoleum, dissolve plastic, or burn foliage.
- Cost. Product prices may vary substantially, based on the active ingredients present and the complexity of delivering active ingredients in specific formulations.

Individuals such as commercial pest control technicians or farm workers who may not be involved in the selection process but are responsible for the actual application should also be made aware of the type of formulation they are using, its dangers and of the safety measures needed. This choice of formulation type can have an impact on human health and the environment. Inattention to the type of formulation being used could mean the difference between a routine application and one that is the source of environmental contamination - or worse, a serious human exposure.

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Integrated Pest Management

Integrated pest management (IPM) is the control strategy of choice for homeowners, growers, and commercial applicators. IPM is an approach to pest management that blends all available management techniques - nonchemical and chemical - into one strategy: Monitor pest problems, use nonchemical pest control, and resort to pesticides **only** when pest damage exceeds an economic or aesthetic threshold.

Labels and regulations change and new products are introduced routinely. Therefore, the pesticide selection process should be conducted just prior to **each** growing season.

The selection of a pesticide requires planning and knowledge of the alternatives. Begin by developing a comprehensive list of available pesticides for a specific crop, turf, or home garden pest. Pesticide recommendations for controlling any insect, weed, or disease can be suggested by numerous sources: the Cooperative Extension Service; consultants; agrichemical and urban pesticide dealers; product manufacturers; garden and nursery centers; association newsletters; trade journals; and expert applicators. After developing a pesticide list, the user should obtain labels of all products under consideration so that their strengths and weaknesses can be analyzed on a product profile worksheet. Labels generally are available locally from retail outlets or their suppliers.

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Water Quality

Four factors influence groundwater vulnerability to pesticide contamination:

1. Chemical properties of the pesticide
    - Low soil adsorption
    - Persistence
2. Soil Types
    - Sandy or gravel texture
    - Low organic matter content
3. Site Characteristics
    - Shallow water table
    - Sinkholes
    - Abandoned wells
4. Management Practices
    - Improper chemical storage, handling, and use

Options for protecting surface water near application sites include:

- No-spray strips around surface water supplies, wells, or irrigation ditches
- Grass waterways and grass buffers to resist runoff
- Use of conservation practices on erodible lands
- Plow berms around sinkholes

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Soil / Water Adsorption Coefficient (Kd)

The Kd value is a measure of how tightly the pesticide binds or sticks to soil particles. The greater the Kd value, the less likely a chemical will leach or contribute to runoff. A very high value means it is strongly adsorbed onto soil and organic matter and does not move throughout the soil.

Higher is better. Pesticides are less likely to leach or occur as surface runoff when the Kd is greater than 5.

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Water Solubility

Solubility is a measure of how easily a chemical dissolves in water. The lower a chemical's solubility, the less likely it is to move with water through the soil.

Lower is better. Pesticides are less likely to leach when their water solubility is less than 30 parts per million.

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Half-Life

Half-life is a measure of how quickly a chemical breaks down in soil (soil half-life) or water (hydrolysis half-life). The longer a chemical remains in water or soil without breaking down, the more likely it is to leach through the soil.

Shorter is better. Pesticides are less likely to leach when their hydrolysis half-life is less than six months and their soil half-life is less than three weeks.

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Movement Off Target

Pesticide particle drift and volatilization pose risks to neighbors, field workers, and the environment. Keeping products on the target site increases the effectiveness of pest control while reducing injury to nontarget susceptible plants, domestic animals, and wildlife. The proximity of an application site to sensitive areas such as nursing homes, subdivisions, schools, day-care centers, parks, playgrounds and hospitals is a critical factor requiring extra safety precautions. Misapplication can endanger public health and violate the law.

Two options exist for the applicator who is concerned about drift:

- Alter routine spray practices
- Switch to products than can be more easily managed to prevent particle drift or volatilization

Management decisions that can help prevent off-target movement include:

- Allowing for buffer zones and planting setbacks
- Incorporating pesticides into the soil
- Slowing the speed of the equipment
- Altering application methods
- Applying sprays nearer the target pest
- Applying at lower pressure
- Altering the time of application.

Products may vary in their ability to move out of the target treatment area. Evaluate each product to determine the best choice for your site requirements.

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Crop Production Study Questions

Identify the definition that best fits the following terms:

1. **U.S. farmers produce about $___________________ worth of crops each year.**

   - 1,000,000
   - 1,000,000,000
   - 10,000,000,000
   - 100,000,000,000

   Feedback

2. **Soybeans produced in the United States account for about ________% of world soybean trade.**

   - 1
   - 10
   - 25
   - 50

   Feedback

3. **Most corn grown in the United States is used for _________________________ production.**

   - animal feed
   - corn chip
   - high fructose corn syrup
   - ethanol

   Feedback

4. **Which of the following is the number one cash crop grown by U.S. farmers?**

   - Wheat
   - Corn
   - Soybeans
   - Rice

   Feedback

5. **There are approximately how many farms in the United States?**

   - 10,000
   - 1,000,000
   - 2,000,000
   - 20,000,000

   Feedback

6. **Which of the following is an off-farm impact of soil erosion?**

- Lower soil fertility levels
- Development of rills and gullies in the field
- Less water infiltration into the soil
- Decreased water quality downstream

Feedback

7. **The practice of planting along the slope instead of up-and-down slopes is called:**

- Contour farming
- Cover cropping
- Strip cropping
- Terracing

Feedback

8. **Nitrogen fertilizer is most efficient when applied**

- In the fall
- In late winter
- At or after planting
- In late summer

Feedback

9. **Sources of nutrients that can cause eutrophication and hypoxia in the Gulf of Mexico include:**

- Sewage treatment plant discharge
- The atmosphere
- Fertilizer or manure application
- All of the above

Feedback

10. **Restricted-use pesticides**

- Cannot be applied on agricultural fields
- Can only be applied by Certified Applicators
- Should only be applied in the fall
- Are illegal on most crops

Feedback

11. **Which of the following is not a reason that irrigation is used?**

- To facilitate pesticide application
- Insurance against possible drought
- Moisture may not be available at the optimum time for crop growth
- To improve crop quality

Feedback

12. **Since 1987, irrigated acres in the U.S. have been**

- Steadily decreasing
- Steadily increasing
- Staying about the same
- Increasing in the West but decreasing in the East

Feedback

13. **Positive effects of drainage on water quality include:**

- Decreased loss of nitrogen to streams
- Decreased soil erosion
- Increased health of aquatic and wetland vegetation
- All of the above

Feedback

14. **Perforated subsurface drains are often called "tiles" because**

- They are square like tiles
- They are placed in a grid like a tiled floor
- An early plastic tubing manufacturer called them “tiles” as part of its brand name
- They used to be made of clay pipe called tiles

Feedback

15. **Drainage systems are usually designed to:**

- Lower the water table within a few hours after a rain
- Lower the water table within a few days after a rain
- Flow throughout the year
- Prevent excessive loss of nitrogen from the field

Feedback

See Results RESET

Score in Percentage:	

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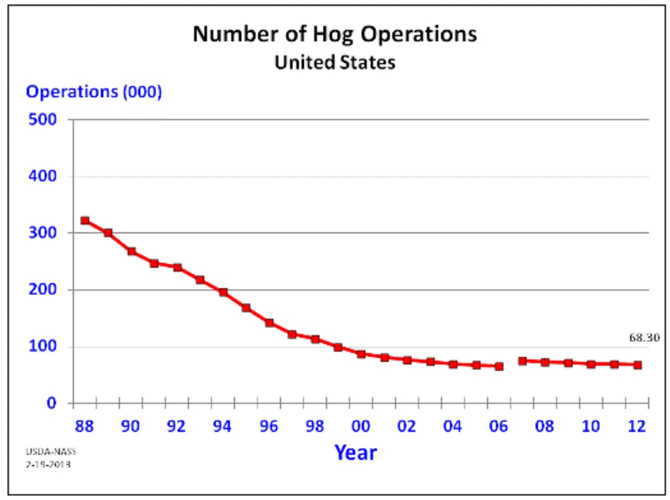
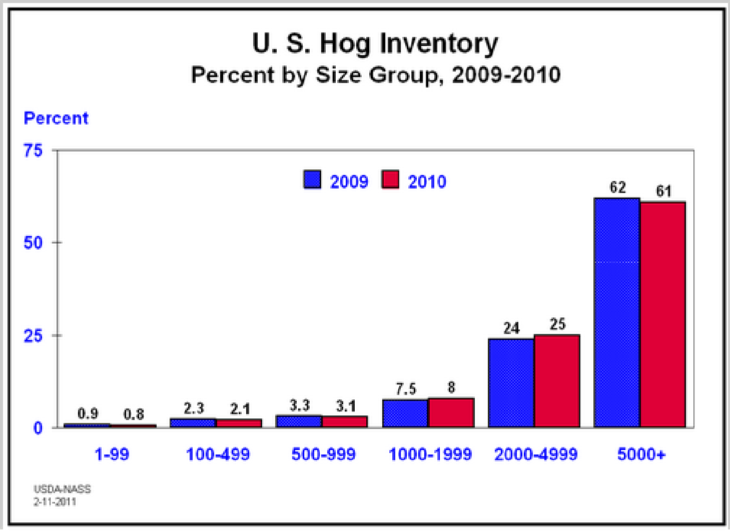
Background of Pork Production in U.S.



Wild boars domesticated in N. Europe c.1500 B.C., are believed to be the ancestor of modern domesticated hogs, along with a genetic input from smaller Asian species domesticated in China around 3000 B.C. Pork, the meat from swine, was widely consumed throughout the ancient world and the Roman Empire. Pigs were not indigenous to the Americas, but came from Europe and the Orient. Columbus brought hogs on his second voyage to the Americas in 1493. Polynesians may have brought pigs from the Orient to the Hawaiian Islands even earlier.



For much of the 19th and 20th centuries, pork was the preferred meat in the U.S. Hogs were valued not just for their meat but for the lard, which was used for everything from cooking and lamp oil to baking and making candles and soap. As Americans became more health conscious, they lost much of their appetite for animal fats, switching to more healthy vegetable oils. Production began to focus on the pigs' ability to efficiently convert feed into protein, which resulted in a much leaner type of pig being produced.

There has also been a significant change in how and where hogs are produced in the U.S. over the past 50 years. Low consumer prices, and therefore low producer prices, have resulted in larger, more efficient operations, with many smaller farms no longer able to produce pigs profitably. Since the late 1990s, the number of farms with hogs decreased by over 70 percent. (USDA Hogs & Pork Background) However, even with the decline in farms with hogs, the U.S. is the third largest pork producer and consumer and the largest exporter of pork and pork products. (USDA; Hogs & Pork Overview)

In 2007, sales of all animals in the U.S. totaled over $80 billion. Included in the total sales of animals is the number of hog and pig sales which totaled $18.1 billion. (2007 Census of Agriculture) Currently, most of the swine in the United States are produced in in the Midwest--Iowa and Southern Minnesota, particularly--and in eastern North Carolina. Worldwide, China is by far the largest producer of pork, producing nearly four times as much as the U.S.

There are many breeds of swine, such as Hampshire, Duroc, Poland, China, Landrace, etc., but most farms use crossbreeds to try to gain the best traits of each breed.

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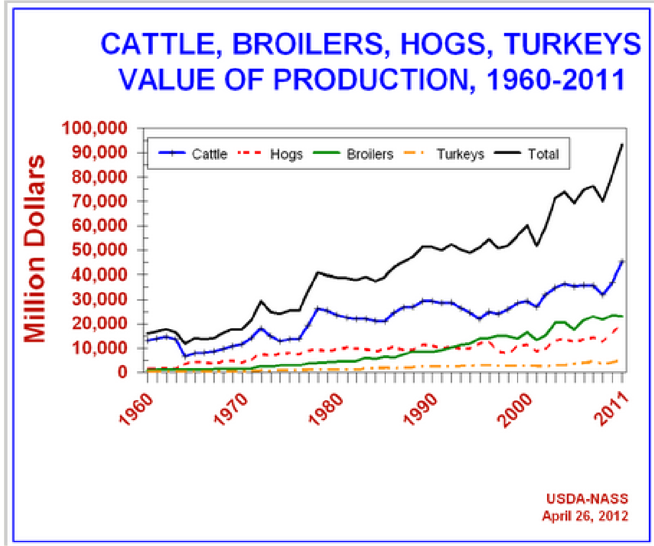

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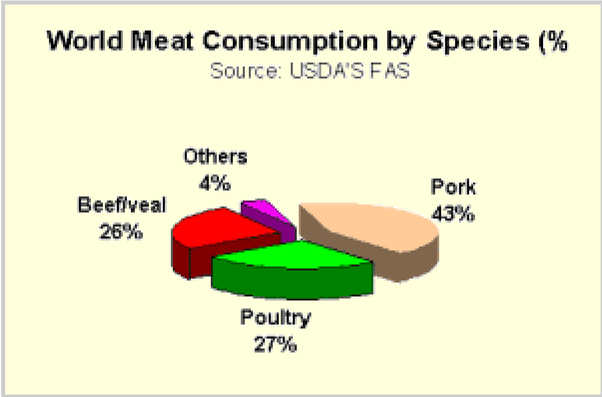
Products from Pork



Pork is the most widely consumed meat in the world. People eat many different pork products, such as bacon, sausage, pork chops and ham. A 250-pound market hog yields about 150 pounds of pork.

Several valuable products or by-products, in addition to meat, come from swine. These include insulin for the regulation of diabetes; valves for human heart surgery; suede for shoes and clothing; and gelatin for many food and non-food uses. Swine by-products are also important parts of such products as water filters, insulation, rubber, antifreeze, certain plastics, floor waxes, crayons, chalk, adhesives and fertilizer.

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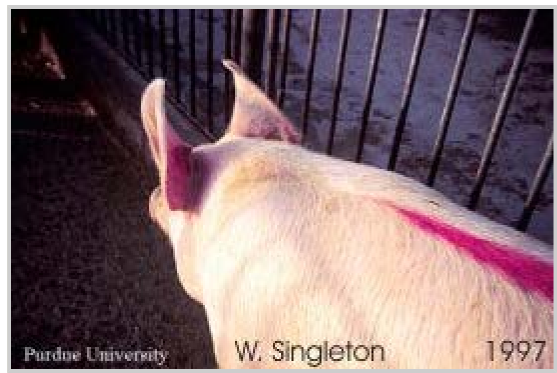
Pork Production Phases

The phases of pork production that take place on the farm to produce hogs ready for market are called: breeding-gestation, farrowing, nursery, and grow-finish.

Breeding-Gestation



Swine production can be logically separated into a number of phases, beginning with the sow being bred. Historically, this has been done by placing a number of sows in a pen with one or more boars. In confinement buildings, boars are often rotated between sow pens to make sure that all sows are bred while they were in heat. Sows in enclosed shelters come into estrous, 3 until 5 days after their pigs are weaned. The estrous period, or standing heat, is the period when the sow can be bred. Estrous only lasts a short time, so it is critical that the sow is bred at this time. During estrous, the sow shows outward signs of being willing to accept the boar, such as standing still when the producer applies downward pressure on her back or holding her ears erect. If the sow is not bred during this period, she normally returns to estrous about 21 days later. These two periods are known as "first heat breeding" and "second heat breeding". The non-pregnant sow is considered "unproductive" during this 3-week period, since she still must be fed and housed. Most modern operations have sows bred only on first heat. Sows that fail to breed during this estrous are often sent to market and replaced in the sow herd by gilts, or young females that are removed from the grow-finish group of pigs. After breeding, the sow "gestates" her "litter" for 113 to 116 days before the pigs are born or "farrowed." A good way to remember gestation length for swine is that it is approximately "3 months, 3 weeks and 3 days".

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Farrowing

Just before giving birth, called farrowing, sows are normally moved into a "farrowing room." Sows typically farrow from eight to twelve piglets, which as a group are called a litter. Most confinement operations place the sow in a temperature-controlled


Pen farrowing
Source: USDA

Protecting baby pigs in a farrowing crate
Source: Purdue University

environment and usually in a farrowing pen or crate which restricts her movement to protect her baby pigs. The baby pigs spend most of their time in a "creep area on one or both sides of the crate where they have ready access to their mother, but are protected from crushing when she lies down. A few farrowing operations in the U.S. use larger pens and provide deep straw bedding on solid floors. While this is a more natural process for the sow, it involves more labor and often results in higher crushing losses.

An average sow will raise three to five litters of pigs in her lifetime. Sows may be culled and sent to market, because of age, health problems, failure to conceive, or if they are able to raise only a low number of pigs per litter.

Pigs are born with eight needle-sharp teeth and curly tails. The tips of the teeth are clipped at birth to prevent injury to the sow's udder and other piglets and the tail is shortened to prevent tail biting. Piglets weigh about three pounds at birth and are weaned from the sow at anywhere from five days to four weeks, with most operations weaning pigs at two to three weeks.

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Nursery Pigs

Source: Purdue University

After weaning, pigs are normally placed in a "nursery" where they are kept in a temperature-controlled environment, usually on slotted floors. The floors in a nursery are usually constructed from plastic or plastic covered steel instead of concrete to provide additional comfort for the small pigs. Pigs are normally given around three square feet of space each and provided with ready access to water and feed. Nursery pens are sometimes elevated, with their slotted floor above the room floor level 8 to 12 inches. This is done to minimize the possibility of cold floor drafts chilling the young pigs. Immediately after weaning, the temperature in the nursery may be as much as 85 degrees, and then dropped gradually to about 70 degrees as the pigs grow. Pigs are normally removed from the nursery at about 6 to 10 weeks of age and placed in a "grow-finishing" building. Nursery rooms are almost always heated with furnaces and ventilated with mechanical fans, controlled by a thermostat, in order to keep the pigs warm and dry throughout the year.

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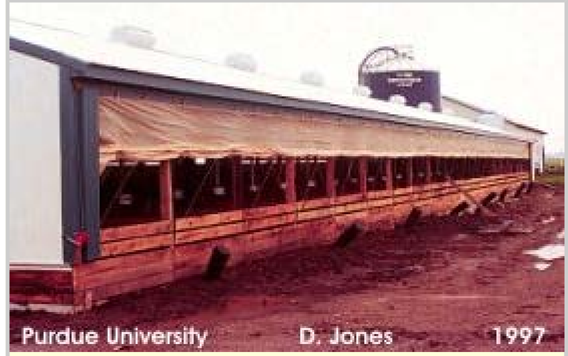
Grow-Finishing

This phase is where pigs are fed as much as they wish to eat until they reach market weight of 250 to 275 pounds and provided around 8 sq. ft. of space per pig. Marketing normally occurs at five to six months of age, depending on genetics and any disease problems encountered. Some gilts are returned from the grow-finish phase to the sow herd for breeding purposes, to replace older sows that are culled.

Grow-finish pigs on concrete slotted floor
Source: Purdue University



Naturally ventilated (grow-finish building)

Mechanical ventilation in grow-finish building
Source: Purdue University

Animals in a grow-finish operation are larger and produce a great deal of body heat. Ventilation to keep the animals cool is usually more of a concern than providing heat in winter. Animals at this age grow best at around 60-70 degrees. In winter, they are protected from winter winds in a moderately well insulated building. Enough ventilation must be provided to remove moisture and to provide fresh air for the animals. In summer, large sidewall vents are opened or large ventilation fans are operated to keep the animals comfortable. This is referred to, respectively, as naturally ventilated (air change due to the wind) or mechanically ventilated (where air is drawn into the buildings through vents due to a negative pressure created with wall fans that exhaust inside air.

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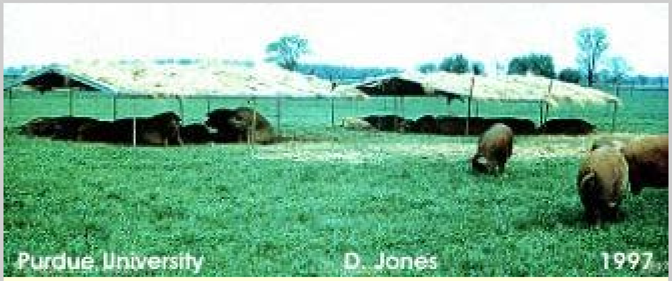
Production Systems



Gestation sows on pasture

Before the 1960s, most pork in the U.S. was raised in outside lots or on pasture systems. With the development of slotted floors and liquid manure handling equipment, it became possible for producers to more easily care for larger numbers of animals, and to do so protected from the weather. Enclosed buildings overcame most weather problems, predators and minimized the potential pollution from outside lot runoff. It also made it practical to farrow sows twice a year, rather than once. This was the beginning of intensive production schedules on relatively small areas as found throughout the world today.

Enclosed housing for swine

In a continuous flow barn, animals of many different stages of development may be housed in close proximity to one another and the facilities are never empty. Advantages are that space is efficiently used, because pigs can be moved to larger pens as they grow, and new arrivals replace them in the smaller pens. Continuous systems also simple to plan; if the producer wants to wean two litters each week, two sows must be bred each week.

Disadvantages are that different ages of animals (with different degrees of disease resistance) are housed together, facilitating disease spread, stress levels can be heightened with changing social groups, adequate cleaning and disinfecting are not feasible, and higher levels of antibiotics and other medications are normally required to control disease.

Most swine today are raised in “all-in, all-out” (AIAO) systems, where each room or building is completely emptied and sanitized between groups of pigs. Each new group of pigs enters a freshly disinfected environment, and stays there for this phase of their life. The facility has a separate room or building for each group of pigs weaned, with extra space if needed to allow workers time to clean the room before the next group of pigs. AIAO animals in each room are of a uniform age and size and are isolated to the extent possible to decrease the possibility of diseases spreading from older animal groups to younger ones.

The primary advantages are that disease spread can be better contained, animals are less stressed because they remain with the same age and social group throughout their development, and complete cleaning and disinfecting between groups is possible. The disadvantage is that space is less efficiently allocated, and that more space may be needed to allow rooms to be empty for cleaning between groups.

Until around 1990, swine production systems were usually housed on a single site, because of labor savings and convenience. Health concerns have since caused many swine operations to house the various production phases at different sites to further minimize contact between pigs of different ages. This is either a two-site or a three-site system. A two-site system has breeding and gestation at one site and farrowing/nursery and grow finish pigs at a separate site, while a three site also places the nursery at a separate site.

In the last few years, some producers have constructed "wean to finish" barns where pigs go immediately after weaning, and stay until market. This combines the nursery and grow-finish phases of production. These barns provide substantially more space per pig than is needed initially, but provide the advantage of only moving pigs once during their lifetime. This reduces stress on the animals and saves labor since buildings are not cleaned until the hogs are marketed.

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Nutrition

Swine have a digestive system similar to humans and different from ruminants such as cattle and sheep, which can eat forages or grasses. Pigs are fed a diet that is primarily ground corn to supply heat and energy and soybean meal to provide protein. Vitamins and minerals are also added in their feed. Rations are closely tailored to optimize health and growth at each stage in their life. Many producers even modify the ration based on the pig's gender.

The ration is normally changed to provide more energy and less protein as the pig grows. The goal is to optimize feed utilization for different stages of growth. Since nutritional needs are different for male and female grow-finish pigs, larger operations may even modify the ration, based on gender. Recent studies indicate that ration modifications that can reduce the amount of nitrogen and phosphorous excreted in the manure, while maintaining optimum pig growth and health. It takes nearly 1000 pounds of feed to raise a hog to market weight. This same pig drinks about one-and-a-half to two gallons of water a day over its six-month life.

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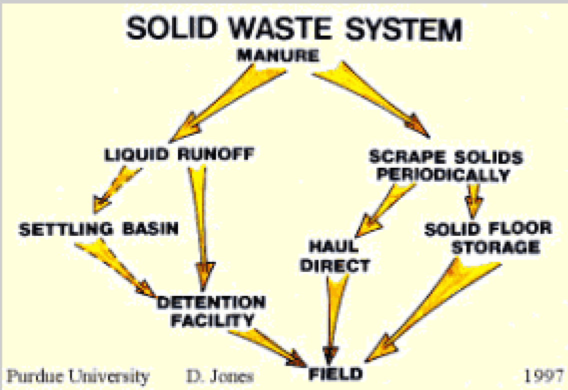
Common Manure Handling Systems

Solid Manure



Schematic of solid manure systems
Source: Purdue University

Surface application of solid manure
Source: Purdue University

Swine manure was historically handled as a solid, either deposited directly by grazing animals, or collected in bedding placed on solid shelter floors to absorb the urine. Pastured animals spread the manure over the land as they grazed. Manure deposited on solid floors is typically stored where it falls, with more bedding added as needed to maintain a dry floor. Liquid drains away from the manure dropped on an outside lot and must be collected in a storage, leaving the solid manure behind. The manure composts in place somewhat and is removed every few months. Fertilizer value is recovered by spreading on cropland to complete the nutrient cycle. Solid manure is normally surface applied, but in some cases may be incorporated into the soil with a farm tillage operation shortly after spreading. Composting is another option for solid manure management.

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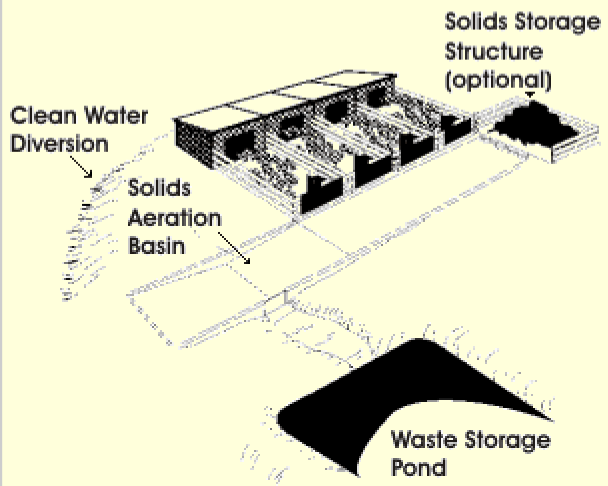
Lot Runoff



Options for handling manure from open lot
Source: Purdue University

Options for handling manure from open lot holding pond for runoff from outside lot
Source: Davis-Purdue Farms

Manure is typically scraped from outside lots every week or two and stacked until it can be hauled to cropland. It is important to keep an outside lot relatively free of manure to control odor and so that rainfall runoff stays mostly free of manure. This facilitates storage of relatively clean runoff for irrigation onto cropland. It is even possible to divert runoff from small operations directly to pasture or to a vegetated filter strip where it can infiltrate. It must be prevented from entering waterways. Clean upslope water and roof water should be diverted away from the open lot to minimize the amount of wastewater that must be handled as a manure.

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Liquid Manure

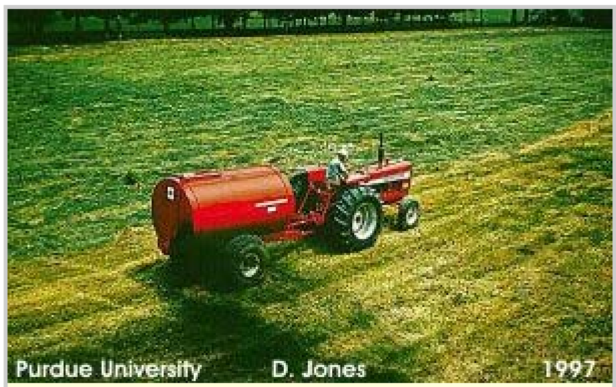
Grow-finish pigs on slotted floor
Source: Purdue University

Most swine manure is handled as a liquid. Manure typically falls through a slotted floor (with the size of slot depending on the size and age of animal) into either a gutter or a concrete storage pit. Storage pits provides from 3-12 months storage of the manure. This pit may either be located directly under the slotted floor and may be from 4' to 10' deep. In some operations, the manure falls into a shallow pit or gutter which is periodically pumped, flushed or drained to a large outside storage. The outside storage may either be constructed in the earth or a commercial steel or concrete storage purchased and erected onsite . Storage size is dictated by regulatory agencies in most states and are usually sized large enough to hold at least six month's accumulation in Midwestern states. This avoids the need to apply manure during the crop growing season and when weather conditions are unsuitable – such as on frozen ground or when the soil is wet enough that heavy application vehicles could compact and damage the soil for crop production.

A sheepsfoot roller is used to compact soil for an earthen storage structure

Fabricated steel manure storage

Liquid manure pit agitation
Source: Purdue University



Surface applied liquid manure
Source: Purdue University

Liquid manure from storage is normally agitated thoroughly to make the manure nutrient content between loads more uniform and hauled to the field for application in large tanker wagons or trucks. Liquid manure is either applied to the soil surface or is incorporated during or shortly after application to control loss of volatile ammonia and release of odors. Incorporation is very effective at controlling runoff of manure nutrients and reducing odor from land application if done during or within a few hours after application. One method is a soil injector, where liquid manure is “injected” directly into the soil to a depth of 6 to 9” as the tanker passes over the field. This immediate contact between the manure and soil is highly effective at controlling odor.

In remote areas, liquid manure may be pumped to the land application site and then irrigated onto cropland. Spray irrigating liquid manure is a very efficient method of land application, in terms of speed and labor, but odor emissions can be significant; therefore, it is not feasible to use this method in populated areas.

Injecting liquid manure
Source: Purdue University

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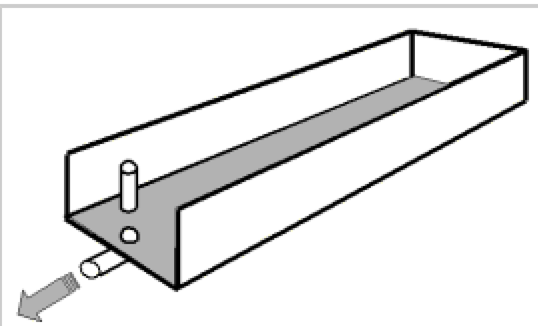
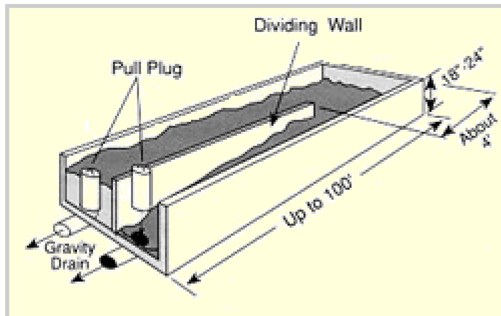
Lagoons

Lagoons are different from liquid manure storage because they are operated to encourage anaerobic digestion of organic material while it is being stored. This reduces odor when the treated manure is land applied. A properly designed and operated treatment lagoon is much larger and more expensive than a liquid manure storage with the same storage time, and the organic solids are much less concentrated in the liquid.

Two-stage lagoon system
Source: Purdue University

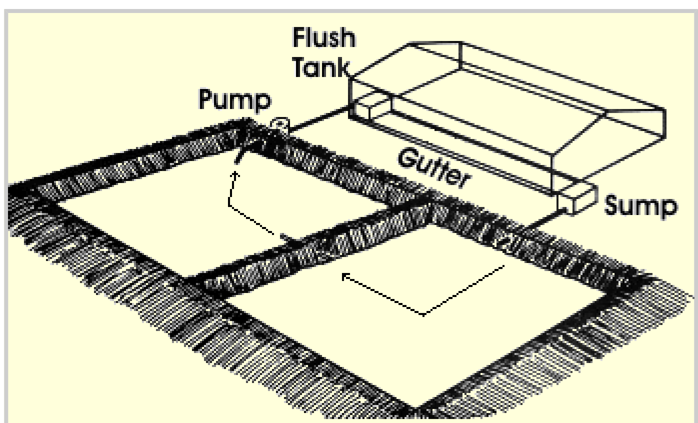


Gravity drain, flat bottom gutter
Source: Purdue University



Reverse hairpin, flat-bottom gutter
Source: Purdue University

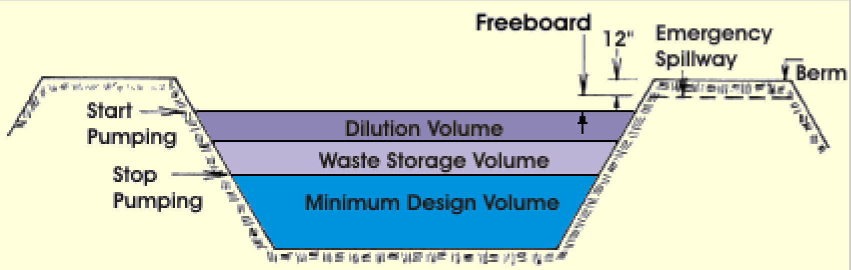
In the Midwest, an equal part of relatively clean dilution water must be added for each part manure. Furthermore, manure must be added slowly and uniformly to the lagoon, to avoid an upset (and subsequent release of odors) to the biological treatment system. One common method of doing this is to utilize shallow pits or gutters under slotted floors and drain or flush manure to the lagoon on a frequent basis, usually every three days to three weeks. This is done by simply pulling a plug in the bottom of the pit, called gravity drain, use of a scraper system running in the underfloor



Recirculating lagoon water to flush manure from a gutter

under a slotted floor
Source: Purdue University

gutter, through a process called a "hairpen" gutter or by recirculating a volume of relatively clean effluent from the lagoon to flush manure out of the building and into the lagoon. Recirculation involves either a flushing action that takes place several times a day or a "pit recharge" system that works basically like a toilet that is flushed every few days.



Single cell waste treatment lagoon
Source: Purdue University

A portion of the lagoon contents or "minimum design volume" must be left in the lagoon after its contents are pumped to the land to provide a large number of microbial organisms to treat the new manure entering the system. In spite of proper operation, there is an “over turning” of the lagoon contents that occurs in the fall of the year for a couple of weeks, as ambient temperature drops and cools the top layer of liquid in the lagoon. As its density increases, it “overturns” or drops to the bottom of the lagoon, forcing the bottom layer, containing partially digested manure solids, to the top. This phenomenon results in higher odor levels for a week or two around the lagoon. Multiple Lagoons in series normally emit fewer odors than single cell lagoons.

Irrigation of lagoon effluent onto cropland
Source: Purdue University

Lagoon contents are normally applied to cropland by spray irrigation systems. If the lagoon is properly designed and operated, spray irrigation should not release much odor because most of the organic solids should have been biologically degraded. In a well-operated lagoon, typical effluent should have only about 20% as much nitrogen (N) and about 30% to 40% as much phosphorous (P) and potassium (K) as the raw manure, because of treatment and sedimentation of solids to the bottom of the lagoon. Note that the P and K "lost" actually accumulate in the sludge and must be utilized properly when removed. These solids, or sludge, must be removed every few years and the operation should plan to handle them as a part of their nutrient management plan. Because this material is more concentrated, it may be practical to haul the sludge off site to more distant cropland that can better utilize the nutrients contained in the sludge. Because of the nuisance potential of this partially stabilized material, it should be incorporated as a liquid manure if possible.

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Potential Environmental Impacts of Animal Feeding Operations

(Adapted in part from Livestock and Poultry Environmental Stewardship Curriculum, MidWest Plan Service; and Proposed US EPA Confined Feeding Rule.)

USEPA's 1998 *National Water Quality Inventory* indicates that agricultural operations, including animal feeding operations (AFOs), are a significant source of water pollution in the U.S. States estimate that agriculture contributes in part to the impairment of at least 170,750 river miles, 2,417,801 lake acres, and 1,827 estuary square miles (Table 1). Agriculture was reported to be the most common pollutant of rivers and streams.

However, one should not overlook the many positive environmental benefits of agriculture. For example, agricultural practices that conserve soil and increase productivity while improving soil quality also increase the amount of carbon-rich organic matter in soils, thereby providing a global depository for carbon dioxide drawn from the atmosphere by growing plants. The same farming practices that promote soil conservation also decrease the amount of carbon dioxide accumulating in the atmosphere and threatening global warming.

Other benefits compared to urban or industrial land use include greatly reduced storm runoff, groundwater recharge and water purification as infiltrating surface water filters through plant residue, roots and several feet of soil to reach groundwater.

In many watersheds, animal manures represent a significant portion of the total fertilizer nutrients added. In a few counties, with heavy concentrations of livestock and poultry, nutrients from confined animals exceed the uptake potential of non-legume harvested cropland and hayland. USDA estimates that recoverable manure nitrogen exceeds crop system needs in 266 of 3,141 counties in the U.S. (8%) and that recoverable manure phosphorus exceeds crop system needs in 485 counties (15%). It should be pointed out that while legumes are able to produce their own nitrogen, they will use applied nitrogen instead if it is available. The USDA analysis does not consider actual manure management practices used or transport of applied nutrients outside the county; however, it is a useful indicator of excess nutrients on a broad scale. Whole-farm nutrient balance is a very useful tool to identify potential areas of excess.

Air emissions from Animal Feeding Operations (AFO) can be odorous. Furthermore, volatilized ammonia can be redeposited on the earth and contribute to eutrophication of surface waters.

Animal manures are a valuable fertilizer and soil conditioner, if applied under proper conditions at crop nutrient requirements. Potential sources of manure pollution include open feedlots, pastures, treatment lagoons, manure stockpiles or storage, and land application fields. Oxygen-demanding substances, ammonia, nutrients (particularly nitrogen and phosphorus), solids, pathogens, and odorous compounds are the pollutants most commonly associated with manure. Manure is also a potential source of salts and trace metals, and to a lesser extent, antibiotics, pesticides and hormones. This problem has been magnified as poultry and livestock production has become more concentrated. AFO pollutants can impact surface water, groundwater, air, and soil. In surface water, manure's oxygen demand and ammonia content can result in fish kills and reduced biodiversity. Solids can increase turbidity and smother benthic organisms. Nitrogen and phosphorus can contribute to eutrophication and associated algae blooms which can produce negative aesthetic impacts and increase drinking water treatment costs. Turbidity from the blooms can reduce penetration of sunlight in the water column and thereby limit growth of seagrass beds and other submerged aquatic vegetation, which serve as critical habitat for fish, crabs, and other aquatic organisms. Decay of the algae (as well as night-time algal respiration) can lead to depressed oxygen levels, which can result in fish kills and reduced biodiversity. Eutrophication is also a factor in blooms of toxic algae and other toxic estuarine microorganisms, such as *Pfiesteria piscicida*. These organisms can impact human health as well as animal health. Human and animal health can also be impacted by pathogens and nitrogen in animal manure. Nitrogen is easily transformed into the nitrate form and if transported to drinking water sources can result in potentially fatal health risks to infants. Trace elements in manure may also present human and ecological risks. Salts can contribute to salinization and disruption of the ecosystem. Antibiotics, pesticides, and hormones may have low-level, long-term ecosystem effects.

In ground water, pathogens and nitrates from manure can impact human health via drinking water. Nitrate contamination is more prevalent in ground waters than surface waters. According to the U.S. EPA, nitrate is the most widespread agricultural contaminant in drinking water wells, and nearly 2% of our population (1.5 million people) is exposed to elevated nitrate levels from drinking water wells.

Table 1. Summary of U.S. Water Quality Impairment Survey

Total Quantity in US	Amount of Waters Surveyed	Quantity Impaired by All Sources	Quantity Impaired by Agriculture
Rivers 3,662,255 miles	23% of total 840,402 miles	36% of surveyed 248,028 miles	59% of impaired 170,750 miles
Lakes, Ponds, and Reservoirs 41,600,000 acres	42% of total 17,400,000 acres	39% of surveyed 6,541,060 acres	31% of impaired 2,417,801 acres
Estuaries 90,500 square miles	32% of total 28,889 square miles	38% of surveyed 11,025 square miles	15% of impaired 1,827 square miles

Reference: National Water Quality Inventory: 1998 Report to Congress (EPA, 2000a). AFOs are a subset of the agriculture category. Summaries of impairment by other sources are not presented here.

Table 2 lists the leading pollutants impairing surface water quality in the U.S. Agricultural production is a potential source of most of these.

Table 2. Five Leading Pollutants Causing Water Quality Impairment in the U.S.
(Percent of incidence of each pollutant is shown in parentheses. For example, siltation is listed as a cause of impairment in 38% of impaired river miles.)

Rank	Rivers	Lakes	Estuaries
1	Siltation (38%)	Nutrients (44%)	Pathogens (47%)
2	Pathogens (36%)	Metals (27%)	Oxygen-Depleting Substances (42%)
3	Nutrients (29%)	Siltation (15%)	Metals (23%)
4	Oxygen-Depleting Substances (23%)	Oxygen-Depleting Substances (14%)	Nutrients (23%)
5	Metals (21%)	Suspended Solids (10%)	Thermal Modifications (18%)

List of Contaminants in Animal Manure:

- Oxygen-Demanding Substances
- Nitrogen
- Ammonia
- Nitrate
- Phosphorus
- Pathogens
- Antibiotics, Pesticides, and Hormones
- Airborne Emissions from Animal Production Systems
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Pork Production Study Questions

Identify the definition that best fits the following terms:

1. **Boar**

   - A female pig
   - An adult male hog, normally used for breeding
   - A tedious individual
   - A type of feeding system

   Feedback

2. **Gilt**

   - An older female swine that failed to conceive
   - A non-innocent individual
   - A male hog
   - A female pig that has not yet farrowed

   Feedback

3. **Farrowing**

   - Conservation process whereby land lies dormant
   - Feeding program for grow-finish hogs
   - Period when pigs are born to the sow
   - Practice of moving pigs from sow to sow to create more uniform litters

   Feedback

4. **Production Schedule**

   - Feeding program for pigs, from birth to market
   - Marketing program for a swine operation
   - Schedule by which sows are bred, farrowed, pigs are weaned, moved from production phase to production phase and eventually marketed

   Feedback

5. **Mating**

- ○ Sometimes follows dating
- ○ Matching baby pigs at birth to their mothers
- ○ Process by which pigs are matched by weight to determine pen mates
- ○ Inseminating sows or gilts at estrous via exposure to a boar (or artificial insemination)

Feedback

6. **Pen**

- ○ Something to write with
- ○ Confined area where swine or other animals are kept
- ○ Farmstead area
- ○ Prison facilities

Feedback

7. **Shoat**

- ○ A large male swine
- ○ An immature swine
- ○ A type of knife used for castration
- ○ A type of portable shelter used when swine are kept when placed on pasture land

Feedback

8. **Slotted floors**

- ○ A type of flooring used under stacked hay, to facilitate drying
- ○ Flooring that has been grooved to improve footing for animals
- ○ A type of porous floor that allows waste to drain away, keeping animals dry and comfortable

Feedback

9. **Barrow**

- ○ The container located above the wheel in a wheelbarrow
- ○ A male swine who has been castrated to reduce aggressiveness and improve the flavor of the meat
- ○ An excavated pit from which soil or gravel is removed for a construction project

Feedback

10. **Estrus**

- An indication that the sow is ready to be bred
- A type of grain fed to grow-finish swine
- The process of removing pigs from the sow
- An important religious holiday

Feedback

11. **Number of tons of pork produced in the U.S. each year**

- 500,000,000
- 100,000,000
- 9,000,000
- 1,000,000

Feedback

12. **Leading hog producing state, in terms of market animals**

- North Carolina
- Indiana
- Iowa
- Missouri

Feedback

13. **Hoop structure**

- A popular game in the U.S. during the 1950s
- A type of portable, low cost shelter used for gestation and grow finish swine. Limited mainly to smaller operations
- A general purpose building used mainly as a utility building for farm shops, feed or machinery storage.
- A sound making device used to herd animals

Feedback

14. **Land application**

- Legal forms that much be completed when applying for financing to purchase a farm
- The application of manure to cropland at a rate that matches the nutrients needed by the plants
- Application of irrigation water to a farm field

Feedback

15. **Whole farm nutrient balance**

- ○ A type of pork cut from the loin area
- ○ A method of balancing the nutrients in a ration for swine
- ○ Balancing nutrient inputs to the production unit with the use and removal of those nutrients from the operation

Feedback

See Results RESET

Score in Percentage:	

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Pork Glossary

All-in, All-out production - A production system whereby animals are moved into and out of facilities in distinct groups. By preventing the commingling of groups, the hope is to reduce the spread of disease. Facilities are normally cleaned and disinfected thoroughly between groups of animals

Barrow - A neutered male is a barrow and the adult male is a boar.

Biosecurity - Diseases can be easily spread between herds and a strict isolation and sanitation program is normally practiced.

Boar - a term for a male domestic swine suitable for breeding.

Cooling - Cooling systems normally involve evaporating water to lower the temperature of the pigs. Generally used only for the breeding-gestation herd. Cooling also takes place by air movement in hot weather.

Corn Belt - The area of the United States where corn is a principal cash crop, including Iowa, Indiana, most of Illinois, and parts of Kansas, Missouri, Nebraska, South Dakota, Minnesota, Ohio, and Wisconsin.

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Denitrification - The biochemical reduction of nitrate or nitrite to gaseous nitrogen, either as molecular nitrogen or as an oxide of nitrogen.

Estrous - See Heat

Farrowing - The period from birth to weaning.

Farrow to Finish Operation - A production system that contains all production phases, from breeding to gestation to farrowing to nursery to grow-finishing to market.

Feeder Pig Operation - Breeder sells pigs out of the nursery phase to a finishing operation to grow them out to market weight.

Finisher Pig - Production phase between the nursery and market.

Finishing Operation - The operation purchases feeder pigs from a feeder pig operation and feeds them to market weight at 240 to 260 lbs. Historically, producers purchased feeder pigs at auctions, but because of disease transmission concerns, most operations now bypass auctions and buy all of their animals from the same supplier.

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Gestation - The 113 to 116 day period when the sow is pregnant from breeding until farrowing.

Gilt -Young female, up to about 6 mos old.

Grow-Finish - Pig between nursery and market, usually takes14-16 weeks.

Hand Mating - An individual female that is ready to be bred is exposed to an individual boar in a small pen for a few minutes, under the supervision of the producer.

Heat - Refers to the estrous period for the sow. The first estrous normally occurs 3 to 5 days after the pigs are weaned.

Hog - Generic term, usually applied to growing swine.

Hoop Structure - A low cost, uninsulated and naturally ventilated building used for older swine. The floor is mostly earthen and typically bedded with straw.

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Lactating - Period when a sow is providing milk to her pigs.

Legume - Any of thousands of plant species that have seed pods that split along both sides when ripe. Some of the more common legumes used for human consumption are beans, lentils, peanuts, peas, and soybeans. Others, such as clover and alfalfa, are used as animal feed. Legumes have a unique ability to obtain much or all of their nitrogen requirements from symbiotic nitrogen fixation.

Limit Feeding - Feeding strategy in which pigs are fed a specific amount of food in a specific time period Vs free access to feed. Limit feeding is common in Europe, but normally only used for gestation animals in the U.S.

Litter - The pigs that are born at one time to one sow - normally 8-12 pigs.

Marketing - When they reach market weight, the grow-finish pigs are sold for processing to the packing plant.

Market Weight - 240 to 260 lbs.

Mating - Breeding a sow or gilt after the onset of estrus and before ovulation, may include at least two services by different boars to ensure successful mating.

Mechanical Ventilation - The use of mechanical ventilation fans to pull air through the animal building.

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Natural Ventilation - The design and placement of the building to allow adequate ventilation by controlling wind blowing against the building.

Nitrification - The biochemical oxidation of ammonium to nitrate, predominantly by autotrophic bacteria.

Non-Productive Sow Days - Days a sow is neither lactating or gestating.

Nursery - The growth phase from weaning until they enter the grow-finish building.

Pen - Most swine are grouped together in pens, whether kept in a shelter or in a fenced open lot. The number of animals penned together may be less than 10 to several hundred, but is normally between 15 and 30.

Pen Mating - Boar is placed in a pen with group of sows to allow for breeding.

Pig - Term usually applied to young, immature swine.

Piglet - The offspring of a male boar and a female sow are called piglets, or just pigs.

Puberty - Time of first estrus in sows, usually occurring at 6 mo. of age.

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Segregated Early Weaning - Removal of pigs from mother at 10 - 14 days of age in order to reduce transmission of disease from the mother to her offspring. The milk produced immediately after birth helps to protect the pigs from disease, but this protection decrease over time.

Service - Breeding, the deposition of boar semen into the female. Breeding may be by done naturally by a boar or artificially by the manager, using semen obtained from a local boar or purchased from a supplier. Producers often use artificial insemination as a way to bring new genetics into their herd, without the biosecurity concerns involved with bringing new animals onto their farm.

Shoat - A growing pig. This term has been largely replaced with the terms nursery pig or grow-finish pig.

Slotted Floors - A type of flooring developed in the late 1950's. Narrow open slots in the floor allow manure and water to drain, keeping the floor dry and clean. Slotted floors for larger swine are normally constructed of concrete, but is normally plastic, wire or plastic covered wire for smaller animals. The manure that falls through the slots is collected in a gutter or pit and removed from the building periodically.

Sow - After a female has borne a litter she is called a sow**.**

Standing Heat - A sow or gilt will assume a rigid stance and maintain it during servicing if she is ready to be bred.

Supplemental Heat - Furnace or radiant heat provided to maintain a comfortable temperature for the animals

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Tunnel Ventilation - A type of ventilation system where air enters at one end and is exhausted by ventilation fans on the other.

Ventilation - Process of providing fresh air for the animals and removing stale air and moisture along with dilution of noxious gases, particulates, etc. in the room.

Weaning - The process of removing the pigs from the sow and moving them to the nursery.

Wild Boar - These wild hogs are still found in parts of the United States. Pigs used in modern pork production are thought to be descendants of the European wild boar. Wild boars are considered to be descendants of European wild boars introduced into the US for sport hunting, or the hybrid offspring of escaped domestic hogs.

Adapted in part from Pitcher, P. and S. Springer, 1997. University of Pennsylvania School of Veterinary Medicine.

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- Animal Science and Industry
- MidWest Plan Service. MWPS-8. Swine Housing and Equipment Handbook
- Confined animal production and manure nutrients Citation:
- Gollehon, N; Caswell, M; Ribaudo, M; Kellogg, R; Lander, C; Letson, D: Confined animal production and manure nutrients. ERS Agriculture Information Bulletin 771 : 1-39, 2001.

Links EXIT Disclaimer

This information is provided for reference. Over time, links to the items may become unavailable, in these cases the item will remain listed, but no link will be provided.

- The Pig Page – Australia
- Livestock Library: Swine Resources
- National Pork Producers Council, Industry site on pork production
- The Joy of Pigs - Nature Magazine web site
- The Pig Site
- Purdue Pork Page
- The Columbia Electronic, Encyclopedia, Sixth Edition Copyright © 2000, Columbia, University Press.
- Pork Industry Handbook, select Publications at the bottom of the left sidebar, then select Pork Industry Handbook Summaries from the list of publications at the top of the page
- USDA Web sites:
  - USDA Agricultural Marketing Service - How to Buy Meat
  - USDA Foreign Agricultural Service - FASonline

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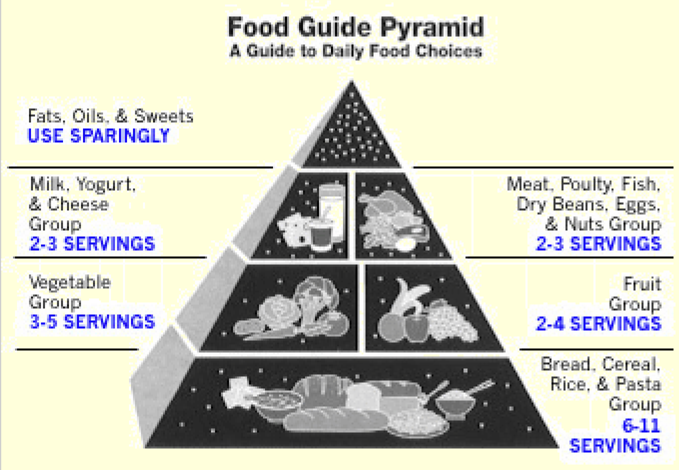
Pork Production

Pork production is an important component of American agriculture and an important part of the American diet and way of life. Fewer than100,000 farms were producing pork in 2000 with production is concentrated in the Corn Belt states and in North Carolina.

Modern pork production is mostly done in enclosed buildings to protect animals from the weather, from predators and from the spread of diseases. While larger operations enabled farmers to significantly increase the efficiency of production using less labor, it resulted in environmental challenges with larger amounts of manure concentrated in a small area.

This module will look at pork production as it has evolved over the past 300 years in the U.S., at the economic value of pork to the U.S. and American agriculture and at typical production and manure handling systems in use today.

Background of Pork Production in U.S.

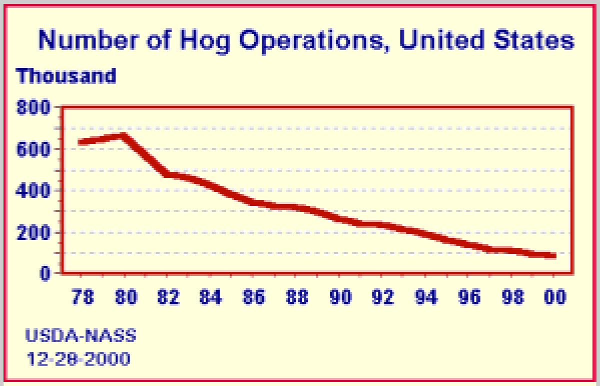


Source: U.S. Dept. of Agriculture / Dept. of Health and Human Services

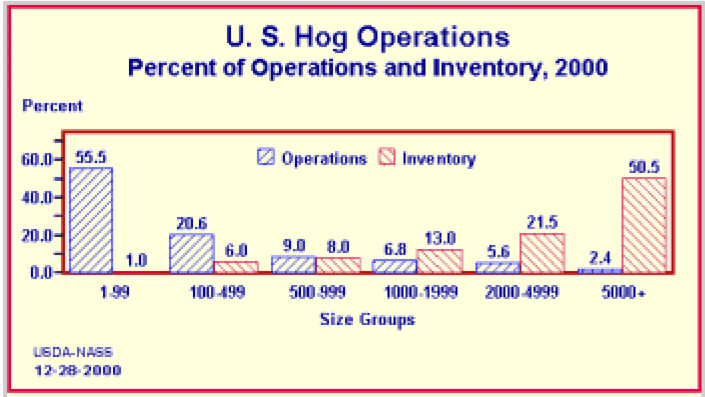
Wild boars domesticated in N. Europe c.1500 B.C., are believed to be the ancestor of modern domesticated hogs, along with a genetic input from smaller Asian species domesticated in China around 3000 B.C. Pork, the meat from swine, was widely consumed throughout the ancient world and the Roman Empire. Pigs were not indigenous to the Americas, but came from Europe and the Orient. Columbus brought hogs on his second voyage to the Americas in 1493. Polynesians may have brought pigs from the Orient to the Hawaiian Islands even earlier.

For much of the 19th and 20th centuries, pork was the preferred meat in the U.S. Hogs were valued not just for their meat but for the lard, which was used for everything from cooking and lamp oil to baking and making candles and soap. As Americans became more health conscious, they lost much of their appetite for animal fats, switching to more healthy vegetable oils. Production began to focus on the pigs' ability to efficiently convert feed into protein, which resulted in a much leaner type of pig being produced.

There has also been a significant change in how and where hogs are produced in the U.S. over the past 50 years. Low consumer prices, and therefore low producer prices, have resulted in larger, more efficient operations, with many smaller farms no longer able to produce pigs profitably.



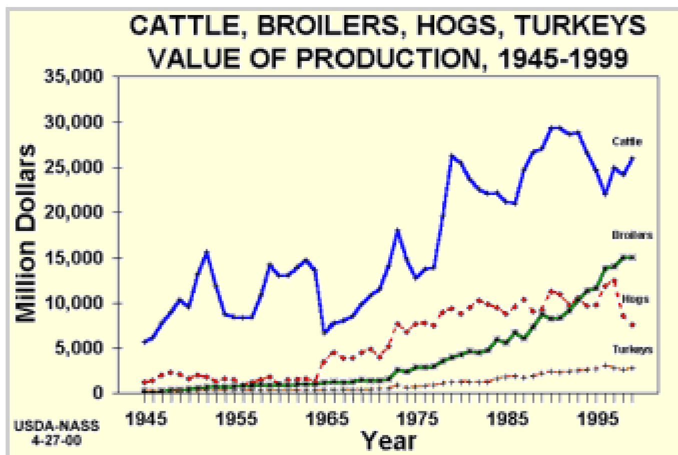
Source: USDA - NASS



Source: USDA - NASS

In 1997, sales of all animals in the U.S. totaled over $75 billion. Currently, most of the swine in the United States are produced in North Carolina and the Midwestern and plains states, including Nebraska, Iowa, Minnesota, Missouri, Indiana and Illinois. Worldwide, China is by far the largest producer of pork, producing nearly four times as much as the U.S.

There are many breeds of swine, such as Hampshire, Duroc, Poland, China, Landrace, etc., but most farms use crossbreeds to try to gain the best traits of each breed.



Source: USDA - NASS

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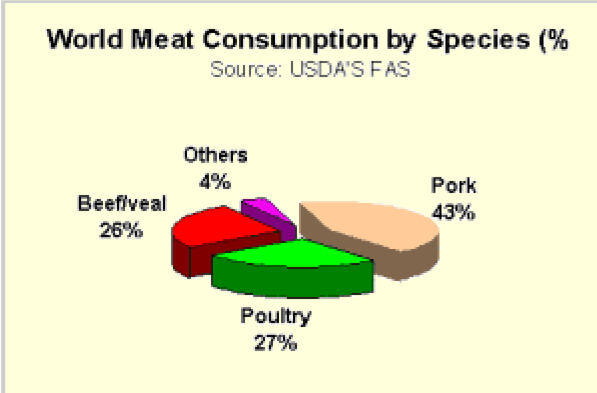
Products from Pork

Pork is the most widely consumed meat in the world. People eat many different pork products, such as bacon, sausage, pork chops and ham. A 250-pound market hog yields about 150 pounds of pork.

Several valuable products or by-products, in



addition to meat, come from swine. These include insulin for the regulation of diabetes; valves for human heart surgery; suede for shoes and clothing; and gelatin for many food and non-food uses. Swine by-products are also important parts of such products as water filters, insulation, rubber, antifreeze, certain plastics, floor waxes, crayons, chalk, adhesives and fertilizer.

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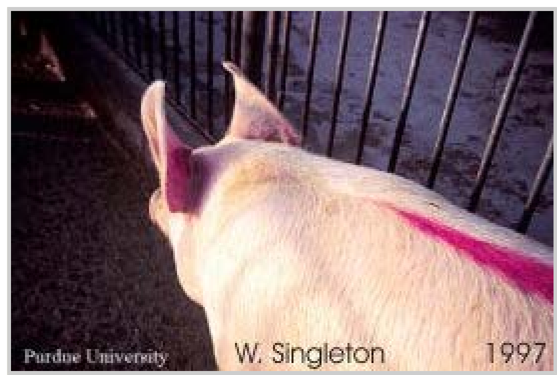
Pork Production Phases

The phases of pork production that take place on the farm to produce hogs ready for market are called: breeding-gestation, farrowing, nursery and grow-finish.

Breeding-Gestation



Swine production can be logically separated into a number of phases, beginning with the sow being bred. Historically, this has been done by placing a number of sows in a pen with one or more boars. In confinement buildings, boars are often rotated between sow pens to make sure that all sows are bred while they were in heat. Sows in enclosed shelters come into estrous, 3 until 5 days after their pigs are weaned. The estrous period, or standing heat, is the period when the sow can be bred. Estrous only lasts a short time, so it is critical that the sow is bred at this time. During estrous, the sow shows outward signs of being willing to accept the boar, such as standing still when the producer applies downward pressure on her back or holding her ears erect. If the sow is not bred during this period, she normally returns to estrous about 21 days later. These two periods are known as "first heat breeding" and "second heat breeding". The non-pregnant sow is considered "unproductive" during this 3-week period, since she still must be fed and housed. Most modern operations have sows bred only on first heat. Sows that fail to breed during this estrous are often sent to market and replaced in the sow herd by gilts, or young females that are removed from the grow-finish group of pigs. After breeding, the sow "gestates" her "litter" for 113 to 116 days before the pigs are born or "farrowed." A good way to remember gestation length for swine is that it is approximately "3 months, 3 weeks and 3 days".

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Farrowing

Protecting baby pigs in a farrowing crate
Source: Purdue University

Pen farrowing
Source: USDA

Just before giving birth, called farrowing, sows are normally moved into a "farrowing room." Sows typically farrow from eight to twelve piglets, which as a group are called a litter. Most confinement operations place the sow in a temperature-controlled environment and usually in a farrowing pen or crate which restricts her movement to protect her baby pigs. The baby pigs spend most of their time in a "creep area on one or both sides of the crate where they have ready access to their mother, but are protected from crushing when she lies down. A few farrowing operations in the U.S. use larger pens and provide deep straw bedding on solid floors. While this is a more natural process for the sow, it involves more labor and often results in higher crushing losses.

An average sow will raise three to five litters of pigs in her lifetime. Sows may be culled and sent to market, because of age, health problems, failure to conceive, or if they are able to raise only a low number of pigs per litter.

Pigs are born with eight needle-sharp teeth and curly tails. The tips of the teeth are clipped at birth to prevent injury to the sow's utter and other piglets and the tail is shortened to prevent tail biting. Piglets weigh about three pounds at birth and are weaned from the sow at anywhere from five days to four weeks, with most operations weaning pigs at two to three weeks.

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Nursery Pigs

Source: Purdue University

After weaning, pigs are normally placed in a "nursery" where they are kept in a temperature-controlled environment, usually on slotted floors. The floors in a nursery are usually constructed from plastic or plastic covered steel instead of concrete to provide additional comfort for the small pigs. Pigs are normally given around three square feet of space each and provided with ready access to water and feed. Nursery pens are sometimes elevated, with their slotted floor above the room floor level 8 to 12 inches. This is done to minimize the possibility of cold floor drafts chilling the young pigs. Immediately after weaning, the temperature in the nursery may be as much as 85 degrees, and then dropped gradually to about 70 degrees as the pigs grow. Pigs are normally removed from the nursery at about 6 to 10 weeks of age and placed in a "grow-finishing" building. Nursery rooms are almost always heated with furnaces and ventilated with mechanical fans, controlled by a thermostat, in order to keep the pigs warm and dry throughout the year.

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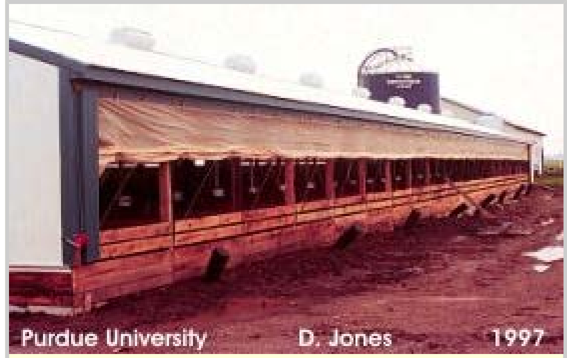
Grow-Finishing

This phase is where pigs are fed as much as they wish to eat until they reach market weight of 250 to 275 pounds and provided around 8 sq. ft. of space per pig. Marketing normally occurs at five to six months of age, depending on genetics and any disease problems encountered. Some gilts are returned from the grow-finish phase to the sow herd for breeding purposes, to replace older sows that are culled.

Grow-finish pigs on concrete slotted floor
Source: Purdue University



Naturally ventilated (grow-finish building)

Animals in a grow-finish operation are larger and produce a great deal of body heat. Ventilation to keep the animals cool is usually more of a concern than providing heat in winter. Animals at this age grow best at around 60-70 degrees. In winter, they are protected from winter winds in a moderately well insulated building. Enough ventilation must be provided to remove moisture and to provide fresh air for the animals. In summer, large sidewall vents are opened or large ventilation fans are operated to keep the animals comfortable. This is referred to, respectively, as naturally ventilated (air change due to the wind) or mechanically ventilated (where air is drawn into the buildings through vents due to a negative pressure created with wall fans that exhaust inside air.

Mechanical ventilation in grow-finish building
Source: Purdue University

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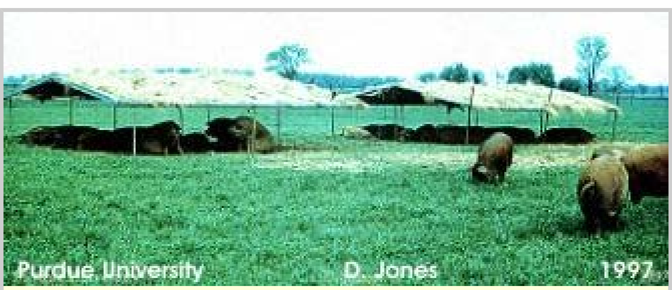
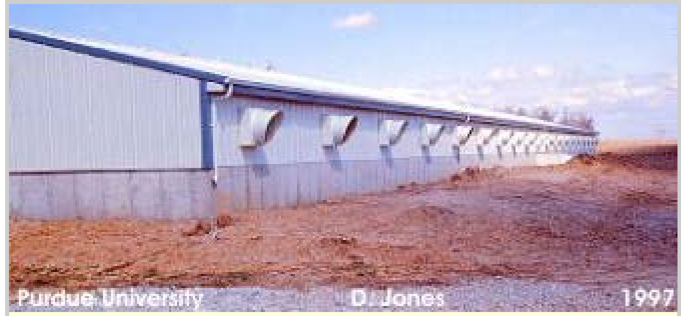
Production Systems



Gestation sows on pasture

Before the 1960s, most pork in the U.S. was raised in outside lots or on pasture systems. With the development of slotted floors and liquid manure handling equipment, it became possible for producers to more easily care for larger numbers of animals, and to do so protected from the weather. Enclosed buildings overcame most weather problems, predators and minimized the potential pollution from outside lot runoff. It also made it practical to farrow sows twice a year, rather than once. This was the beginning of intensive production schedules on relatively small areas as found throughout the world today.

In a continuous flow barn, animals of many different stages of development may be housed in close proximity to one another and the facilities are never empty. Advantages are that space is efficiently used, because pigs can be moved to larger pens as they grow, and new arrivals replace them in the smaller pens. Continuous systems also simple to plan; if the producer wants to wean two litters each week, two sows must be bred each week.



Enclosed housing for swine

Disadvantages are that different ages of animals (with different degrees of disease resistance) are housed together, facilitating disease spread, stress levels can be heightened with changing social groups, adequate cleaning and disinfecting are not feasible, and higher levels of antibiotics and other medications are normally required to control disease.

Most swine today are raised in “all-in, all-out” (AIAO) systems, where each room or building is completely emptied and sanitized between groups of pigs. Each new group of pigs enters a freshly disinfected environment, and stays there for this phase of their life. The facility has a separate room or building for each group of pigs weaned, with extra space if needed to allow workers time to clean the room before the next group of pigs. AIAO animals in each room are of a uniform age and size and are isolated to the extent possible to decrease the possibility of diseases spreading from older animal groups to younger ones.

The primary advantages are that disease spread can be better contained, animals are less stressed because they remain with the same age and social group throughout their development, and complete cleaning and disinfecting between groups is possible. The disadvantage is that space is less efficiently allocated, and that more space may be needed to allow rooms to be empty for cleaning between groups.

Until around 1990, swine production systems were usually housed on a single site, because of labor savings and convenience. Health concerns have since caused many swine operations to house the various production phases at different sites to further minimize contact between pigs of different ages. This is either a two-site or a three-site system. A two-site system has breeding and gestation at one site and farrowing/nursery and grow finish pigs at a separate site, while a three site also places the nursery at a separate site.

In the last few years, some producers have constructed “wean to finish” barns where pigs go immediately after weaning, and stay until market. This combines the nursery and grow-finish phases of production. These barns provide substantially more space per pig than is needed initially, but provide the advantage of only moving pigs once during their lifetime. This reduces stress on the animals and saves labor since buildings are not cleaned until the hogs are marketed.

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Nutrition

Swine have a digestive system similar to humans and different from ruminants such as cattle and sheep, which can eat forages or grasses. Pigs are fed a diet that is primarily ground corn to supply heat and energy and soybean meal to provide protein. Vitamins and minerals are also added in their feed. Rations are closely tailored to optimize health and growth at each stage in their life. Many producers even modify the ration based on the pig’s gender.

The ration is normally changed to provide more energy and less protein as the pig grows. The goal is to optimize feed utilization for different stages of growth. Since nutritional needs are different for male and female grow-finish pigs, larger operations may even modify the ration, based on gender. Recent studies indicate that ration modifications that can reduce the amount of nitrogen and phosphorous excreted in the manure, while maintaining optimum pig growth and health. It takes nearly 1000 pounds of feed to raise a hog to market weight. This same pig drinks about one-and-a-half to two gallons of water a day over its six-month life.

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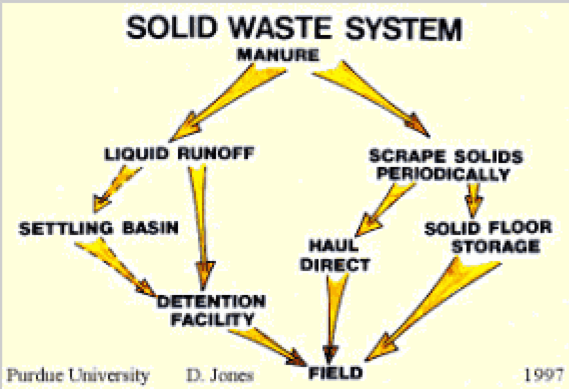
Common Manure Handling Systems

- Solid
- Lot Runoff
- Liquid Manure
- Lagoons

Solid Manure



Schematic of solid manure systems
Source: Purdue University

Surface application of solid manure
Source: Purdue University

Swine manure was historically handled as a solid, either deposited directly by grazing animals, or collected in bedding placed on solid shelter floors to absorb the urine. Pastured animals spread the manure over the land as they grazed. Manure deposited on solid floors is typically stored where it falls, with more bedding added as needed to maintain a dry floor. Liquid drains away from the manure dropped on an outside lot and must be collected in a storage, leaving the solid manure behind. The manure composts in place somewhat and is removed every few months. Fertilizer value is recovered by spreading on cropland to complete the nutrient cycle. Solid manure is normally surface applied, but in some cases may be incorporated into the soil with a farm tillage operation shortly after spreading. Composting is another option for solid manure management.

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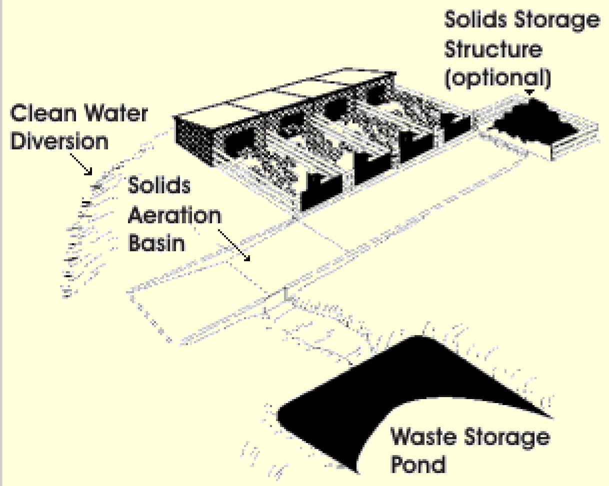
Lot Runoff



Options for handling manure from open lot
Source: Purdue University

Options for handling manure from open lot holding pond for runoff from outside lot
Source: Davis-Purdue Farms

Manure is typically scraped from outside lots every week or two and stacked until it can be hauled to cropland. It is important to keep an outside lot relatively free of manure to control odor and so that rainfall runoff stays mostly free of manure. This facilitates storage of relatively clean runoff for irrigation onto cropland. It is even possible to divert runoff from small operations directly to pasture or to a vegetated filter strip where it can infiltrate. It must be prevented from entering waterways. Clean upslope water and roof water should be diverted away from the open lot to minimize the amount of wastewater that must be handled as a manure.

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Liquid Manure

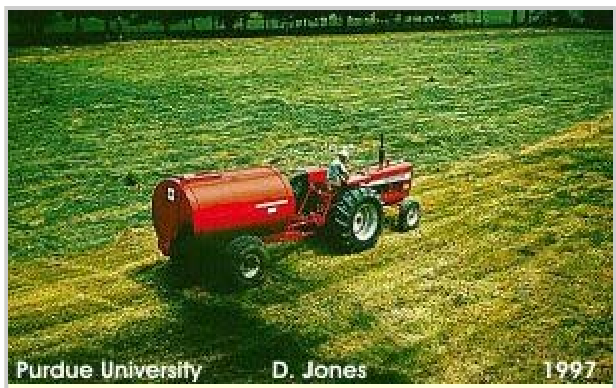
Grow-finish pigs on slotted floor
Source: Purdue University

Most swine manure is handled as a liquid. Manure typically falls through a slotted floor (with the size of slot depending on the size and age of animal) into either a gutter or a concrete storage pit. Storage pits provides from 3-12 months storage of the manure. This pit may either be located directly under the slotted floor and may be from 4' to 10' deep. In some operations, the manure falls into a shallow pit or gutter which is periodically pumped, flushed or drained to a large outside storage. The outside storage may either be constructed in the earth or a commercial steel or concrete storage purchased and erected onsite . Storage size is dictated by regulatory agencies in most states and are usually sized large enough to hold at least six month's accumulation in Midwestern states. This avoids the need to apply manure during the crop growing season and when weather conditions are unsuitable – such as on frozen ground or when the soil is wet enough that heavy application vehicles could compact and damage the soil for crop production.

A sheepsfoot roller is used to compact soil for an earthen storage structure

Fabricated steel manure storage

Liquid manure pit agitation
Source: Purdue University



Surface applied liquid manure
Source: Purdue University

Liquid manure from storage is normally agitated thoroughly to make the manure nutrient content between loads more uniform and hauled to the field for application in large tanker wagons or trucks. Liquid manure is either applied to the soil surface or is incorporated during or shortly after application to control loss of volatile ammonia and release of odors. Incorporation is very effective at controlling runoff of manure nutrients and reducing odor from land application if done during or within a few hours after application. One method is a soil injector, where liquid manure is “injected” directly into the soil to a depth of 6 to 9” as the tanker passes over the field. This immediate contact between the manure and soil is highly effective at controlling odor.

In remote areas, liquid manure may be pumped to the land application site and then irrigated onto cropland. Spray irrigating liquid manure is a very efficient method of land application, in terms of speed and labor, but odor emissions can be significant; therefore, it is not feasible to use this method in populated areas.

Injecting liquid manure
Source: Purdue University

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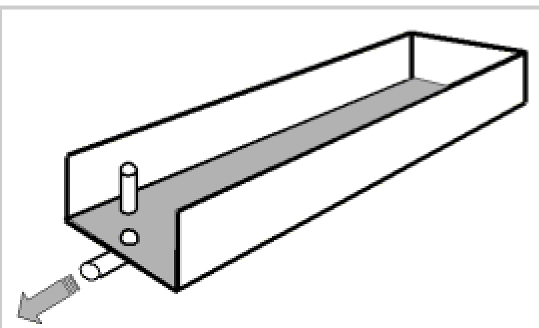
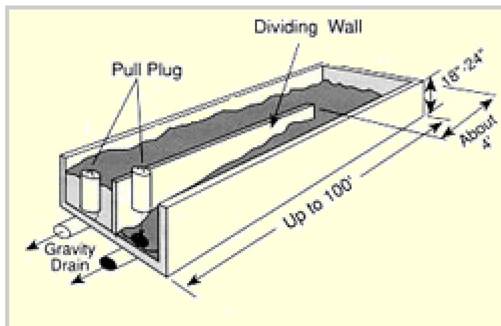
Lagoons

Lagoons are different from liquid manure storage because they are operated to encourage anaerobic digestion of organic material while it is being stored. This reduces odor when the treated manure is land applied. A properly designed and operated treatment lagoon is much larger and more expensive than a liquid manure storage with the same storage time, and the organic solids are much less concentrated in the liquid.

Two-stage lagoon system
Source: Purdue University

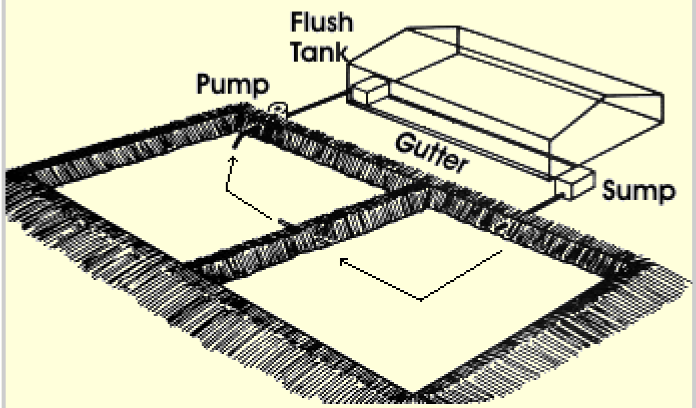


Gravity drain, flat bottom gutter
Source: Purdue University



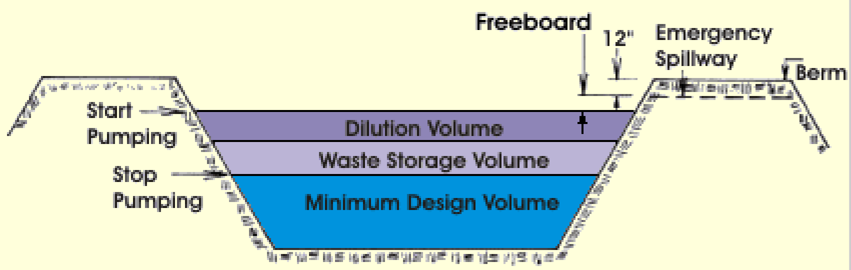
Reverse hairpin, flat-bottom gutter
Source: Purdue University

In the Midwest, an equal part of relatively clean dilution water must be added for each part manure. Furthermore, manure must be added slowly and uniformly to the lagoon, to avoid an upset (and subsequent release of odors) to the biological treatment system. One common method of doing this is to utilize shallow pits or gutters under [slotted floors](#) and drain or flush manure to the lagoon on a frequent basis, usually every three days to three weeks. This is done by simply pulling a plug in the bottom of



Recirculating lagoon water to flush manure from a gutter under a slotted floor
Source: Purdue University

the pit, called gravity drain, use of a scraper system running in the underfloor gutter, through a process called a "hairpen" gutter or by recirculating a volume of relatively clean effluent from the lagoon to flush manure out of the building and into the lagoon. Recirculation involves either a flushing action that takes place several times a day or a "pit recharge" system that works basically like a toilet that is flushed every few days.



Single cell waste treatment lagoon
Source: Purdue University

A portion of the lagoon contents or "minimum design volume" must be left in the lagoon after its contents are pumped to the land to provide a large number of microbial organisms to treat the new manure entering the system. In spite of proper operation, there is an “over turning” of the lagoon contents that occurs in the fall of the year for a couple of weeks, as ambient temperature drops and cools the top layer of liquid in the lagoon. As its density increases, it “overturns” or drops to the bottom of the lagoon, forcing the bottom layer, containing partially digested manure solids, to the top. This phenomenon results in higher odor levels for a week or two around the lagoon. Multiple Lagoons in series normally emit fewer odors than single cell lagoons.


Irrigation of lagoon effluent onto cropland
Source: Purdue University

Lagoon contents are normally applied to cropland by spray irrigation systems. If the lagoon is properly designed and operated, spray irrigation should not release much odor because most of the organic solids should have been biologically degraded. In a well-operated lagoon, typical effluent should have only about 20% as much nitrogen (N) and about 30% to 40% as much phosphorous (P) and potassium (K) as the raw manure, because of treatment and sedimentation of solids to the bottom of the lagoon. Note that the P and K "lost" actually accumulate in the sludge and must be utilized properly when removed. These solids, or sludge, must be removed every few years and the operation should plan to handle them as a part of their nutrient management plan. Because this material is more concentrated, it may be practical to haul the sludge off site to more distant cropland that can better utilize the nutrients contained in the sludge. Because of the nuisance potential of this partially stabilized material, it should be incorporated as a liquid manure if possible.

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Potential Environmental Impacts of Animal Feeding Operations

(Adapted in part from Livestock and Poultry Environmental Stewardship Curriculum, MidWest Plan Service; and Proposed US EPA Confined Feeding Rule.)

USEPA's 1998 *National Water Quality Inventory* indicates that agricultural operations, including animal feeding operations (AFOs), are a significant source of water pollution in the U.S. States estimate that agriculture contributes in part to the impairment of at least 170,750 river miles, 2,417,801 lake acres, and 1,827 estuary square miles (Table 1). Agriculture was reported to be the most common pollutant of rivers and streams.

However, one should not overlook the many positive environmental benefits of agriculture. For example, agricultural practices that conserve soil and increase productivity while improving soil quality also increase the amount of carbon-rich organic matter in soils, thereby providing a global depository for carbon dioxide drawn from the atmosphere by growing plants. The same farming practices that promote soil conservation also decrease the amount of carbon dioxide accumulating in the atmosphere and threatening global warming.

Other benefits compared to urban or industrial land use include greatly reduced storm runoff, groundwater recharge and water purification as infiltrating surface water filters through plant residue, roots and several feet of soil to reach groundwater.

In many watersheds, animal manures represent a significant portion of the total fertilizer nutrients added. In a few counties, with heavy concentrations of livestock and poultry, nutrients from confined animals exceed the uptake potential of non-legume harvested cropland and hayland. USDA estimates that recoverable manure nitrogen exceeds crop system needs in 266 of 3,141 counties in the U.S. (8%) and that recoverable manure phosphorus exceeds crop system needs in 485 counties (15%). It should be pointed out that while legumes are able to produce their own nitrogen, they will use applied nitrogen instead if it is available. The USDA analysis does not consider actual manure management practices used or transport of applied nutrients outside the county; however, it is a useful indicator of excess nutrients on a broad scale. Whole-farm nutrient balance is a very useful tool to identify potential areas of excess.

Air emissions from Animal Feeding Operations (AFO) can be odorous. Furthermore, volatilized ammonia can be redeposited on the earth and contribute to eutrophication of surface waters.

Animal manures are a valuable fertilizer and soil conditioner, if applied under proper conditions at crop nutrient requirements. Potential sources of manure pollution include open feedlots, pastures, treatment lagoons, manure stockpiles or storage, and land application fields. Oxygen-demanding substances, ammonia, nutrients (particularly nitrogen and phosphorus), solids, pathogens, and odorous compounds are the pollutants most commonly associated with manure. Manure is also a potential source of salts and trace metals, and to a lesser extent, antibiotics, pesticides and hormones. This problem has been magnified as poultry and livestock production has become more concentrated. AFO pollutants can impact surface water, groundwater, air, and soil. In surface water, manure's oxygen demand and ammonia content can result in fish kills and reduced biodiversity. Solids can increase turbidity and smother benthic organisms. Nitrogen and phosphorus can contribute to eutrophication and associated algae blooms which can produce negative aesthetic impacts and increase drinking water treatment costs. Turbidity from the blooms can reduce penetration of sunlight in the water column and thereby limit growth of seagrass beds and other submerged aquatic vegetation, which serve as critical habitat for fish, crabs, and other aquatic organisms. Decay of the algae (as well as night-time algal respiration) can lead to depressed oxygen levels, which can result in fish kills and reduced biodiversity. Eutrophication is also a factor in blooms of toxic algae and other toxic estuarine microorganisms, such as *Pfiesteria piscicida*. These organisms can impact human health as well as animal health. Human and animal health can also be impacted by pathogens and nitrogen in animal manure. Nitrogen is easily transformed into the nitrate form and if transported to drinking water sources can result in potentially fatal health risks to infants. Trace elements in manure may also present human and ecological risks. Salts can contribute to salinization and disruption of the ecosystem. Antibiotics, pesticides, and hormones may have low-level, long-term ecosystem effects.

In ground water, pathogens and nitrates from manure can impact human health via drinking water. Nitrate contamination is more prevalent in ground waters than surface waters. According to the

U.S. EPA, nitrate is the most widespread agricultural contaminant in drinking water wells, and nearly 2% of our population (1.5 million people) is exposed to elevated nitrate levels from drinking water wells.

Table 1. Summary of U.S. Water Quality Impairment Survey

Total Quantity in US	Amount of Waters Surveyed	Quantity Impaired by All Sources	Quantity Impaired by Agriculture
Rivers 3,662,255 miles	23% of total 840,402 miles	36% of surveyed 248,028 miles	59% of impaired 170,750 miles
Lakes, Ponds, and Reservoirs 41,600,000 acres	42% of total 17,400,000 acres	39% of surveyed 6,541,060 acres	31% of impaired 2,417,801 acres
Estuaries 90,500 square miles	32% of total 28,889 square miles	38% of surveyed 11,025 square miles	15% of impaired 1,827 square miles

Reference: National Water Quality Inventory: 1998 Report to Congress (EPA, 2000a). AFOs are a subset of the agriculture category. Summaries of impairment by other sources are not presented here.

Table 2 lists the leading pollutants impairing surface water quality in the U.S. Agricultural production is a potential source of most of these.

Table 2. Five Leading Pollutants Causing Water Quality Impairment in the U.S. ***(Percent of incidence of each pollutant is shown in parentheses. For example, siltation is listed as a cause of impairment in 38% of impaired river miles.)***

Rank	Rivers	Lakes	Estuaries
1	Siltation (38%)	Nutrients (44%)	Pathogens (47%)
2	Pathogens (36%)	Metals (27%)	Oxygen-Depleting Substances (42%)
3	Nutrients (29%)	Siltation (15%)	Metals (23%)
4	Oxygen-Depleting Substances (23%)	Oxygen-Depleting Substances (14%)	Nutrients (23%)
5	Metals (21%)	Suspended Solids (10%)	Thermal Modifications (18%)

List of Contaminants in Animal Manure:

- Oxygen-Demanding Substances
- Nitrogen
- Ammonia
- Nitrate
- Phosphorus
- Pathogens
- Antibiotics, Pesticides, and Hormones
- Airborne Emissions from Animal Production Systems
- Comprehensive Nutrient Management Planning
- Study Questions

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Oxygen-Demanding Substances

When discharged to surface water, biodegradable material is decomposed by aquatic bacteria and other microorganisms. During this process, dissolved oxygen is consumed, reducing the amount available for aquatic animals. Severe depressions in dissolved oxygen levels can result in fish kills. There are numerous examples nationwide of fish kills resulting from manure discharges and runoff from various types of AFOs.

Manure may be deposited directly into surface waters by grazing animals. Manually-collected manure may also be introduced into surface waters. This is typically via storage structure failure, overflow, operator error, etc.

Manure can also enter surface waters via runoff if it is over-applied or misapplied to land. For example, manure application to saturated or frozen soils may result in a discharge to surface waters. Factors that promote runoff to surface waters are steep land slope, high rainfall, low soil porosity, and proximity to surface waters. Incorporation of the manure into the soil decreases runoff.

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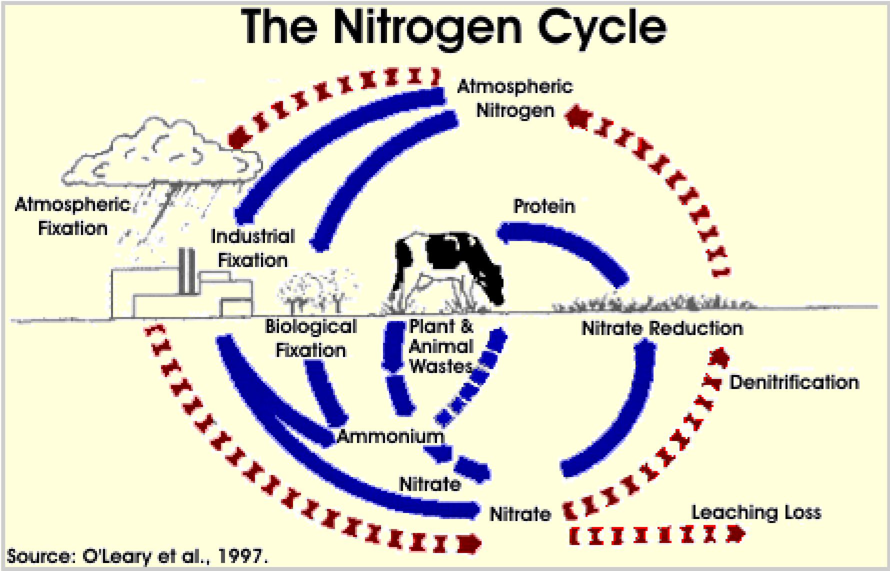
Nitrogen



Nitrogen (N) is an essential nutrient required by all living organisms. It is ubiquitous in the environment, accounting for 78 percent of the atmosphere as elemental nitrogen (N_2). This form of nitrogen is inert and does not impact environmental quality since it is not bioavailable to most organisms and therefore has no fertilizer value. Nitrogen can form other compounds, however, which are bioavailable, mobile, and potentially harmful to the environment. The nitrogen cycle shows the various forms of nitrogen and the processes by which they are transformed and lost to the environment.

Nitrogen in manure is primarily in the form of organic nitrogen and ammonia nitrogen compounds. In its organic form, nitrogen is unavailable to plants. However, organic nitrogen can be transformed into ammonium (NH_4^+) and nitrate (NO_3^-) forms, via microbial processes which are bioavailable and have fertilizer value. These forms can also produce negative environmental impacts when they are transported in the environment.

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Ammonia

"Ammonia-nitrogen" includes the ionized form (ammonium, NH_4^+) and the un-ionized form (ammonia, NH_3). Ammonium is produced when microorganisms break down organic nitrogen products such as urea and proteins in manure. This decomposition occurs in both aerobic and anaerobic environments. In solution, ammonium is in chemical equilibrium with ammonia.

Ammonia exerts a direct biochemical oxygen demand (BOD) on the receiving water since dissolved oxygen is consumed as ammonia is oxidized. Moderate depressions of dissolved oxygen are associated with reduced species diversity, while more severe depressions can produce fish kills.

Additionally, ammonia can lead to eutrophication, or nutrient over-enrichment, of surface waters. While nutrients are necessary for a healthy ecosystem, the overabundance of nutrients (particularly nitrogen and phosphorus) can lead to nuisance algae blooms.

Pfiesteria often lives as a nontoxic predatory animal, becoming toxic in response to fish excretions or secretions (NCSU, 1998). While nutrient-enriched conditions are not required for toxic outbreaks to occur, excessive nutrient loadings can help create an environment rich in microbial prey and organic matter that *Pfiesteria* uses as a food supply. By increasing the concentration of *Pfiesteria*, nutrient loads increase the likelihood of a toxic outbreak (Citizens *Pfiesteria* Action Commission, 1997).

The degree of ammonia volatilization is dependent on the manure management system. For example, losses are greater when manure remains on the land surface rather than being incorporated into the soil, and are particularly high when the manure is spray irrigated onto land. Environmental conditions also affect the extent of volatilization. For example, losses are greater at higher pH levels, warmer temperatures and drier conditions, and in soils with low cation exchange capacity, such as sands. Losses are decreased by the presence of growing plants. (Follett, 1995)

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Nitrate

Nitrifying bacteria can oxidize ammonium to nitrite (NO_2^-) and then to nitrate (NO_3^-). Nitrite is toxic to most fish and other aquatic species, but it typically does not accumulate in the environment because it is rapidly transformed to nitrate in an aerobic environment. Alternatively, nitrite (and nitrate) can undergo bacterial denitrification in an anoxic environment. In denitrification, nitrate is converted to nitrite, and then further converted to gaseous forms of nitrogen - elemental nitrogen (N_2), nitrous oxide (N_2O), nitric oxide (NO), and/or other nitrogen oxide (NO_x) compounds. Nitrification occurs readily in the aerobic environments of receiving streams and dry soils while denitrification can be significant in anoxic bottom waters and saturated soils.

Nitrate is a useful form of nitrogen because it is biologically available to plants and is therefore a valuable fertilizer. However, excessive levels of nitrate in drinking water can produce negative health impacts on infant humans and animals. Nitrate poisoning affects infants by reducing the oxygen-carrying capacity of the blood. The resulting oxygen starvation can be fatal. Nitrate poisoning, or methemoglobinemia, is commonly referred to as "blue baby syndrome" because the lack of oxygen can cause the skin to appear bluish in color. To protect human health, EPA has set a drinking water Maximum Contaminant Level (MCL) of 10 mg/l for nitrate-nitrogen. Once a water source is contaminated, the costs of protecting consumers from nitrate exposure can be significant. Nitrate is not removed by conventional drinking water treatment processes; its removal requires additional, relatively expensive treatment units.

Nitrogen in livestock manure is almost always in the organic, ammonia or ammonium form but may become oxidized to nitrate after being diluted. It can reach surface waters via direct discharge of animal wastes. Lagoon leachate and land-applied manure can also contribute nitrogen to surface and ground waters. Nitrate is water soluble and moves freely through most soils. Nitrate contributions to surface water from agriculture are primarily from groundwater connections and other subsurface flows rather than overland runoff (Follett, 1995).

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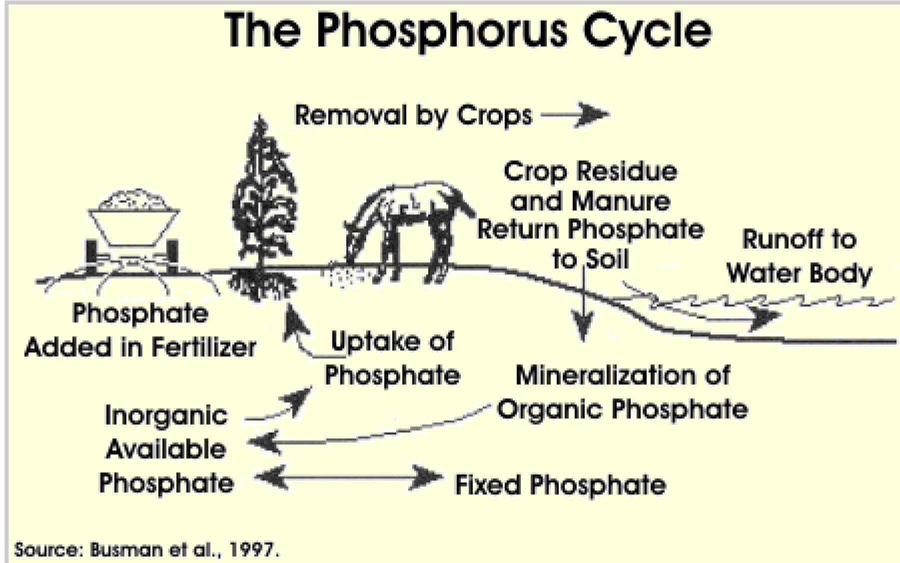
Phosphorus

Animal wastes contain both organic and inorganic forms of phosphorus (P). As with nitrogen, the organic form must mineralize to the inorganic form to become available to plants. This occurs as the manure ages and the organic P hydrolyzes to inorganic forms. The phosphorus cycle is much simpler than the nitrogen cycle because phosphorus lacks an atmospheric connection and is less subject to biological transformation.



Phosphorus is of concern in surface waters because it can lead to eutrophication. Phosphorus is also a concern because phosphate levels greater than 1.0 mg/l may interfere with coagulation in drinking water treatment plants (Bartenhagen et al., 1994). A number of research studies are currently underway to decrease the amount of P in livestock manure, primarily through enzymes and animal ration modifications that make phosphorous in the feed more available (and usable) by the animal. This means that less phosphorus must be fed to ensure an adequate amount for the animal and, as a result, less phosphorous is excreted in the manure.

Phosphorus predominantly reaches surface waters via direct discharge and runoff from land application of fertilizers and animal manure. Once in receiving waters, the phosphorus can become available to aquatic plants. Land-applied phosphorus is much less mobile than nitrogen since the mineralized form (inorganic Phosphate) is easily adsorbed to soil particles. For this reason, most agricultural phosphorus control measures have focused on soil erosion control to limit transport of particulate phosphorus. However, soils do not have infinite phosphate adsorption capacity and with long-term over-application, inorganic phosphates can eventually enter waterways even if soil erosion is controlled.

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Pathogens

Both manure and animal carcasses contain pathogens (disease-causing organisms) which can impact human health, other livestock, aquatic life, and wildlife when introduced into the environment. Several pathogenic organisms found in manure can infect humans.

Table 1. Some Diseases and Parasites Transmittable to Humans from Animal Manure		
Disease	**Responsible Organism**	**Symptoms**
Bacteria		
Anthrax	*Bacillus anthracis*	Skin sores, fever, chills, lethargy, headache, nausea, vomiting, shortness of breath, cough, nose/throat congestion, pneumonia, joint stiffness, joint pain
Brucellosis	*Brucella abortus*, *Brucella melitensis*, *Brucella suis*	Weakness, lethargy, fever, chills, sweating, headache
Colibaciliosis	*Escherichia coli* (some serotypes)	Diarrhea, abdominal gas

Coliform mastitis-metritis	*Escherichia coli* (some serotypes)	Diarrhea, abdominal gas
Erysipelas	*Erysipelothrix rhusiopathiae*	Skin inflammation, rash, facial swelling, fever, chills, sweating, joint stiffness, muscle aches, headache, nausea, vomiting
Leptospirosis	*Leptospira Pomona*	Abdominal pain, muscle pain, vomiting, fever
Listeriosis	*Listeria monocytogenes*	Fever, fatigue, nausea, vomiting, diarrhea
Salmonellosis	Salmonella species	Abdominal pain, diarrhea, nausea, chills, fever, headache
Tetanus	*Clostridium tetani*	Violent muscle spasms, "lockjaw" spasms of jaw muscles, difficulty breathing
Tuberculosis	*Mycobacterium tuberculosis*, *Mycobacterium avium*	Cough, fatigue, fever, pain in chest, back, and/or kidneys
Rickettsia		
Q fever	*Coxiella burneti*	Fever, headache, muscle pains, joint pain, dry cough, chest pain, abdominal pain, jaundice
Viruses		
Foot and Mouth	Virus	Rash, sore throat, fever
Hog Cholera	Virus	
New Castle	Virus	
Psittacosis	Virus	Pneumonia
Fungi		
Coccidioidycosis	*Coccidioides immitus*	Cough, chest pain, fever, chills, sweating, headache, muscle stiffness, joint stiffness, rash wheezing
Histoplasmosis	*Histoplasma capsulatum*	Fever, chills, muscle ache, muscle stiffness, cough, rash, joint pain, join stiffness
Ringworm	Various *microsporum* and *trichophyton*	Itching, rash
Protozoa		
Balantidiasis	*Balatidium coli*	
Coccidiosis	*Eimeria* species	Diarrhea, abdominal gas
Cryptosporidiosis	*Cryptosporidium* species	Watery diarrhea, dehydration, weakness, abdominal cramping
Giardiasis	*Giardia lamblia*	Diarrhea, abdominal pain, abdominal gas, nausea, vomiting, headache, fever
Toxoplasmosis	*Toxoplasma* species	Headache, lethargy, seizures, reduced cognitive function
Parasites/Metazoa		
Ascariasis	*Ascaris lumbricoides*	Worms in stool or vomit, fever, cough, abdominal pain, bloody sputum, wheezing, skin rash, shortness of breath
Sarcocystiasis	*Sarcosystis* species	Fever, diarrhea, abdominal pain

References: USDA, 1992 (for diseases and responsible organisms). Symptom descriptions were obtained from various medical and public health service Internet websites. Pathogens in animal manure are a potential source of disease in humans and other animals. This list represents a sampling of diseases that may be transmittable to humans.

The treatment of public water supplies reduces the risk of infection via drinking water. However, protecting source water is the best way to ensure safe drinking water. Cryptosporidium parvum, a protozoan that can produce gastrointestinal illness, is a concern, since it is resistant to conventional treatment. Healthy people typically recover relatively quickly from such illnesses. However, they can be fatal in people with weakened immune systems such as the elderly and small children.

Runoff from fields where manure has been applied can be a source of pathogen contamination, particularly if a rainfall event occurs soon after application. The natural filtering and adsorption action of soils typically strands microorganisms in land-applied manure near the soil surface (Crane et al., 1980). This protects underlying groundwater, but increases the likelihood of runoff losses to surface waters. Depending on soil type and operating conditions, however, subsurface flows can be a mechanism for pathogen transport.

Soil type, manure application rate, and soil pH are dominating factors in bacteria survival (Dazzo et al., 1973; Ellis and McCalla, 1976; Morrison and Martin, 1977; Van Donsel et al., 1967). Experiments on land-applied poultry manure have indicated that the population of fecal organisms decreases rapidly as the manure is heated, dried, or exposed to sunlight on the soil surface (Crane et al., 1980).

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Antibiotics, Pesticides, and Hormones

Antibiotics, pesticides, and hormones are organic compounds which are used in animal feeding operations and may pose risks if they enter the environment. For example, chronic toxicity may result from low-level discharges of antibiotics and pesticides. Estrogen hormones have been implicated in the reduction in sperm counts among Western men (Sharpe and Skakkebaek, 1993) and reproductive disorders in a variety of wildlife (Colburn et al., 1993). Other sources of antibiotics and hormones include municipal waste waters, septic tank leachate, and runoff from land-applied sewage sludge. Sources of pesticides include crop runoff and urban runoff.

Little information is available regarding the concentrations of these compounds in animal wastes, or their fate/transport behavior and bioavailability in waste-amended soils. These compounds may reach surface waters via runoff from land-application sites.

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Airborne Emissions from Animal Production Systems

With the trend toward larger, more concentrated production operations, odors and other airborne emissions are rapidly becoming an important issue for agricultural producers.

Whether there is a direct impact of airborne emissions from animal operations on human health is still being debated. There are anecdotal reports about health problems and quality-of-life factors for those living near animal facilities have been documented.

- Source of Airborne Emissions
- Emission Movement or Dispersion

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Source of Airborne Emissions

Odor emissions from animal production systems originate from three primary sources: manure storage facilities, animal housing, and land application of manure.

In an odor study in a United Kingdom county

(Hardwick 1985), 50% of all odor complaints were traced back to land application of manure, about 20% were from manure storage facilities, and another 25% were from animal production buildings. Other sources include feed production, processing centers, and silage storage. With the increased use of manure injection for land application, and longer manure storage times, there may be a higher percentage of complaints in the future associated with manure storage facilities and animal buildings and less from land application.

Animal wastes include manure (feces and urine), spilled feed and water, bedding materials (i.e., straw, sunflower hulls, wood shaving), wash water, and other wastes. This highly organic mixture includes carbohydrates, fats, proteins, and other nutrients that are readily degradable by microorganisms under a wide variety of suitable environments. Moisture content and temperature also affect the rate of microbial decomposition.

A large number of volatile compounds have been identified as byproducts of animal waste decomposition. O'Neill and Phillips (1992) compiled a list of 168 different gas compounds identified in swine and poultry wastes. Some of the gases (ammonia, methane, and carbon dioxide) also have implications for global warming and acid rain issues. It has been estimated that one third of the methane produced each year comes from industrial sources, one third from natural sources, and one third from agriculture (primarily animals and manure storage units). Although animals produce more carbon dioxide than methane, methane has as much as 15 times more impact on the greenhouse effect than carbon dioxide.

Dust, pathogens, and flies are from animal operations also airborne emission concerns. Dust, a combination of manure solids, dander, feathers, hair, and feed, is very difficult to eliminate from animal production units. It is typically more of a problem in buildings that have solid floors and use bedding as opposed to slotted floors and liquid manure. Concentrations inside animal buildings and near outdoor feedlots have been measured in a few studies; however, dust emission rates from animal production are mostly unknown.

Pathogens are another airborne emission concern. Although pathogens are present in buildings and manure storage units, they typically do not survive aerosolization well, but some may be transported by dust particles.

Flies are an additional concern from certain types of poultry and livestock operations. The housefly completes a cycle from egg to adult in 6 to 7 days when temperatures are 80 to 90°F. Females can produce 600 to 800 eggs, larvae can survive burial at depths up to 4 feet, and adults can fly up to 20 miles. Large populations of flies can be produced relatively quickly if the correct environment is provided. Flies tend to proliferate in moist animal production areas with low animal traffic.

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Emission Movement or Dispersion

The movement or dispersion of airborne emissions from animal production facilities is difficult to predict and is affected by many factors including topography, prevailing winds, and building orientation. Prevailing winds must be considered to minimize odor transport to close or sensitive neighbors. A number of dispersion models have been developed to Airborne Emission Regulations.

Most states and local units of government deal with agricultural air quality issues through zoning or land use ordinances. Setback distances may be required for a given size operation or for land application of manure. A few states (for example, Minnesota) have an ambient gas concentration (H_2S for Minnesota) standard at the property line. Gas and odor standards are difficult to enforce since on-site measurements of gases and especially odor are hard to do with any high degree of accuracy. Producers should be aware of odor- or dust-related emissions regulations applicable to their livestock operation.

Source: Lesson 40 of the LPES: Adapted from Livestock and Poultry Environmental Stewardship curriculum, lesson authored by Larry Jacobson, University of Minnesota; Jeff Lorimor, Iowa State University; Jose Bicudo, University of Kentucky; and David Schmidt, University of Minnesota, courtesy of MidWest Plan Service, Iowa State University, Ames, Iowa 50011-3080, Copyright (c) 2001.

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Environmental Impacts of Animal Feeding Operations Study Questions

Identify the definition that best fits the following terms:

1. **What are some of the positive environmental benefits of production agriculture?**

   - ◯ Improved soil quality
   - ◯ Carbon repository
   - ◯ Reduced storm runoff
   - ◯ Ground water recharge
   - ◯ All of the above

   Feedback

2. **USDA estimates that manure phosphorous exceeds crop needs in what percent of U.S. countries?**

   - ◯ 0%
   - ◯ 15%
   - ◯ 30%
   - ◯ 45%

   Feedback

3. **What is the common name for the class of production agricultural plants that do not need commercial nitrogen fertilizer?**

   - ◯ N Converters
   - ◯ Maize
   - ◯ Legumes
   - ◯ Algae

Feedback

4. **If biodegradable organic matter is added to a stream, fish kills most often result from:**

   - Lack of oxygen
   - Turbulence
   - Lack of visibility
   - Build up of sludge deposits

Feedback

5. **Most manure spills that enter streams result from:**

   - Pastured animals with stream access
   - Rupture of manure storage
   - Improper land application of manure
   - Damage to manure transfer or irrigation pipes
   - Feedlot runoff from animal area
   - All of the above

Feedback

6. **Nitrogen gas (N_2) account for ___________ % of the atmosphere?**

   - 0%
   - 24%
   - 62%
   - 78%
   - 92%

Feedback

7. **Nitrogen in manure can take many chemical forms. Which of the following is NOT included?**

   - Nitrogen gas
   - Organic nitrogen
   - Catatonic nitrogen
   - Ammonia
   - Ammonium

Feedback

8. **Which nutrient in runoff from agricultural land has been blamed for the hypoxia problem in the Gulf of Mexico?**

- Phosphorous
- Chlorine
- Sulfur
- Nitrogen
- Soil erosion

Feedback

9. **Which of the forms of nitrogen are volatile?**

- NH_3
- NO_3
- NO_2
- NH_4

Feedback

10. **High nitrate levels in drinking water can lead to the following serious condition in infants:**

- "Green baby syndrome"
- Headaches
- Methemoglobinemia
- Colic
- Alzheimer's

Feedback

11. **The most important method of reducing phosphorous entering streams is:**

- Placing riprap along edge of stream
- Preventing soil erosion
- Improving field drainage

Feedback

12. **Which of the following is NOT a significant source of air emissions around a livestock or animal production operation?**

- Feed processing
- Land application of manure
- Animal production lots and buildings
- Manure Storage

Feedback

See Results RESET

Score in Percentage:	

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Comprehensive Nutrient Management Planning

Recently, the concept of Comprehensive Nutrient Management Planning (CNMP) was introduced by the U. S. Environmental Protection Agency (EPA) and U.S. Department of Agriculture's (USDA's) Natural Resources Conservation Service (NRCS). It is anticipated that the CNMP will serve as a cornerstone of environmental plans assembled by animal feeding operations to address federal and state regulations. EPA and NRCS guidelines for CNMP are given in Table 1.

Table 1. Summary of Issues addressed by a CNMP as initially definied by EPA's Guidance

Planning components of CNMP	Issues addressed
A manure handling and storage plan	1. Diversion of clean water 2. Prevention of leakage storage plan 3. Adequate storage 4. Manure treatment 5. Management of mortality
Land application plan	1. Proper nutrient application rates to achieve a crop nutrient balance 2. Selection of timing and application methods to limit risk of runoff
Site management plan	Soil conservation practices that minimize movement of soil and manure components to surface and groundwater
Record keeping	Manure production, utilization, and export to off-farm users
Other utilization options	Alternative safe manure utilization strategies such as sale of manure, treatment technologies, or energy generation
Feed management plan	Alternative feed programs to minimize the nutrients in manure

Reference: USDA/EPA Unified National Strategy for Animal Feeding Operations (PDF) (34 pp, 404K)

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Pork Production Study Questions

Identify the definition that best fits the following terms:

1. **Boar**

   - A female pig

- An adult male hog, normally used for breeding
- A tedious individual
- A type of feeding system

Feedback

2. **Gilt**

- An older female swine that failed to conceive
- A non-innocent individual
- A male hog
- A female pig that has not yet farrowed

Feedback

3. **Farrowing**

- Conservation process whereby land lies dormant
- Feeding program for grow-finish hogs
- Period when pigs are born to the sow
- Practice of moving pigs from sow to sow to create more uniform litters

Feedback

4. **Production Schedule**

- Feeding program for pigs, from birth to market
- Marketing program for a swine operation
- Schedule by which sows are bred, farrowed, pigs are weaned, moved from production phase to production phase and eventually marketed

Feedback

5. **Mating**

- Sometimes follows dating
- Matching baby pigs at birth to their mothers
- Process by which pigs are matched by weight to determine pen mates
- Inseminating sows or gilts at estrous via exposure to a boar (or artificial insemination)

Feedback

6. **Pen**

- Something to write with

- Confined area where swine or other animals are kept
- Farmstead area
- Prison facilities

Feedback

7. **Shoat**

- A large male swine
- An immature swine
- A type of knife used for castration
- A type of portable shelter used when swine are kept when placed on pasture land

Feedback

8. **Slotted floors**

- A type of flooring used under stacked hay, to facilitate drying
- Flooring that has been grooved to improve footing for animals
- A type of porous floor that allows waste to drain away, keeping animals dry and comfortable

Feedback

9. **Barrow**

- The container located above the wheel in a wheelbarrow
- A male swine who has been castrated to reduce aggressiveness and improve the flavor of the meat
- An excavated pit from which soil or gravel is removed for a construction project

Feedback

10. **Estrus**

- An indication that the sow is ready to be bred
- A type of grain fed to grow-finish swine
- The process of removing pigs from the sow
- An important religious holiday

Feedback

11. **Number of tons of pork produced in the U.S. each year**

- 500,000,000
- 100,000,000
- 9,000,000
- 1,000,000

Feedback

12. **Leading hog producing state, in terms of market animals**

- North Carolina
- Indiana
- Iowa
- Missouri

Feedback

13. **Hoop structure**

- A popular game in the U.S. during the 1950s
- A type of portable, low cost shelter used for gestation and grow finish swine. Limited mainly to smaller operations
- A general purpose building used mainly as a utility building for farm shops, feed or machinery storage.
- A sound making device used to herd animals

Feedback

14. **Land application**

- Legal forms that much be completed when applying for financing to purchase a farm
- The application of manure to cropland at a rate that matches the nutrients needed by the plants
- Application of irrigation water to a farm field

Feedback

15. **Whole farm nutrient balance**

- A type of pork cut from the loin area
- A method of balancing the nutrients in a ration for swine
- Balancing nutrient inputs to the production unit with the use and removal of those nutrients from the operation

Feedback

See Results RESET

Score in Percentage:	

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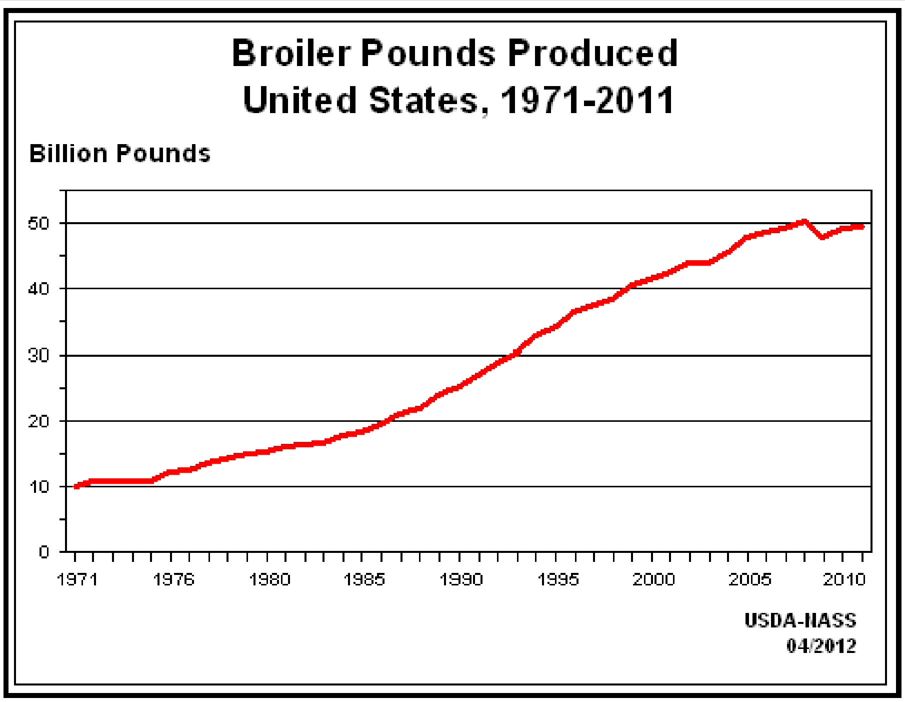
National Agriculture Compliance Assistance Center (Ag Center)

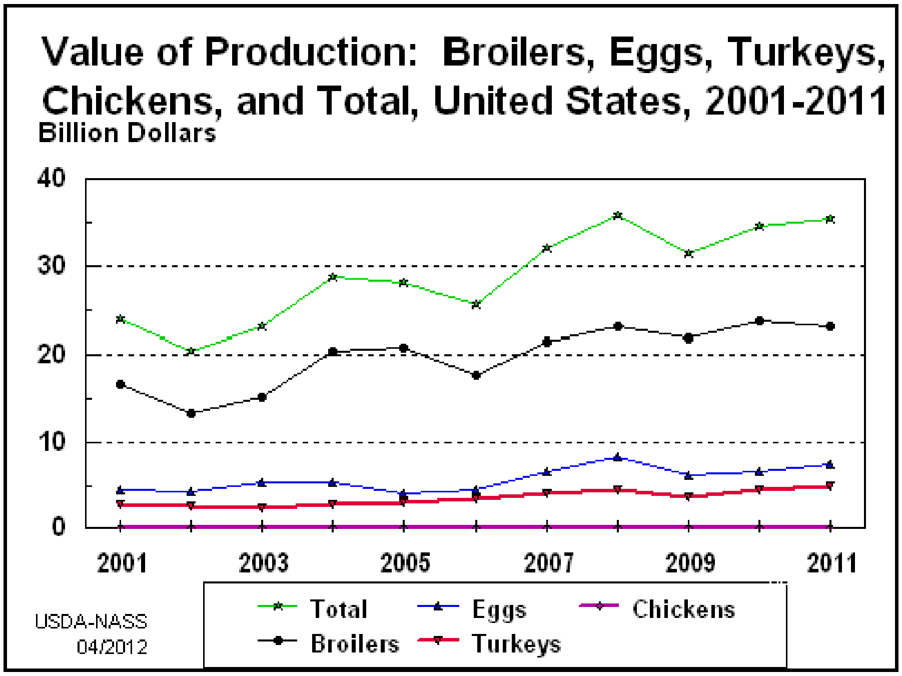
Background of Poultry Production in U.S.

Source: J. Sell, Iowa State University

Chickens are the most numerous birds in the world. The chicken is believed to have been domesticated nearly 5000 years ago from wild birds in Southeast Asia. On the other hand, the domestication of the turkey occurred much more recently, by American Indians in prehistoric times. The turkey was introduced into Europe in the sixteenth century by returning Spanish explorers. Settlers emigrating to the U.S. who later bred this European stock with wild turkeys in the Eastern U.S. to produce the ancestors of today's commercially grown turkeys.

The poultry industry has largely grown from backyard operations which provided supplemental income for the family to a vertically integrated industry (PDF). (28 pp, 717K) EXIT Disclaimer Poultry consumption in the U.S. has increased from the 1900s, when chicken was eaten only on Sundays to making poultry an everyday item today.





U.S. Poultry Inventory

Specie	# / year	lb
Broiler	8.6 billion	49.2 billion
Turkey	244 million	7.1 billion
Layers	339 million	91.4 billion eggs
Chickens	455 million	N/A

per US Census 2010 EXIT Disclaimer

Broiler production has been increasing since the 1980s due to Americans becoming more health conscious and through an unprecedented increase in exports. Part of this increase has also been attributed to the poultry industry supplying products that are further processed and easier for the consumer to prepare. These increases have led to an all time high in poultry production in the U.S. (**Table**). Currently, most poultry production in the United States is in the Southeastern states. EXIT Disclaimer

At one time, there were many distinct breeds of chicken, each having particular traits or characteristics. Through selective breeding, only a few strains of birds dominate the market today. There are many primary breeding companies of poultry, but only a handful are responsible for most of the broiler chicken, laying hen, and turkey production in the world.

Concentration and specialization of the poultry industry have led to the development of allied industries. These industries supply housing, feeding and other equipment, hatchery equipment, processing supplies and equipment, drugs and other health products, feed additives, and several other items.

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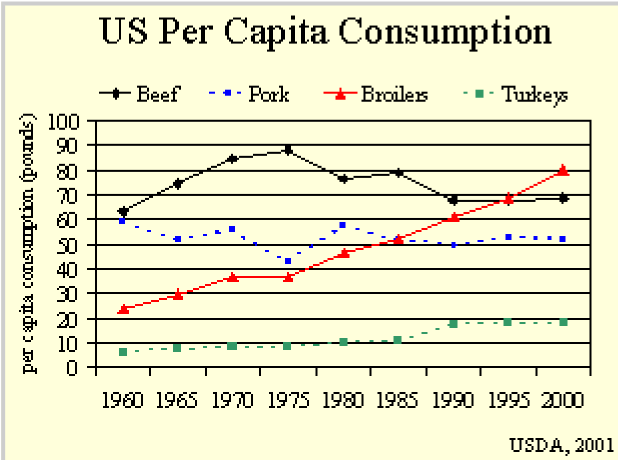
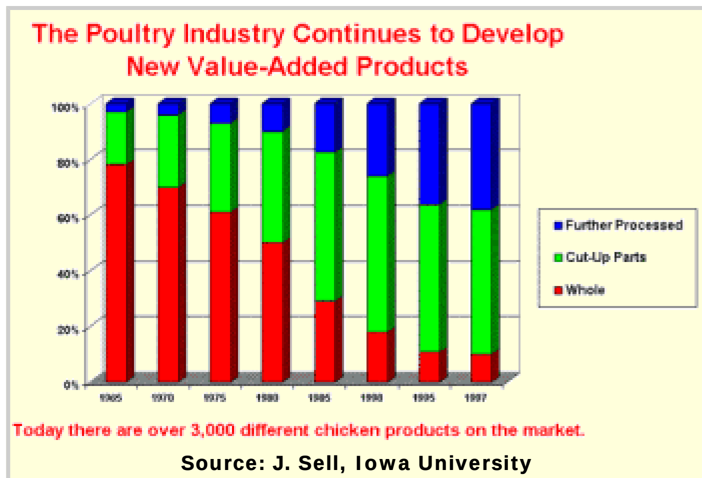
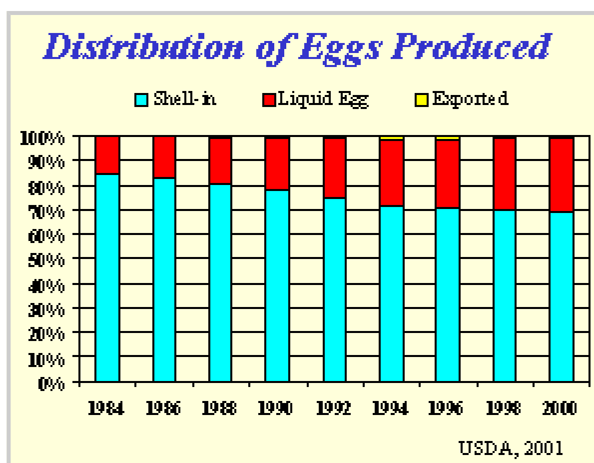
Products from Poultry







Poultry products (broiler meat in particular) has the highest per capita consumption in the United States. People eat many different poultry products, including eggs, turkey ham, buffalo wings, hot dogs, chicken nuggets, chicken-patties, fried, roasted, glazed, marinated, etc. Not all of poultry products, however, are directly consumed by humans. For example, eggs are also used for the production of therapeutic vaccines and are beginning to be used for production of antibodies and pharmacological proteins. Part of the increase in poultry production in the 1980s and 1990s can be attributed to the development of new, further-processed, value-added products. Similarly, the egg market has changed in scope through the late 1980s such that a greater proportion of eggs that are produced are destined for a liquid egg market. Liquid egg is used in a variety of institutions including hotels, restaurants, hospitals, and if dried, included in numerous other products, such as cake mixes. Today, the U.S. produces 33% of the world's broiler meat, 53.7% of the turkey meat, and 11% of the eggs (USDA-FAS, 2001).

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Poultry Production Phases

Poultry production encompasses a number of different species, including the chicken (reared for laying eggs-"layers", or meat production-"broilers"), turkeys, ducks, and other waterfowl and gamebirds. Each species and particular type of production is uniquely different. We will primarily focus on laying hens, broiler production, turkey production, and duck production.

Breeding Flocks

Lighting and Housing Types

Lighting plays a very important role in bird growth, development, and maturity. Most commercial poultry specie are photosensitive animals. For example, a constant or decreasing amount of daily light (as occurs during the fall and winter months) will delay sexual maturity in growing birds. An increasing amount of light (as occurs in the spring) will stimulate sexual maturity. Since lighting plays such an important role in the development of sexual maturity, adolescent birds are generally reared in black-out houses. This allows the producer to have complete control over the lighting cycle of the birds by providing artificial light.

Housing for breeder broilers
Source: J. Sell, Iowa State University

Once birds reach the age of sexual maturity, they are moved to the laying house. Breeder broilers and ducks are generally be kept in a barn with a slotted floor or with a wire floor with litter in the middle of the house to act as a mating area. Breeder turkeys are generally reared in all litter houses. Clean, nesting boxes are provided so that the birds may lay their eggs without being disturbed by other birds and so that the eggs may be kept clean and easily collected.

Restricted Feeding

Adolescent broilers (especially), turkeys, and ducks, when given the opportunity, will eat until they become obese. Therefore, restricted feeding is necessary if the birds are going to be used as breeder stock. Otherwise, the obesity severely limits the numbers of eggs laid and the fertility of those eggs. For this reason, restricted feeding is necessary. There are two main types of restrictive feeding programs. The first of these is every day feeding of a limited amount, or lower nutrient content diet. The amount fed will ensure adequate growth but not result in obesity. Another type of restrictive feeding is an every other day feeding program. where birds are fed a specific quantity of feed every other day. Since male broiler chickens grow faster, they often are reared separately from the females until they are moved into the breeder house. Specific ratios of male-to-females are kept in the breeder house (typically, broilers-1 male :15 females, turkeys and ducks-1:8 to 10) to ensure fertility of hatching eggs.

Hatchery

Eggs are typically collected from breeder farms, taken to a hatchery and stored from 0 to 10 days prior to being set in an incubator. These eggs will be stored at temperatures between 55-68° F, depending on when they are to be incubated. When the eggs are placed in incubators, embryonic development begins. Different species of birds require different incubation times. Chickens hatch in 21 days while turkeys and ducks need 28 days. The hatchlings (chicks, poults, or ducklings) are processed (vaccinated, gender sorted, and/or other procedures) then transported to commercial grow-out facilities. Transport typically will take anywhere from a few hours to one day.

Hatchlings destined for grow-out facilities
Source: Purdue University

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Laying Hens

The modern laying hen is a biological marvel. She begins laying eggs at approximately 18 weeks of age and by the end of her first year, she may have produced upwards of 200 eggs - nearly 25 pounds. The hen reaches peak egg production (95 + %) within 4 to 6 weeks after she begins to lay eggs. In order to produce such a hen, it is critical that the hen be carefully managed during her first 17 weeks of life.

At the beginning of a pullet's life in the hatchery, she is vaccinated to prevent future diseases. On the farm, pullets will be grown in cages until they are moved into the laying house at 16 to 17 weeks of age. Pullet chicks will typically be beak trimmed during their first three weeks of life in the pullet house to minimize cannibalism.

Lighting programs are very similar to what was described for breeding flocks.

Induced molting

Molting is the process of the bird shedding and re-growing feathers. Molting occurs naturally in the wild, as seasonal daylight shortens and females stop laying eggs. Laying hens are generally molted once or twice during their productive lives. Molting usually does not affect egg size, but allows for an improved egg laying rate, improved shell quality, and increased albumin height. It also allows a producer to keep the birds longer than they might otherwise be kept. To induce molt, a producer may use a period of fasting and a reduced amount of daylight, giving the birds water and allowing them to lose a proportion of their body weight. Daylight length will then be increased, and the hens begin laying eggs again.

In-line vs. Off-line production

In-line layer operation
Source: Purdue University

Laying hen farms are composed of two different types, in-line and off-line.

In-line production - Hen houses are placed side-by-side and linked by a conveyor belt. The conveyor belt leads to a centralized processing building, where the eggs from all houses are sorted, graded, either packed or broken and further processed, and refrigerated prior to shipping.

Off-line production - This is similar to the in-line production, but the eggs that are collected on a conveyor belt and sent to a main building are packed and refrigerated prior to shipping to another facility to be processed.

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Broilers, Turkeys, Ducks (meat-bird production)


Source: Purdue University

Broilers


Brooder rings keep broilers near heat, feed, and water
Source: Purdue University

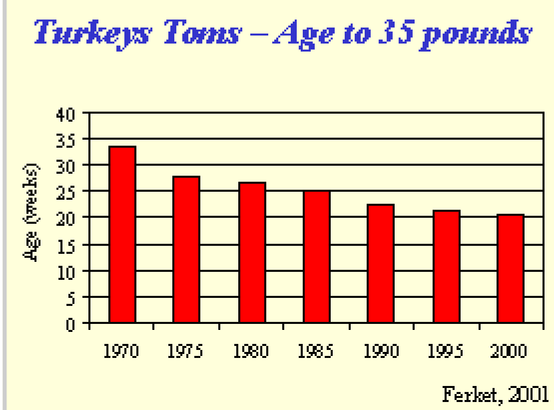

Waterer in broiler house
Source: Purdue University

Broilers are relatively easy to raise. To begin with, the whole house is heated and brooder rings are placed around each brooder (heating) unit. These rings create a "microclimate" relative to the rest of the room to prevent drafts and keep the birds near each other and near the feed and water. The nipple or cup waterers in each pen must be fully functional and supplemental jug waterers in the brooder rings must be kept filled. When the birds arrive, they are placed into the rings and introduced to the waterers and feed. Feed is placed in the feeders and on paper placed on the floor of the pen to encourage young birds to eat. Generally, broilers are brooded in a portion of the house until a certain age before being given access to the entire barn. These facilities, or "houses" generally have litter floors. Depending on the geographical location of the house, natural ventilation will be either provided by opening curtain-sided walls or large insulated door panels on the sides of the house.

Some farms separate male and female birds, a practice called separate-sex feeding. Separate-sex feeding accomplishes a number of goals. When birds are separated and fed according to gender (versus rearing males and females together), there will be more uniformity among males and among females in the flock. Separation of the birds also allows producers to feed diets that more closely meet the nutritional needs of the male and female birds.

Turkey Housing

Source: Purdue University



Source: Purdue University

In previous decades, turkeys have been mainly considered a holiday product. However, with advances of further-processing as well as an increasingly health-conscious population in the U.S., the turkey has become a popular year-round meat. Raising turkeys takes more time than raising broilers, as turkeys take longer to mature. Generally, a turkey is sent to market anywhere between 15 and 25 weeks of age. At 20 weeks of age, a male turkey should weigh about 35-40 pounds.

Turkey poults
Source: Purdue University

Getting poults (baby turkeys) started is not as easy as starting broilers. Both benefit from brooder rings in order to keep them close to the heat source, food, and water and to prevent drafts. Additionally, the farm worker must physically show the poults where the water and feed are when placing poults into the brooder rings; otherwise, some birds will never manage to find it.

Poults are usually gender-sorted at the hatchery and the males (toms) and females (hens) are reared separately. They may also toe-trimmed, and beak-trimmed at the hatchery to prevent the birds from injuring each other.

Over their life cycle, turkeys may live in 2 or 3 different barns. The brooder barn, is used for the first 6 to 8 weeks of life. After that, the turkeys may be moved to an intermediate barn. Lastly, they are moved into a grow-out facility. By having multiple barns for different ages, a farm is able to rear a greater number of birds in a shorter amount of time.

Ducks

While broilers and turkeys may seem like fast-growing birds, the duck is the most rapidly growing animal of all poultry species. A typical duck will weigh 7 pounds in only 6 or 7 weeks!

Ducks can be raised in a number of different types of houses. Some are raised on all-litter floors while others have slats or wire for the flooring. Some houses contain a litter floor with a ramp leading up to raised-wire or expanded plastic flooring over a shallow pit. Since ducks like to play with the watering system (typically a nipple-waterer system), it is located over the raised flooring. Generally, ducks go through two or three stages of housing. Each stage would house anywhere from 13 to 20 groups of ducks per year.

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Print As-Is

Last updated on July 29, 47489

Production Systems

Small poultry operation with dirt floor
Source: J. Sell, Iowa State University

Make-shift ventilation in poultry house
Source: J. Sell, Iowa State University

Prior to WWII, the majority of poultry were reared in backyard flocks on dirt-floored pens, in small sheds with natural or make-shift ventilation.

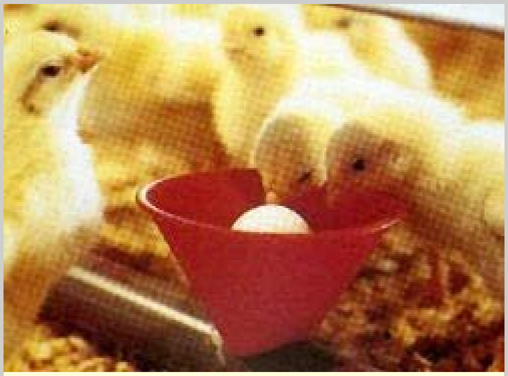
An early year-round production building
Source: J. Sell, Iowa State University

Poultry grown in large outdoor areas
Source: J. Sell, Iowa State University

Between 1940 and 1960, advancements in nutrition and genetics allowed the broiler market to shift from being able to produce a 3-3.5 pound bird at 16 weeks to one that only took 8 weeks. Due to advances in production efficiency and refrigerated trucking, markets expanded to a much larger geography while the price of poultry per pound dropped dramatically from approximately 65 cents in 1940 to 29 cents in 1960. Due largely to changes in price versus other meat options, demand for broilers increased dramatically. Production systems during this time also underwent dramatic changes from the seasonal, small backyard sheds to large year-round naturally ventilated buildings and during some seasons, large outdoor pens.

Modern enclosed poultry building
Source: Purdue University

On-demand feeder line
Source: Purdue University



On-demand cup waterer
Source: Purdue University

Nipple waterer
Source: Purdue University

Turkey and broiler flocks are reared in enclosed buildings with updated equipment. For instance, birds are now reared in confinement with on-demand feeder lines, on-demand cup or nipple waterers, or on-demand bell-type waterers. These developments overcame most problems with weather, predators, potential pollution from lot runoff, and allowed the use of more intensive production schedules. Almost all turkeys and broilers are reared on litter floors. Ducks, turkeys, and occasionally broilers are reared in multi-stage facilities with facilities for brooding birds, and in larger facilities (either a separate room or separate building) that they will be moved into at an older age.

Wire cages
Source: Purdue University

Slotted floor facilities
Source: Purdue University

Young pullets, laying hens, and broiler breeders are reared in either wire-cages or slotted-floor systems. If a slotted flooring system is used, there may or may not be a central area containing litter. Duck facilities encompass a number of different production types and may or may not have multistage facilities. Systems in use include all-litter houses, raised-wire flooring over a shallow pit (which would be located below a nipple water line) and houses with raised-wire floors.

Mechanically ventilated building
Source: Purdue University

Layers in commercial facilities produce a great deal of body heat. Ventilation to keep the hens cool is usually more of a concern than providing heat in winter. Non-brooding birds (3-4 weeks and older) grow best at around 70-75 degrees. In winter, they are protected from winter winds in an insulated building. Enough ventilation must be provided to remove moisture produced by the animals and to provide fresh air. In summer, large sidewall vents are opened or large ventilation fans are operated to keep the animals comfortable. This is referred to as either naturally ventilated (air change due to the wind) or mechanically ventilated (where air is drawn into the buildings through vents due to a negative pressure created with wall fans that exhaust inside air to the outdoors. Further information on poultry ventilation. EXIT Disclaimer

Disadvantages associated with large enclosed, production facilities are that different ages of birds with different degrees of disease resistance are housed in close proximity which can facilitate disease spread if adequate cleaning and disinfecting are not feasible in some situations, and higher levels of medication may be required to control disease. The primary rule of thumb for workers on a farm with multiple ages of birds is to always travel from the youngest birds on the farm to the oldest, and not vice-versa. Biosecurity plans between farms, and between multiple production buildings on the same farm can help reduce the incidence and spread of disease from one flock to the next.

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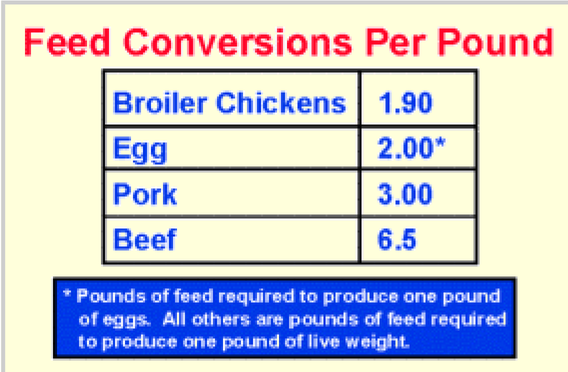
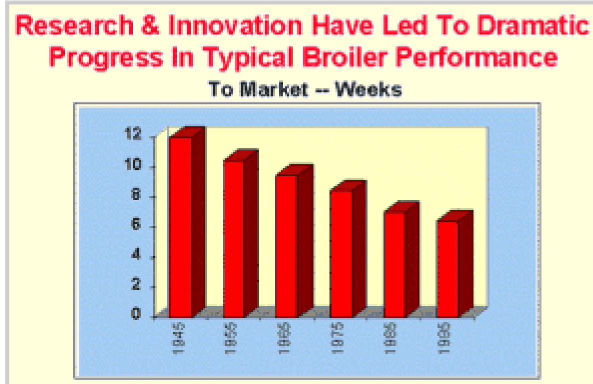
Nutrition



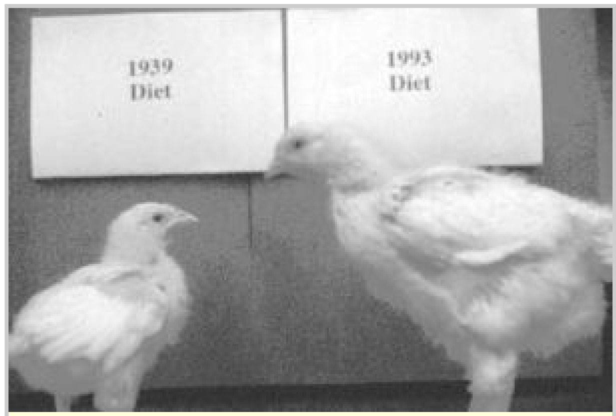
Feed Conversions Per Pound

Broiler Chickens	1.90
Egg	2.00*
Pork	3.00
Beef	6.5

* Pounds of feed required to produce one pound of eggs. All others are pounds of feed required to produce one pound of live weight.



Poultry in the U.S. are fed diets which are primarily ground corn to supply heat and energy and soybean meal to provide protein. Vitamins and minerals are also added in their feed. It takes only 11.4 pounds of feed to rear a broiler to a 6 pound market weight. This same broiler would drink about 3 gallons of water during this time (approximately 7 weeks). Part of the poultry industry's increase in productiveness has largely been attributed to the efficiency of conversion of feed to gain -or- egg production. This increased efficiency can be largely attributed to improvements in genetics and nutrition.



Improvement in diet have resulted in dramatic improvements in growth
Source: J. Sell, Iowa State University

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Common Manure Handling Systems

Litter

Poultry manure is handled as a solid litter, either deposited directly by animals on pastureland, or collected in bedding placed on solid shelter floors to absorb the urine. Some turkeys, broilers, and ducks are raised on concrete or earthen floors. After every flock, the litter is either:

1. Removed and fresh litter applied,
2. Tilled and fresh litter placed on top, or
3. Cake manure removed, remaining litter tilled or mixed, and fresh litter placed on top.

Tractor-drawn decaker/cruster
Source: Kelly Manufacturing Co.

Solid manure spreader
Source: Purdue University

Cake manure is sometimes removed with a tractor-drawn decaker/cruster which removes the top layer of manure, breaks it apart, and separates the larger manure particles from the finer litter particles (which are placed back into the house). Poultry litter is normally surface applied, but in some cases may be incorporated into the soil with a farm tillage operation shortly after spreading.

For further information on proper sampling of poultry litter. EXIT Disclaimer

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Layer Manure - Dry

Laying hens on wire floors
Source: Purdue University

Surface applied solid manure
Source: Purdue University

Manure from pullets and laying hens is relatively dry as it falls through layer cages into a concrete storage area. Manure composition in these facilities can range in dry matter between 20 and 60 percent. The storage pit provides for long-term storage of the manure. Manure is then typically surface applied. Composting is another option for solid manure management.

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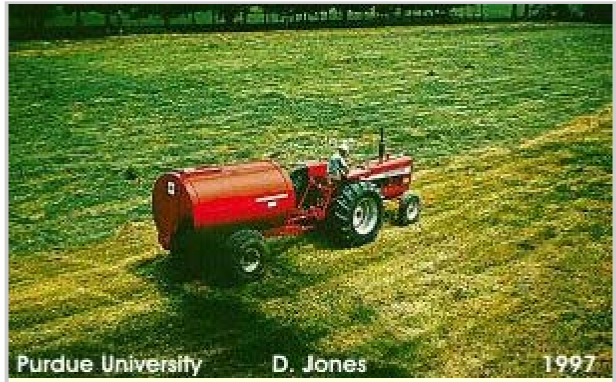
Layer Manure - Semi-Solid / Liquid

Some laying hen facilities contain shallow pits with scrapers or belts, or shallow flush pits. This manure typically can not be stacked and requires some type of containment storage. Liquid manure that is mostly water (< 12% solids) must be kept in a watertight storage. Liquid manure can be handled with tank trucks/wagons, injection-type spreaders, or irrigation equipment. Semi-solid manure (12 to 20 percent solids), on the other hand, does not flow readily but still requires containment with walls. This type of manure can be handled easily with bucket loaders and open broadcast spreaders. Most Midwestern states require manure storages for larger operations to be large enough to hold six month's accumulation. This avoids the need to apply manure during the crop growing season and when weather conditions are unsuitable – such as on frozen or snow-covered ground or when the soil is wet enough that heavy application vehicles could compact and damage the soil.

Liquid manure pit agitation
Source: Purdue University



Surface applied liquid manure
Source: Purdue University


Injecting liquid manure
Source: Purdue University

Liquid manure from storages is normally agitated thoroughly before removal and hauled to the field for application using large tanker wagons or trucks. Liquid manure is either applied on the soil surface or incorporated shortly after application to control loss of volatile ammonia and release of odors. Incorporation is very effective at controlling runoff of manure nutrients and odor from land application if done within a few hours after application. An alternative application method is the use of a soil injector, where liquid manure is "injected" directly into the soil to a depth of 6 to 9" as the tanker passes over the field. This immediate contact between the manure and soil is highly effective against the release of odors.

In larger operations, liquid manure may be pumped to nearby application sites and irrigated onto cropland. Spray irrigating liquid manure is a very efficient method of land application, in terms of speed and labor, but odor emissions can be significant; therefore, it is seldom possible to use this method in heavily populated areas.

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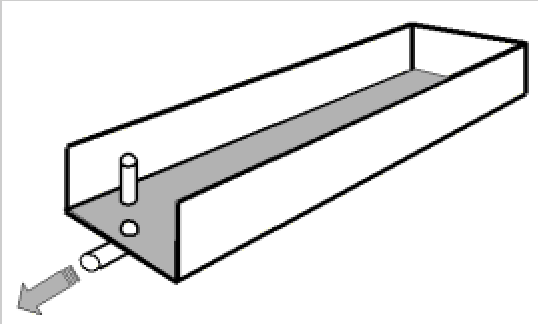
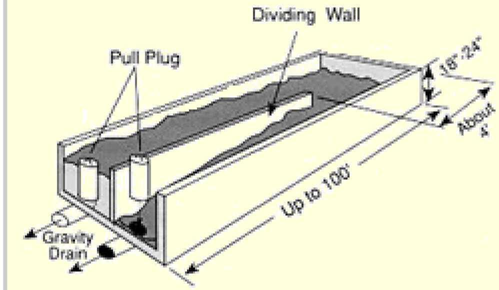
Lagoons - Duck

Two-stage lagoon system
Source: Purdue University

Lagoons are typically used only for laying hen production with flush-type pit systems, and in some duck production systems. Lagoons are different from liquid manure storages because they are operated to encourage anaerobic digestion of organic material while it is being stored. This reduces odor when the treated manure is land applied. A properly designed and operated lagoon is much larger and more expensive than a liquid manure storage with the same storage time, and should be much less concentrated, in terms of organic solids present.

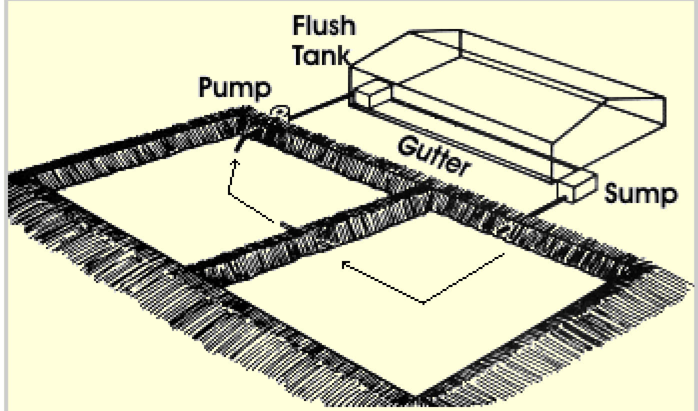


Gravity drain, flat bottom gutter
Source: Purdue University

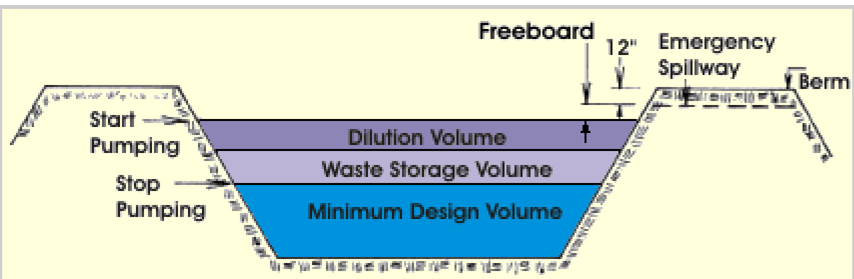


Reverse hairpin, flat-bottom gutter
Source: Purdue University

In the Midwest, an equal part of relatively clean dilution water must be added for each part manure. Furthermore, manure must be added slowly and uniformly to the lagoon, to avoid an upset (and subsequent release of odors) to the biological treatment system. One common method of doing this is to utilize shallow pits or gutters under slotted floors and drain or flush manure to the lagoon on a frequent basis, usually from three days to three weeks. This is done by pulling a drain plug in the bottom of the pit, called gravity drain, use of a scraper system running in the underfloor gutter, through a process called a "hairpen" gutter or by recirculating a volume of relatively clean effluent from the lagoon to flush manure out of the building and into the lagoon. Recirculation involves either a flushing action that takes place one or more times a day or a "pit recharge" system that works basically like a toilet that is flushed every few days.



Recirculating lagoon water to flush manure from a gutter under a slotted floor
Source: Purdue University



Single stage lagoon
Source: Purdue University

A portion of the lagoon contents must be left in the lagoon after contents are pumped to the land (a minimum treatment volume) to retain a large number of microbial organisms to treat the fresh manure entering the system. In spite of proper operation, there is an "over turning" of the lagoon contents that occurs in the fall of the year for a couple of weeks, as ambient temperature drops and cools the top layer of liquid in the lagoon. As its density increases, it drops to the bottom of the lagoon, forcing the bottom layer, containing partially digested manure solids, to the top. This phenomenon can result in higher odor levels for a week or two around the lagoon.

Lagoon contents are normally applied to cropland by spray irrigation systems. If the lagoon is properly designed and operated, spray irrigation should not release much odor, because most of the organic solids should have been biologically stabilized. In a well-operated lagoon, effluent should have only about 20% as much nitrogen and about 30% to 40% as much phosphorous and potassium as raw manure, because of treatment and sedimentation of solids to the bottom of the lagoon. These solids, or sludge, must be removed every few years and the operation should plan to handle them as a part of

Irrigation of lagoon effluent
Source: Purdue University

their nutrient management plan. Because this material is very concentrated, it may be possible to haul the sludge off site or to more distant cropland that can better utilize the nutrients contained in the sludge. Because of the nuisance potential of this partially stabilized material, it should normally be injected or otherwise incorporated as with liquid manure.

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Lagoons - Egg Wash Water

Since eggs from laying hen houses contain traces of manure on the shell, most states require that the water used to wash the eggs be collected and processed accordingly. Many laying hen operations collect this dilute wash-water in lagoon systems and apply the nutrients to croplands via irrigation systems (typically spray irrigation). Some producers treat this low-nutrient, wastewater using constructed wetlands or other systems prior to land application.

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Poultry Production Study Questions

Identify the definition that best fits the following terms:

1. **Chickens are the most numerous birds in the world.**

   - True
   - False

   Feedback

2. **Egg products are used for:**

   - Cake mixes
   - Therapeutic vaccines
   - Antibodies
   - All of the above

   Feedback

3. **What led broiler chicken production to expand beyond a seasonal, local market during the 1940s and 1950s?**

   - Advent of commercial poultry vaccines
   - Mechanical ventilation systems
   - Refrigerated trucking
   - All of the above

   Feedback

4. **Most broiler chickens and turkeys are reared on raised wire flooring.**

   - True
   - False

   Feedback

5. **Molting refers to:**

   - Process of making a pelleted diet with heat
   - Process of reproductive rest where hens shed/regrow feathers
   - Process of ventilation with electric or pneumatic fans

Feedback

6. **The breeding chicken flock has moved to "black-out" housing to:**

   - Save on electrical costs
   - Take advantage of the photosensitive nature of the bird for sexual maturation
   - Prevent cannibalism

Feedback

7. **Restricted feeding of broiler breeder birds is done to:**

   - Prevent obesity
   - Save on feed costs
   - Reduce labor costs

Feedback

8. **The incubation period of a chicken egg is:**

   - 18 days
   - 21 days
   - 28 days
   - 32 days

Feedback

9. **A pullet is a:**

   - Male chicken of reproductive age
   - Means of raising/lowering curtains in a naturally ventilated poultry house
   - An immature hen

Feedback

10. **Male turkey toms reach 40 pounds when marketed at 18 to 20 weeks of age.**

   - True
   - False

Feedback

11. **Poultry manure is routinely applied to fields through:**

- ○ Injection
- ○ Surface application

Feedback

12. **This type of poultry routinely uses liquid-flush pit and lagoon systems:**

- ○ Broiler breeder
- ○ Duck
- ○ Turkey

Feedback

13. **These 2 factors have largely reduced time to market for broiler chickens from 12 weeks (1945) to 7 weeks (2002):**

- ○ Feeding and watering systems
- ○ Nutrition and genetics
- ○ Ventilation systems and vaccination programs

Feedback

14. **To prevent the spread of disease, worker should always travel from:**

- ○ Housing for younger birds to older bird housing
- ○ Housing for older birds to younger bird housing

Feedback

15. **A laying hen reaches peak egg production:**

- ○ 4 to 6 days after beginning to lay
- ○ 4 to 6 weeks after beginning to lay
- ○ 4 to 6 months after beginning to lay

Feedback

See Results RESET

Score in Percentage:	

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Poultry Glossary

Biosecurity - System of procedures and other means to reduce or eliminate exposure of poultry flocks to any type of infectious agent, whether it be viral, bacterial, fungal, or parasitic in nature.

For more information on specifics of biosecurity systems, please visit the following links EXIT Disclaimer
Biosecurity for Poultry
Poultry Facility Biosecurity (PDF) (5 pp, 96.1K)

Black-out House - houses that do not allow any natural light into the building.

Breeder - A bird that is utilized to produce offspring.

Broiler - Chicken, sometimes called fryers, reared primarily for meat production. Age to market weight is typically 6 to 8 weeks (5 to 8 pounds), and are the epitome of efficient meat production.

Brooding - Early period of growth when supplemental heat must be provided, due to the birds inability to generate enough body heat.

Cake Manure - Surface manure on top of litter, typically only a few inches deep.

Cooling - Using ventilation to prevent hens from becoming too hot.

Corn Belt - The area of the United States where corn is a principal cash crop, including Iowa, Indiana, most of Illinois, and parts of Kansas, Missouri, Nebraska, South Dakota, Minnesota, Ohio, and Wisconsin.

Denitrification - The biochemical reduction of nitrate or nitrite to gaseous nitrogen, either as molecular nitrogen or as an oxide of nitrogen.

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Environmental Control - Temperature control in poultry barns.

Legume - Any of thousands of plant species that have seed pods that split along both sides when ripe. Some of the more common legumes used for human consumption are beans, lentils, peanuts, peas, and soybeans. Others, such as clover and alfalfa, are used as animal feed. Legumes have a unique ability to obtain much or all of their nitrogen requirements from symbiotic nitrogen fixation.

Liquid Egg - Contents of egg (white, yolk, or both) that have been removed and shipped as a product in bulk.

Litter - Substance applied to dirt or concrete flooring systems that is absorbent in nature, including: wood shavings, rice hulls, chopped straw, sand, sawdust, oat hulls, and several other materials.

Marketing - Increasing awareness of a product by advertising.

Mechanical Ventilation - The use of fans, either electric or pneumatic, to ventilate houses.

Molting - The process of shedding and then regrowing feathers in laying hens. It corresponds with a period of no egg laying.

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Natural Ventilation - Air circulation is provided by opening barn doors or windows and allowing the wind to draw through the barn.

Nitrification - The biochemical oxidation of ammonium to nitrate, predominantly by autotrophic bacteria.

Peak Egg Production - The point in a hen's laying cycle where she will lay the highest percentage of eggs.

Poult - A baby turkey.

Pullet - A laying hen before it lays its first egg.

Tunnel Ventilation - Placement of large fans at end of building to draw air from one end to the other.

Ventilation - The circulation of air through a building in order to expel noxious air and admit clean, fresh air.

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- Natural Resource, Agriculture, and Engineering Service. NRAES-132. Poultry Waste Management Handbook. EXIT Disclaimer 1999.
- Poultry Production.1990. R.E. Austic and M.C. Nesheim. Lea & Febiger, Philadelphia, PA.
- Poultry Science and Production. 1985. R.E. Moreng and J.S. Avens. Reston Publ. Co., Inc., Reston, VA.

Links EXIT Disclaimer

- U.S. Poultry and Egg Association
- U.S. Poultry and Egg Export Council
- American Egg Board
- National Chicken Council
- National Turkey Federation
- United Egg Producers
- Purdue Avian Sciences Extension Publications
- The Columbia Electronic, Encyclopedia, Sixth Edition, Copyright © 2008, Columbia University Press.
- USDA - How to Buy Eggs (PDF) (12 pp, 358K, About PDF)
- USDA - How to Buy Poultry (PDF) (12 pp, 262K, About PDF)
- USDA Foreign Agricultural Service - FASonline

Links to Primary Turkey Breeders EXIT Disclaimer

British United Turkeys

Hybrid Turkeys

Nicholas Turkeys

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Poultry Production

Poultry production is an important and diverse component of American agriculture. Poultry products including eggs, chicken and turkey meat are a healthy part of the diets of most Americans. In 1997, nearly 99,700 farms were producing poultry and poultry products (egg, broiler, and turkey; NASS/USDA). While broiler chicken production is concentrated primarily in the southern and southeastern U.S., turkey production occurs primarily in the Corn Belt and in North Carolina. Egg production is distributed throughout the U.S.

Modern poultry production occurs primarily in enclosed buildings to protect the birds from weather, predators, and the spread of diseases from wild birds. This has allowed farmers to greatly increase production efficiency while significantly reducing the amount of labor required. As with pork production, this has resulted in environmental challenges with production of larger volumes of manure in much smaller areas.

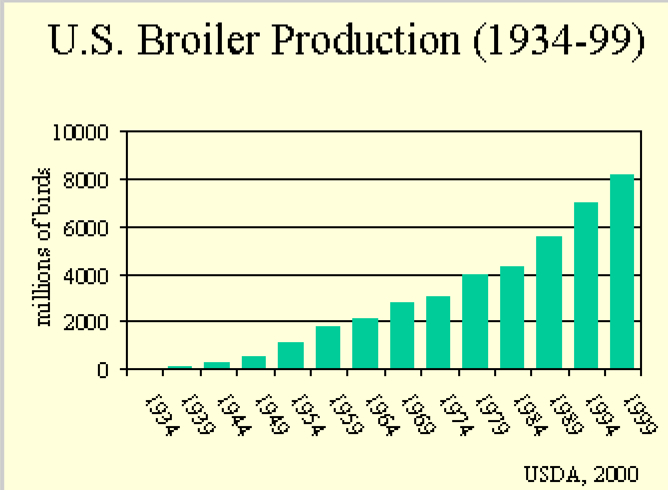
This module will cover the modernization of poultry production over the past 60 years, different phases of production and the production systems in which they occur.

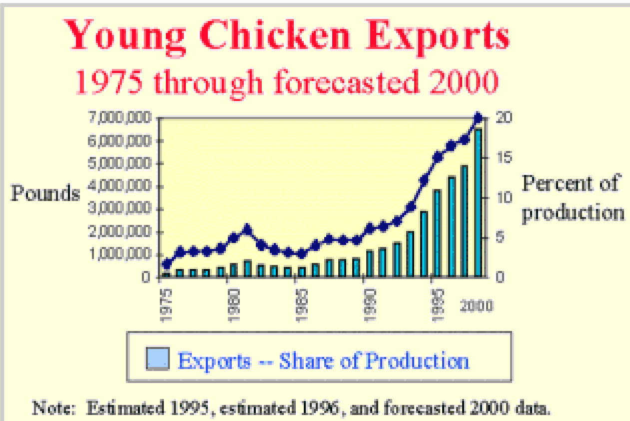
Background of Poultry Production in U.S.

Source: J. Sell, Iowa State University

Chickens are the most numerous birds in the world. The chicken is believed to have been domesticated nearly 5000 years ago from wild birds in Southeast Asia. On the other hand, the domestication of the turkey occurred much more recently, by American Indians in prehistoric times. The turkey was introduced into Europe in the sixteenth century by returning Spanish explorers. Settlers emigrating to the U.S. who later bred this European stock with wild turkeys in the Eastern U.S. to produce the ancestors of today's commercially grown turkeys.

The poultry industry has largely grown from backyard operations which provided supplemental income for the family to a vertically integrated industry (PDF). (28 pp, 717K) EXIT Disclaimer Poultry consumption in the U.S. has increased from the 1900s, when chicken was eaten only on Sundays to making poultry an every day item today.





Increase in young chicken exports
Source: J. Sell, Iowa State University

U.S. Poultry Inventory

Specie	# / year	kg
Broiler	8 billion	18.5 billion
Turkey	273 million	3.2 billion
Layers	269 million	72 billion eggs
Ducks	20 million	~ 64 million

per USDA 1999

Broiler production greatly increased throughout the 1980s and 1990s due to Americans becoming more health conscious and through an unprecedented increase in exports. Part of this increase has also been attributed to the poultry industry supplying products that are further processed and easier for the consumer to prepare. These increases have led to an all time high in poultry production in the U.S. (**Table**). Currently, most poultry production in the United States is in the Southeastern states.

At one time, there were many distinct breeds of chicken, each having particular traits or characteristics. Through selective breeding, only a few strains of birds dominate the market today. There are many primary breeding companies of poultry, but only a handful are responsible for most of the broiler chicken, laying hen, and turkey production in the world.

Concentration and specialization of the poultry industry have led to the development of allied industries. These industries supply housing, feeding and other equipment, hatchery equipment, processing supplies and equipment, drugs and other health products, feed additives, and several other items.

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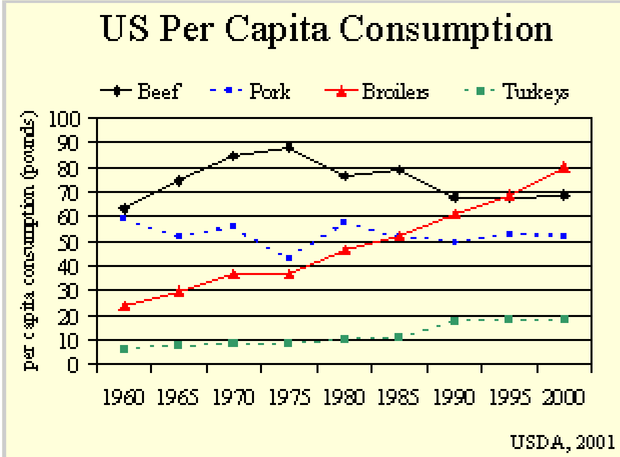
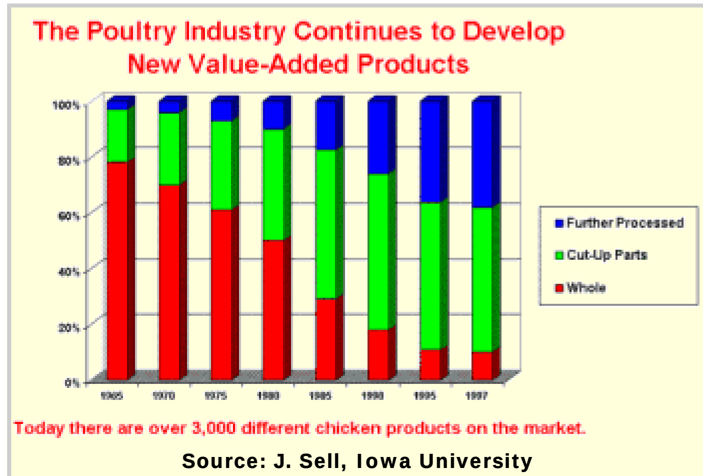
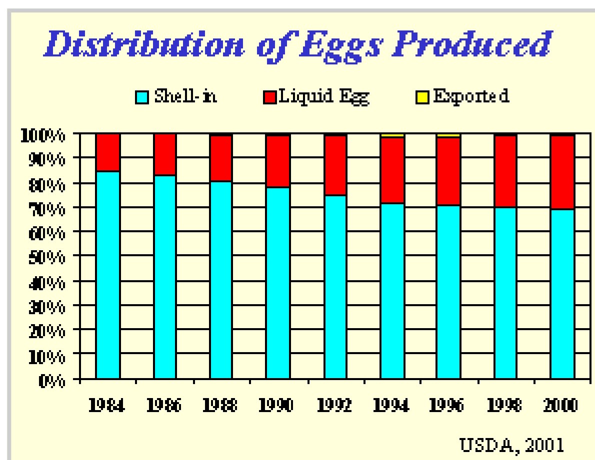
Products from Poultry







Poultry products (broiler meat in particular) has the highest per capita consumption in the United States. People eat many different poultry products, including eggs, turkey ham, buffalo wings, hot dogs, chicken nuggets, chicken-patties, fried, roasted, glazed, marinated, etc. Not all of poultry products, however, are directly consumed by humans. For example, eggs are also used for the production of therapeutic vaccines and are beginning to be used for production of antibodies and pharmacological proteins. Part of the increase in poultry production in the 1980s and 1990s can be attributed to the development of new, further-processed, value-added products. Similarly, the egg market has changed in scope through the late 1980s such that a greater proportion of eggs that are produced are destined for a liquid egg market. Liquid egg is used in a variety of institutions including hotels, restaurants, hospitals, and if dried, included in numerous other products, such as cake mixes. Today, the U.S. produces 33% of the world's broiler meat, 53.7% of the turkey meat, and 11% of the eggs (USDA-FAS, 2001).

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Poultry Production Phases

- Breeding Flocks
- Laying Hens
- Broilers, Turkeys, Ducks (meat-bird production)

Poultry production encompasses a number of different species, including the chicken (reared for laying eggs-"layers", or meat production-"broilers"), turkeys, ducks, and other waterfowl and gamebirds. Each species and particular type of production is uniquely different. We will primarily focus on laying hens, broiler production, turkey production, and duck production.

Breeding Flocks

Lighting and Housing Types

Lighting plays a very important role in bird growth, development, and maturity. Most commercial poultry specie are photosensitive animals. For example, a constant or decreasing amount of daily light (as occurs during the fall and winter months) will delay sexual maturity in growing birds. An increasing amount of light (as occurs in the spring) will stimulate sexual maturity. Since lighting plays such an important role in the development of sexual maturity, adolescent birds are generally reared in black-out houses. This allows the producer to have complete control over the lighting cycle of the birds by providing artificial light.

Housing for breeder broilers
Source: J. Sell, Iowa State University

Once birds reach the age of sexual maturity, they are moved to the laying house. Breeder broilers and ducks are generally be kept in a barn with a slotted floor or with a wire floor with litter in the middle of the house to act as a mating area. Breeder turkeys are generally reared in all litter houses. Clean, nesting boxes are provided so that the birds may lay their eggs without being disturbed by other birds and so that the eggs may be kept clean and easily collected.

Restricted Feeding

Adolescent broilers (especially), turkeys, and ducks, when given the opportunity, will eat until they become obese. Therefore, restricted feeding is necessary if the birds are going to be used as breeder stock. Otherwise, the obesity severely limits the numbers of eggs laid and the fertility of those eggs. For this reason, restricted feeding is necessary. There are two main types of restrictive feeding programs. The first of these is every day feeding of a limited amount, or lower nutrient content diet. The amount fed will ensure adequate growth but not result in obesity. Another type of restrictive feeding is an every other day feeding program. where birds are fed a specific quantity of feed every other day. Since male broiler chickens grow faster, they often are reared separately from the females until they are moved into the breeder house. Specific ratios of male-to-females are kept in the breeder house (typically, broilers-1 male :15 females, turkeys and ducks-1:8 to 10) to ensure fertility of hatching eggs.

Hatchery

Eggs are typically collected from breeder farms, taken to a hatchery and stored from 0 to 10 days prior to being set in an incubator. These eggs will be stored at temperatures between 55-68° F, depending on when they are to be incubated. When the eggs are placed in incubators, embryonic development begins. Different species of birds require different incubation times. Chickens hatch in 21 days while turkeys and ducks need 28 days. The hatchlings (chicks, poults, or ducklings) are processed (vaccinated, gender sorted, and/or other procedures) then transported to commercial grow-out facilities. Transport typically will take anywhere from a few hours to one day.

Hatchlings destined for grow-out facilities
Source: Purdue University

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Laying Hens

The modern laying hen is a biological marvel. She begins laying eggs at approximately 18 weeks of age and by the end of her first year, she may have produced upwards of 200 eggs - nearly 25 pounds. The hen reaches peak egg production (95 + %) within 4 to 6 weeks after she begins to lay eggs. In order to produce such a hen, it is critical that the hen be carefully managed during her first 17 weeks of life.

At the beginning of a pullet's life in the hatchery, she is vaccinated to prevent future diseases. On the farm, pullets will be grown in cages until they are moved into the laying house at 16 to 17 weeks of age. Pullet chicks will typically be beak trimmed during their first three weeks of life in the pullet house to minimize cannibalism.

Lighting programs are very similar to what was described for breeding flocks.

Induced molting

Molting is the process of the bird shedding and re-growing feathers. Molting occurs naturally in the wild, as seasonal daylight shortens and females stop laying eggs. Laying hens are generally molted once or twice during their productive lives. Molting usually does not affect egg size, but allows for an improved egg laying rate, improved shell quality, and increased albumin height. It also allows a producer to keep the birds longer than they might otherwise be kept. To induce molt, a producer may use a period of fasting and a reduced amount of daylight, giving the birds water and allowing them to lose a proportion of their body weight. Daylight length will then be increased, and the hens begin laying eggs again.

In-line vs. Off-line production

In-line layer operation
Source: Purdue University

Laying hen farms are composed of two different types, in-line and off-line.

In-line production - Hen houses are placed side-by-side and linked by a conveyor belt. The conveyor belt leads to a centralized processing building, where the eggs from all houses are sorted, graded, either packed or broken and further processed, and refrigerated prior to shipping.

Off-line production - This is similar to the in-line production, but the eggs that are collected on a conveyor belt and sent to a main building are packed and refrigerated prior to shipping to another facility to be processed.

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Broilers, Turkeys, Ducks (meat-bird production)

Broilers

Source: Purdue University

Brooder rings keep broilers near heat, feed, and water
Source: Purdue University

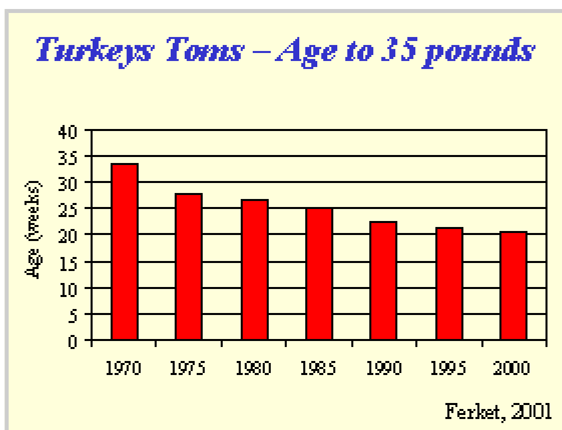
Waterer in broiler house
Source: Purdue University

Broilers are relatively easy to raise. To begin with, the whole house is heated and brooder rings are placed around each brooder (heating) unit. These rings create a "microclimate" relative to the rest of the room to prevent drafts and keep the birds near each other and near the feed and water. The nipple or cup waterers in each pen must be fully functional and supplemental jug waterers in the brooder rings must be kept filled. When the birds arrive, they are placed into the rings and introduced to the waterers and feed. Feed is placed in the feeders and on paper placed on the floor of the pen to encourage young birds to eat. Generally, broilers are brooded in a portion of the house until a certain age before being given access to the entire barn. These facilities, or "houses" generally have litter floors. Depending on the geographical location of the house, natural ventilation will be either provided by opening curtain-sided walls or large insulated door panels on the sides of the house.

Some farms separate male and female birds, a practice called separate-sex feeding. Separate-sex feeding accomplishes a number of goals. When birds are separated and fed according to gender (versus rearing males and females together), there will be more uniformity among males and among females in the flock. Separation of the birds also allows producers to feed diets that more closely meet the nutritional needs of the male and female birds.

Turkey Housing

Source: Purdue University



Source: Purdue University

In previous decades, turkeys have been mainly considered a holiday product. However, with advances of further-processing as well as an increasingly health-conscious population in the U.S., the turkey has become a popular year-round meat. Raising turkeys takes more time than raising broilers, as turkeys take longer to mature. Generally, a turkey is sent to market anywhere between 15 and 25 weeks of age. At 20 weeks of age, a male turkey should weigh about 35-40 pounds.

Turkey poults
Source: Purdue University

Getting poults (baby turkeys) started is not as easy as starting broilers. Both benefit from brooder rings in order to keep them close to the heat source, food, and water and to prevent drafts. Additionally, the farm worker must physically show the poults where the water and feed are when placing poults into the brooder rings; otherwise, some birds will never manage to find it.

Poults are usually gender-sorted at the hatchery and the males (toms) and females (hens) are reared separately. They may also toe-trimmed, and beak-trimmed at the hatchery to prevent the birds from injuring each other.

Over their life cycle, turkeys may live in 2 or 3 different barns. The brooder barn, is used for the first 6 to 8 weeks of life. After that, the turkeys may be moved to an intermediate barn. Lastly, they are moved into a grow-out facility. By having multiple barns for different ages, a farm is able to rear a greater number of birds in a shorter amount of time.

Ducks

While broilers and turkeys may seem like fast-growing birds, the duck is the most rapidly growing animal of all poultry species. A typical duck will weigh 7 pounds in only 6 or 7 weeks!

Ducks can be raised in a number of different types of houses. Some are raised on all-litter floors while others have slats or wire for the flooring. Some houses contain a litter floor with a ramp leading up to raised-wire or expanded plastic flooring over a shallow pit. Since ducks like to play with the watering system (typically a nipple-waterer system), it is located over the raised flooring. Generally, ducks go through two or three stages of housing. Each stage would house anywhere from 13 to 20 groups of ducks per year.

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Production Systems

Small poultry operation with dirt floor
Source: J. Sell, Iowa State University

Make-shift ventilation in poultry house
Source: J. Sell, Iowa State University

Prior to WWII, the majority of poultry were reared in backyard flocks on dirt-floored pens, in small sheds with natural or make-shift ventilation.

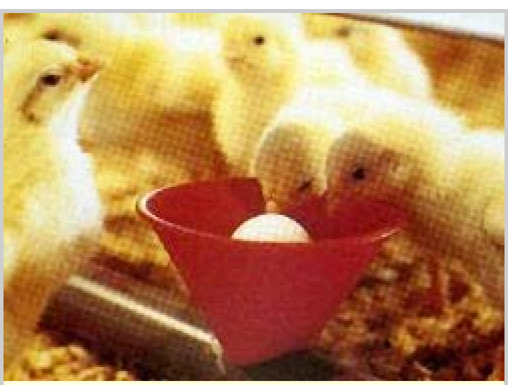
An early year-round production building
Source: J. Sell, Iowa State University

Poultry grown in large outdoor areas
Source: J. Sell, Iowa State University

Between 1940 and 1960, advancements in nutrition and genetics allowed the broiler market to shift from being able to produce a 3-3.5 pound bird at 16 weeks to one that only took 8 weeks. Due to advances in production efficiency and refrigerated trucking, markets expanded to a much larger geography while the price of poultry per pound dropped dramatically from approximately 65 cents in 1940 to 29 cents in 1960. Due largely to changes in price versus other meat options, demand for broilers increased dramatically. Production systems during this time also underwent dramatic changes from the seasonal, small backyard sheds to large year-round naturally ventilated buildings and during some seasons, large outdoor pens.

Modern enclosed poultry building
Source: Purdue University

On-demand feeder line
Source: Purdue University



On-demand cup waterer
Source: Purdue University

Nipple waterer
Source: Purdue University

Turkey and broiler flocks are reared in enclosed buildings with updated equipment. For instance, birds are now reared in confinement with on-demand feeder lines, on-demand cup or nipple waterers, or on-demand bell-type waterers. These developments overcame most problems with weather, predators, potential pollution from lot runoff, and allowed the use of more intensive production schedules. Almost all turkeys and broilers are reared on litter floors. Ducks, turkeys, and occasionally broilers are reared in multi-stage facilities with facilities for brooding birds, and in larger facilities (either a separate room or separate building) that they will be moved into at an older age.

Wire cages
Source: Purdue University

Slotted floor facilities
Source: Purdue University

Young pullets, laying hens, and broiler breeders are reared in either wire-cages or slotted-floor systems. If a slotted flooring system is used, there may or may not be a central area containing litter. Duck facilities encompass a number of different production types and may or may not have multistage facilities. Systems in use include all-litter houses, raised-wire flooring over a shallow pit (which would be located below a nipple water line) and houses with raised-wire floors.

Mechanically ventilated building
Source: Purdue University

Layers in commercial facilities produce a great deal of body heat. Ventilation to keep the hens cool is usually more of a concern than providing heat in winter. Non-brooding birds (3-4 weeks and older) grow best at around 70-75 degrees. In winter, they are protected from winter winds in an insulated building. Enough ventilation must be provided to remove moisture produced by the animals and to provide fresh air. In summer, large sidewall vents are opened or large ventilation fans are operated to keep the animals comfortable. This is referred to as either naturally ventilated (air change due to the wind) or mechanically ventilated (where air is drawn into the buildings through vents due to a negative pressure created with wall fans that exhaust inside air to the outdoors. Further information on poultry ventilation. EXIT Disclaimer

Disadvantages associated with large enclosed, production facilities are that different ages of birds with different degrees of disease resistance are housed in close proximity which can facilitate disease spread if adequate cleaning and disinfecting are not feasible in some situations, and higher levels of medication may be required to control disease. The primary rule of thumb for workers on a farm with multiple ages of birds is to always travel from the youngest birds on the farm to the oldest, and not vice-versa. Biosecurity plans between farms, and between multiple production buildings on the same farm can help reduce the incidence and spread of disease from one flock to the next.

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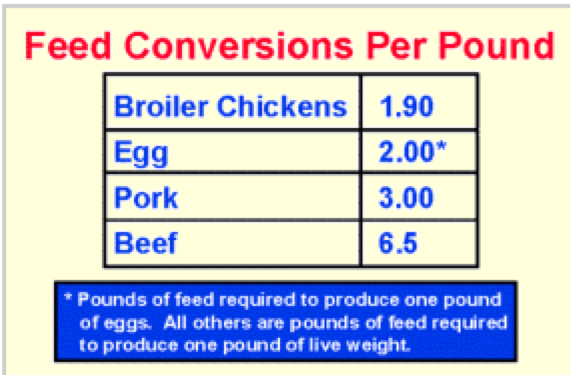
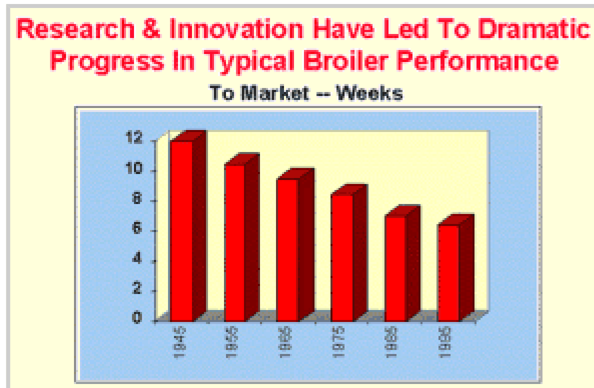
Nutrition



Feed Conversions Per Pound

Broiler Chickens	1.90
Egg	2.00*
Pork	3.00
Beef	6.5

* Pounds of feed required to produce one pound of eggs. All others are pounds of feed required to produce one pound of live weight.



Poultry in the U.S. are fed diets which are primarily ground corn to supply heat and energy and soybean meal to provide protein. Vitamins and minerals are also added in their feed. It takes only 11.4 pounds of feed to rear a broiler to a 6 pound market weight. This same broiler would drink about 3 gallons of water during this time (approximately 7 weeks). Part of the poultry industry's increase in productiveness has largely been attributed to the efficiency of conversion of feed to gain -or- egg production. This increased efficiency can be largely attributed to improvements in genetics and nutrition.

Improvement in diet have resulted in dramatic improvements in growth
Source: J. Sell, Iowa State University

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Common Manure Handling Systems

- Litter
- Layer Manure - Dry
- Layer Manure - Liquid
- Lagoons - Duck
- Lagoons - Egg Wash Water

Litter

Poultry manure is handled as a solid litter, either deposited directly by animals on pastureland, or collected in bedding placed on solid shelter floors to absorb the urine. Some turkeys, broilers, and ducks are raised on concrete or earthen floors. After every flock, the litter is either:

1. Removed and fresh litter applied,
2. Tilled and fresh litter placed on top, or
3. Cake manure removed, remaining litter tilled or mixed, and fresh litter placed on top.

Tractor-drawn decaker/cruster
Source: Kelly Manufacturing Co.

Solid manure spreader
Source: Purdue University

Cake manure is sometimes removed with a tractor-drawn decaker/cruster which removes the top layer of manure, breaks it apart, and separates the larger manure particles from the finer litter particles (which are placed back into the house). Poultry litter is normally surface applied, but in some cases may be incorporated into the soil with a farm tillage operation shortly after spreading.

For further information on proper sampling of poultry litter. EXIT Disclaimer

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Layer Manure - Dry

Laying hens on wire floors
Source: Purdue University

Surface applied solid manure
Source: Purdue University

Manure from pullets and laying hens is relatively dry as it falls through layer cages into a concrete storage area. Manure composition in these facilities can range in dry matter between 20 and 60 percent. The storage pit provides for long-term storage of the manure. Manure is then typically surface applied. Composting is another option for solid manure management.

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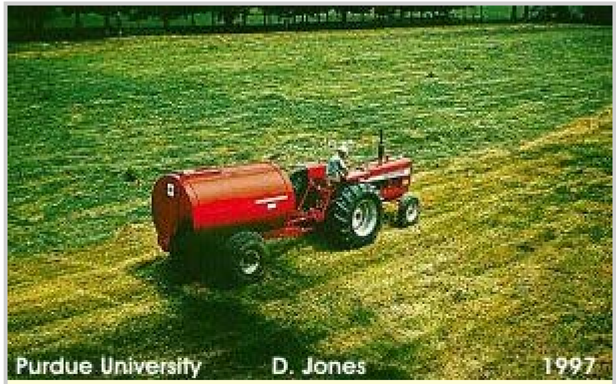
Layer Manure - Semi-Solid/Liquid

Some laying hen facilities contain shallow pits with scrapers or belts, or shallow flush pits. This manure typically can not be stacked and requires some type of containment storage. Liquid manure that is mostly water (< 12% solids) must be kept in a watertight storage. Liquid manure can be handled with tank trucks/wagons, injection-type spreaders, or irrigation equipment. Semi-solid manure (12 to 20 percent solids), on the other hand, does not flow readily but still requires containment with walls. This type of manure can be handled easily with bucket loaders and open broadcast spreaders. Most Midwestern states require manure storages for larger operations to be large enough to hold six month's accumulation. This avoids the need to apply manure during the crop growing season and when weather conditions are unsuitable – such as on frozen or snow-covered ground or when the soil is wet enough that heavy application vehicles could compact and damage the soil.

Liquid manure pit agitation
Source: Purdue University



Surface applied liquid manure
Source: Purdue University

Liquid manure from storages is normally agitated thoroughly before removal and hauled to the field for application using large tanker wagons or trucks. Liquid manure is either applied on the soil surface or incorporated shortly after application to control loss of volatile ammonia and release of odors. Incorporation is very effective at controlling runoff of manure nutrients and odor from land application if done within a few hours after application. An alternative application method is the use of a soil injector, where liquid manure is "injected" directly into the soil to a depth of 6 to 9" as the tanker passes over the field. This immediate contact between the manure and soil is highly effective against the release of odors.

Injecting liquid manure
Source: Purdue University

In larger operations, liquid manure may be pumped to nearby application sites and irrigated onto cropland. Spray irrigating liquid manure is a very efficient method of land application, in terms of speed and labor, but odor emissions can be significant; therefore, it is seldom possible to use this method in heavily populated areas.

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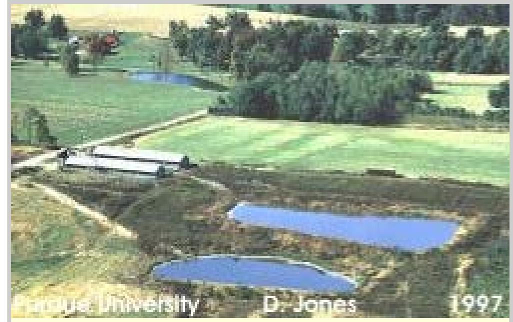
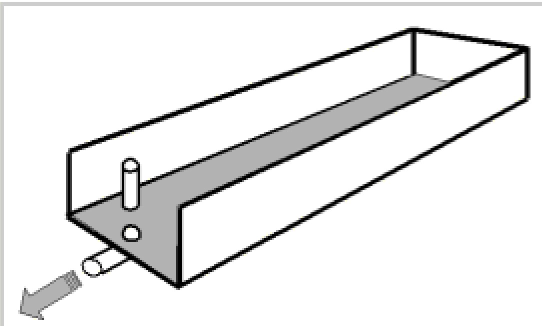
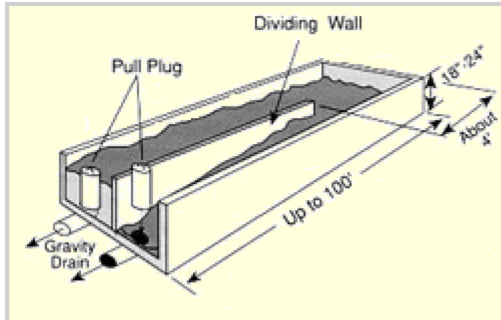
Lagoons - Duck



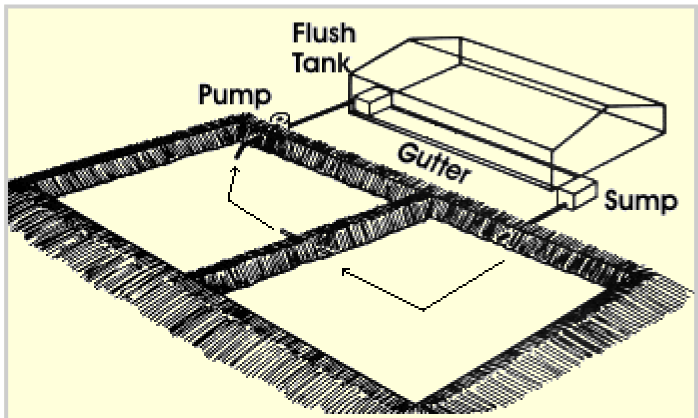
Two-stage lagoon system
Source: Purdue University

Lagoons are typically used only for laying hen production with flush-type pit systems, and in some duck production systems. Lagoons are different from liquid manure storages because they are operated to encourage anaerobic digestion of organic material while it is being stored. This reduces odor when the treated manure is land applied. A properly designed and operated lagoon is much larger and more expensive than a liquid manure storage with the same storage time, and should be much less concentrated, in terms of organic solids present.


Gravity drain, flat bottom gutter
Source: Purdue University

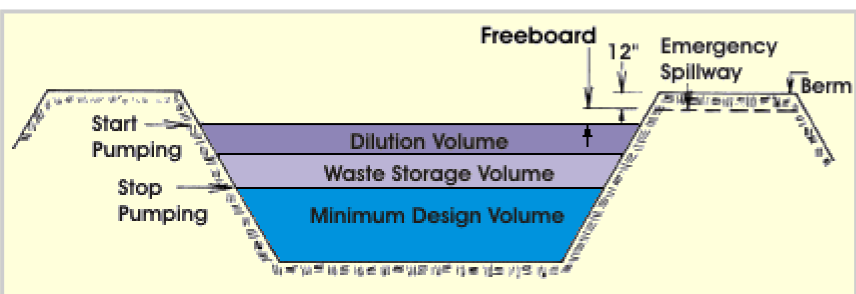


Reverse hairpin, flat-bottom gutter
Source: Purdue University



Recirculating lagoon water to flush manure from a gutter under a slotted floor
Source: Purdue University

In the Midwest, an equal part of relatively clean dilution water must be added for each part manure. Furthermore, manure must be added slowly and uniformly to the lagoon, to avoid an upset (and subsequent release of odors) to the biological treatment system. One common method of doing this is to utilize shallow pits or gutters under slotted floors and drain or flush manure to the lagoon on a frequent basis, usually from three days to three weeks. This is done by pulling a drain plug in the bottom of the pit, called gravity drain, use of a scraper system running in the underfloor gutter, through a process called a "hairpen" gutter or by recirculating a volume of relatively clean effluent from the lagoon to flush manure out of the building and into the lagoon. Recirculation involves either a flushing action that takes place one or more times a day or a "pit recharge" system that works basically like a toilet that is flushed every few days.



A portion of the lagoon contents must be left in the lagoon after contents are pumped to the land (a minimum treatment volume) to retain a large number of microbial organisms to treat the fresh manure entering the system. In spite of proper

Single stage lagoon
Source: Purdue University

operation, there is an "over turning" of the lagoon contents that occurs in the fall of the year for a couple of weeks, as ambient temperature drops and cools the top layer of liquid in the lagoon. As its density increases, it drops to the bottom of the lagoon, forcing the bottom layer, containing partially digested manure solids, to the top. This phenomenon can result in higher odor levels for a week or two around the lagoon.

Irrigation of lagoon effluent
Source: Purdue University

Lagoon contents are normally applied to cropland by spray irrigation systems. If the lagoon is properly designed and operated, spray irrigation should not release much odor, because most of the organic solids should have been biologically stabilized. In a well-operated lagoon, effluent should have only about 20% as much nitrogen and about 30% to 40% as much phosphorous and potassium as raw manure, because of treatment and sedimentation of solids to the bottom of the lagoon. These solids, or sludge, must be removed every few years and the operation should plan to handle them as a part of their nutrient management plan. Because this material is very concentrated, it may be possible to haul the sludge off site or to more distant cropland that can better utilize the nutrients contained in the sludge. Because of the nuisance potential of this partially stabilized material, it should normally be injected or otherwise incorporated as with liquid manure.

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Lagoons - Egg Wash Water

Since eggs from laying hen houses contain traces of manure on the shell, most states require that the water used to wash the eggs be collected and processed accordingly. Many laying hen operations collect this dilute wash-water in lagoon systems and apply the nutrients to croplands via irrigation systems (typically spray irrigation). Some producers treat this low-nutrient, wastewater using constructed wetlands or other systems prior to land application.

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Potential Environmental Impacts of Animal Feeding Operations

(Adapted in part from Livestock and Poultry Environmental Stewardship Curriculum, MidWest Plan Service; and Proposed US EPA Confined Feeding Rule.)

USEPA's 1998 *National Water Quality Inventory* indicates that agricultural operations, including animal feeding operations (AFOs), are a significant source of water pollution in the U.S. States estimate that agriculture contributes in part to the impairment of at least 170,750 river miles, 2,417,801 lake acres, and 1,827 estuary square miles (Table 1). Agriculture was reported to be the most common pollutant of rivers and streams.

However, one should not overlook the many positive environmental benefits of agriculture. For example, agricultural practices that conserve soil and increase productivity while improving soil quality also increase the amount of carbon-rich organic matter in soils, thereby providing a global depository for carbon dioxide drawn from the atmosphere by growing plants. The same farming practices that promote soil conservation also decrease the amount of carbon dioxide accumulating in the atmosphere and threatening global warming.

Other benefits compared to urban or industrial land use include greatly reduced storm runoff, groundwater recharge and water purification as infiltrating surface water filters through plant residue, roots and several feet of soil to reach groundwater.

In many watersheds, animal manures represent a significant portion of the total fertilizer nutrients added. In a few counties, with heavy concentrations of livestock and poultry, nutrients from confined animals exceed the uptake potential of non-legume harvested cropland and hayland. USDA estimates that recoverable manure nitrogen exceeds crop system needs in 266 of 3,141 counties in the U.S. (8%) and that recoverable manure phosphorus exceeds crop system needs in 485 counties (15%). It should be pointed out that while legumes are able to produce their own nitrogen, they will use applied nitrogen instead if it is available. The USDA analysis does not consider actual manure management practices used or transport of applied nutrients outside the county; however, it is a useful indicator of excess nutrients on a broad scale. Whole-farm nutrient balance is a very useful tool to identify potential areas of excess.

Air emissions from Animal Feeding Operations (AFO) can be odorous. Furthermore, volatilized ammonia can be redeposited on the earth and contribute to eutrophication of surface waters.

Animal manures are a valuable fertilizer and soil conditioner, if applied under proper conditions at crop nutrient requirements. Potential sources of manure pollution include open feedlots, pastures, treatment lagoons, manure stockpiles or storage, and land application fields. Oxygen-demanding substances, ammonia, nutrients (particularly nitrogen and phosphorus), solids, pathogens, and odorous compounds are the pollutants most commonly associated with manure. Manure is also a potential source of salts and trace metals, and to a lesser extent, antibiotics, pesticides and hormones. This problem has been magnified as poultry and livestock production has become more concentrated. AFO pollutants can impact surface water, groundwater, air, and soil. In surface water, manure's oxygen demand and ammonia content can result in fish kills and reduced biodiversity. Solids can increase turbidity and smother benthic organisms. Nitrogen and phosphorus can contribute to eutrophication and associated algae blooms which can produce negative aesthetic impacts and increase drinking water treatment costs. Turbidity from the blooms can reduce penetration of sunlight in the water column and thereby limit growth of seagrass beds and other submerged aquatic vegetation, which serve as critical habitat for fish, crabs, and other aquatic organisms. Decay of the algae (as well as night-time algal respiration) can lead to depressed oxygen levels, which can result in fish kills and reduced biodiversity. Eutrophication is also a factor in blooms of toxic algae and other toxic estuarine microorganisms, such as *Pfiesteria piscicida*. These organisms can impact human health as well as animal health. Human and animal health can also be impacted by pathogens and nitrogen in animal manure. Nitrogen is easily transformed into the nitrate form and if transported to drinking water sources can result in potentially fatal health risks to infants. Trace elements in manure may also present human and ecological risks. Salts can contribute to salinization and disruption of the ecosystem. Antibiotics, pesticides, and hormones may have low-level, long-term ecosystem effects.

In ground water, pathogens and nitrates from manure can impact human health via drinking water. Nitrate contamination is more prevalent in ground waters than surface waters. According to the U.S. EPA, nitrate is the most widespread agricultural contaminant in drinking water wells, and nearly 2% of our population (1.5 million people) is exposed to elevated nitrate levels from drinking water wells.

Table 1. Summary of U.S. Water Quality Impairment Survey

Total Quantity in US	Amount of Waters Surveyed	Quantity Impaired by All Sources	Quantity Impaired by Agriculture
Rivers 3,662,255 miles	23% of total 840,402 miles	36% of surveyed 248,028 miles	59% of impaired 170,750 miles
Lakes, Ponds, and Reservoirs 41,600,000 acres	42% of total 17,400,000 acres	39% of surveyed 6,541,060 acres	31% of impaired 2,417,801 acres
Estuaries 90,500 square miles	32% of total 28,889 square miles	38% of surveyed 11,025 square miles	15% of impaired 1,827 square miles

Reference: National Water Quality Inventory: 1998 Report to Congress (EPA, 2000a). AFOs are a subset of the agriculture category. Summaries of impairment by other sources are not presented here.

Table 2 lists the leading pollutants impairing surface water quality in the U.S. Agricultural production is a potential source of most of these.

Table 2. Five Leading Pollutants Causing Water Quality Impairment in the U.S. ***(Percent of incidence of each pollutant is shown in parentheses. For example, siltation is listed as a cause of impairment in 38% of impaired river miles.)***

Rank	Rivers	Lakes	Estuaries
1	Siltation (38%)	Nutrients (44%)	Pathogens (47%)
2	Pathogens (36%)	Metals (27%)	Oxygen-Depleting Substances (42%)
3	Nutrients (29%)	Siltation (15%)	Metals (23%)
4	Oxygen-Depleting Substances (23%)	Oxygen-Depleting Substances (14%)	Nutrients (23%)
5	Metals (21%)	Suspended Solids (10%)	Thermal Modifications (18%)

List of Contaminants in Animal Manure:

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Oxygen-Demanding Substances

When discharged to surface water, biodegradable material is decomposed by aquatic bacteria and other microorganisms. During this process, dissolved oxygen is consumed, reducing the amount available for aquatic animals. Severe depressions in dissolved oxygen levels can result in fish kills. There are numerous examples nationwide of fish kills resulting from manure discharges and runoff from various types of AFOs.

Manure may be deposited directly into surface waters by grazing animals. Manually-collected manure may also be introduced into surface waters. This is typically via storage structure failure, overflow, operator error, etc.

Manure can also enter surface waters via runoff if it is over-applied or misapplied to land. For example, manure application to saturated or frozen soils may result in a discharge to surface waters. Factors that promote runoff to surface waters are steep land slope, high rainfall, low soil porosity, and proximity to surface waters. Incorporation of the manure into the soil decreases runoff.

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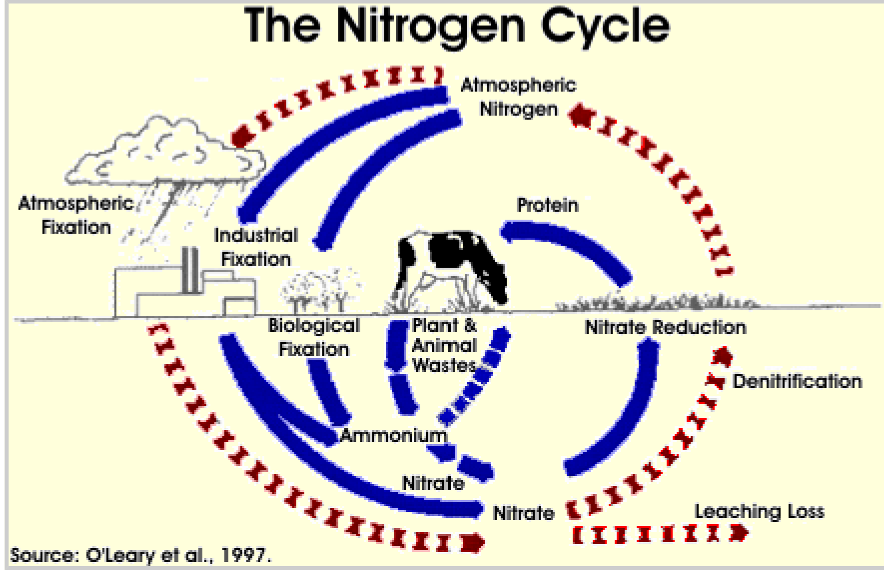
Nitrogen



Nitrogen (N) is an essential nutrient required by all living organisms. It is ubiquitous in the environment, accounting for 78 percent of the atmosphere as elemental nitrogen (N_2). This form of nitrogen is inert and does not impact environmental quality since it is not bioavailable to most organisms and therefore has no fertilizer value. Nitrogen can form other compounds, however, which are bioavailable, mobile, and potentially harmful to the environment. The nitrogen cycle shows the various forms of nitrogen and the processes by which they are transformed and lost to the environment.

Nitrogen in manure is primarily in the form of organic nitrogen and ammonia nitrogen compounds. In its organic form, nitrogen is unavailable to plants. However, organic nitrogen can be transformed into ammonium (NH_4^+) and nitrate (NO_3^-) forms, via microbial processes which are bioavailable and have fertilizer value. These forms can also produce negative environmental impacts when they are transported in the environment.

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Ammonia

"Ammonia-nitrogen" includes the ionized form (ammonium, NH_4^+) and the un-ionized form (ammonia, NH_3). Ammonium is produced when microorganisms break down organic nitrogen products such as urea and proteins in manure. This decomposition occurs in both aerobic and anaerobic environments. In solution, ammonium is in chemical equilibrium with ammonia.

Ammonia exerts a direct biochemical oxygen demand (BOD) on the receiving water since dissolved oxygen is consumed as ammonia is oxidized. Moderate depressions of dissolved oxygen are associated with reduced species diversity, while more severe depressions can produce fish kills.

Additionally, ammonia can lead to eutrophication, or nutrient over-enrichment, of surface waters. While nutrients are necessary for a healthy ecosystem, the overabundance of nutrients (particularly nitrogen and phosphorus) can lead to nuisance algae blooms.

Pfiesteria often lives as a nontoxic predatory animal, becoming toxic in response to fish excretions or secretions (NCSU, 1998). While nutrient-enriched conditions are not required for toxic outbreaks to occur, excessive nutrient loadings can help create an environment rich in microbial prey and organic matter that *Pfiesteria* uses as a food supply. By increasing the concentration of *Pfiesteria*, nutrient loads increase the likelihood of a toxic outbreak (Citizens *Pfiesteria* Action Commission, 1997).

The degree of ammonia volatilization is dependent on the manure management system. For example, losses are greater when manure remains on the land surface rather than being incorporated into the soil, and are particularly high when the manure is spray irrigated onto land. Environmental conditions also affect the extent of volatilization. For example, losses are greater at higher pH levels, warmer temperatures and drier conditions, and in soils with low cation exchange capacity, such as sands. Losses are decreased by the presence of growing plants. (Follett, 1995)

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Nitrate

Nitrifying bacteria can oxidize ammonium to nitrite (NO_2^-) and then to nitrate (NO_3^-). Nitrite is toxic to most fish and other aquatic species, but it typically does not accumulate in the environment because it is rapidly transformed to nitrate in an aerobic environment. Alternatively, nitrite (and nitrate) can undergo bacterial denitrification in an anoxic environment. In denitrification, nitrate is converted to nitrite, and then further converted to gaseous forms of nitrogen - elemental nitrogen (N_2), nitrous oxide (N_2O), nitric oxide (NO), and/or other nitrogen oxide (NO_x) compounds. Nitrification occurs readily in the aerobic environments of receiving streams and dry soils while denitrification can be significant in anoxic bottom waters and saturated soils.

Nitrate is a useful form of nitrogen because it is biologically available to plants and is therefore a valuable fertilizer. However, excessive levels of nitrate in drinking water can produce negative health impacts on infant humans and animals. Nitrate poisoning affects infants by reducing the oxygen-carrying capacity of the blood. The resulting oxygen starvation can be fatal. Nitrate poisoning, or methemoglobinemia, is commonly referred to as "blue baby syndrome" because the lack of oxygen can cause the skin to appear bluish in color. To protect human health, EPA has set a drinking water Maximum Contaminant Level (MCL) of 10 mg/l for nitrate-nitrogen. Once a water source is contaminated, the costs of protecting consumers from nitrate exposure can be significant. Nitrate is not removed by conventional drinking water treatment processes; its removal requires additional, relatively expensive treatment units.

Nitrogen in livestock manure is almost always in the organic, ammonia or ammonium form but may become oxidized to nitrate after being diluted. It can reach surface waters via direct discharge of animal wastes. Lagoon leachate and land-applied manure can also contribute nitrogen to surface and ground waters. Nitrate is water soluble and moves freely through most soils. Nitrate contributions to surface water from agriculture are primarily from groundwater connections and other subsurface flows rather than overland runoff (Follett, 1995).

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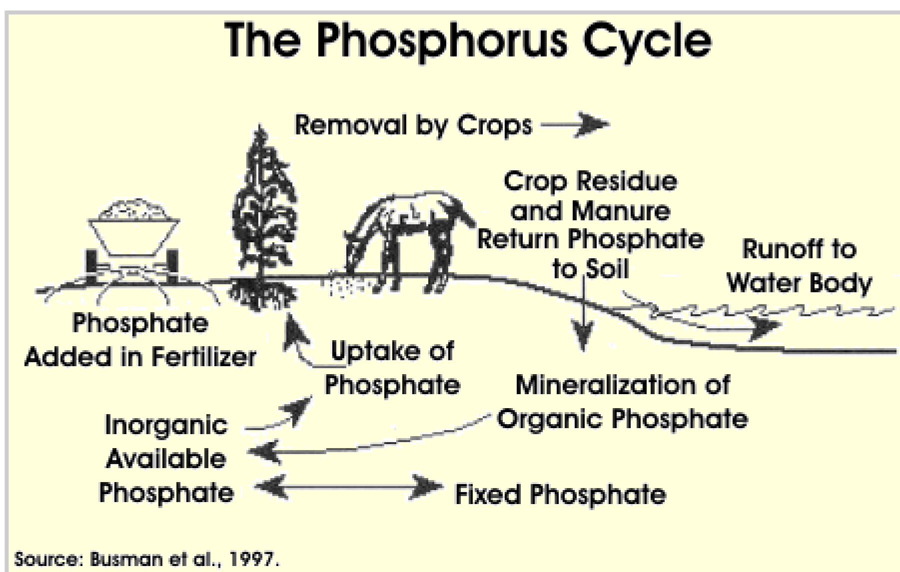
Phosphorus



Animal wastes contain both organic and inorganic forms of phosphorus (P). As with nitrogen, the organic form must mineralize to the inorganic form to become available to plants. This occurs as the manure ages and the organic P hydrolyzes to inorganic forms. The phosphorus cycle is much simpler than the nitrogen cycle because phosphorus lacks an atmospheric connection and is less subject to biological transformation.

Phosphorus is of concern in surface waters because it can lead to eutrophication. Phosphorus is also a concern because phosphate levels greater than 1.0 mg/l may interfere with coagulation in drinking water treatment plants (Bartenhagen et al., 1994). A number of research studies are currently underway to decrease the amount of P in livestock manure, primarily through enzymes and animal ration modifications that make phosphorous in the feed more available (and usable) by the animal. This means that less phosphorus must be fed to ensure an adequate amount for the animal and, as a result, less phosphorous is excreted in the manure.

Phosphorus predominantly reaches surface waters via direct discharge and runoff from land application of fertilizers and animal manure. Once in receiving waters, the phosphorus can become available to aquatic plants. Land-applied phosphorus is much less mobile than nitrogen since the mineralized form (inorganic Phosphate) is easily adsorbed to soil particles. For this reason, most agricultural phosphorus control measures have focused on soil erosion control to limit transport of particulate phosphorus. However, soils do not have infinite phosphate adsorption capacity and with long-term over-application, inorganic phosphates can eventually enter waterways even if soil erosion is controlled.

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Pathogens

Both manure and animal carcasses contain pathogens (disease-causing organisms) which can impact human health, other livestock, aquatic life, and wildlife when introduced into the environment. Several pathogenic organisms found in manure can infect humans.

Table 1. Some Diseases and Parasites Transmittable to Humans from Animal Manure

Disease	Responsible Organism	Symptoms
Bacteria		
Anthrax	*Bacillus anthracis*	Skin sores, fever, chills, lethargy, headache, nausea, vomiting, shortness of breath, cough, nose/throat congestion, pneumonia, joint stiffness, joint pain
Brucellosis	*Brucella abortus*, *Brucella melitensis*, *Brucella suis*	Weakness, lethargy, fever, chills, sweating, headache
Colibaciliosis	*Escherichia coli* (some serotypes)	Diarrhea, abdominal gas
Coliform mastitis-metritis	*Escherichia coli* (some serotypes)	Diarrhea, abdominal gas
Erysipelas	*Erysipelothrix rhusiopathiae*	Skin inflammation, rash, facial swelling, fever, chills, sweating, joint stiffness, muscle aches, headache, nausea, vomiting
Leptospirosis	*Leptospira Pomona*	Abdominal pain, muscle pain, vomiting, fever
Listeriosis	*Listeria monocytogenes*	Fever, fatigue, nausea, vomiting, diarrhea
Salmonellosis	Salmonella species	Abdominal pain, diarrhea, nausea, chills, fever, headache
Tetanus	*Clostridium tetani*	Violent muscle spasms, “lockjaw” spasms of jaw muscles, difficulty breathing
Tuberculosis	*Mycobacterium tuberculosis*, *Mycobacterium avium*	Cough, fatigue, fever, pain in chest, back, and/or kidneys
Rickettsia		
Q fever	*Coxiella burneti*	Fever, headache, muscle pains, joint pain, dry cough, chest pain, abdominal pain, jaundice
Viruses		

Foot and Mouth	Virus	Rash, sore throat, fever
Hog Cholera	Virus	
New Castle	Virus	
Psittacosis	Virus	Pneumonia
Fungi		
Coccidioidycosis	*Coccidioides immitus*	Cough, chest pain, fever, chills, sweating, headache, muscle stiffness, joint stiffness, rash wheezing
Histoplasmosis	*Histoplasma capsulatum*	Fever, chills, muscle ache, muscle stiffness, cough, rash, joint pain, join stiffness
Ringworm	Various *microsporum* and *trichophyton*	Itching, rash
Protozoa		
Balantidiasis	*Balatidium coli*	
Coccidiosis	*Eimeria* species	Diarrhea, abdominal gas
Cryptosporidiosis	*Cryptosporidium* species	Watery diarrhea, dehydration, weakness, abdominal cramping
Giardiasis	*Giardia lamblia*	Diarrhea, abdominal pain, abdominal gas, nausea, vomiting, headache, fever
Toxoplasmosis	*Toxoplasma* species	Headache, lethargy, seizures, reduced cognitive function
Parasites/Metazoa		
Ascariasis	*Ascaris lumbricoides*	Worms in stool or vomit, fever, cough, abdominal pain, bloody sputum, wheezing, skin rash, shortness of breath
Sarcocystiasis	*Sarcosystis* species	Fever, diarrhea, abdominal pain

References: USDA, 1992 (for diseases and responsible organisms). Symptom descriptions were obtained from various medical and public health service Internet websites. Pathogens in animal manure are a potential source of disease in humans and other animals. This list represents a sampling of diseases that may be transmittable to humans.

The treatment of public water supplies reduces the risk of infection via drinking water. However, protecting source water is the best way to ensure safe drinking water. Cryptosporidium parvum, a protozoan that can produce gastrointestinal illness, is a concern, since it is resistant to conventional treatment. Healthy people typically recover relatively quickly from such illnesses. However, they can be fatal in people with weakened immune systems such as the elderly and small children.

Runoff from fields where manure has been applied can be a source of pathogen contamination, particularly if a rainfall event occurs soon after application. The natural filtering and adsorption action of soils typically strands microorganisms in land-applied manure near the soil surface (Crane et al., 1980). This protects underlying groundwater, but increases the likelihood of runoff losses to surface waters. Depending on soil type and operating conditions, however, subsurface flows can be a mechanism for pathogen transport.

Soil type, manure application rate, and soil pH are dominating factors in bacteria survival (Dazzo et al., 1973; Ellis and McCalla, 1976; Morrison and Martin, 1977; Van Donsel et al., 1967). Experiments on land-applied poultry manure have indicated that the population of fecal organisms decreases rapidly as the manure is heated, dried, or exposed to sunlight on the soil surface (Crane et al., 1980).

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Antibiotics, Pesticides, and Hormones

Antibiotics, pesticides, and hormones are organic compounds which are used in animal feeding operations and may pose risks if they enter the environment. For example, chronic toxicity may result from low-level discharges of antibiotics and pesticides. Estrogen hormones have been implicated in the reduction in sperm counts among Western men (Sharpe and Skakkebaek, 1993) and reproductive disorders in a variety of wildlife (Colburn et al., 1993). Other sources of antibiotics and hormones include municipal waste waters, septic tank leachate, and runoff from land-applied sewage sludge. Sources of pesticides include crop runoff and urban runoff.

Little information is available regarding the concentrations of these compounds in animal wastes, or their fate/transport behavior and bioavailability in waste-amended soils. These compounds may reach surface waters via runoff from land-application sites.

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Airborne Emissions from Animal Production Systems

With the trend toward larger, more concentrated production operations, odors and other airborne emissions are rapidly becoming an important issue for agricultural producers.

Whether there is a direct impact of airborne emissions from animal operations on human health is still being debated. There are anecdotal reports about health problems and quality-of-life factors for those living near animal facilities have been documented.

- Source of Airborne Emissions
- Emission Movement or Dispersion

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Source of Airborne Emissions

Odor emissions from animal production systems originate from three primary sources: manure storage facilities, animal housing, and land application of manure.

In an odor study in a United Kingdom county (Hardwick 1985), 50% of all odor complaints were traced back to land application of manure, about 20% were from manure storage facilities, and another 25% were from animal production buildings. Other sources include feed production, processing centers, and silage storage. With the increased use of manure injection for land application, and longer manure storage times, there may be a higher percentage of complaints in the future associated with manure storage facilities and animal buildings and less from land application.

Animal wastes include manure (feces and urine), spilled feed and water, bedding materials (i.e., straw, sunflower hulls, wood shaving), wash water, and other wastes. This highly organic mixture includes carbohydrates, fats, proteins, and other nutrients that are readily degradable by microorganisms under a wide variety of suitable environments. Moisture content and temperature also affect the rate of microbial decomposition.

A large number of volatile compounds have been identified as byproducts of animal waste decomposition. O'Neill and Phillips (1992) compiled a list of 168 different gas compounds identified in swine and poultry wastes. Some of the gases (ammonia, methane, and carbon dioxide) also have implications for global warming and acid rain issues. It has been estimated that one third of the methane produced each year comes from industrial sources, one third from natural sources, and one third from agriculture (primarily animals and manure storage units). Although animals produce more carbon dioxide than methane, methane has as much as 15 times more impact on the greenhouse effect than carbon dioxide.

Dust, pathogens, and flies are from animal operations also airborne emission concerns. Dust, a combination of manure solids, dander, feathers, hair, and feed, is very difficult to eliminate from animal production units. It is typically more of a problem in buildings that have solid floors and use bedding as opposed to slotted floors and liquid manure. Concentrations inside animal buildings and near outdoor feedlots have been measured in a few studies; however, dust emission rates from animal production are mostly unknown.

Pathogens are another airborne emission concern. Although pathogens are present in buildings and manure storage units, they typically do not survive aerosolization well, but some may be transported by dust particles.

Flies are an additional concern from certain types of poultry and livestock operations. The housefly completes a cycle from egg to adult in 6 to 7 days when temperatures are 80 to 90°F. Females can produce 600 to 800 eggs, larvae can survive burial at depths up to 4 feet, and adults can fly up to 20 miles. Large populations of flies can be produced relatively quickly if the correct environment is provided. Flies tend to proliferate in moist animal production areas with low animal traffic.

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Emission Movement or Dispersion

The movement or dispersion of airborne emissions from animal production facilities is difficult to predict and is affected by many factors including topography, prevailing winds, and building orientation. Prevailing winds must be considered to minimize odor transport to close or sensitive neighbors. A number of dispersion models have been developed to Airborne Emission Regulations.

Most states and local units of government deal with agricultural air quality issues through zoning or land use ordinances. Setback distances may be required for a given size operation or for land application of manure. A few states (for example, Minnesota) have an ambient gas concentration (H_2S for Minnesota) standard at the property line. Gas and odor standards are difficult to enforce since on-site measurements of gases and especially odor are hard to do with any high degree of accuracy. Producers should be aware of odor- or dust-related emissions regulations applicable to their livestock operation.

Source: Lesson 40 of the LPES: Adapted from Livestock and Poultry Environmental Stewardship curriculum, lesson authored by Larry Jacobson, University of Minnesota; Jeff Lorimor, Iowa State University; Jose Bicudo, University of Kentucky; and David Schmidt, University of Minnesota, courtesy of MidWest Plan Service, Iowa State University, Ames, Iowa 50011-3080, Copyright (c) 2001.

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Environmental Impacts of Animal Feeding Operations Study Questions

Identify the definition that best fits the following terms:

1. **What are some of the positive environmental benefits of production agriculture?**

- Improved soil quality
- Carbon repository
- Reduced storm runoff
- Ground water recharge
- All of the above

Feedback

2. **USDA estimates that manure phosphorous exceeds crop needs in what percent of U.S. countries?**

   - 0%
   - 15%
   - 30%
   - 45%

Feedback

3. **What is the common name for the class of production agricultural plants that do not need commercial nitrogen fertilizer?**

   - N Converters
   - Maize
   - Legumes
   - Algae

Feedback

4. **If biodegradable organic matter is added to a stream, fish kills most often result from:**

   - Lack of oxygen
   - Turbulence
   - Lack of visibility
   - Build up of sludge deposits

Feedback

5. **Most manure spills that enter streams result from:**

   - Pastured animals with stream access
   - Rupture of manure storage
   - Improper land application of manure
   - Damage to manure transfer or irrigation pipes
   - Feedlot runoff from animal area
   - All of the above

Feedback

6. **Nitrogen gas (N_2) account for ___________ % of the atmosphere?**

   - 0%
   - 24%
   - 62%
   - 78%
   - 92%

Feedback

7. **Nitrogen in manure can take many chemical forms. Which of the following is NOT included?**

   - Nitrogen gas
   - Organic nitrogen
   - Catatonic nitrogen
   - Ammonia
   - Ammonium

Feedback

8. **Which nutrient in runoff from agricultural land has been blamed for the hypoxia problem in the Gulf of Mexico?**

   - Phosphorous
   - Chlorine
   - Sulfur
   - Nitrogen
   - Soil erosion

Feedback

9. **Which of the forms of nitrogen are volatile?**

   - NH_3
   - NO_3
   - NO_2
   - NH_4

Feedback

10. **High nitrate levels in drinking water can lead to the following serious condition in**

infants:

- "Green baby syndrome"
- Headaches
- Methemoglobinemia
- Colic
- Alzheimer's

Feedback

11. **The most important method of reducing phosphorous entering streams is:**

- Placing riprap along edge of stream
- Preventing soil erosion
- Improving field drainage

Feedback

12. **Which of the following is NOT a significant source of air emissions around a livestock or animal production operation?**

- Feed processing
- Land application of manure
- Animal production lots and buildings
- Manure Storage

Feedback

See Results RESET

Score in Percentage:	

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Comprehensive Nutrient Management Planning

Recently, the concept of Comprehensive Nutrient Management Planning (CNMP) was introduced by the U. S. Environmental Protection Agency (EPA) and U.S. Department of Agriculture's (USDA's) Natural Resources Conservation Service (NRCS). It is anticipated that the CNMP will serve as a cornerstone of environmental plans assembled by animal feeding operations to address federal and state regulations. EPA and NRCS guidelines for CNMP are given in Table 1.

Table 1. Summary of Issues addressed by a CNMP as initially defined by EPA's Guidance	
Planning	

components of CNMP	Issues addressed
A manure handling and storage plan	1. Diversion of clean water 2. Prevention of leakage storage plan 3. Adequate storage 4. Manure treatment 5. Management of mortality
Land application plan	1. Proper nutrient application rates to achieve a crop nutrient balance 2. Selection of timing and application methods to limit risk of runoff
Site management plan	Soil conservation practices that minimize movement of soil and manure components to surface and groundwater
Record keeping	Manure production, utilization, and export to off-farm users
Other utilization options	Alternative safe manure utilization strategies such as sale of manure, treatment technologies, or energy generation
Feed management plan	Alternative feed programs to minimize the nutrients in manure

Reference: USDA/EPA Unified National Strategy for Animal Feeding Operations (PDF) (34 pp, 404K)

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Poultry Production Study Questions

Identify the definition that best fits the following terms:

1. **Chickens are the most numerous birds in the world.**

   - True
   - False

   Feedback

2. **Egg products are used for:**

   - Cake mixes
   - Therapeutic vaccines
   - Antibodies
   - All of the above

   Feedback

3. **What led broiler chicken production to expand beyond a seasonal, local market during the 1940s and 1950s?**

   - Advent of commercial poultry vaccines
   - Mechanical ventilation systems
   - Refrigerated trucking

All of the above

Feedback

4. **Most broiler chickens and turkeys are reared on raised wire flooring.**

- True
- False

Feedback

5. **Molting refers to:**

- Process of making a pelleted diet with heat
- Process of reproductive rest where hens shed/regrow feathers
- Process of ventilation with electric or pneumatic fans

Feedback

6. **The breeding chicken flock has moved to "black-out" housing to:**

- Save on electrical costs
- Take advantage of the photosensitive nature of the bird for sexual maturation
- Prevent cannibalism

Feedback

7. **Restricted feeding of broiler breeder birds is done to:**

- Prevent obesity
- Save on feed costs
- Reduce labor costs

Feedback

8. **The incubation period of a chicken egg is:**

- 18 days
- 21 days
- 28 days
- 32 days

Feedback

9. **A pullet is a:**

   - ○ Male chicken of reproductive age
   - ○ Means of raising/lowering curtains in a naturally ventilated poultry house
   - ○ An immature hen

   Feedback

10. **Male turkey toms reach 40 pounds when marketed at 18 to 20 weeks of age.**

    - ○ True
    - ○ False

    Feedback

11. **Poultry manure is routinely applied to fields through:**

    - ○ Injection
    - ○ Surface application

    Feedback

12. **This type of poultry routinely uses liquid-flush pit and lagoon systems:**

    - ○ Broiler breeder
    - ○ Duck
    - ○ Turkey

    Feedback

13. **These 2 factors have largely reduced time to market for broiler chickens from 12 weeks (1945) to 7 weeks (2002):**

    - ○ Feeding and watering systems
    - ○ Nutrition and genetics
    - ○ Ventilation systems and vaccination programs

    Feedback

14. **To prevent the spread of disease, worker should always travel from:**

    - ○ Housing for younger birds to older bird housing
    - ○ Housing for older birds to younger bird housing

    Feedback

15. **A laying hen reaches peak egg production:**

- 4 to 6 days after beginning to lay
- 4 to 6 weeks after beginning to lay
- 4 to 6 months after beginning to lay

Feedback

See Results RESET

Score in Percentage:	

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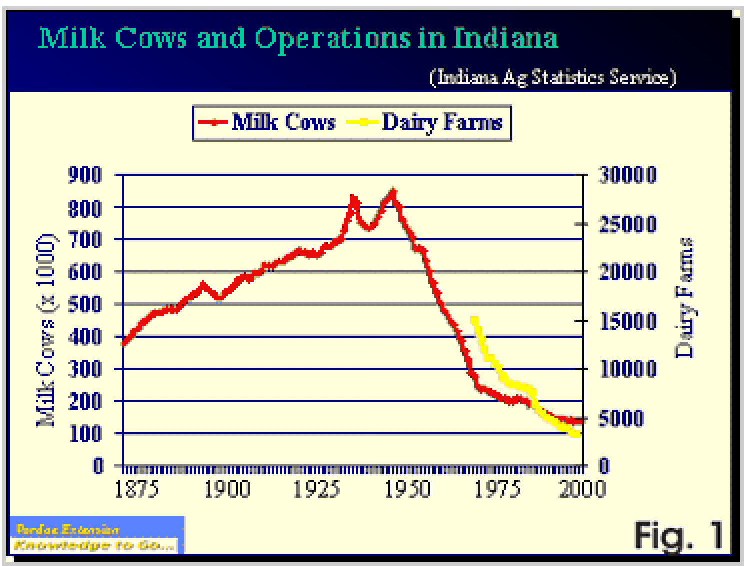
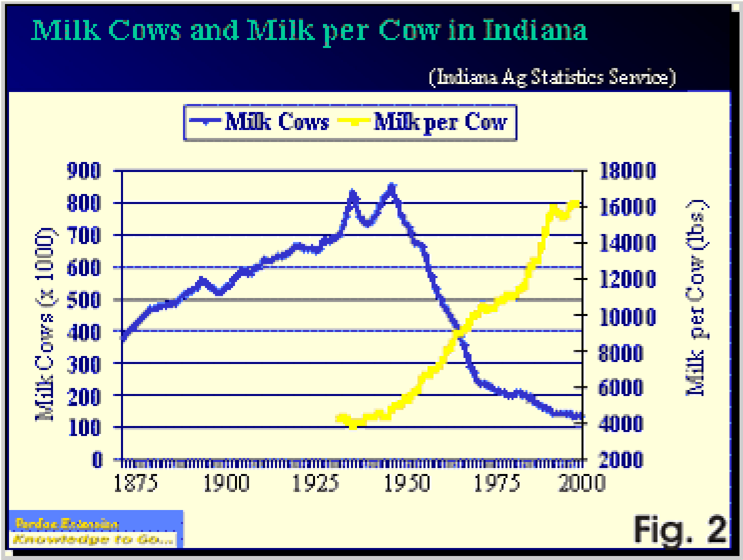
Background of Dairy Production in the U.S.

The first cattle in the western hemisphere arrived with Christopher Columbus on his second voyage. Other cows began to arrive along with settlers from Europe and followed the pioneers westward. Until the mid 1850s, the dairy industry in America revolved around the family-owned dairy cow, with little sales of milk or other dairy products outside the family. The dairy industry began to change dramatically in the early 1900s, after a series of developments. Principles of bacteriology that led to improved milk quality and safety by Louis Pasteur with the process of pasteurization; development of breed associations that promoted the genetic selection of cows for their ability to produce milk; the Land Grant act of 1862 that established colleges of agriculture to educate farmers in the scientific principles of breeding, feeding, and management; the centrifugal separator that allowed milk fat to be removed and allowed the manufacture of more products; determination of milk fat content by the Babcock test (named for Professor S. M. Babcock of the University of Wisconsin); and tuberculin testing of dairy herds that eliminated milk as a source of tuberculosis all played a role in the growth of U.S. dairy production.



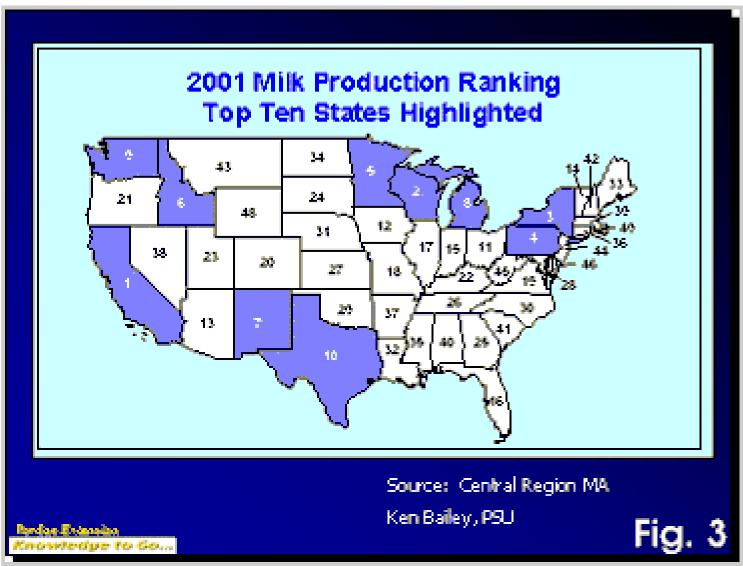
As the dairy industry grew in the first half of the Twentieth Century, the largest numbers of cows and dairy herds were located in the Great Lakes region of the U.S. This area was very suitable for pasturing cattle and for producing forages which could be stored as winter feed. It was also conveniently situated near the population centers of the U.S. at that time. The location of farms near the point of use was critical since milk is a highly perishable commodity and modern refrigeration and transportation systems were not yet available. Thus, milk was bottled at the farm or taken to a local creamery and delivered to stores and households daily. Cows and farms reached peak numbers in the 1940s, when rural electrification allowed for the rapid cooling and on farm bulk storage of milk and allowed it to be transported over longer distances to markets. This allowed dairy production to become more concentrated. Cow numbers and dairy farm numbers for Indiana, which is typical of states in the Great Lakes region are in Fig. 1.

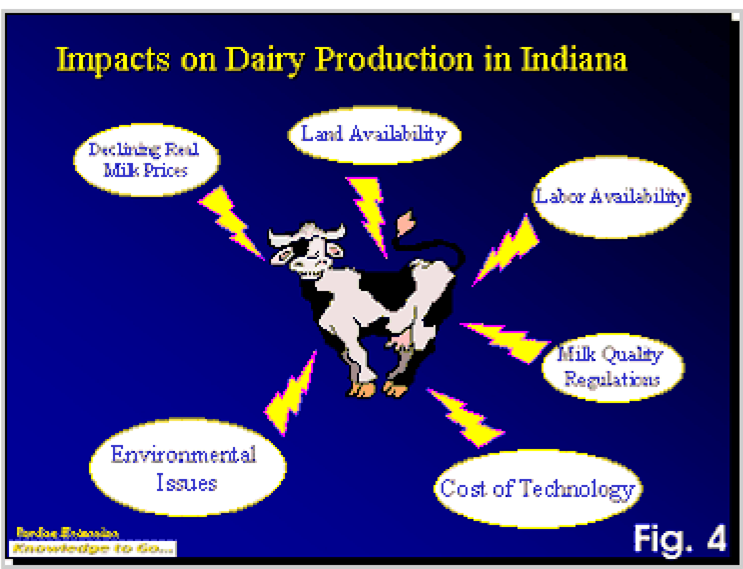
The concentration of more cows on fewer farms was accompanied by dramatic increases in production per cow (Fig. 2), arising from improved genetic selection, feeds, health care, and management techniques. Better roads enhanced the ability to transport milk to processing plants, improvements in housing and environment to keep cows more comfortable, less competition for alternative land uses, and the ability to raise feed under irrigation has led to a shift in dairy production to



Western states. California surpassed Wisconsin in milk produced in 1993 and in number of dairy cows in 1998.

Presently, there are about 9 million dairy cows on 100,000 farms in the U.S. California, Wisconsin, New York, Pennsylvania, Minnesota, and Idaho are the leading dairy producing states (Fig. 3). Production continues to increase in Idaho, New Mexico, and California, while it is declining in most of the Midwest and Northeast. In the upper Midwest, dairy farms have been discontinuing production at the rate of more than three per day over the past five years.





The tri-state region of Indiana, Michigan, and Ohio, however, appear to be maintaining or increasing cow numbers, as the industry reacts to relatively inexpensive feed costs and access to the high-demand markets for fluid milk in the Southeastern U.S. Continued growth of the industry is expected in the Eastern Corn Belt and in the High Plains, just east of the Rocky Mountains. External pressures on the dairy industry due to environmental concerns will limit its growth in some areas or force farms to relocate (Fig. 4).

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Dairy Products

Dairy Products

- Fluid Milk
- Egg Nog
- Cheese
- Butter
- Yogurt
- Ice Cream
- Powdered Milk
- Whey Powder
- Butter Powder
- Meat
- Leather goods
- Fertilizers
- Cosmetics

A trip to the grocery store's dairy case shows the variety of products resulting from the milk. Fluid milk is available in several varieties - Skim Milk (0% fat), 1%, 2%, and Whole (approximately 3.5%). Raw milk is separated into skim milk and cream, and then re-blended to a standard fat content for each product. Because cows' milk averages more than 3.5% fat, the extra cream is used to make other liquid products like whipping cream, half and half, and eggnog or it is manufactured into butter or ice cream. Fluid milk in the U.S. is pasteurized (milk is pasteurized by rapidly heating it to 72 - 75 °C for 15 to 20 seconds, and then quickly cooling) to kill potentially harmful bacteria. Fluid milk is also homogenized (fat droplets are dispersed so they do not float to the top) and is fortified with vitamins A and D, which along with the absorbable calcium naturally in milk are needed for strong healthy bones and teeth. Over the most recent two decades, fluid milk consumption per capita has declined, and sales of low-fat milk have increased relative to whole milk. Recent innovative marketing of convenient single servings of milk and introduction of a wide variety of milk flavors have increased sales of individual servings.

Following the increased health consciousness of U.S. consumers in the late 1980s and 1990s, there was a period of decreased sales of butter, which is made by churning the cream portion of milk. However, sales have increased recently, as have sales of other high-fat products, such as premium ice cream and full-fat cheese. Cheese, which is made primarily from the protein (casein) portion of milk, also contains butterfat and currently accounts for a large percentage of dairy product demand and consumption. Per capita consumption of cheese consistently increases from year to year in the U.S. and is largely driven by demand for fast food and pizza. While demand for buttermilk (the portion of cream remaining after butter is churned out) and whey (the portion of milk remaining after cheese curd is removed) are negligible, the dried-powdered forms of these products are used as additives in the baking, candy, sport-drink, and animal feed industries. Whey powder also forms the basis for many brands of calf milk-replacers.

Health conscious consumers have also begun to purchase more yogurt relative to ice cream, and numerous low fat frozen deserts are available in grocery stores. Furthermore, milk is used directly in baked goods, candy and other ready to eat foods, like sauces and salad dressings.

In many states, the sales of meat from cull cows and bull calves that are raised as veal or dairy steers account for a significant portion of total beef production. Most cull cows, because they are older and produce less tender cuts of meat, are utilized for production of ground beef. Dairy veal and dairy steers are sold in similar markets and under identical USDA grading systems to more traditional beef breed steers. Byproducts of dairy beef production include leather, fertilizer, cosmetics, glue, and pharmaceuticals.

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National Agriculture Compliance Assistance Center (Ag Center)

Dairy Production Systems

Black and White Holstein

Source: USDA - ARC

In the U.S., milk comes from breeds of cattle genetically selected for milk production. At one time in the U.S., cattle were selected simultaneously for beef and milk production. This is still the case in many parts of the world. The common dairy breeds in the U.S. today have been selected almost exclusively for milk production for many generations.

Black and white Holstein cows make up over 90% of the U.S. dairy herd. Some Holsteins are red and white, but, aside from color, indistinguishable from black and white Holsteins. The U.S. Holstein is well known around the world for her ability to produce large volumes of milk, butterfat and protein. She is a very profitable cow for farmers when large amounts of feed with high levels of grain are available. The U.S. Holstein is relatively new to North America, with the first imports of registered Holsteins arriving in the 1880s. However, the breed has dominated production in the U.S. since the end of World War II, and advances in artificial insemination have increased her popularity in breeding programs around the world largely owing to her advantage in production over all other breeds.

provided by Hoard's Dairyman Jersey

Source: USDA - ARC

The Jersey is the second most popular cow in the U.S. and makes up about 7% of the U.S. dairy herd. She is known for her smaller size (1000 lbs. for a mature Jersey cow versus 1500 lbs. for a mature Holstein cow), higher percentages of fat and protein in her milk, early maturity, and efficiency of milk production. Payment by milk processors to dairy producers based on the content of butterfat and protein in milk has increased the popularity of the Jersey, especially in markets where milk is manufactured into cheese. Other dairy breeds make up only around 2% of the dairy cattle population. These include:

- Ayrshires - moderately large cows that are red and white to mahogany and white and are known for producing milk that is quite rich in butterfat and for the conformation of their udders;
- Brown Swiss - large brown cattle that are known for their docile manner, high milk protein to milk fat ratio, sound feet and legs, and purported resistance to heat stress in hot and humid regions;
- Guernseys - red and white to mostly red and are somewhat larger than Jerseys and are known for the yellow color of the butterfat in their milk, which is rich in Beta-Carotene; and
- Milking Shorthorns - a rugged breed of cattle that are red and white to mostly red, mostly white, or roan (speckled) and are known for milk that is well suited for cheese production

and for their grazing ability.

More information about the breeds of dairy cattle. EXIT Disclaimer

A few other dairy breeds have become popular more recently. Dutch Belted, Danish Jersey, Normandy, Montbeliarde, Danish Red, British Friesian, and Norwegian Red have gained notoriety for their purported superiority under grazing management (pasture production systems). Many of these breeds have been developed in countries where grazing is widely practiced. Nevertheless, many U.S. dairy producers have good success grazing Holsteins and other traditional U.S. breeds of dairy cattle.

Until recently, very little crossbreeding was practiced in the U.S. Crossbreeding, which refers to mating cows to bulls of a different breed, is gaining in popularity for several reasons. Much of the genetic improvement in Holsteins has been for milk production alone, while other breeds have been selected for other traits like fertility, moderate size, disease resistance, and strength. Thus, crossbreeding allows the breeds to compliment each other's strengths. There is also some level of hybrid vigor expected in the progeny; that is, first generation crosses may be better than the average of the parents.

Grazing versus Intensive Dairy Production Systems

In the United States, most milk is produced by cows raised in intensive production systems. These include tie stall barns, free stall barns, and open lots. The more intensively managed systems feed cows rations that are relatively high in concentrates and stored forages. Other cows are raised in pasture-based systems, which are the primary production system in several dairy producing countries in the world, such as New Zealand. Pasture-based systems often strive to optimize rather than maximize milk production while paying careful attention to controlling input costs. Some producers use a combination of the two systems, which is appealing in that it reduces costs, but still allows the feeding of concentrate to improve milk production levels.

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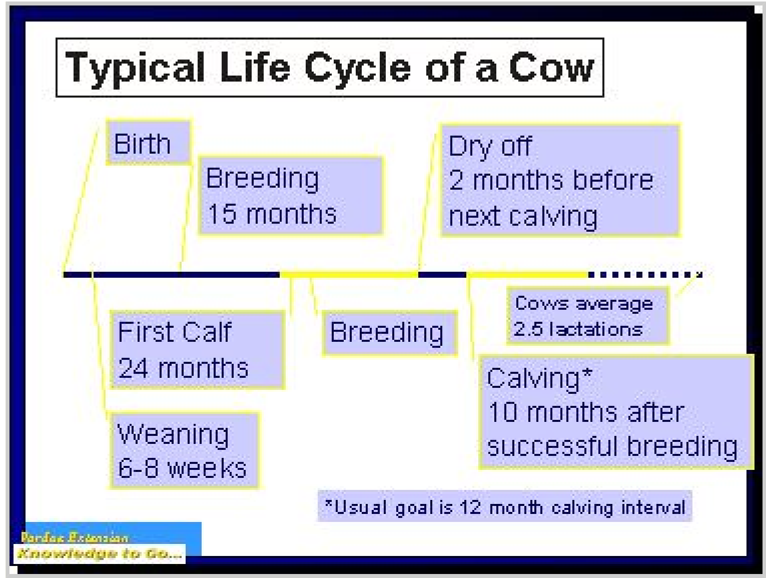
Lifecycle Production Phases

- Calves and Heifers
- Cows
- Typical Herd



A cow typically remains in the dairy herd until about 5 years of age, although many cows are capable of remaining productive in the herd for 12 to 15 years. Following birth, the calf is usually removed from her dam after only a few hours. The newborn calf is fed milk or milk replacer until weaning at 6 to 8 weeks of age. The calf will then be raised until it reaches appropriate breeding weight at about 15 months of age. Heifers are then maintained and continue to grow through their gestation. They usually calve, or give birth, at about 24 months of age. However, they do not reach mature size until at least 4 years of age.

Normally cows begin to produce milk only after calving, but some heifers may be milked early to reduce stress and udder edema. Each period of production or lactation lasts for 12 to 14 months or longer and spans the time period from calving to dry-off, which is when milking is terminated about 60 days before the next anticipated calving. Thus, cows are bred while they are producing milk, usually beginning at about 60 days after calving to maintain a yearly calving schedule. Indeed, dairy producers attempt to get cows bred precisely during the time they are producing the most milk, which has negative implications for cow fertility. Following the 2-month dry period, the cow calves again and lactation cycle begins anew. Cows average about 2.5 lactations, although many remain productive considerably longer. Cows tend to survive longer in less-intensive pasture systems than when on concrete all of the time. The leading reasons cows leave the dairy herd are low production, infertility, mastitis (inflammation of the udder), and lameness.

Calves and Heifers

Immediately after birth, the calf is fed 2 quarts of colostrum and at least another 2 quarts within 12 hours. The ability of the calf to directly absorb immunoglobulins from the cow's


Source: University of Wisconsin

initial milk declines rapidly after the first 12 hours. Thus every effort is made to get the calf to consume colostrum early. Calves' navels are then dipped with iodine to prevent infection and the calf is moved to an individual pen or hutch as soon as it is dry. Choices for individual housing for calves include calf hutches, indoor crates, and indoor pens. Group pens allow too much nose-to-nose contact and permit disease to spread quickly for very young calves. Hutches provide very suitable ventilation for the calves and automated equipment can be used to simplify feeding calves in hutches. But indoor facilities are convenient for the calf feeders, especially in cold weather. Often indoor calf facilities are made of converted buildings, greenhouse barns, or coverall hoop barns.

Prior to weaning at 6 to 8 weeks, calves are vaccinated, dehorned, have extra teats removed, and male calves may be castrated to be raised as steers. Female calves are either raised by the dairy farm as replacement heifers, contract raised for the dairy farm by a heifer grower, or sold to other dairy farms. Male calves are mainly sold as veal calves or raised as steers, either by the farm or a buyer. A small number of bull calves may be raised for breeding stock and sold to local dairies as natural service bulls. A tiny percentage of bull calves from exceptionally good cows with registered pedigrees may be sold through contract to Artificial Insemination companies. Formerly, the image of the veal industry is that calves were kept in tiny crates in total darkness so they would remain anemic. The modern veal industry is more likely to be in more open facilities with excellent lighting and ventilation.

Protein Sources		
Best	**Acceptable**	**Inferior**
Skim Milk	Specially manufactured soy flour	Unprocessed soy flour
Buttermilk	Soy concentrate	Meat solubles
Whole Whey	Hydrolyzed fish protein	Fish Flour
Delactosed whey		Distiller solubles
Casein		Brewer's yeast
Milk albumin		Oat flour
Whey protein concentrate		Wheat flour
Fat Sources		
Lard	Hydrogenated vegetable oils	Liquid vegetable oils
Tallow		
Stabilized greases		

Aside from the very first days when calves are fed colostrum, they are fed discarded milk or milk replacer. The best protein sources for milk replacer are from dairy products. At the same time, the calf is offered water and calf starter feed, which it should be consuming readily prior to weaning it off of milk. Calves should be offered starter within the first week and should be getting adequate energy from the starter by weaning. Often calves are encouraged to eat the starter by addition of molasses. It is not necessary to feed hay to calves prior to weaning, but it is sometimes made available.

Protein Sources			
	Grain Starters		
	1	**2**	**3**
Ingredients (air dry			

basis)			
Corn (cracked or coarse ground), %	50	30	
Ear Corn (coarse ground), %			50
Oats (rolled or crushed), %	22	18	
Barley (rolled or coarse ground), %		20	21
Wheat Bran, %		8	
Soybean Meal, %	20	16	21
Molasses, %	5	5	5
Dicalcium phosphate, %	0.5	0.5	0.5
Limestone, %	1.5	1.5	1.5
TM Salt and Vitamins, %	1	1	1
Composition (dry matter basis)			
Crude protein, %	18.1	18.0	18.4
TDN, %	80.0	78.8	78.0
ADF, %	7.0	6.9	9.1
Calcium, %	0.8	0.8	0.82
Phosphorus, %	0.48	0.56	0.47
Vitamin A, IU/lb	1000	1000	1000
Vitamin D, IU/lb	150	150	150
Vitamin E, IU/lb	11	11	11

At weaning, calves are moved to group housing. Forms of group housing include superhutches, drive-through freestall barns, drive-by freestall barns, and open housing on bedded pack. Some calves are weaned directly onto pasture. Normally, heifers are kept in these housing systems until they reach breeding age at 12 to 15 months. Feeds tend to include some calf starter, perhaps some other grain or corn silage; and excellent quality hay is offered.

Following breeding, heifers are maintained until moving to the dairy farm for calving. Facilities are often less extensive. Often heifers are raised in feedlots, or on pasture, although some heifers are also raised in freestall barns.

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Cows

For cows, the period from 60 days prior to calving until 40 days after calving is called the transition period, because cows make a transition to producing milk and consuming a higher energy ration. Heifers and dry cows are usually moved to a close-up dry area for close observation beginning at 3 weeks prior to calving. Usually the close-up dry cows are housed in freestalls, or on pasture or open lot. When calving appears imminent, cows are moved to individual maternity pens or an

open calving area. Diligent efforts are made to keep these areas clean. Even cows raised on pasture are sometimes moved to pens for calving to allow close observation in case the delivery must be assisted, to keep the calf out of cold drafts, and to allow careful attention to the calf immediately after birth. Calving pens are usually bedded with lots of clean wheat or oat straw, although sand and sawdust are used too.

Some dairy producers prefer to keep cows on pasture. There are certainly advantages in reduced costs of feed harvest and storage, reduced cost for manure management and storage, improved foot health, and perhaps less disease when the cows are not as heavily concentrated in a limited area. These grazing systems often depend on the principles of managed intensive grazing to optimize grass and milk production. Some, but not all, grazers also practice seasonal calving to allow the cow's highest milk yield and energy demands to match with seasons of maximal grass production. Thus calving is planned for Spring in the Northeast and Midwest, and Fall in the far South. Due to less rainfall, little grazing is practiced west of the Great Plains. Grass is far and away the key component of diets on grazing dairies. Even stored feed may include excess grass from pastures that is ensiled and fed when grass is not available. Most grazing dairies supplement the grass with some level of ground corn or other concentrate feeds, and perhaps with some purchased alfalfa hay and/or corn silage. Often the grass is baled in round bales, wrapped in plastic, and stored as baleage.

In the Midwest and elsewhere it is common for small to medium-sized dairies to house cows in barns for most of the year, but to provide supplemental grazing during the summer. Even then, cows may only get a small portion of their forage from pasture, with most feed fed in the barn or a feedlot.

Traditionally, cows in the Midwest and Northeast were housed in tie-stall barns. Often cows were maintained in these barns and fed and milked right in their own stalls. While several of these barns are still in use, the inefficiency of labor and difficulty of milking have made new tie stall barns relatively uncommon.

The concept of providing cows with the opportunity to freely move from her stall to the feeding area was developed in Washington State in the mid 1950s. Freestall barns have become the mainstay of the dairy industry in recent years. Older freestalls were often constructed of

wood and the stall was bedded with lots of straw. Even these older stalls can still be very useful today if plenty of bedding is provided to keep cows comfortable. Modern freestalls are more likely to be constructed of steel loops or dividers and bedded with sawdust or sand. The fact that sand provides little organic matter as food for bacteria, keeps cows dry, and helps cool cows in summer makes it the "gold standard" of bedding materials. Occasionally, freestalls are lined with rubber mattresses filled with ground tires, other cushion materials, or even water. Modern barns are constructed of wood or steel supports and rafters or trusses, steel roofing with an open ridge, and curtain sides that may be opened to maximize airflow in summer. Ventilation is usually assisted with fans. In some facilities, tunnel ventilation is used, in which air is mechanically drawn through the length of the building at rapid speed, which eliminates the dependence on wind speed needed for natural ventilation. To attain rapid air movement, the roof and sides are built solid with no air inlets. Greenhouse barns and other kinds of hoop structures are available to dairy producers for freestall barns. Their advantage is in reduced construction costs, although covering may need to be replaced as often as every 5 years. The additional light in these barns is an advantage for observing cattle, and the sun may be partially blocked out by covering with shade cloth in summer. Cow cooling systems, such as misters or sprinklers, are often present above feeding areas during hot weather. In the arid Southwestern states, newer dairy facilities are investing in state-of the art evaporative cooling systems to keep cows comfortable and productive. Supplemental cow cooling should be available any time the temperature exceeds 72 to 75 degrees.

Dry cows, during the period in which they are not lactating, are often housed in less expensive buildings. Because dry cows do not metabolize as much energy as lactating cows, they produce less heat, and so it is not as difficult to keep them cool in summer.

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Typical Herd

The typical mix of animals in a dairy herd for 100 milking cows is:

Milking herd:

- 92 healthy cows
- 4 cows that have recently given birth
- 4 cows with special needs

and

- 16-20 dry (not lactating) cows and close-up heifers (close to calving)
- 70-90 replacement calves and heifers

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Last updated on July 29, 47489

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Feeding and Feed Storage

Total Mixed Rations for Cows (Midwest Rations)

- Corn silage
- Alfalfa/grass silage
- Alfalfa hay
- Corn
- Soybean meal
- Fuzzy whole cottonseed
- Commodity feeds (corn gluten, distillers grains, soybean hulls, citrus pulp, candy bars, etc.)

Mixer

Typical rations fed to dairy cows in the Midwest often contain corn silage, alfalfa or grass silage, alfalfa hay, ground or high-moisture shelled corn, soybean meal, fuzzy whole cottonseed, and perhaps commodity feeds (corn gluten, distillers grains, soybean hulls, citrus pulp, candy bars, etc.). Proximity to crop processing plants and industries may dictate the availability of commodity feeds in different locales and some regions may have different feedstuffs. For example, short growing seasons may limit use of corn silage in far Northern climates and may be replaced by alfalfa silage in the ration. Cows are usually fed rations that are balanced for their milk production level or stage of lactation, which reflects the differences in energy and protein required for different amounts of milk produced. A cow produces the most milk immediately after the birth of her calf, but production drops off over the next several months. Usually, all of the feedstuffs are blended together in a mixer and fed as a Total Mixed Ration or TMR. Keeping every bite of feed a cow eats as uniform as possible helps to maintain a healthy population of bacteria in the cow's rumen (second stomach). It is the bacteria that digest the forages in the cows ration and allow her to consume and process foods that other animals and humans could not. Blending all feeds is difficult to accomplish in tie stalls, and is obviously not practiced with cows on pasture where cows eat only grass while on pasture and are fed grain at the time of milking.

Feed storage and feeding systems account for a considerable number of buildings and structures on dairy farms. Dry hay may be stored in a hay loft, or second story, in the barn, in separate hay barns or stacked outside and covered with plastic. For many years, the primary storage structure for silage was an upright

Upright concrete stave silos

silo. Concrete stave silos and oxygen limiting silos, of which Harvestore™ is a familiar brand name, were popular storage structures for chopped and ensiled (fermented) corn, alfalfa, and grass. This method of storage was successful and cows readily ate well-fermented crops. However, the physical removal of silage from such storage was relatively slow and increasing herd sizes dictated more labor-efficient storage methods, such as silage bags and bunker silos, and silage stacks. These methods also preserve silage well, provided that the silage is adequately packed to eliminate oxygen that can hinder the fermentation process. Fermentation lowers the pH of the stored feed and preserves its feed value.

Feed Alley

Commodity feeds are added to silage or hay to provide a complete and balanced ration. Commodity feeds are usually stored in a commodity barn that has several bays, one for each commodity. Commodity sheds are usually constructed to allow delivery of one semi-trailer of the commodity in each bay. Cows are usually fed at feed bunks in an outside lot, in a drive through feed alley in the barn, or at a drive-by feed alley, for cows housed in open lots.

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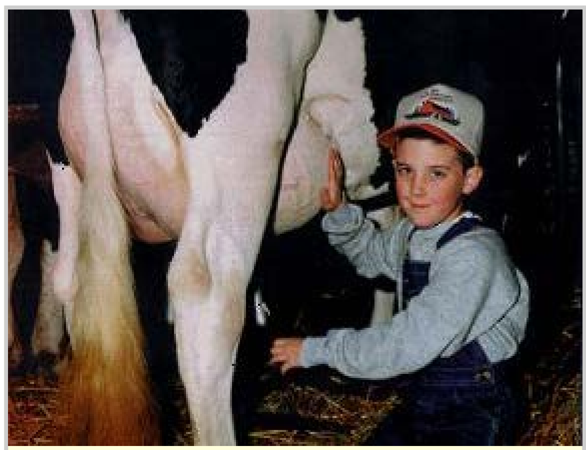
Milking Parlors

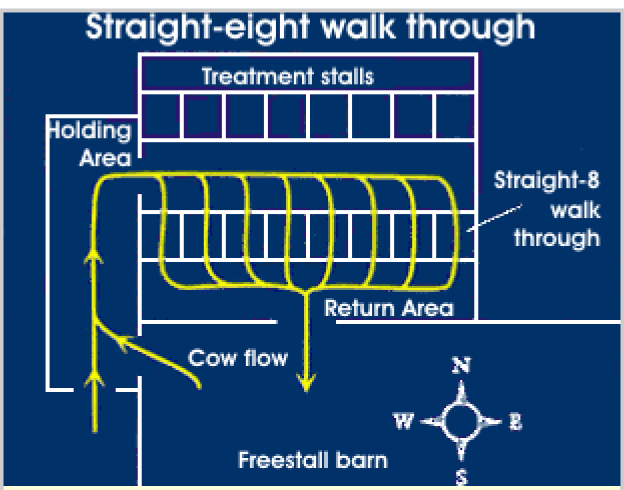
Cows are milked twice per day on most farms. However, 10% increased milk production can be obtained by milking the cows 3 times per day, and many dairy farms are beginning to do so. Some operations even milk a portion of their cows 4 times per day. Cows housed in tiestall barns are often milked in their stalls. A number of dairy farms, primarily those whose owners are members of religious denominations that do not utilize electricity, still milk cows by hand rather than with milking equipment. These are not common and usually involve only a few cows. The milk from such operations does not enter the fresh milk market and is utilized only for manufacturing purposes. Most cows milked in tiestall barns are either milked with bucket milkers or pipeline milking systems. Milking cows in tiestall barns is extremely labor intensive and requires much stooping and bending. The desire to reduce this type of labor has led to many types of milking parlor designs, in which the milker need not bend to be at the level of the cows udder.

Some cows in the Midwest and Northeast are milked in Tie Stall Barns.

- Hand Milking (Amish)
- Bucket Milkers
- Pipelines



Source: Gennex, CRI

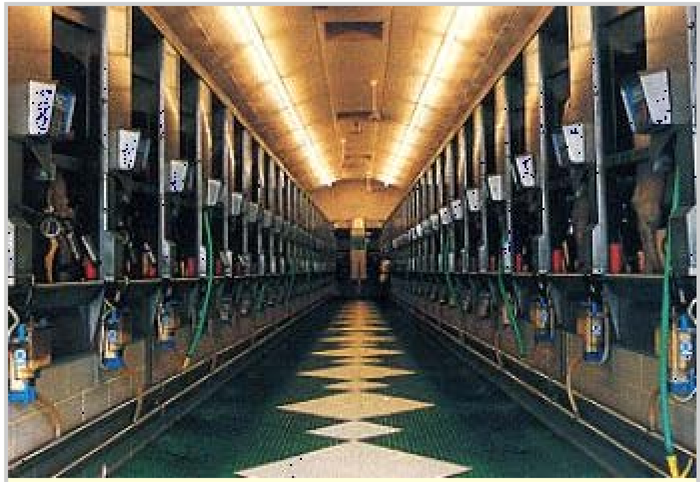


Walk-through Parlor

Walk-through or step-up parlors are often installed or retrofitted into existing tiestall barns as a cost effective way of alleviating the demands of the milking chore. In these parlors cows enter from the rear, step up onto an elevated platform for milking, and then exit forward through a headgate. Walk through parlors are inexpensive, but labor demands are still relatively high.

Step-up Parlor

One of the most popular types of parlors is the herringbone, so named because the cows enter and stand next to each other, but face away from the operator's pit at an angle. Milkers attach the milking clusters to the teats from the side of the cow, and to have better visual contact with the cow's udder while she is being milked. It is usually easier to keep the milker positioned properly beneath the cow's udder.



Herringbone Parlor
Source: Midwest Plan Service

Parallel Parlor
Source: Midwest Plan Service

Parallel parlors are similar to the herringbone parlors except that cows stand perpendicular to the operator pit and the cows are milked from the rear, between the cow's hind legs. Advantages are that the cows stand closer together so the worker has to walk less between cows that are being milked. Disadvantages are that the cow's tail is often in the way and it may be a long reach for some milkers to reach the cow's front teats.

Rotary parlors are gaining in popularity. Some older styles of rotary parlors were not very efficient or dependable. New ones, however, have proven to be a viable alternative for large dairy farms. With the rotary parlor, the platform on which the cows stand moves around, while the cleaners and milkers stand in one location.

Milking cows is still a demanding task, however, because the cows come by so quickly that each task must be performed in about 10 to 12 seconds with no break between cows.

Rotary Parlor

No matter what kind of parlor is used, there are some key components of milking procedures that are followed in each. Namely, the cow's teats must be thoroughly cleaned and dried, the milking equipment must be working properly and attached properly, and the teats must be disinfected with an approved teat dip following milking. This is to prevent possible spread of mastitis from cow to cow. Similarly, the milk must be handled properly after it leaves the cow. It must be cooled to under 45 degrees Fahrenheit within 2 hours of milking. Plate coolers are often more efficient at cooling milk than bulk tanks and are used on most farms. Bulk tanks manufactured after January 1, 2000 must be equipped with a recording thermometer so that the temperature history of the milk can be monitored. A sample of milk from each bulk tank accompanies the milk truck to the receiving plant. The milk undergoes a battery of tests to assure that it is safe and of high quality before it is accepted for processing. Dairy producers must meet specific requirements for bacteria counts and somatic cells (white blood cells) in milk; and they are paid a premium for high quality milk. No added water or antibiotic residues are allowed, under penalty of losing one's permit to sell milk.

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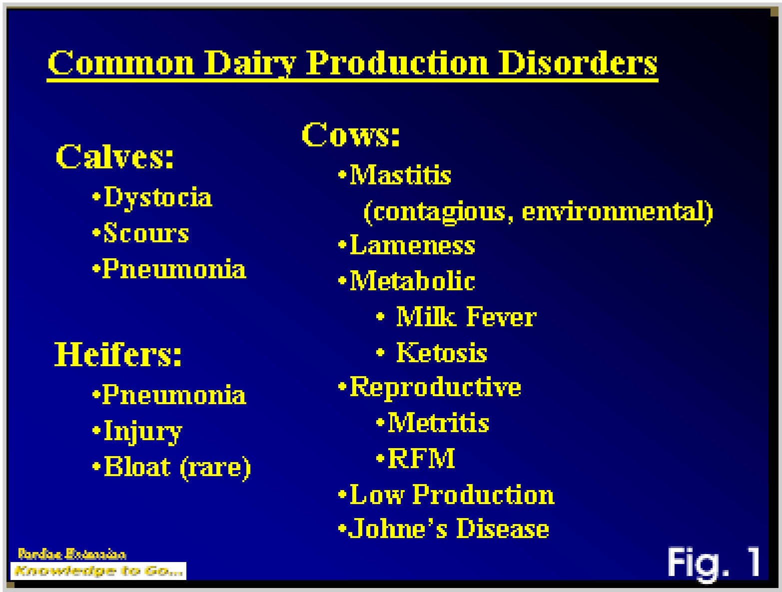
Diseases



There are a number of common diseases and disorders that affect cattle at various stages of life (**Fig. 1**). Cows may experience a difficult birth, and death losses at birth may be as high as 5%, though these losses can be overcome by selecting bulls known for the calving ease of their offspring. Diarrhea, caused by any of several species of bacteria, and pneumonia are the leading cause of death loss in calves. Calves may also be afflicted with less harmful disorders like pink eye. In older heifers, the primary risks include pneumonia, injury, and bloat. Cows may be afflicted by any of a number of disorders that result in a loss of milk production. Mastitis (inflammation of the udder), lameness, milk fever (hypocalcemia), ketosis, reproductive disorders, and bacterial diarrhea are some of the more common ones. Vaccination programs are effective at controlling or decreasing the severity of many of these diseases.

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Common Manure Handling Systems

Cows differ considerably in the amount of manure they produce. Jerseys, for example, produce only 60% as much manure as Holsteins. With respect to many environmental rules, especially state regulations, however, no consideration is made for breed or body size. Composition of typical dairy manure is known (**Table 1**). Consideration must be given to the kind(s) of bedding used (**Table 2**) and the milking system (**Table 3**), both of which contribute to the amount of manure produced on a dairy farm.

Table 1. Manure Production per 200 Cows*

	Per Day (lb.)	**Per Year (LB)**
Feces and Urine	24,100	8,800,000
Total Solids	3,360	1,230,000
Volatile Solids	2,800	1,020,000
Total N	126	46,000
Total P	26	9,610
Total K	812	23,600

*does not include wastewater and bedding
*estimates may increase with milk production

Table 2. Bedding

	ft^3 / cow / day	
Housing Type	**Chopped Straw**	**Sawdust**
Tiestall	0.8	0.1
Freestall	0.3	0.2
Loose Housing	1.1	---

0.6 ft^3 per cow is a good guide

Table 3. Wastewater

# Milking Cows	**gal / cow / d**	**ft^3**
0 - 50	5 - 8	0.6 - 1.0
50 - 100	4 - 6	0.5 - 0.8
150 +	2 - 4	0.2 - 0.5

1 ft^3 = 7.48 Gallons

A number of manure handling systems are utilized in dairy production. For tiestall barns, manure is collected in gutters behind the cows and removed from the barn as a solid material by a barn cleaner. Outside of the barn, the barn cleaner places the manure on a storage stack or directly into a manure spreader.

Skidsteer loading a manure spreader

There are three types of manure handling systems used for freestall barns:

1. Manual scraping,
2. Flush systems, and
3. Automatic alley scrapers.


Flush systems work very well

Some freestall barns use slotted concrete floors above a pit, but these are quite rare in the U.S. With manual scrape systems, manure is scraped to the end of the barns by a skidsteer or mechanical loader with a scraping attachment. The manure is either stored temporarily in a solid stack, or loaded directly onto a manure spreader. Some barns are equipped with a freestall alleyway that is flushed with recycled wastewater to convey the manure to a storage pit or lagoon. Mechanical alley scrapers consist of a hinged v-shaped plough driven by a cable or chain. The plough is continuously or periodically dragged forward to draw manure to the end of an alley. When being pulled, the plough's blade splays across the entire alley between two curbs. After completing a pass, the chain or cable reverses direction and pulls the plough backward as the plough's blades fold together so as not to pull manure the opposite direction. Flush systems are comprised of a tank that delivers copious amounts of water to flush all manure off the alleys. Provided there is adequate slope along the channel and adequate water pressure from the tank, flush systems work very well. However, some concerns have been raised that a number of bacterial pathogens may be circulated through the barn by flush systems.

Frequently manure from the freestall barn is stored temporarily in a storage pit and combined with more dilute waste from the milking parlor. Milking parlor waste often contains very little manure, but does have much residual milk from cleaning and may have various cleaning products as well. Manure from pits is agitated and then loaded onto a slurry wagon for application onto cropland, often with direct incorporation into the soil.


Storage Containers
Source: Al Sutton, Purdue University

Effluent drips down for collection

Collection pits may also be used when solids are to be separated from the liquid portion of the manure. Solid separation can be mechanical, in which the liquid portion of the manure is squeezed though a screen. This provides a relatively dry solid that may be composted and perhaps even reused as a bedding material after drying. Sloped screen separators work by trickling the manure over a sloped screen so that the effluent drips through the screen with the solids sliding down for collection. Other mechanical separators draw an apron across the manure to force it across a screen. Concrete pit separators work by using a porous "weeping wall" in which the effluent is allowed to weep through the slots between boards or screens while the solids are retained. The solids then can then be removed as a semi-solid from the concrete pits. Composting is another option for solid manure management.

With sloping screen separators or other mechanical methods, the effluent may go into a settling pond to settle out even more solids before the effluent enters the lagoon. Many lagoons have been constructed with clay or compactible soil. In sandy or lighter soils, dairies must line the lagoons with compacted clay or synthetic liners.

Settling Pond

Recently, there has been much interest expressed in developing technology to utilize methane produced by anaerobic digestion of manure . As cost of the technology declines and pressure to manage manure and control odors on larger farm units increases, this technology will become more common. On some very large farms, these systems are used to generate electricity and hot water for the farm. Some are able to to sell electricity back into the grid through their local cooperatives. Cost of this technology remains too expensive for all but the largest producers at this time. Furthermore, anaerobic digestion should be viewed as a value-added process, but not as a solution to nutrient management difficulties, since nitrogen, phosphorus, and potassium remain in the effluent following digestion. Advantages appear to be in reduced energy costs, potentially reduced odors, and a more stable manure slurry.

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Dairy Production Study Questions

Identify the definition that best fits the following terms:

1. **Heifer**

- A female bovine that has not borne a calf
- An adult male bovine, normally used for breeding
- A really long time
- A type of silo unloader

Feedback

2. **Holstein**

- An older cow that is pregnant
- A full mug of beer
- A cow of the most common breed of dairy cattle
- A brown beef bull

Feedback

3. **Freestall**

- Complimentary room at the rural motel
- Feeding program for high producing cows
- A housing arrangement where cows can move freely between their feeding area and resting areas.
- A calf's hesitation when it is first removed from its hutch

Feedback

4. **Leading Dairy Producing States**

- Wisconsin, Texas, Indiana, North Carolina, Michigan
- California, Wisconsin, New York, Pennsylvania, Minnesota
- California, Idaho, Washington, New Mexico, Nevada
- Michigan, Ohio, Indiana, Illinois, California
- California, Wisconsin, New York, Pennsylvania, Indiana

Feedback

5. **Pasteurization**

- Process to make penicillin
- Removing cream from the skim milk
- Rapidly heating milk to 72 - 75 °C for 15 to 20 seconds, and then quickly cooling to slow growth of bacteria
- Managed intensive grazing of cows
- Boiling the milk to sterilize it

Feedback

6. **Whey**

- Juice that seeps from a silo when wheat silage is harvested and stored
- Portion of cream remaining after butter is made
- Oil used on clippers to trim hair from cows' udders
- Portion of milk remaining after cheese curd is removed
- Sarcastic response to someone who says "No way!"

Feedback

7. **Guernsey**

- A red and white to mostly red breed of cattle that are known for the yellow color of their milk.
- A famous garden seed company
- A type of portable shelter used where calves are kept when placed on pasture land
- A bracket for a milk pipeline
- A mostly black breed of cow with a belt white hair around its belly

Feedback

8. **Dry Cow**

- A martini made with milk and non-sweet vermouth
- A cow that is not producing milk prior to second or subsequent calving
- A cow with a very mildly humorous personality
- An indication of inadequate water intake
- The weight of a cow after the weight of water is discounted

Feedback

9. **Calf Hutch**

- A small, outdoor, individual housing unit for a calf
- A cabinet for calf medicine
- A disease of the calf's navel, sometimes called "navel ill"

- The most popular brand of calf milk replacer
- Calf Starsky's partner

Feedback

10. **Estrus**

- An indication that the cow is ready to be bred
- A type of grain fed to bulls
- The process of removing calves from the cow
- A hook used to hold rafters together
- An important religious holiday

Feedback

11. **Bedding**

- A cow blanket
- Sand, bare concrete, dirt
- Silage, soybean meal, feather meal
- Cotton seed, hay, tallow
- Sand, straw, newspaper, wood shavings

Feedback

12. **Total Mixed Ration**

- A feeding system where all feeds are blended together
- A feeding system where the cow is fed a single, but different, feed everyday
- A kind of cereal fed to cows
- A feeding system that allows the same feed to be fed to calves, heifers, and cows
- Limit feeding cows

Feedback

13. **Rumen**

- A chocolate brown breed of dairy cattle
- An additive in feed to prevent hardware disease
- A common antibiotic
- The largest compartment of a cow's "stomach"
- The act of renting a farm

Feedback

14. **Parallel Parlor**

- A long narrow room in the dairy farm office to receive sales persons
- A milking system in which cows stand side by side and milked from between the rear legs
- Two herringbone parlors set up side by side
- A completely automatic milking system
- The area just behind a cow's flank

Feedback

15. **Mastitis**

- Rigging in a ship's sail
- A breed of very large dogs
- Inflammation of the udder
- A swelling under the cow's jaw
- A young male calf

Feedback

See Results RESET

Score in Percentage:	

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National Agriculture Compliance Assistance Center (Ag Center)

Dairy Glossary

Acid Rinse - Part of the equipment cleaning process for stainless steel and rubber parts, removes fat, protein and minerals and also reduces bacteria. (See Equipment Sanitization)

Acute - Used to describe disease where symptoms are readily evident. Treatment is generally required.

Alley - A walking area for cattle within a barn such as a loafing alley, feeding alley or cross alley (walkway) from a barn to the milking parlor.

Alley Scraper - A "V" shaped mechanical blade that is dragged over an alley by chain or cable to pull manure to collection channel at the end of the alley (or possibly the center of the barn). The blade then collapses and is drawn back to the opposite end of the alley.

Antibiotic - A metabolic product of one microorganism or a chemical that in low concentrations is detrimental to activities of specific other microorganisms. Examples include penicillin, tetracycline, and streptomycin. Not effective against viruses. A drug that kills microorganisms that cause mastitis or other infectious disease.

Antibiotic Residues - The presence of traces of antibiotics or their derivatives in milk or meat.

Antibiotic Test Kit - Test kit for use on the farm to detect residues of antibiotics in milk before the milk is picked up for delivery to the plant.

Automatic Detacher or Automatic Take-off - A device for sensing the end of milk flow in the milking machine which shuts of the milking vacuum and releases the milking machine from the cow's udder.

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Barn Cleaner - Usually a chain linked system of paddles that moved manure from gutters, up a chute, into a waiting manure spreader. Most often seen in tie-stall or stanchion barns.

Bedded Pack - Open housing in a barn that is commonly used in conjunction with an outside feeding area.

Bedding - Material used to absorb moisture and provide cushion. It is easily cleaned to provide a clean, dry surface and reduce the incidence of mastitis. Possible bedding materials include: straw, sawdust, wood chips, sand, ground limestone, separated manure solids, shredded newspaper, corn stalks, bark, peanut hulls, sunflower hulls and rice hulls.

Biosecurity - Any of a broad range of practices enforced at a dairy farm to prevent transmittal of pathogens from other sources by feed, cattle, people, or other animals.

Blind Quarter - A quarter of an udder that does not secrete milk or one that has an obstruction in the teat that prevents the removal of milk. A nonfunctional mammary gland.

Bovine - Refers to cattle or oxen.

Brisket Board - A raised part of the freestall platform about 6.5 feet in front of rear of the stall to keep cows positioned properly while lying. Usually made of wood or plastic, but occasionally concrete.

Broken Udder - Term used to describe an udder that is loosely attached or pendulous.

Bucket Milking System - A system in which the milk coming from the cow is drawn into a bucket or pail and manually transferred to a collection area or the milk house.

Bull - A sexually mature, uncastrated bovine male.

Bulk Tank - A refrigerated, stainless steel vessel in which milk is cooled quickly to 2 to 4°C (35 - 39°F) and stored until collected by a bulk tank truck for shipping to the milk plant.

Bunk - A feed trough or feeding station for cattle.

Feed Bunk

Bunker - (Sometimes called Bunker Silo) A flat rectangular structure with concrete floors and walls used to ensile and store forages.


Bunker Silo


Bunker Silo

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Calf - A young male or female bovine. Usually referred to as calves until reaching sexual maturity.

Cannula - A special tube designed for placing drugs into the udder through the teat end and [streak canal](#).

Chalk Sticks - Used to mark treated, fresh, or special-needs cows.

Cheese Curd - The clumps of casein and other milk components that are formed during the cheese making process. These curds are then pressed into blocks or barrels for proper aging and curing of the cheese.

Churning - The process of stirring and agitating cream in the process of making butter. Churning causes the fat globules in cream to clump together and separate from the liquid.

Chronic - Used to describe recurring symptoms or disease.

Clinical - Symptoms are present, supportive therapy or treatment is necessary.

Colostrum - First milk following calving. High in fat, protein, and immunoglobulins that may be directly absorbed by the newborn calf in its first 24 hours of life.

Commodity Storage - Usually a steel framed shed that provides storage for commodity feeds, such as cottonseed, brewers grains, chopped hay, etc.

Commodity Barn

Composting Pad - A concrete or hard packed surface that provides an area on which manure and discarded feed may be composted with ready access to aerate the composting materials.

Concentrates - High energy or high protein feeds consisting primarily of the seed of the plant, but with out stems and leaves.

Conformation - The body form or physical traits of an animal or parts of the animal in the case of udder conformation.

Contagious - Disease that can be passed from one cow to another through a number of possible ways.

Corn Belt - The area of the United States where corn is a principal cash crop, including Iowa, Indiana, most of Illinois, and parts of Kansas, Missouri, Nebraska, South Dakota, Minnesota, Ohio, and Wisconsin.

Cow - A mature female bovine. Usually referring to any dairy females that have borne a calf. Some may consider females having given birth only once as "first-calf heifers" until they have a second calf.

Cow Trainer - A tin or wire structure supported a few inches above a cow to prevent her from soiling the platform of her stall by administering a gentle electric shock if she arches her back to urinate or defecate while too far forward in the stall.

Coverall - A brand name, but commonly referring to any of a group of hoop type barns with opaque or mylar fabric covers over a tubular steel frame.

Crate - An elevated stall for a calf in an indoor facility.

Crowd Gate - A motorized or manual gate at the end of the holding pen that may be moved forward to guide cows toward the entrance to the milking parlor.

Cull - To remove a cow from the herd. Culling reasons in clued voluntary culling of cows for low milk production, or involuntary culling of cows for reasons of health or injury.

Cull Cow - A cow having been identified to be removed from the herd or having recently left.

Culture - In microbiology, a population of microorganisms in a growth medium or the act of growing bacteria in media for identification. A pure culture contains only organisms that initially arose from a single cell. Cultures are used in manufacturing cultured dairy products and most cheeses.

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Dairy Cow - A bovine from which milk production is intended for human consumption, or is kept for raising replacement dairy heifers.

Dairy Herd Improvement (DHI) - A specific testing plan which requires supervision and compliance with all official DHI rules.

Dairy Herd Improvement Association (DHIA) - An organization with programs and objectives intended to improve the production and profitability of dairy farming. Aids farmers in keeping milk production and management records.

Dairy Herd Improvement Registry (DHIR) - A modification of the DHIA program to make milk production records acceptable by the specific dairy breed associations.

DHI Records - Generic term used to refer to records computed by the Dairy Record Processing Centers.

DHI Supervisor - An officially trained and DHIA-certified employee qualified to collect milk samples and record milk weights on the farm for all official types of testing plans.

Dairy Steer - A neutered male of any of the dairy cattle breeds. The "dairy steers" are raised for meat production and usually managed like beef cattle.

Dam - Mother or female parent in a pedigree.

Denitrification - The biochemical reduction of nitrate or nitrite to gaseous nitrogen, either as molecular nitrogen or as an oxide of nitrogen.

Direct Microscopic Somatic Cell Count (DMSCC) - Microscopic count of the actual number of somatic cells in milk. This system is used to check and verify electronic cell count machines used in DHI laboratories.

Dock - To remove a cow's tail. This practice may keep cows udders cleaner, but may also result in cows being less content, especially in fly season.

Downer Cow - A cow unable to arise due to disease or injury.

Dry Cow - A cow that is not lactating or secreting milk after it has completed a lactation period following calving.

Dry Lot - An open lot that may be covered with concrete, but that has no vegetative cover. Generally used as exercise areas in most of US, but may be used as primary cow housing in the more arid climates.

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Edema - The presence of abnormally large amounts of fluid in the intercellular tissue spaces of the body, as in a swelling of mammary glands commonly accompanying the initiation of the birthing process in many farm animals.

Electronic Feeders - Stations in which cows are fed specified amounts of feed by a computer that recognizes their unique electronic identification transponders.

Environmental - Derived from the animal's environment, bedding, housing, etc.

Equipment Sanitization - The removal of microorganisms and fat, protein, and mineral residues in milking equipment through use of water, heat, and chemicals.

Extra-Label Drug Use - An antibiotic or other chemical used on the advice of a veterinarian in a dosage, route of administration, for a different disease or in some other manner not included on the approved printed package label.

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Fibrosis (fibrotic) - Of a condition marked by the presence of interstitial fibrous tissue, especially in the mammary gland resulting from mastitis.

Flat Barn - An area for milking cattle where the person milking is on the same level as the cow. May be used with a pipeline or bucket milking system. Generally the same area is used for cow housing.

Flush System - A manure removal system in which an area is cleaned by high volumes of fresh water, or gray water that is recycled from a manure pit or lagoon.

Food and Drug Administration (FDA) - An agency of the U.S. Government responsible for the safety of the human food supply.

Footbath - A long shallow tub or depression in the concrete where cows walk through a mild solution (usually including copper sulfate or formalin) to promote foot health. Usually located along an alley where cows return from the milking parlor.

Forage - Feedstuffs composed primarily of the whole plant, including stems and leaves.

Forestripping - Expressing streams of milk from the teat prior to machine milking to determine visual quality and to stimulate "milk letdown."

Forequarters - The two front quarters of a cow. Also called the fore udder.

Freestalls - Resting cubicles or "beds" in which dairy cows are free to enter and leave, as opposed to being confined in stanchions or pens.

Drive-through Freestall Barn
Source: Stacy Nichols, Land O'Lakes

Fresh Cow - A cow that has recently given birth to a calf.

Fresh Milk - Dairy products having original qualities unimpaired and those recently produced or processed.

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Garget - A common term for an inflammation of the udder of the cow or the resulting abnormal milk. More accurately referred to as mastitis.

Germicidal - A substance that has the ability to kill germs.

Gray Water - Water that is considered waste and not to be used for cleaning milking systems. Usually including recycled water from a lagoon or milk house waste. Even water only used to cool milk in a plate cooler is considered gray water, though it is often fed to cows to reduce total usage.

Greenhouse Barn - Commonly referring to any of a group of hoop type barns with translucent or plastic covers over a tubular steel frame.

Grooved Concrete - Floor surfaces with grooved patterns cut or depressed into concrete to provide better traction for cattle.

Gutter - A shallow to deep channel located behind cows in tiestall barns capture manure and urine.

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Handlers - Processors or dealers of milk who commonly purchase raw milk and sell pasteurized milk and milk products.

Hand Milking - The manual milking of an animal as opposed to the use of mechanical milking devices.

Source: Genex, CRI

Harvestore Silo - A brand of oxygen limiting (air tight) upright silos with bottom unloading.

Hay - Dried feed consisting of the entire plant. Alfalfa, clover, grass, and oat hay are used in dairy rations.

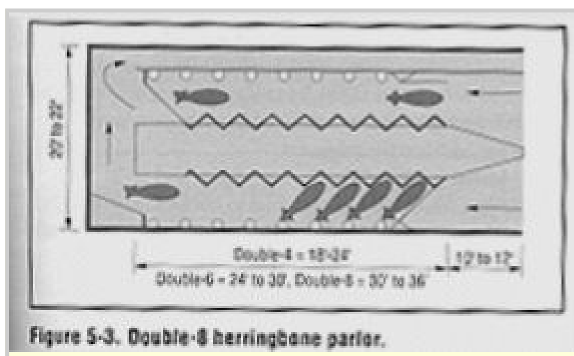
Headlocks - Self-locking [stanchions](#) along a feed alley in which cows voluntarily enter the head slot when going to eat. All cows may be held until herd health work is completed, and then all cows may be simultaneously released. Headlocks may be adjusted to remain open, allowing cows to come an go at will, when restraining the cows is not necessary.

Heifer - A bovine female less than three years of age who has not borne a calf. Young cows with their first calves are often called first-calf heifers.

Herd - A group of animals (especially cattle), collectively considered as a unit.

Herringbone Parlor - A milking parlor in which cows stand side-by-side, angled towards the pit. This allows milking from the side of the udder.

Herringbone Parlor
Source: Midwest Plan Service



Herringbone Parlor
Source: Midwest Plan Service

Holding Pen - An area in which cows congregate prior to entering a milking parlor to be milked.

Hot Quarter - A quarter of the udder that is infected and may actually feel hard or hot to the touch due to elevated temperatures.

Hutch - An individual housing unit for young calves. Often made of white fiberglass or polyvinyl.

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Immunity - The power an animal has to resist and/or overcome an infection to which most of its species are susceptible. Active immunity is due to the presence of antibodies formed by an animal in response to previous exposure to the disease or through live or modified-live vaccines. Passive immunity is produced by giving the animal preformed or synthetic antibodies as with killed vaccines.

Inflammation - Swelling caused by the accumulation of lymph and blood cells at the site of infection or injury.

Inorganic - Not capable of sustaining life. Often refers to dirt or soil.

Intramuscular - Injections given in the muscle.

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Lactate - To secrete or produce milk.

Lagoon - An earthen pond used as a primary storage site for manure.

Leg Bands - Cloth or plastic strips of a bright color used for marking treated cows, fresh cows, or cows needing special handling.

Legume - Any of thousands of plant species that have seed pods that split along both sides when ripe. Some of the more common legumes used for human consumption are beans, lentils, peanuts, peas, and soybeans. Others, such as clover and alfalfa, are used as animal feed. Legumes have a unique ability to obtain much or all of their nitrogen requirements from symbiotic nitrogen fixation.

Letdown - The process in a cow where physical stimulation causes a release of oxytocin and the contraction of smooth muscles surrounding milk alveoli resulting in fluid pressure within the udder and milk flow.

Liner - A flexible sleeve in the milking teat cup or rigid-walled liner holder. Responsible for massaging the teat end and intermittently cutting vacuum at the teat end during milking. Also called an inflation.

Liner Slips or Squawks - Slippage of the liner and teat cup during milking. Caused by a sharp change of milking vacuum within the unit or cluster by drawing in air alongside the teat. Generally creates a "squawking" sound.

Loose Housing - Facilities that allow cattle access to a large, open bedded area for resting (also known as free housing). Loose housing should provide at least 200 square feet per animal for feeding and resting (freestall housing uses only 90 square feet per animal). (See Open Barns)

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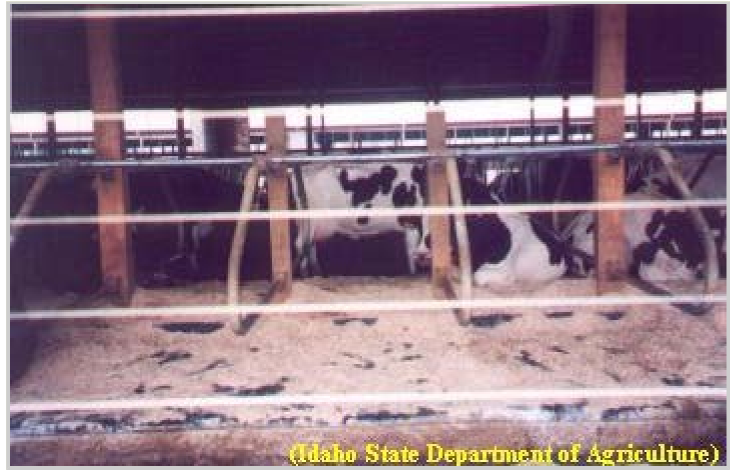
Mastitis - An inflammation of the mammary gland (or glands), usually caused by bacteria.

Maternity Barn - A special needs facility where cows can be closely monitored during the period immediately before and after they give birth.

Mattress - Bedding material compacted to 3 to 4 inches and sandwiched in a heavyweight polypropolene or other fabric. Possible fillers include: long or chopped straw, poor quality hay, sawdust, shavings, rice hulls and, most commonly, shredded rubber.



Milk Handlers - Processors or dealers of milk who commonly purchase raw milk and sell pasteurized milk and milk products.

Milk House - The area near a milking parlor where the bulk milk tank, cleaning units, and equipment are located.

Milk House Waste - Water having been used in cleaning the milking equipment and washing the parlor.

Milking Pit - A sunken area that houses both the milker and some milking equipment during milking. This places the milker at shoulder level with udders and reduces physical demands.

Mycoplasma - An organism capable of causing mastitis.

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Nitrification - The biochemical oxidation of ammonium to nitrate, predominantly by autotrophic bacteria.

Non-Return Dip Cup - A dip cup that does not allow the liquid to reenter and potentially contaminate the storage container.

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Open Barns/Tromp Sheds/Loose Housing - Open spaced shelter in which cattle are free to move about or rest wherever they might prefer, usually on a pack of bedding and manure. Organic - A substance that contains carbon and capable of sustaining life.

Organic Material - Substances containing plant or animal substance. In the context of milking equipment this usually refers to manure.

Over the Counter Drugs - Medications available without prescription.

Oxytocin - A naturally secreted hormone that is important in milk letdown and the contraction of the smooth uterine muscles during the birthing process.

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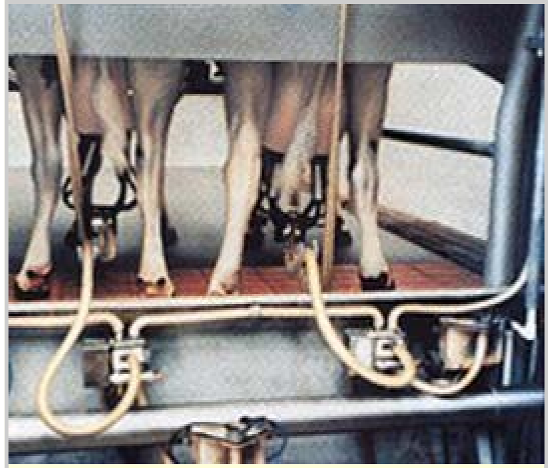
Paddocks - Subdivision of a pasture designed to provide short-duration grazing followed by an appropriate (related to species, soil type and weather conditions) rest period for regrowth and stand maintenance.

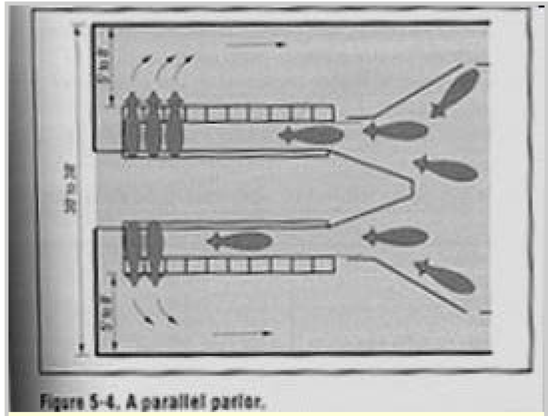
Paint Sticks - Contain liquid or chalky paint used for marking treated cows.

Parakeratosis - Any abnormality of the horny layer of the outer skin which prevents the formation of keratin.

Parallel Parlor- A raised milking area or platform where the cow stands perpendicular to the operator and milking units are attached between the rear legs. This may also be referred to as a side-by-side.



Parallel Parlors
Source: Midwest Plan Service



Parallel Parlors
Source: Midwest Plan Service

Parlor - The specialized area on the dairy farm where milking is performed. Parlors come in many types:

- Flat Barn,
- Walk-through,
- Herringbone,
- Parallel,
- Swing and
- Rotary.

Pasture - Plants, such as grass, grown for feeding or grazing animals. Also serves as a place to feed cattle and other livestock.

Pathogen - Any microorganism that produces disease (bacteria, viruses, yeasts, molds and parasites).

Pendulous Udder - A loosely attached udder.

Pipeline - A stainless steel or glass pipe used for transporting milk.

Pit - A contained unit usually with concrete walls in which liquid or semi-liquid manure is stored.

Plate Cooler - A heat exchanger in which water at ground temperature or chilled water is used to cool milk prior to its movement to the bulk milk tank.

Post-Milking Teat Dip - A product applied after milking to protect the teat from contagious pathogens that may have come into contact with the teat during the milking process.

Pre-Milking Teat Dip - A product applied in preparation for milking to clean the teat and reduce the spread of disease and maintain healthy teats.

Prescription Drugs - Drugs that the FDA has determined must be used only under the direction and supervision of a licensed veterinarian.

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Rapid Exit - Panels or rails that raise to release all cows on one side of the milking parlor at once.

Replacements Heifers - Often ones being raised to replace the cows currently in the herd.

Return Alley - The alley through which cows must pass when moving from the milking parlor back to the cow housing area after milking.

Ring Feeder - A steel hoop with individual head gates that may be placed over a large round bale of hay when feeding it.

Robotic Parlor - A completely automated system for milking cows that requires limited human contact.

Rotary Parlor - A raised, round rotating platform or carousel on which cows ride while being milked.

Rotary Parlor

Ruminant - Animals having four stomach compartments - rumen, reticulum, omasum and abomasums - through which food passes in digestion. These animals chew their cud or regurgitate partially digested food for further breakdown in the mouth. Ruminant animals include cattle, sheep, goats, deer and camels.

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Sand Separator - A mechanical device or series of course ways used to settle sand from sand-laden manure.

Scrape-and-Haul - Manure handling system in which manure is scrape manually or with a skidloader, placed in a solid manure spreader and directly applied to appropriate crop land.

Sensitivity Tests - Tests used to determine the most effective method of treatment of disease by testing the resistance of the microorganism to classes of antibiotics.

Separator -

1. Formerly a centrifuge device used to remove the fat from milk on the farm, but now used primarily at processing plants.
2. A device used to separate manure into solids and effluent and accomplished by trickling manure over a sloped screen or mechanically forcing through a screen.

Settling Pond - A manure pit where the flow rate of liquid manure is slowed to allow suspended materials to collect at the bottomed, where they can later be removed.

Silage - A feed prepared by chopping green forage (e.g. grass, legumes, field corn) and placing the material in a structure or container designed to exclude air. The material then undergoes fermentation, retarding spoilage. Silage has a water content of between 60 and 80%.

Silage Bags - Large plastic tubes in which forages are fermented. Plastic is removed and discarded as the ensiled feed is fed.

Silo - A storage facility for silage. Usually referring to upright concrete or fiberglass silos.

Sire - Father or male parent in a pedigree.

Slotted Floor - A concrete floor design in which slats are positioned in the floor so that cow traffic may work manure through the slats and into a pit beneath the floor of the barn.

Somatic cell count (SCC) - The number of white blood cells per milliliter of milk or measurement of the number of somatic cells present in a sample of milk. A high concentration of more than 500,000 somatic cells per milliliter of milk indicates abnormal condition in the udder. This serves as an indicator of mastitis infection when elevated above 200,000.

Somatic Cell Score - A logarithmic representation of the SCC, often referred to as linear scores because they are linearly related to milk production loss.

Somatic Cells - The combination of the leukocytes (white blood cells) from blood and the epithelial cells from the secretory tissue of the udder which indicate the presence of infection or injury in the animal.

Sphincter - A ring-shaped muscle that allows an opening to close tightly, such as the sphincter muscle in the lower end of a cow's teat.

Stall - A cow housing cubicle.

Stanchion - a device with two rails that was closed around a cows neck after she entered a stall and to keep her restrained in the stall.

Step-Up Parlor - Cows step onto raised platforms for milking. The milking units are attached from the side.

Sterile - Clean, free of any living organisms. Also means unable to reproduce.

Streak canal - Small canal located in the end of each teat, through which the milk passes immediately prior to expulsion. Also called the teat meatus.

Strip Cup - A small cup or device to collect forestrippings and which makes abnormal milk easier to observe.

Subclinical - A disease condition without symptoms but often resulting in decreased production or impaired milk quality.

Subcutaneous - Under the skin.

Subway - An area beneath the milking pit that houses milk meters, pipelines, vacuum lines and transfer tanks to reduce noise and improve the milker's ability to move around in the pit.

Superhutches - Calf housing structures, often open on one side, designed for a small number of calves when first grouped immediately after weaning.

Swing Parlor - Parlor characterized by having the milking units positioned in the middle of the parlor for use by cows on both sides.

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Tail Bands - Used for marking treated cows. Rubber bands are sometimes used to dock cow's tails.

Tandem Parlor - Parlor design where cows line up head to tail in individually opening stalls.

Teat - The appendage on the udder through which milk from the udder flows.

Teat Dip - Pre and Post-milking - Substance that kills bacteria and helps to seal the teat end to prevent entry of bacteria into the udder between milkings. May contain emollients to improve teat end condition for use in cold, winter conditions.

Teat Sealant - A product that forms a mechanical barrier on the teat end to protect the teat. Generally used at dry-off after antibiotic infusion.

10 Point Milk and Dairy Beef Residue Prevention Protocol - Designed by veterinarians and milk producer organizations to avoid contamination of milk with antibiotics. It identifies the 10 points in milk production where milk is at greatest risk for antibiotic contamination of milk.

Throughput - The number of cows that can be milked in a parlor in a given period of time.

Tie Stall Parlor - Facility is frequently used for both housing and milking. Cows are tied and milked with the cow and operator on the same level.

Total Mixed Ration (TMR) - Ration formulated to meet requirements of the cow in which all of the ingredients are blended together in a mixer.

Toxic - Harmful.

Transition Cow - A cow that is from 2 months before 1 month after expected calving date.

Transition Housing - Barns designed especially for transition cows, often including a maternity area.

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Udder - The encased group of mammary glands provided with teats or nipples as in a cow, ewe, mare or sow. Also referred to as a bag.

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Veal - A calf (usually male) that is raised on milk and is intended to be used for meat at a young age. Veal meat is served at many restaurants and is very popular in cultural cuisine.

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Walk-Through Parlor - Upon completion of milking, cows walk through the front of the stall to exit.

Withdrawal Time - Time required after the last drug treatment to lower drug residues to acceptable levels. These times are established using healthy animals according to label directions. An amount of time required following use of a medication in an animal before milk or meat can be entered into the human food supply. Ensures residues are maintained at levels approved by the USDA.

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Yeast - An organism that can grow and develop in the udder, causing mastitis.

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Links EXIT Disclaimer

- Dairy @ Purdue
- National Biosecurity Resource Center For Animal Health Emergencies
- Moo Milk
- National Dairy Shrine
- World Dairy Expo
- Oklahoma State University Cattle Breeds
- American Dairy Science Association
- National Milk Producers Federation
- Understanding Dairy Markets
- Dairy Management Inc.
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Dairy Production

Dairy production is an important part of American agriculture. Milk and other dairy products remain a staple in the diets of most Americans. In 2000, there were about 90,000 dairy farms in the United States. During the 1980s and 1990s, dairy production markedly shifted from the Midwest and Great Lakes regions to the West.

Modern dairy production is diverse with systems ranging from cows housed indoors year-round to cows maintained on pasture nearly year-round. Expansion to larger herd sizes has allowed producers to increase the efficiency of production and capitalize on economies of scale, but it has resulted in environmental challenges with larger numbers of cattle and more manure concentrated in smaller areas.

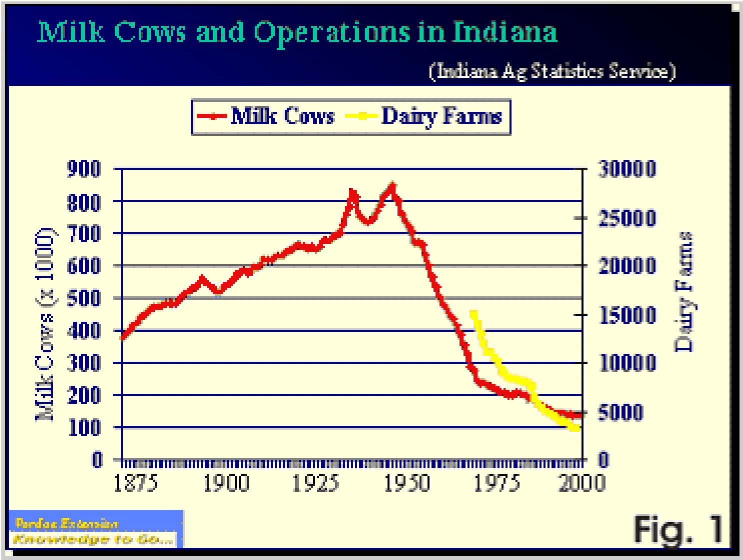
This module will look at dairy production as it has evolved in the U.S., the array of dairy products available, dairy production systems, milking systems, and typical manure handling systems in use today.

All photos are from M. Schutz, Purdue University unless otherwise noted.

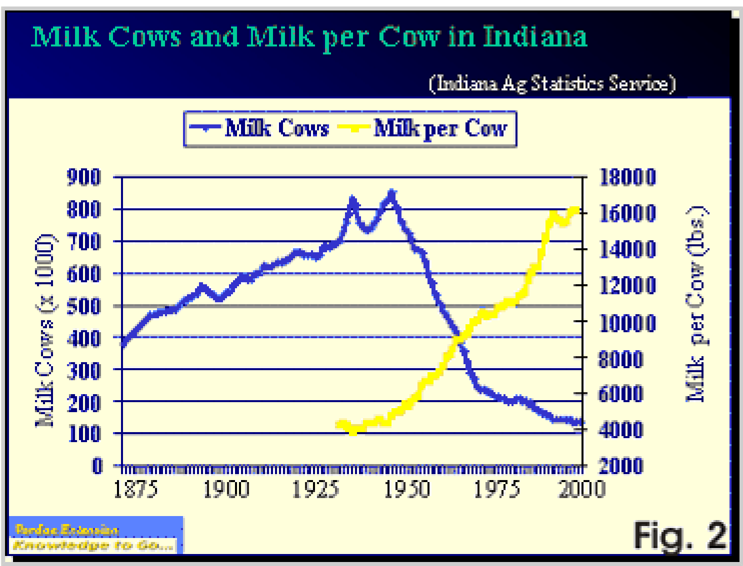
Background of Dairy Production in the U.S.

The first cattle in the western hemisphere arrived with Christopher Columbus on his second voyage. Other cows began to arrive along with settlers from Europe and followed the pioneers westward. Until the mid 1850s, the dairy industry in America revolved around the family-owned dairy cow, with little sales of milk or other dairy products outside the family. The dairy industry began to change dramatically in the early 1900s, after a series of developments. Principles of bacteriology that led to improved milk quality and safety by Louis Pasteur with the process of pasteurization; development of breed associations that promoted the genetic selection of cows for their ability to produce milk; the Land Grant act of 1862 that established colleges of agriculture to educate farmers in the scientific principles of breeding, feeding, and management; the centrifugal separator that allowed milk fat to be removed and allowed the manufacture of more products; determination of milk fat content by the Babcock test (named for Professor S. M. Babcock of the University of Wisconsin); and tuberculin testing of dairy herds that eliminated milk as a source of tuberculosis all played a role in the growth of U.S. dairy production.

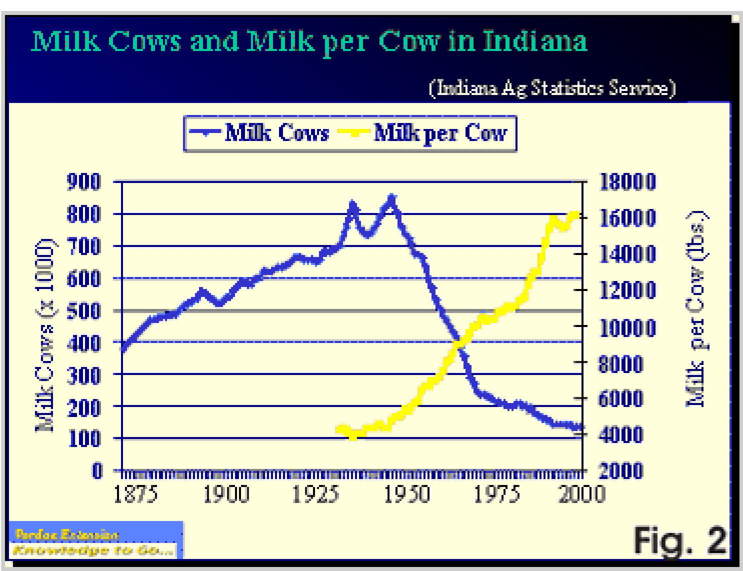
As the dairy industry grew in the first half of the Twentieth Century, the largest numbers of cows and dairy herds were located in the Great Lakes region of the U.S. This area



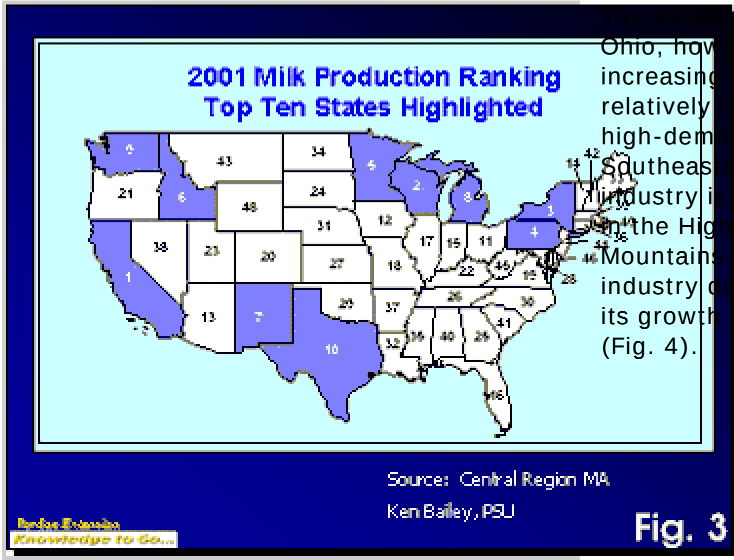
was very suitable for pasturing cattle and for producing forages which could be stored as winter feed. It was also conveniently situated near the population centers of the U.S. at that time. The location of farms near the point of use was critical since milk is a highly perishable commodity and modern refrigeration and transportation systems were not yet available. Thus, milk was bottled at the farm or taken to a local creamery and delivered to stores and households daily. Cows and farms reached peak numbers in the 1940s, when rural electrification allowed for the rapid cooling and on farm bulk storage of milk and allowed it to be transported over longer distances to markets. This allowed dairy production to become more concentrated. Cow numbers and dairy farm numbers for Indiana, which is typical of states in the Great Lakes region are in Fig. 1.



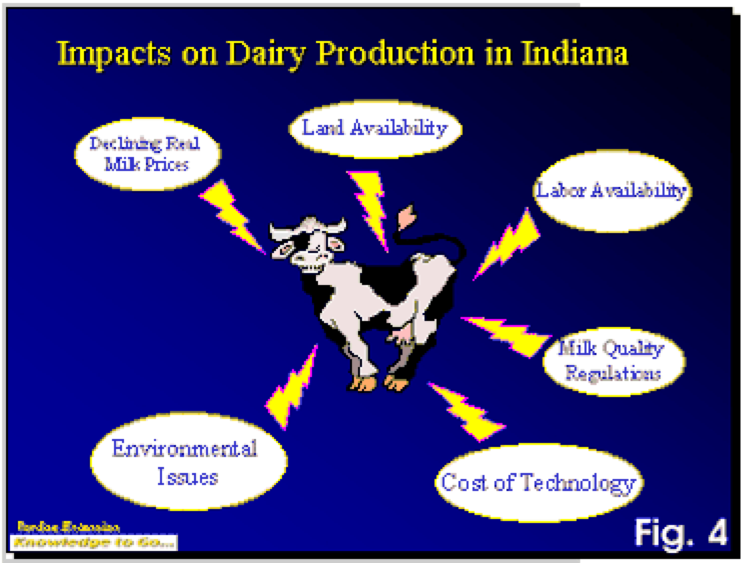
The concentration of more cows on fewer farms was accompanied by dramatic increases in production per cow (Fig. 2), arising from improved genetic selection, feeds, health care, and management techniques. Better roads enhanced the ability to transport milk to processing plants, improvements in housing and environment to keep cows more comfortable, less competition for alternative land uses, and the ability to raise feed under irrigation has led to a shift in dairy production to Western states. California surpassed Wisconsin in milk produced in 1993 and in number of dairy cows in 1998.



Presently, there are about 9 million dairy cows on 900,000 farms in the U.S. California, Wisconsin, New York, Pennsylvania, and Idaho are the leading dairy producing states (Fig. 3). Production continues to increase in Idaho, New Mexico and California, while it is declining in most of the Midwest and Northeast. In the upper Midwest, dairy farms have been discontinuing production at the rate of more than three per day over the past five years.



The tri-state region of Indiana, Michigan, and Ohio, however, appear to be maintaining or increasing cow numbers, as the industry reacts to relatively inexpensive feed costs and access to the high-demand markets for fluid milk in the Southeastern U.S. Continued growth of the industry is expected in the Eastern Corn Belt and in the High Plains, just east of the Rocky Mountains. External pressures on the dairy industry due to environmental concerns will limit its growth in some areas or force farms to relocate (Fig. 4).



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Dairy Products

- Fluid Milk
- Egg Nog
- Cheese
- Butter
- Yogurt
- Ice Cream
- Powdered Milk
- Whey Powder
- Butter Powder
- Meat
- Leather goods
- Fertilizers
- Cosmetics

A trip to the grocery store's dairy case shows the variety of products resulting from the milk. Fluid milk is available in several varieties - Skim Milk (0% fat), 1%, 2%, and Whole (approximately

3.5%). Raw milk is separated into skim milk and cream, and then re-blended to a standard fat content for each product. Because cows' milk averages more than 3.5% fat, the extra cream is used to make other liquid products like whipping cream, half and half, and eggnog or it is manufactured into butter or ice cream. Fluid milk in the U.S. is pasteurized (milk is pasteurized by rapidly heating it to 72 - 75 °C for 15 to 20 seconds, and then quickly cooling) to kill potentially harmful bacteria. Fluid milk is also homogenized (fat droplets are dispersed so they do not float to the top) and is fortified with vitamins A and D, which along with the absorbable calcium naturally in milk are needed for strong healthy bones and teeth. Over the most recent two decades, fluid milk consumption per capita has declined, and sales of low-fat milk have increased relative to whole milk. Recent innovative marketing of convenient single servings of milk and introduction of a wide variety of milk flavors have increased sales of individual servings.

Following the increased health consciousness of U.S. consumers in the late 1980s and 1990s, there was a period of decreased sales of butter, which is made by churning the cream portion of milk. However, sales have increased recently, as have sales of other high-fat products, such as premium ice cream and full-fat cheese. Cheese, which is made primarily from the protein (casein) portion of milk, also contains butterfat and currently accounts for a large percentage of dairy product demand and consumption. Per capita consumption of cheese consistently increases from year to year in the U.S. and is largely driven by demand for fast food and pizza. While demand for buttermilk (the portion of cream remaining after butter is churned out) and whey (the portion of milk remaining after cheese curd is removed) are negligible, the dried-powdered forms of these products are used as additives in the baking, candy, sport-drink, and animal feed industries. Whey powder also forms the basis for many brands of calf milk-replacers.

Health conscious consumers have also begun to purchase more yogurt relative to ice cream, and numerous low fat frozen deserts are available in grocery stores. Furthermore, milk is used directly in baked goods, candy and other ready to eat foods, like sauces and salad dressings.

In many states, the sales of meat from cull cows and bull calves that are raised as veal or dairy steers account for a significant portion of total beef production. Most cull cows, because they are older and produce less tender cuts of meat, are utilized for production of ground beef. Dairy veal and dairy steers are sold in similar markets and under identical USDA grading systems to more traditional beef breed steers. Byproducts of dairy beef production include leather, fertilizer, cosmetics, glue, and pharmaceuticals.

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Dairy Production Systems

In the U.S., milk comes from breeds of cattle genetically selected for milk production. At one time in the U.S., cattle were selected simultaneously for beef and milk production. This is still the case in many parts of the world. The common dairy breeds in the U.S. today have been selected almost exclusively for milk production for many generations.

Black and White Holstein

Source: USDA - ARC

Black and white Holstein cows make up over 90% of the U.S. dairy herd. Some Holsteins are red and white, but, aside from color, indistinguishable from black and white Holsteins. The U.S. Holstein is well known around the world for her ability to produce large volumes of milk, butterfat and protein. She is a very profitable cow for farmers when large amounts of feed with high levels of grain are available. The U.S. Holstein is relatively new to North America, with the first imports of registered Holsteins arriving in the 1880s. However, the breed has dominated production in the U.S. since the end of World War II, and advances in artificial insemination have increased her popularity in breeding programs around the world largely owing to her advantage in production over all other breeds.

provided by Hoard's Dairyman Jersey

Source: USDA - ARC

The Jersey is the second most popular cow in the U.S. and makes up about 7% of the U.S. dairy herd. She is known for her smaller size (1000 lbs. for a mature Jersey cow versus 1500 lbs. for a mature Holstein cow), higher percentages of fat and protein in her milk, early maturity, and efficiency of milk production. Payment by milk processors to dairy producers based on the content of butterfat and protein in milk has increased the popularity of the Jersey, especially in markets where milk is manufactured into cheese. Other dairy breeds make up only around 2% of the dairy cattle population. These include:

- **Ayrshires** - moderately large cows that are red and white to mahogany and white and are known for producing milk that is quite rich in butterfat and for the conformation of their udders;
- **Brown Swiss** - large brown cattle that are known for their docile manner, high milk protein to milk fat ratio, sound feet and legs, and purported resistance to heat stress in hot and humid regions;
- **Guernseys** - red and white to mostly red and are somewhat larger than Jerseys and are known for the yellow color of the butterfat in their milk, which is rich in Beta-Carotene; and
- **Milking Shorthorns** - a rugged breed of cattle that are red and white to mostly red, mostly white, or roan (speckled) and are known for milk that is well suited for cheese production and for their grazing ability.

More information about the breeds of dairy cattle. EXIT Disclaimer

A few other dairy breeds have become popular more recently. Dutch Belted, Danish Jersey, Normandy, Montbeliarde, Danish Red, British Friesian, and Norwegian Red have gained notoriety for their purported superiority under grazing management (pasture production systems). Many of these breeds have been developed in countries where grazing is widely practiced. Nevertheless, many U.S. dairy producers have good success grazing Holsteins and other traditional U.S. breeds of dairy cattle.

Until recently, very little crossbreeding was practiced in the U.S. Crossbreeding, which refers to mating cows to bulls of a different breed, is gaining in popularity for several reasons. Much of the genetic improvement in Holsteins has been for milk production alone, while other breeds have been selected for other traits like fertility, moderate size, disease resistance, and strength. Thus, crossbreeding allows the breeds to compliment each other's strengths. There is also some level of hybrid vigor expected in the progeny; that is, first generation crosses may be better than the average of the parents.

Grazing versus Intensive Dairy Production Systems

In the United States, most milk is produced by cows raised in intensive production systems. These include tie stall barns, free stall barns, and open lots. The more intensively managed systems feed cows rations that are relatively high in concentrates and stored forages. Other cows are raised in pasture-based systems, which are the primary production system in several dairy producing countries in the world, such as New Zealand. Pasture-based systems often strive to optimize rather than maximize milk production while paying careful attention to controlling input costs. Some producers use a combination of the two systems, which is appealing in that it reduces costs, but still allows the feeding of concentrate to improve milk production levels.

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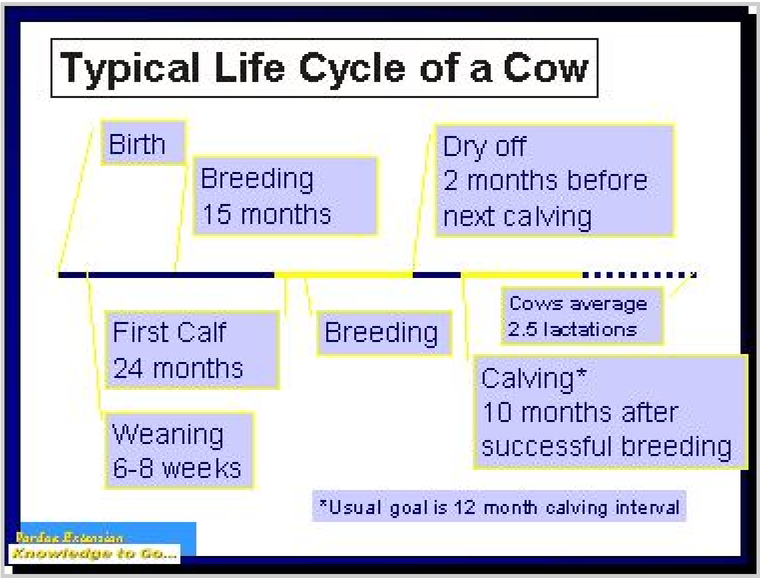
Lifecycle Production Phases

- Calves and Heifers
- Cows
- Typical Herd



A cow typically remains in the dairy herd until about 5 years of age, although many cows are capable of remaining productive in the herd for 12 to 15 years. Following birth, the calf is usually removed from her dam after only a few hours. The newborn calf is fed milk or milk replacer until weaning at 6 to 8 weeks of age. The calf will then be raised until it reaches appropriate breeding weight at about 15 months of age. Heifers are then maintained and continue to grow through their gestation. They usually calve, or give birth, at about 24 months of age. However, they do not reach mature size until at least 4 years of age.

Normally cows begin to produce milk only after calving, but some heifers may be milked early to reduce stress and udder edema. Each period of production or lactation lasts for 12 to 14 months or longer and spans the time period from calving to dry-off, which is when milking is terminated about 60

days before the next anticipated calving. Thus, cows are bred while they are producing milk, usually beginning at about 60 days after calving to maintain a yearly calving schedule. Indeed, dairy producers attempt to get cows bred precisely during the time they are producing the most milk, which has negative implications for cow fertility. Following the 2-month dry period, the cow calves again and lactation cycle begins anew. Cows average about 2.5 lactations, although many remain productive considerably longer. Cows tend to survive longer in less-intensive pasture systems than when on concrete all of the time. The leading reasons cows leave the dairy herd are low production, infertility, mastitis (inflammation of the udder), and lameness.

Calves and Heifers

Source: University of Wisconsin

Immediately after birth, the calf is fed 2 quarts of colostrum and at least another 2 quarts within 12 hours. The ability of the calf to directly absorb immunoglobulins from the cow's initial milk declines rapidly after the first 12 hours. Thus every effort is made to get the calf to consume colostrum early. Calves' navels are then dipped with iodine to prevent infection and the calf is moved to an individual pen or hutch as soon as it is dry. Choices for individual housing for calves include calf hutches, indoor crates, and indoor pens. Group pens allow too much nose-to-nose contact and permit disease to spread quickly for very young calves. Hutches provide very suitable ventilation for the calves and automated equipment can be used to simplify feeding calves in hutches. But indoor facilities are convenient for the calf feeders, especially in cold weather. Often indoor calf facilities are made of converted buildings, greenhouse barns, or coverall hoop barns.

Prior to weaning at 6 to 8 weeks, calves are vaccinated, dehorned, have extra teats removed, and male calves may be castrated to be raised as steers. Female calves are either raised by the dairy farm as replacement heifers, contract raised for the dairy farm by a heifer grower, or sold to other dairy farms. Male calves are mainly sold as veal calves or raised as steers, either by the farm or a buyer. A small number of bull calves may be raised for breeding stock and sold to local dairies as natural service bulls. A tiny percentage of bull calves from exceptionally good cows with registered pedigrees may be sold through contract to Artificial Insemination companies. Formerly, the image of the veal industry is that calves were kept in tiny crates in total darkness so they would remain anemic. The modern veal industry is more likely to be in more open facilities with excellent lighting and ventilation.

Protein Sources		
Best	**Acceptable**	**Inferior**
Skim Milk	Specially manufactured soy flour	Unprocessed soy flour
Buttermilk	Soy concentrate	Meat solubles

Whole Whey	Hydrolyzed fish protein	Fish Flour
Delactosed whey		Distiller solubles
Casein		Brewer's yeast
Milk albumin		Oat flour
Whey protein concentrate		Wheat flour
Fat Sources		
Lard	Hydrogenated vegetable oils	Liquid vegetable oils
Tallow		
Stabilized greases		

Aside from the very first days when calves are fed colostrum, they are fed discarded milk or milk replacer. The best protein sources for milk replacer are from dairy products. At the same time, the calf is offered water and calf starter feed, which it should be consuming readily prior to weaning it off of milk. Calves should be offered starter within the first week and should be getting adequate energy from the starter by weaning. Often calves are encouraged to eat the starter by addition of molasses. It is not necessary to feed hay to calves prior to weaning, but it is sometimes made available.

Protein Sources			
	Grain Starters		
	1	**2**	**3**
Ingredients (air dry basis)			
Corn (cracked or coarse ground), %	50	30	
Ear Corn (coarse ground), %			50
Oats (rolled or crushed), %	22	18	
Barley (rolled or coarse ground), %		20	21
Wheat Bran, %		8	
Soybean Meal, %	20	16	21
Molasses, %	5	5	5
Dicalcium phosphate, %	0.5	0.5	0.5
Limestone, %	1.5	1.5	1.5
TM Salt and Vitamins, %	1	1	1
Composition (dry matter basis)			
Crude protein, %	18.1	18.0	18.4
TDN, %	80.0	78.8	78.0
ADF, %	7.0	6.9	9.1
Calcium, %	0.8	0.8	0.82
Phosphorus, %	0.48	0.56	0.47
Vitamin A, IU/lb	1000	1000	1000
Vitamin D, IU/lb	150	150	150
Vitamin E, IU/lb	11	11	11

At weaning, calves are moved to group housing. Forms of group housing include superhutches, drive-through freestall barns, drive-by freestall barns, and open housing on bedded pack. Some calves are weaned directly onto pasture. Normally, heifers are kept in these housing systems until they reach breeding age at 12 to 15 months. Feeds tend to include some calf starter, perhaps some other grain or corn silage; and excellent quality hay is offered.

Following breeding, heifers are maintained until moving to the dairy farm for calving. Facilities are often less extensive. Often heifers are raised in feedlots, or on pasture, although some heifers are also raised in freestall barns.

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Cows

For cows, the period from 60 days prior to calving until 40 days after calving is called the transition period, because cows make a transition to producing milk and consuming a higher energy ration. Heifers and dry cows are usually moved to a close-up dry area for close observation beginning at 3 weeks prior to calving. Usually the close-up dry cows are housed in freestalls, or on pasture or open lot. When calving appears imminent, cows are moved to individual maternity pens or an open calving area. Diligent efforts are made to keep these areas clean. Even cows raised on pasture are sometimes moved to pens for calving to allow close observation in case the delivery must be assisted, to keep the calf out of cold drafts, and to allow careful attention to the calf immediately after birth. Calving pens are usually bedded with lots of clean wheat or oat straw, although sand and sawdust are used too.

Some dairy producers prefer to keep cows on pasture. There are certainly advantages in reduced costs of feed harvest and storage, reduced cost for manure management and storage, improved foot health, and perhaps less disease when the cows are not as heavily concentrated in a limited area. These grazing systems often depend on the principles of managed intensive grazing to optimize grass and milk production. Some, but not all, grazers also practice seasonal calving to allow the cow's highest milk yield and energy demands to match with seasons of maximal grass production. Thus calving is planned for Spring in the Northeast and Midwest, and Fall in the far South. Due to less rainfall, little grazing is practiced west of the Great Plains. Grass is far and away the key component of diets on grazing dairies. Even stored feed may include excess grass from pastures that is ensiled and fed when grass is not available. Most grazing dairies supplement the grass with some level of ground corn or other concentrate feeds, and perhaps with some purchased alfalfa hay and/or corn silage. Often the grass is baled in round bales, wrapped in plastic, and stored as baleage.

In the Midwest and elsewhere it is common for small to medium-sized dairies to house cows in barns for most of the year, but to provide supplemental grazing during the summer. Even then, cows may only get a small portion of their forage from pasture, with most feed fed in the barn or a feedlot.

Traditionally, cows in the Midwest and Northeast were housed in tie-stall barns. Often cows were

maintained in these barns and fed and milked right in their own stalls. While several of these barns are still in use, the inefficiency of labor and difficulty of milking have made new tie stall barns relatively uncommon.

The concept of providing cows with the opportunity to freely move from her stall to the feeding area was developed in Washington State in the mid 1950s. Freestall barns have become the mainstay of the dairy industry in recent years. Older freestalls were often constructed of wood and the stall was bedded with lots of straw. Even these older stalls can still be very useful today if plenty of bedding is provided to keep cows comfortable. Modern freestalls are more likely to be constructed of steel loops or dividers and bedded with sawdust or sand. The fact that sand provides little organic matter as food for bacteria, keeps cows dry, and helps cool cows in summer makes it the "gold standard" of bedding materials. Occasionally, freestalls are lined with rubber mattresses filled with ground tires, other cushion materials, or even water. Modern barns are constructed of wood or steel supports and rafters or trusses, steel roofing with an open ridge, and curtain sides that may be opened to maximize airflow in summer. Ventilation is usually assisted with fans. In some facilities, tunnel ventilation is used, in which air is mechanically drawn through the length of the building at rapid speed, which eliminates the dependence on wind speed needed for natural ventilation. To attain rapid air movement, the roof and sides are built solid with no air inlets. Greenhouse barns and other kinds of hoop structures are available to dairy producers for freestall barns. Their advantage is in reduced construction costs, although covering may need to be replaced as often as every 5 years. The additional light in these barns is an advantage for observing cattle, and the sun may be partially blocked out by covering with shade cloth in summer. Cow cooling systems, such as misters or sprinklers, are often present above feeding areas during hot weather. In the arid Southwestern states, newer dairy facilities are investing in state-of the art evaporative cooling systems to keep cows comfortable and productive. Supplemental cow cooling should be available any time the temperature exceeds 72 to 75 degrees.

Dry cows, during the period in which they are not lactating, are often housed in less expensive buildings. Because dry cows do not metabolize as much energy as lactating cows, they produce less heat, and so it is not as difficult to keep them cool in summer.

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Typical Herd

The typical mix of animals in a dairy herd for 100 milking cows is:

Milking herd:

-

- 92 healthy cows
- 4 cows that have recently given birth
- 4 cows with special needs

and

- 16-20 dry (not lactating) cows and close-up heifers (close to calving)
- 70-90 replacement calves and heifers

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Feeding and Feed Storage

Total Mixed Rations for Cows (Midwest Rations)

- Corn silage
- Alfalfa/grass silage
- Alfalfa hay
- Corn
- Soybean meal
- Fuzzy whole cottonseed
- Commodity feeds (corn gluten, distillers grains, soybean hulls, citrus pulp, candy bars, etc.)

Mixer

Typical rations fed to dairy cows in the Midwest often contain corn silage, alfalfa or grass silage, alfalfa hay, ground or high-moisture shelled corn, soybean meal, fuzzy whole cottonseed, and perhaps commodity feeds (corn gluten, distillers grains, soybean hulls, citrus pulp, candy bars, etc.). Proximity to crop processing plants and industries may dictate the availability of commodity feeds in different locales and some regions may have different feedstuffs. For example, short growing seasons may limit use of corn silage in far Northern climates and may be replaced by alfalfa silage in the ration. Cows are usually fed rations that are balanced for their milk production level or stage of lactation, which reflects the differences in energy and protein required for different amounts of milk produced. A cow produces the most milk immediately after the birth of her calf, but production drops off over the next several months. Usually, all of the feedstuffs are blended together in a mixer and fed as a Total Mixed Ration or TMR. Keeping every bite of feed a cow eats as uniform as possible helps to maintain a healthy population of bacteria in the cow's rumen (second stomach). It is the bacteria that digest the forages in the cows ration and allow her to consume and process foods that other animals and humans could not. Blending all feeds is difficult to accomplish in tie stalls, and is obviously not practiced with cows on pasture where cows eat only grass while on pasture and are fed grain at the time of milking.

Feed storage and feeding systems account for a considerable number of buildings and structures on dairy farms. Dry hay may be stored in a

Upright concrete stave silos

hay loft, or second story, in the barn, in separate hay barns or stacked outside and covered with plastic. For many years, the primary storage structure for silage was an upright silo. Concrete stave silos and oxygen limiting silos, of which Harvestore™ is a familiar brand name, were popular storage structures for chopped and ensiled (fermented) corn, alfalfa, and grass. This method of storage was successful and cows readily ate well-fermented crops. However, the physical removal of silage from such storage was relatively slow and increasing herd sizes dictated more labor-efficient storage methods, such as silage bags and bunker silos, and silage stacks. These methods also preserve silage well, provided that the silage is adequately packed to eliminate oxygen that can hinder the fermentation process. Fermentation lowers the pH of the stored feed and preserves its feed value.

Feed Alley

Commodity feeds are added to silage or hay to provide a complete and balanced ration. Commodity feeds are usually stored in a commodity barn that has several bays, one for each commodity. Commodity sheds are usually constructed to allow delivery of one semi-trailer of the commodity in each bay. Cows are usually fed at feed bunks in an outside lot, in a drive through feed alley in the barn, or at a drive-by feed alley, for cows housed in open lots.

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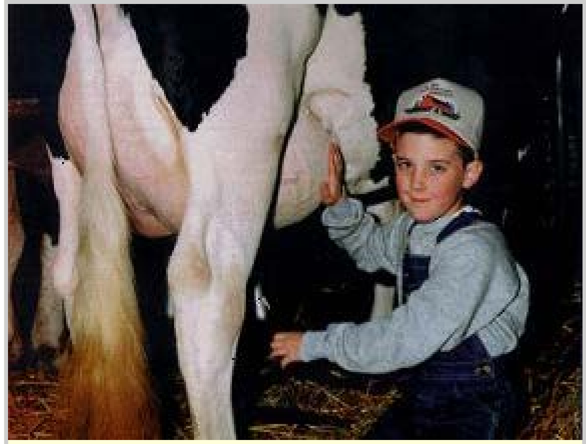
Milking Parlors

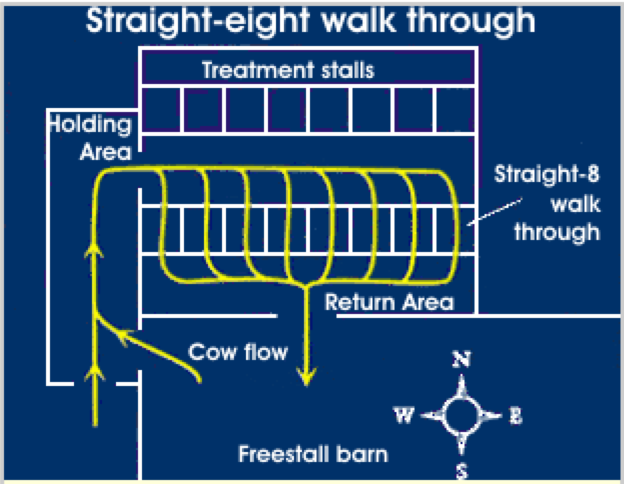
Cows are milked twice per day on most farms. However, 10% increased milk production can be obtained by milking the cows 3 times per day, and many dairy farms are beginning to do so. Some operations even milk a portion of their cows 4 times per day. Cows housed in tiestall barns are often milked in their stalls. A number of dairy farms, primarily those whose owners are members of religious denominations that do not utilize electricity, still milk cows by hand rather than with milking equipment. These are not common and usually involve only a few cows. The milk from such operations does not enter the fresh milk market and is utilized only for manufacturing purposes. Most cows milked in tiestall barns are either milked with bucket milkers or pipeline milking systems. Milking cows in tiestall barns is extremely labor intensive and requires much stooping and bending. The desire to reduce this type of labor has led to many types of milking parlor designs, in which the milker need not bend to be at the level of the cows udder.

Some cows in the Midwest and Northeast are milked in Tie Stall Barns.

- **Hand Milking (Amish)**
- **Bucket Milkers**
- **Pipelines**



Source: Gennex, CRI

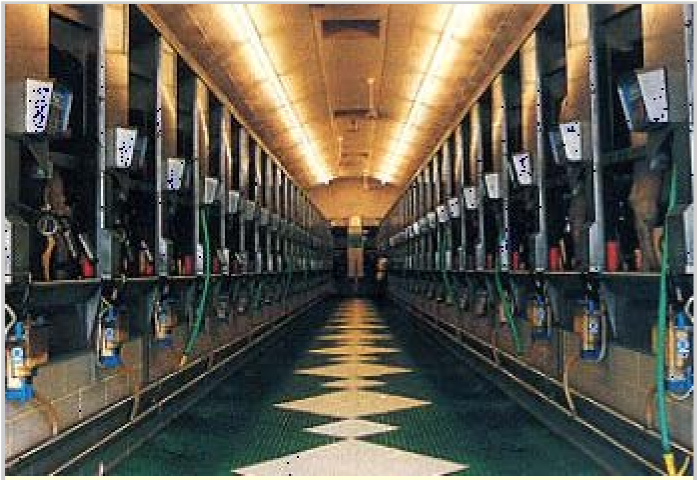


Walk-through Parlor

Walk-through or step-up parlors are often installed or retrofitted into existing tiestall barns as a cost effective way of alleviating the demands of the milking chore. In these parlors cows enter from the rear, step up onto an elevated platform for milking, and then exit forward through a headgate. Walk through parlors are inexpensive, but labor demands are still relatively high.

Step-up Parlor

One of the most popular types of parlors is the herringbone, so named because the cows enter and stand next to each other, but face away from the operator's pit at an angle. Milkers attach the milking clusters to the teats from the side of the cow, and to have better visual contact with the cow's udder while she is being milked. It is usually easier to keep the milker positioned properly beneath the cow's udder.



Herringbone Parlor
Source: Midwest Plan Service

Parallel Parlor
Source: Midwest Plan Service

Parallel parlors are similar to the herringbone parlors except that cows stand perpendicular to the operator pit and the cows are milked from the rear, between the cow's hind legs. Advantages are that the cows stand closer together so the worker has to walk less between cows that are being milked. Disadvantages are that the cow's tail is often in the way and it may be a long reach for some milkers to reach the cow's front teats.

Rotary parlors are gaining in popularity. Some older styles of rotary parlors were not very efficient or dependable. New ones, however, have proven to be a viable alternative for large dairy farms. With the rotary parlor, the platform on which the cows stand moves around, while the cleaners and milkers stand in one location. Milking cows is still a demanding task, however, because the cows come by so quickly that each task must be performed in about 10 to 12 seconds with no break between cows.

Rotary Parlor

No matter what kind of parlor is used, there are some key components of milking procedures that are followed in each. Namely, the cow's teats must be thoroughly cleaned and dried, the milking equipment must be working properly and attached properly, and the teats must be disinfected with an approved teat dip following milking. This is to prevent possible spread of mastitis from cow to cow. Similarly, the milk must be handled properly after it leaves the cow. It must be cooled to under 45 degrees Fahrenheit within 2 hours of milking. Plate coolers are often more efficient at cooling milk than bulk tanks and are used on most farms. Bulk tanks manufactured after January 1, 2000 must be equipped with a recording thermometer so that the temperature history of the milk can be monitored. A sample of milk from each bulk tank accompanies the milk truck to the receiving plant. The milk undergoes a battery of tests to assure that it is safe and of high quality before it is accepted for processing. Dairy producers must meet specific requirements for bacteria counts and somatic cells (white blood cells) in milk; and they are paid a premium for high quality milk. No added water or antibiotic residues are allowed, under penalty of losing one's permit to sell milk.

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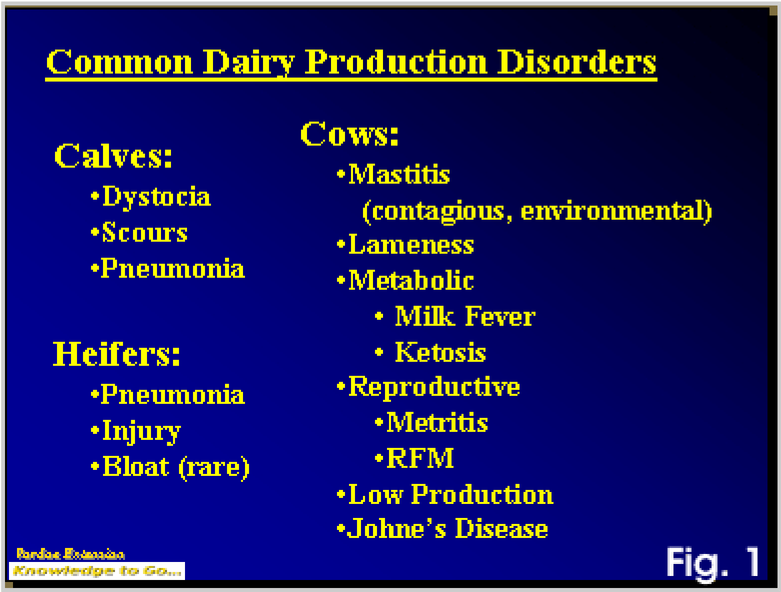
Diseases



There are a number of common diseases and disorders that affect cattle at various stages of life (**Fig. 1**). Cows may experience a difficult birth, and death losses at birth may be as high as 5%, though these losses can be overcome by selecting bulls known for the calving ease of their offspring. Diarrhea, caused by any of several species of bacteria, and pneumonia are the leading cause of death loss in calves. Calves may also be afflicted with less harmful disorders like pink eye. In older heifers, the primary risks include pneumonia, injury, and bloat. Cows may be afflicted by any of a number of disorders that result in a loss of milk production. Mastitis (inflammation of the udder), lameness, milk fever (hypocalcemia), ketosis, reproductive disorders, and bacterial diarrhea are some of the more common ones. Vaccination programs are effective at controlling or decreasing the severity of many of these diseases.

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Common Manure Handling Systems

Cows differ considerably in the amount of manure they produce. Jerseys, for example, produce only 60% as much manure as Holsteins. With respect to many environmental rules, especially state regulations, however, no consideration is made for breed or body size. Composition of typical dairy manure is known (**Table 1**). Consideration must be given to the kind(s) of bedding used (**Table 2**) and the milking system (**Table 3**), both of which contribute to the amount of manure produced on a dairy farm.

Table 1. Manure Production per 200 Cows*

	Per Day (lb.)	Per Year (LB)
Feces and Urine	24,100	8,800,000
Total Solids	3,360	1,230,000
Volatile Solids	2,800	1,020,000
Total N	126	46,000
Total P	26	9,610
Total K	812	23,600
*does not include wastewater and bedding *estimates may increase with milk production		

Table 2. Bedding

	ft^3 / cow / day	
Housing Type	**Chopped Straw**	**Sawdust**
Tiestall	0.8	0.1
Freestall	0.3	0.2
Loose Housing	1.1	---
0.6 ft^3 per cow is a good guide		

Table 3. Wastewater		
# Milking Cows	gal/cow/d	ft^3
0 - 50	5 - 8	0.6 - 1.0
50 - 100	4 - 6	0.5 - 0.8
150 +	2 - 4	0.2 - 0.5
1 ft^3 = 7.48 Gallons		

A number of manure handling systems are utilized in dairy production. For tiestall barns, manure is collected in gutters behind the cows and removed from the barn as a solid material by a barn cleaner. Outside of the barn, the barn cleaner places the manure on a storage stack or directly into a manure spreader.

Skidsteer loading a manure spreader

There are three types of manure handling systems used for freestall barns:

1. Manual scraping,
2. Flush systems, and
3. Automatic alley scrapers.


Flush systems work very well

Some freestall barns use slotted concrete floors above a pit, but these are quite rare in the U.S. With manual scrape systems, manure is scraped to the end of the barns by a skidsteer or mechanical loader with a scraping attachment. The manure is either stored temporarily in a solid stack, or loaded directly onto a manure spreader. Some barns are equipped with a freestall alleyway that is flushed with recycled wastewater to convey the manure to a storage pit or lagoon. Mechanical alley scrapers consist of a hinged v-shaped plough driven by a cable or chain. The plough is continuously or periodically dragged forward to draw manure to the end of an alley. When being pulled, the plough's blade splays across the entire alley between two curbs. After completing a pass, the chain or cable reverses direction and pulls the plough backward as the plough's blades fold together so as not to pull manure the opposite direction. Flush systems are comprised of a tank that delivers copious amounts of water to flush all manure off the alleys. Provided there is adequate slope along the channel and adequate water pressure from the tank, flush systems work very well. However, some concerns have been raised that a number of bacterial pathogens may be circulated through the barn by flush systems.

Frequently manure from the freestall barn is stored temporarily in a storage pit and combined with more dilute waste from the milking parlor. Milking parlor waste often contains very little manure, but does have much residual milk from cleaning and may have various cleaning products as well. Manure from pits is agitated and then loaded onto a slurry wagon for application onto cropland, often with direct incorporation into the soil.

Storage Containers
Source: Al Sutton, Purdue University

Effluent drips down for collection

Collection pits may also be used when solids are to be separated from the liquid portion of the manure. Solid separation can be mechanical, in which the liquid portion of the manure is squeezed though a screen. This provides a relatively dry solid that may be composted and perhaps even reused as a bedding material after drying. Sloped screen separators work by trickling the manure over a sloped screen so that the effluent drips through the screen with the solids sliding down for collection. Other mechanical separators draw an apron across the manure to force it across a screen. Concrete pit separators work by using a porous "weeping wall" in which the effluent is allowed to weep through the slots between boards or screens while the solids are retained. The solids then can then be removed as a semi-solid from the concrete pits. Composting is another option for solid manure management.

With sloping screen separators or other mechanical methods, the effluent may go into a settling pond to settle out even more solids before the effluent enters the lagoon. Many lagoons have been constructed with clay or compactible soil. In sandy or lighter soils, dairies must line the lagoons with compacted clay or synthetic liners.

Settling Pond

Recently, there has been much interest expressed in developing technology to utilize methane produced by anaerobic digestion of manure . As cost of the technology declines and pressure to manage manure and control odors on larger farm units increases, this technology will become more common. On some very large farms, these systems are used to generate electricity and hot water for the farm. Some are able to to sell electricity back into the grid through their local cooperatives.

Cost of this technology remains too expensive for all but the largest producers at this time. Furthermore, anaerobic digestion should be viewed as a value-added process, but not as a solution to nutrient management difficulties, since nitrogen, phosphorus, and potassium remain in the effluent following digestion. Advantages appear to be in reduced energy costs, potentially reduced odors, and a more stable manure slurry.

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Potential Environmental Impacts of Animal Feeding Operations

(Adapted in part from Livestock and Poultry Environmental Stewardship Curriculum, MidWest Plan Service; and Proposed US EPA Confined Feeding Rule.)

USEPA's 1998 *National Water Quality Inventory* indicates that agricultural operations, including animal feeding operations (AFOs), are a significant source of water pollution in the U.S. States estimate that agriculture contributes in part to the impairment of at least 170,750 river miles, 2,417,801 lake acres, and 1,827 estuary square miles (Table 1). Agriculture was reported to be the most common pollutant of rivers and streams.

However, one should not overlook the many positive environmental benefits of agriculture. For example, agricultural practices that conserve soil and increase productivity while improving soil quality also increase the amount of carbon-rich organic matter in soils, thereby providing a global depository for carbon dioxide drawn from the atmosphere by growing plants. The same farming practices that promote soil conservation also decrease the amount of carbon dioxide accumulating in the atmosphere and threatening global warming.

Other benefits compared to urban or industrial land use include greatly reduced storm runoff, groundwater recharge and water purification as infiltrating surface water filters through plant residue, roots and several feet of soil to reach groundwater.

In many watersheds, animal manures represent a significant portion of the total fertilizer nutrients added. In a few counties, with heavy concentrations of livestock and poultry, nutrients from confined animals exceed the uptake potential of non-legume harvested cropland and hayland. USDA estimates that recoverable manure nitrogen exceeds crop system needs in 266 of 3,141 counties in the U.S. (8%) and that recoverable manure phosphorus exceeds crop system needs in 485 counties (15%). It should be pointed out that while legumes are able to produce their own nitrogen, they will use applied nitrogen instead if it is available. The USDA analysis does not consider actual manure management practices used or transport of applied nutrients outside the county; however, it is a useful indicator of excess nutrients on a broad scale. Whole-farm nutrient balance is a very useful tool to identify potential areas of excess.

Air emissions from Animal Feeding Operations (AFO) can be odorous. Furthermore, volatilized ammonia can be redeposited on the earth and contribute to eutrophication of surface waters.

Animal manures are a valuable fertilizer and soil conditioner, if applied under proper conditions at crop nutrient requirements. Potential sources of manure pollution include open feedlots, pastures, treatment lagoons, manure stockpiles or storage, and land application fields. Oxygen-demanding substances, ammonia, nutrients (particularly nitrogen and phosphorus), solids, pathogens, and odorous compounds are the pollutants most commonly associated with manure. Manure is also a potential source of salts and trace metals, and to a lesser extent, antibiotics, pesticides and hormones. This problem has been magnified as poultry and livestock production has become more concentrated. AFO pollutants can impact surface water, groundwater, air, and soil. In surface water, manure's oxygen demand and ammonia content can result in fish kills and reduced biodiversity. Solids can increase turbidity and smother benthic organisms. Nitrogen and phosphorus can contribute to eutrophication and associated algae blooms which can produce negative aesthetic impacts and increase drinking water treatment costs. Turbidity from the blooms can reduce penetration of sunlight in the water column and thereby limit growth of seagrass beds and other submerged aquatic vegetation, which serve as critical habitat for fish, crabs, and other aquatic organisms. Decay of the algae (as well as night-time algal respiration) can lead to depressed oxygen levels, which can result in fish kills and reduced biodiversity. Eutrophication is also a factor in blooms of toxic algae and other toxic estuarine microorganisms, such as *Pfiesteria piscicida*. These organisms can impact human health as well as animal health. Human and animal health can also be impacted by pathogens and nitrogen in animal manure. Nitrogen is easily transformed into the nitrate form and if transported to drinking water sources can result in potentially fatal health risks to infants. Trace elements in manure may also present human and ecological risks. Salts can contribute to salinization and disruption of the ecosystem. Antibiotics, pesticides, and hormones may have low-level, long-term ecosystem effects.

In ground water, pathogens and nitrates from manure can impact human health via drinking water. Nitrate contamination is more prevalent in ground waters than surface waters. According to the U.S. EPA, nitrate is the most widespread agricultural contaminant in drinking water wells, and nearly 2% of our population (1.5 million people) is exposed to elevated nitrate levels from drinking water wells.

Table 1. Summary of U.S. Water Quality Impairment Survey

Total Quantity in US	Amount of Waters Surveyed	Quantity Impaired by All Sources	Quantity Impaired by Agriculture
Rivers 3,662,255 miles	23% of total 840,402 miles	36% of surveyed 248,028 miles	59% of impaired 170,750 miles
Lakes, Ponds, and Reservoirs 41,600,000 acres	42% of total 17,400,000 acres	39% of surveyed 6,541,060 acres	31% of impaired 2,417,801 acres
Estuaries 90,500 square miles	32% of total 28,889 square miles	38% of surveyed 11,025 square miles	15% of impaired 1,827 square miles

Reference: National Water Quality Inventory: 1998 Report to Congress (EPA, 2000a). AFOs are a subset of the agriculture category. Summaries of impairment by other sources are not presented here.

Table 2 lists the leading pollutants impairing surface water quality in the U.S. Agricultural production is a potential source of most of these.

Table 2. Five Leading Pollutants Causing Water Quality Impairment in the U.S. ***(Percent of incidence of each pollutant is shown in parentheses. For example, siltation is listed as a cause of impairment in 38% of impaired river miles.)***

Rank	Rivers	Lakes	Estuaries
1	Siltation (38%)	Nutrients (44%)	Pathogens (47%)
2	Pathogens (36%)	Metals (27%)	Oxygen-Depleting Substances (42%)
3	Nutrients (29%)	Siltation (15%)	Metals (23%)
4	Oxygen-Depleting Substances (23%)	Oxygen-Depleting Substances (14%)	Nutrients (23%)
5	Metals (21%)	Suspended Solids (10%)	Thermal Modifications (18%)

List of Contaminants in Animal Manure:

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Oxygen-Demanding Substances

When discharged to surface water, biodegradable material is decomposed by aquatic bacteria and other microorganisms. During this process, dissolved oxygen is consumed, reducing the amount available for aquatic animals. Severe depressions in dissolved oxygen levels can result in fish kills. There are numerous examples nationwide of fish kills resulting from manure discharges and runoff from various types of AFOs.

Manure may be deposited directly into surface waters by grazing animals. Manually-collected manure may also be introduced into surface waters. This is typically via storage structure failure, overflow, operator error, etc.

Manure can also enter surface waters via runoff if it is over-applied or misapplied to land. For example, manure application to saturated or frozen soils may result in a discharge to surface waters. Factors that promote runoff to surface waters are steep land slope, high rainfall, low soil porosity, and proximity to surface waters. Incorporation of the manure into the soil decreases runoff.

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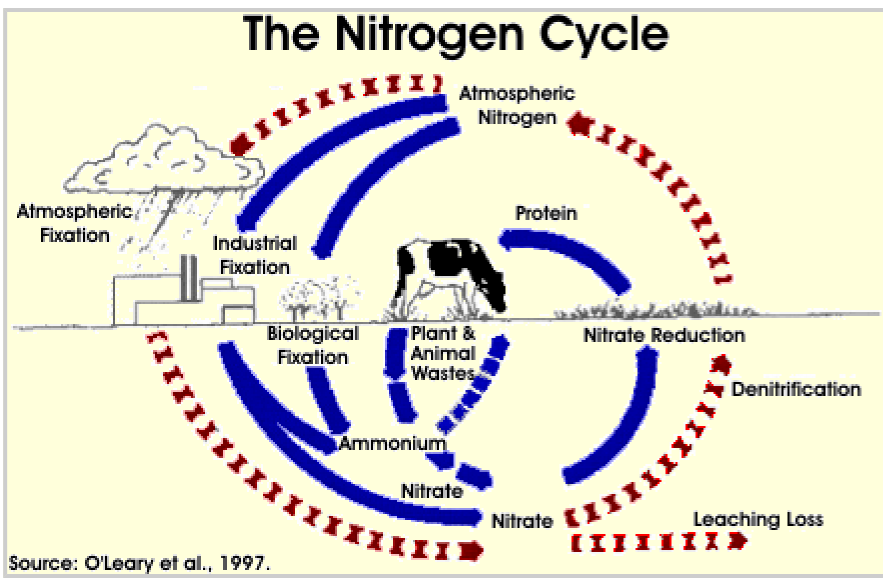
Nitrogen

Nitrogen (N) is an essential nutrient required by all living organisms. It is ubiquitous in the environment, accounting for 78 percent of the atmosphere as elemental nitrogen (N_2). This form of nitrogen is inert and does not impact environmental quality since it is not bioavailable to most organisms and therefore has no fertilizer value. Nitrogen can form other compounds, however,



which are bioavailable, mobile, and potentially harmful to the environment. The nitrogen cycle shows the various forms of nitrogen and the processes by which they are transformed and lost to the environment.

Nitrogen in manure is primarily in the form of organic nitrogen and ammonia nitrogen compounds. In its organic form, nitrogen is unavailable to plants. However, organic nitrogen can be transformed into ammonium (NH_4^+) and nitrate (NO_3^-) forms, via microbial processes which are bioavailable and have fertilizer value. These forms can also produce negative environmental impacts when they are transported in the environment.

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Ammonia

"Ammonia-nitrogen" includes the ionized form (ammonium, NH_4^+) and the un-ionized form (ammonia, NH_3). Ammonium is produced when microorganisms break down organic nitrogen products such as urea and proteins in manure. This decomposition occurs in both aerobic and anaerobic environments. In solution, ammonium is in chemical equilibrium with ammonia.

Ammonia exerts a direct biochemical oxygen demand (BOD) on the receiving water since dissolved oxygen is consumed as ammonia is oxidized. Moderate depressions of dissolved oxygen are associated with reduced species diversity, while more severe depressions can produce fish kills.

Additionally, ammonia can lead to eutrophication, or nutrient over-enrichment, of surface waters. While nutrients are necessary for a healthy ecosystem, the overabundance of nutrients (particularly nitrogen and phosphorus) can lead to nuisance algae blooms.

Pfiesteria often lives as a nontoxic predatory animal, becoming toxic in response to fish excretions or secretions (NCSU, 1998). While nutrient-enriched conditions are not required for toxic outbreaks to occur, excessive nutrient loadings can help create an environment rich in microbial prey and organic matter that *Pfiesteria* uses as a food supply. By increasing the concentration of *Pfiesteria*, nutrient loads increase the likelihood of a toxic outbreak (Citizens *Pfiesteria* Action Commission, 1997).

The degree of ammonia volatilization is dependent on the manure management system. For example, losses are greater when manure remains on the land surface rather than being incorporated into the soil, and are particularly high when the manure is spray irrigated onto land. Environmental conditions also affect the extent of volatilization. For example, losses are greater at higher pH levels, warmer temperatures and drier conditions, and in soils with low cation exchange capacity, such as sands. Losses are decreased by the presence of growing plants. (Follett, 1995)

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Nitrate

Nitrifying bacteria can oxidize ammonium to nitrite (NO_2^-) and then to nitrate (NO_3^-). Nitrite is toxic to most fish and other aquatic species, but it typically does not accumulate in the environment because it is rapidly transformed to nitrate in an aerobic environment. Alternatively, nitrite (and nitrate) can undergo bacterial denitrification in an anoxic environment. In denitrification, nitrate is converted to nitrite, and then further converted to gaseous forms of nitrogen - elemental nitrogen (N_2), nitrous oxide (N_2O), nitric oxide (NO), and/or other nitrogen oxide (NO_x) compounds. Nitrification occurs readily in the aerobic environments of receiving streams and dry soils while denitrification can be significant in anoxic bottom waters and saturated soils.

Nitrate is a useful form of nitrogen because it is biologically available to plants and is therefore a valuable fertilizer. However, excessive levels of nitrate in drinking water can produce negative health impacts on infant humans and animals. Nitrate poisoning affects infants by reducing the oxygen-carrying capacity of the blood. The resulting oxygen starvation can be fatal. Nitrate poisoning, or methemoglobinemia, is commonly referred to as "blue baby syndrome" because the lack of oxygen can cause the skin to appear bluish in color. To protect human health, EPA has set a drinking water Maximum Contaminant Level (MCL) of 10 mg/l for nitrate-nitrogen. Once a water source is contaminated, the costs of protecting consumers from nitrate exposure can be significant. Nitrate is not removed by conventional drinking water treatment processes; its removal requires additional, relatively expensive treatment units.

Nitrogen in livestock manure is almost always in the organic, ammonia or ammonium form but may become oxidized to nitrate after being diluted. It can reach surface waters via direct discharge of animal wastes. Lagoon leachate and land-applied manure can also contribute nitrogen to surface and ground waters. Nitrate is water soluble and moves freely through most soils. Nitrate contributions to surface water from agriculture are primarily from groundwater connections and other subsurface flows rather than overland runoff (Follett, 1995).

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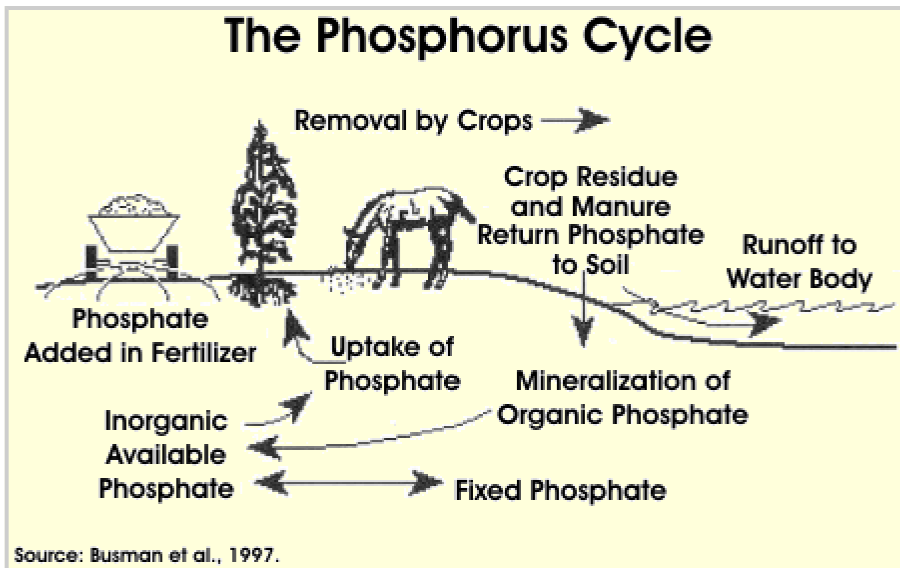
Phosphorus



Animal wastes contain both organic and inorganic forms of phosphorus (P). As with nitrogen, the organic form must mineralize to the inorganic form to become available to plants. This occurs as the manure ages and the organic P hydrolyzes to inorganic forms. The phosphorus cycle is much simpler than the nitrogen cycle because phosphorus lacks an atmospheric connection and is less subject to biological transformation.

Phosphorus is of concern in surface waters because it can lead to eutrophication. Phosphorus is also a concern because phosphate levels greater than 1.0 mg/l may interfere with coagulation in drinking water treatment plants (Bartenhagen et al., 1994). A number of research studies are currently underway to decrease the amount of P in livestock manure, primarily through enzymes and animal ration modifications that make phosphorous in the feed more available (and usable) by the animal. This means that less phosphorus must be fed to ensure an adequate amount for the animal and, as a result, less phosphorous is excreted in the manure.

Phosphorus predominantly reaches surface waters via direct discharge and runoff from land application of fertilizers and animal manure. Once in receiving waters, the phosphorus can become available to aquatic plants. Land-applied phosphorus is much less mobile than nitrogen since the mineralized form (inorganic Phosphate) is easily adsorbed to soil particles. For this reason, most agricultural phosphorus control measures have focused on soil erosion control to limit transport of particulate phosphorus. However, soils do not have infinite phosphate adsorption capacity and with long-term over-application, inorganic phosphates can eventually enter waterways even if soil erosion is controlled.

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Pathogens

Both manure and animal carcasses contain pathogens (disease-causing organisms) which can impact human health, other livestock, aquatic life, and wildlife when introduced into the environment. Several pathogenic organisms found in manure can infect humans.

Table 1. Some Diseases and Parasites Transmittable to Humans from Animal Manure

Disease	Responsible Organism	Symptoms
Bacteria		
Anthrax	*Bacillus anthracis*	Skin sores, fever, chills, lethargy, headache, nausea, vomiting, shortness of breath, cough, nose/throat congestion, pneumonia, joint stiffness, joint pain
Brucellosis	*Brucella abortus*, *Brucella melitensis*, *Brucella suis*	Weakness, lethargy, fever, chills, sweating, headache
Colibaciliosis	*Escherichia coli* (some serotypes)	Diarrhea, abdominal gas
Coliform mastitis-metritis	*Escherichia coli* (some serotypes)	Diarrhea, abdominal gas
Erysipelas	*Erysipelothrix rhusiopathiae*	Skin inflammation, rash, facial swelling, fever, chills, sweating, joint stiffness, muscle aches, headache, nausea, vomiting
Leptospirosis	*Leptospira Pomona*	Abdominal pain, muscle pain, vomiting, fever
Listeriosis	*Listeria monocytogenes*	Fever, fatigue, nausea, vomiting, diarrhea
Salmonellosis	Salmonella species	Abdominal pain, diarrhea, nausea, chills, fever, headache
Tetanus	*Clostridium tetani*	Violent muscle spasms, “lockjaw” spasms of jaw muscles, difficulty breathing
Tuberculosis	*Mycobacterium tuberculosis*, *Mycobacterium avium*	Cough, fatigue, fever, pain in chest, back, and/or kidneys
Rickettsia		
Q fever	*Coxiella burneti*	Fever, headache, muscle pains, joint pain, dry cough, chest pain, abdominal pain, jaundice
Viruses		
Foot and Mouth	Virus	Rash, sore throat, fever
Hog Cholera	Virus	
New Castle	Virus	
Psittacosis	Virus	Pneumonia
Fungi		
Coccidioidycosis	*Coccidioides immitus*	Cough, chest pain, fever, chills, sweating, headache, muscle stiffness, joint stiffness, rash wheezing
Histoplasmosis	*Histoplasma capsulatum*	Fever, chills, muscle ache, muscle stiffness, cough, rash, joint pain, join stiffness
Ringworm	Various *microsporum* and *trichophyton*	Itching, rash
Protozoa		
Balantidiasis	*Balatidium coli*	
Coccidiosis	*Eimeria* species	Diarrhea, abdominal gas

Cryptosporidiosis	*Cryptosporidium* species	Watery diarrhea, dehydration, weakness, abdominal cramping
Giardiasis	*Giardia lamblia*	Diarrhea, abdominal pain, abdominal gas, nausea, vomiting, headache, fever
Toxoplasmosis	*Toxoplasma* species	Headache, lethargy, seizures, reduced cognitive function
Parasites/Metazoa		
Ascariasis	*Ascaris lumbricoides*	Worms in stool or vomit, fever, cough, abdominal pain, bloody sputum, wheezing, skin rash, shortness of breath
Sarcocystiasis	*Sarcosystis* species	Fever, diarrhea, abdominal pain

References: USDA, 1992 (for diseases and responsible organisms). Symptom descriptions were obtained from various medical and public health service Internet websites. Pathogens in animal manure are a potential source of disease in humans and other animals. This list represents a sampling of diseases that may be transmittable to humans.

The treatment of public water supplies reduces the risk of infection via drinking water. However, protecting source water is the best way to ensure safe drinking water. Cryptosporidium parvum, a protozoan that can produce gastrointestinal illness, is a concern, since it is resistant to conventional treatment. Healthy people typically recover relatively quickly from such illnesses. However, they can be fatal in people with weakened immune systems such as the elderly and small children.

Runoff from fields where manure has been applied can be a source of pathogen contamination, particularly if a rainfall event occurs soon after application. The natural filtering and adsorption action of soils typically strands microorganisms in land-applied manure near the soil surface (Crane et al., 1980). This protects underlying groundwater, but increases the likelihood of runoff losses to surface waters. Depending on soil type and operating conditions, however, subsurface flows can be a mechanism for pathogen transport.

Soil type, manure application rate, and soil pH are dominating factors in bacteria survival (Dazzo et al., 1973; Ellis and McCalla, 1976; Morrison and Martin, 1977; Van Donsel et al., 1967). Experiments on land-applied poultry manure have indicated that the population of fecal organisms decreases rapidly as the manure is heated, dried, or exposed to sunlight on the soil surface (Crane et al., 1980).

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Antibiotics, Pesticides, and Hormones

Antibiotics, pesticides, and hormones are organic compounds which are used in animal feeding operations and may pose risks if they enter the environment. For example, chronic toxicity may result from low-level discharges of antibiotics and pesticides. Estrogen hormones have been implicated in the reduction in sperm counts among Western men (Sharpe and Skakkebaek, 1993) and reproductive disorders in a variety of wildlife (Colburn et al., 1993). Other sources of antibiotics and hormones include municipal waste waters, septic tank leachate, and runoff from land-applied sewage sludge. Sources of pesticides include crop runoff and urban runoff.

Little information is available regarding the concentrations of these compounds in animal wastes, or their fate/transport behavior and bioavailability in waste-amended soils. These compounds may reach surface waters via runoff from land-application sites.

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Airborne Emissions from Animal Production Systems

With the trend toward larger, more concentrated production operations, odors and other airborne emissions are rapidly becoming an important issue for agricultural producers.

Whether there is a direct impact of airborne emissions from animal operations on human health is still being debated. There are anecdotal reports about health problems and quality-of-life factors for those living near animal facilities have been documented.

- Source of Airborne Emissions
- Emission Movement or Dispersion

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Source of Airborne Emissions

Odor emissions from animal production systems originate from three primary sources: manure storage facilities, animal housing, and land application of manure.

In an odor study in a United Kingdom county (Hardwick 1985), 50% of all odor complaints were traced back to land application of manure, about 20% were from manure storage facilities, and another 25% were from animal production buildings. Other sources include feed production, processing centers, and silage storage. With the increased use of manure injection for land application, and longer manure storage times, there may be a higher percentage of complaints in the future associated with manure storage facilities and animal buildings and less from land application.

Animal wastes include manure (feces and urine), spilled feed and water, bedding materials (i.e., straw, sunflower hulls, wood shaving), wash water, and other wastes. This highly organic mixture includes carbohydrates, fats, proteins, and other nutrients that are readily degradable by microorganisms under a wide variety of suitable environments. Moisture content and temperature also affect the rate of microbial decomposition.

A large number of volatile compounds have been identified as byproducts of animal waste decomposition. O'Neill and Phillips (1992) compiled a list of 168 different gas compounds identified in swine and poultry wastes. Some of the gases (ammonia, methane, and carbon dioxide) also have implications for global warming and acid rain issues. It has been estimated that one third of the methane produced each year comes from industrial sources, one third from natural sources, and one third from agriculture (primarily animals and manure storage units). Although animals produce more carbon dioxide than methane, methane has as much as 15 times more impact on the greenhouse effect than carbon dioxide.

Dust, pathogens, and flies are from animal operations also airborne emission concerns. Dust, a combination of manure solids, dander, feathers, hair, and feed, is very difficult to eliminate from animal production units. It is typically more of a problem in buildings that have solid floors and use bedding as opposed to slotted floors and liquid manure. Concentrations inside animal buildings and near outdoor feedlots have been measured in a few studies; however, dust emission rates from animal production are mostly unknown.

Pathogens are another airborne emission concern. Although pathogens are present in buildings and manure storage units, they typically do not survive aerosolization well, but some may be transported by dust particles.

Flies are an additional concern from certain types of poultry and livestock operations. The housefly completes a cycle from egg to adult in 6 to 7 days when temperatures are 80 to 90°F. Females can produce 600 to 800 eggs, larvae can survive burial at depths up to 4 feet, and adults can fly up to 20 miles. Large populations of flies can be produced relatively quickly if the correct environment is provided. Flies tend to proliferate in moist animal production areas with low animal traffic.

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Emission Movement or Dispersion

The movement or dispersion of airborne emissions from animal production facilities is difficult to predict and is affected by many factors including topography, prevailing winds, and building orientation. Prevailing winds must be considered to minimize odor transport to close or sensitive neighbors. A number of dispersion models have been developed to Airborne Emission Regulations.

Most states and local units of government deal with agricultural air quality issues through zoning or land use ordinances. Setback distances may be required for a given size operation or for land application of manure. A few states (for example, Minnesota) have an ambient gas concentration (H_2S for Minnesota) standard at the property line. Gas and odor standards are difficult to enforce since on-site measurements of gases and especially odor are hard to do with any high degree of accuracy. Producers should be aware of odor- or dust-related emissions regulations applicable to their livestock operation.

Source: Lesson 40 of the LPES: Adapted from Livestock and Poultry Environmental Stewardship curriculum, lesson authored by Larry Jacobson, University of Minnesota; Jeff Lorimor, Iowa State University; Jose Bicudo, University of Kentucky; and David Schmidt, University of Minnesota, courtesy of MidWest Plan Service, Iowa State University, Ames, Iowa 50011-3080, Copyright (c) 2001.

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Environmental Impacts of Animal Feeding Operations Study Questions

Identify the definition that best fits the following terms:

1. **What are some of the positive environmental benefits of production agriculture?**

   - ○ Improved soil quality
   - ○ Carbon repository
   - ○ Reduced storm runoff
   - ○ Ground water recharge
   - ○ All of the above

   Feedback

2. **USDA estimates that manure phosphorous exceeds crop needs in what percent of U.S. countries?**

   - ○ 0%
   - ○ 15%

- 30%
- 45%

Feedback

3. **What is the common name for the class of production agricultural plants that do not need commercial nitrogen fertilizer?**

- N Converters
- Maize
- Legumes
- Algae

Feedback

4. **If biodegradable organic matter is added to a stream, fish kills most often result from:**

- Lack of oxygen
- Turbulence
- Lack of visibility
- Build up of sludge deposits

Feedback

5. **Most manure spills that enter streams result from:**

- Pastured animals with stream access
- Rupture of manure storage
- Improper land application of manure
- Damage to manure transfer or irrigation pipes
- Feedlot runoff from animal area
- All of the above

Feedback

6. **Nitrogen gas (N_2) account for ___________ % of the atmosphere?**

- 0%
- 24%
- 62%
- 78%
- 92%

Feedback

7. **Nitrogen in manure can take many chemical forms. Which of the following is NOT included?**

- ○ Nitrogen gas
- ○ Organic nitrogen
- ○ Catatonic nitrogen
- ○ Ammonia
- ○ Ammonium

Feedback

8. **Which nutrient in runoff from agricultural land has been blamed for the hypoxia problem in the Gulf of Mexico?**

- ○ Phosphorous
- ○ Chlorine
- ○ Sulfur
- ○ Nitrogen
- ○ Soil erosion

Feedback

9. **Which of the forms of nitrogen are volatile?**

- ○ NH_3
- ○ NO_3
- ○ NO_2
- ○ NH_4

Feedback

10. **High nitrate levels in drinking water can lead to the following serious condition in infants:**

- ○ "Green baby syndrome"
- ○ Headaches
- ○ Methemoglobinemia
- ○ Colic
- ○ Alzheimer's

Feedback

11. **The most important method of reducing phosphorous entering streams is:**

- ○ Placing riprap along edge of stream

- Preventing soil erosion
- Improving field drainage

Feedback

12. **Which of the following is NOT a significant source of air emissions around a livestock or animal production operation?**

- Feed processing
- Land application of manure
- Animal production lots and buildings
- Manure Storage

Feedback

See Results RESET

Score in Percentage:	

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Comprehensive Nutrient Management Planning

Recently, the concept of Comprehensive Nutrient Management Planning (CNMP) was introduced by the U. S. Environmental Protection Agency (EPA) and U.S. Department of Agriculture's (USDA's) Natural Resources Conservation Service (NRCS). It is anticipated that the CNMP will serve as a cornerstone of environmental plans assembled by animal feeding operations to address federal and state regulations. EPA and NRCS guidelines for CNMP are given in Table 1.

Table 1. Summary of Issues addressed by a CNMP as initially defined by EPA's Guidance

Planning components of CNMP	Issues addressed
A manure handling and storage plan	1. Diversion of clean water 2. Prevention of leakage storage plan 3. Adequate storage 4. Manure treatment 5. Management of mortality
Land application plan	1. Proper nutrient application rates to achieve a crop nutrient balance 2. Selection of timing and application methods to limit risk of runoff
Site management plan	Soil conservation practices that minimize movement of soil and manure components to surface and groundwater
Record keeping	Manure production, utilization, and export to off-farm users
Other utilization	Alternative safe manure utilization strategies such as sale of manure,

options	treatment technologies, or energy generation
Feed management plan	Alternative feed programs to minimize the nutrients in manure

Reference: USDA/EPA Unified National Strategy for Animal Feeding Operations (PDF) (34 pp, 404K)

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Dairy Production Study Questions

Identify the definition that best fits the following terms:

1. **Heifer**

   - A female bovine that has not borne a calf
   - An adult male bovine, normally used for breeding
   - A really long time
   - A type of silo unloader

   Feedback

2. **Holstein**

   - An older cow that is pregnant
   - A full mug of beer
   - A cow of the most common breed of dairy cattle
   - A brown beef bull

   Feedback

3. **Freestall**

   - Complimentary room at the rural motel
   - Feeding program for high producing cows
   - A housing arrangement where cows can move freely between their feeding area and resting areas.
   - A calf's hesitation when it is first removed from its hutch

   Feedback

4. **Leading Dairy Producing States**

   - Wisconsin, Texas, Indiana, North Carolina, Michigan
   - California, Wisconsin, New York, Pennsylvania, Minnesota
   - California, Idaho, Washington, New Mexico, Nevada
   - Michigan, Ohio, Indiana, Illinois, California
   - California, Wisconsin, New York, Pennsylvania, Indiana

   Feedback

5. **Pasteurization**

   - Process to make penicillin
   - Removing cream from the skim milk
   - Rapidly heating milk to 72 - 75 °C for 15 to 20 seconds, and then quickly cooling to slow growth of bacteria
   - Managed intensive grazing of cows
   - Boiling the milk to sterilize it

   Feedback

6. **Whey**

   - Juice that seeps from a silo when wheat silage is harvested and stored
   - Portion of cream remaining after butter is made
   - Oil used on clippers to trim hair from cows' udders
   - Portion of milk remaining after cheese curd is removed
   - Sarcastic response to someone who says "No way!"

   Feedback

7. **Guernsey**

   - A red and white to mostly red breed of cattle that are known for the yellow color of their milk.
   - A famous garden seed company
   - A type of portable shelter used where calves are kept when placed on pasture land
   - A bracket for a milk pipeline
   - A mostly black breed of cow with a belt white hair around its belly

   Feedback

8. **Dry Cow**

   - A martini made with milk and non-sweet vermouth
   - A cow that is not producing milk prior to second or subsequent calving
   - A cow with a very mildly humorous personality
   - An indication of inadequate water intake
   - The weight of a cow after the weight of water is discounted

   Feedback

9. **Calf Hutch**

   - A small, outdoor, individual housing unit for a calf

- A cabinet for calf medicine
- A disease of the calf's navel, sometimes called "navel ill"
- The most popular brand of calf milk replacer
- Calf Starsky's partner

Feedback

10. **Estrus**

- An indication that the cow is ready to be bred
- A type of grain fed to bulls
- The process of removing calves from the cow
- A hook used to hold rafters together
- An important religious holiday

Feedback

11. **Bedding**

- A cow blanket
- Sand, bare concrete, dirt
- Silage, soybean meal, feather meal
- Cotton seed, hay, tallow
- Sand, straw, newspaper, wood shavings

Feedback

12. **Total Mixed Ration**

- A feeding system where all feeds are blended together
- A feeding system where the cow is fed a single, but different, feed everyday
- A kind of cereal fed to cows
- A feeding system that allows the same feed to be fed to calves, heifers, and cows
- Limit feeding cows

Feedback

13. **Rumen**

- A chocolate brown breed of dairy cattle
- An additive in feed to prevent hardware disease
- A common antibiotic
- The largest compartment of a cow's "stomach"
- The act of renting a farm

Feedback

14. **Parallel Parlor**

- A long narrow room in the dairy farm office to receive sales persons
- A milking system in which cows stand side by side and milked from between the rear legs
- Two herringbone parlors set up side by side
- A completely automatic milking system
- The area just behind a cow's flank

Feedback

15. **Mastitis**

- Rigging in a ship's sail
- A breed of very large dogs
- Inflammation of the udder
- A swelling under the cow's jaw
- A young male calf

Feedback

See Results RESET

Score in Percentage:	

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Background of Beef Production in U.S.

Beef cattle production is an important industry in the United States and throughout the world. Since beef cattle can graze forages in the open range and pasturelands, they serve a unique role in providing high quality protein for human consumption from byproducts and forage sources that humans do not consume. Considerable land in the U.S. and the world that will not support intensive crop production, can often times sustain grasses and forages that conserve the land, and produce feeds that cattle can utilize. Beef cattle production is dispersed throughout the U.S., but a significant amount of beef is produced on the rangelands of the Western U.S.

Historical Background

The cattle used for beef production in the U.S. historically originated from two areas of the world. These include the *Bos taurus* cattle from Europe and the *Bos indicus* from tropical countries. *Bos taurus* were native to the temperate countries of the UK (Scotland, England and Wales), France, Belgium, Spain, Italy, Germany, Austria and Switzerland. These cattle were used primarily for meat and milk production with other byproducts such as hides tanned for leather. *Bos indicus* were native cattle in the tropical countries of SE Asia, and Africa. They have the characteristic "humped back" appearance, the capability to tolerate high temperature and humidity environments, disease resistance to ticks, mosquitoes and other tropical insects, and often were used for work, meat and milk production.

According to "The Science of Animal Husbandry" by Blakely and Bade, Second edition (1979) and "Animal Science" by Gillespie (1998), when Columbus came to America, there were no domestic type animals. Cattle etc., were brought on Columbus' second voyage in 1493. Small importations continued periodically with Vera Cruz bringing the Spanish type longhorn cattle from Spain into Mexico in 1521. These cattle later spread throughout the western U.S. as they were brought to Christian missions built by the Spanish. Herds of 424,000 cattle at two missions have been recorded. More cattle were brought to the New World by Portuguese traders in 1553. The English were the first to bring large numbers of cattle to the United States when they founded the Jamestown colony in 1611. Following the American Revolution, livestock moved westward, and by the early 1800s were distributed over most of the East, the South and the far West.

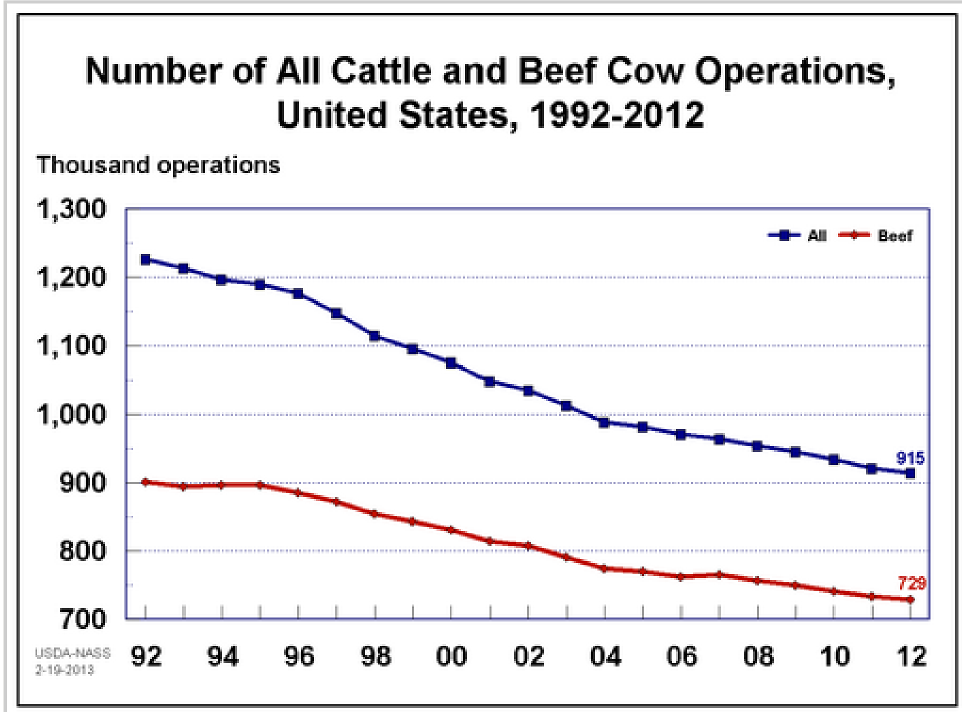
The animals imported from Europe were used mainly for milk, butter, hides and draft. With wild game plentiful, meat was not the citizen's main concern. These animals under the guiding hands of notables like George Washington and Thomas Jefferson multiplied and purebred herds developed in the East.

Cattle production today has become more specialized in the U.S. with concentrations of feedlot cattle in parts of the Corn Belt, Southwest, and Pacific Northwest Cow-calf operations mostly operate on land not suited or needed for crop production. The U.S. is home to the world's largest fed-cattle industry. (USDA, Cattle & Beef Background)

As the standard of living has increased throughout the world, protein consumption has increased and the overall quality of human diets has improved. Beef has become a significant protein source in the U.S. diet with nearly 61 lbs of beef consumed per person each year in the U.S. Beef is offered on the menus of most restaurants and consumption of beef is considered a status of wealth in many countries because it is usually a relatively expensive protein food source. (USDA, Beef From Farm to Table)

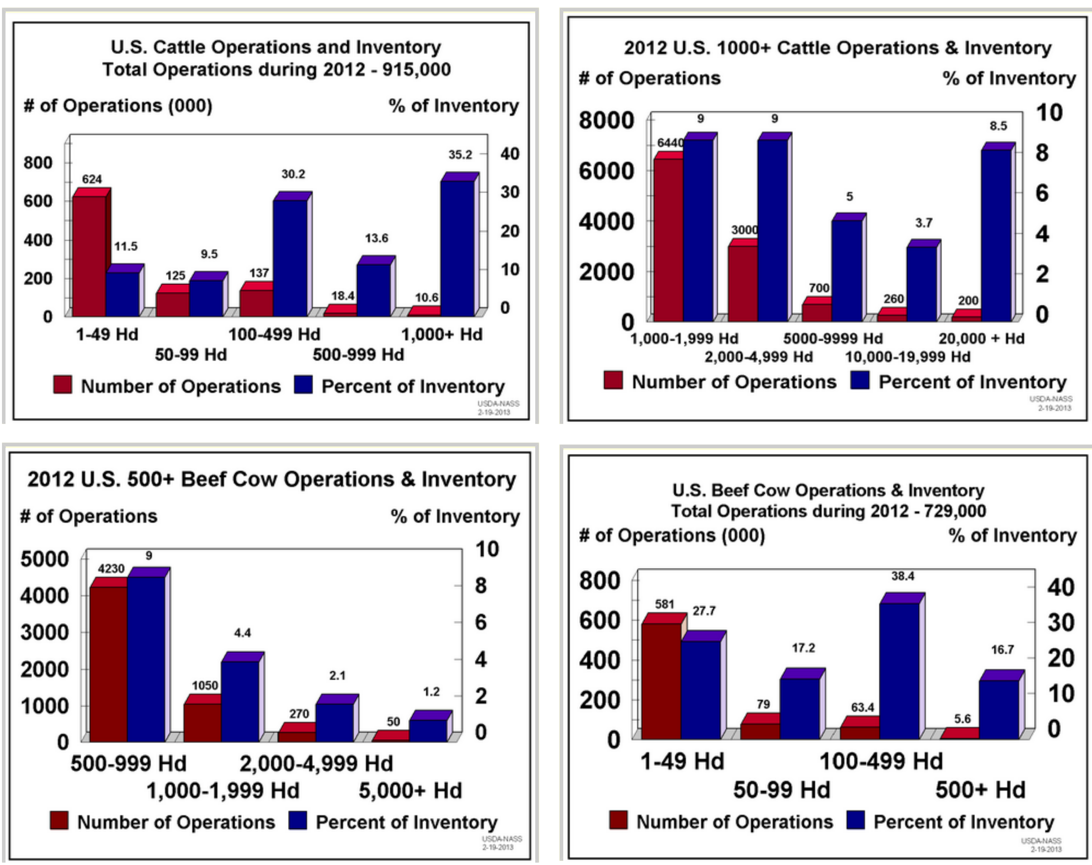
Industry size

The size of the beef industry in the U.S. has declined gradually over the last 20 years. There were 1.0 million beef cow operations in 1986, which had declined to 0.83 million operations in 2000 and down



to .729 million in 2012. The numbers of beef cows, however, have remained stable at about 30 million head. The number of cattle produced for meat consumption has also remained steady with 11.3 million (2012) compared to 11.9 million on feed (1992), and 11.8 million on feed (2001). (USDA, Cattle On Feed) The beef industry provides more than one million jobs in the U.S., creating a ripple effect in the economy. For every dollar of cattle sales, there is approximately five dollars in additional business activity generated. During the 2000s, U.S. Beef production generated more than $49 billion annually in direct economic output, plus about five times that amount per year in related economic output. (Beef Checkoff, U.S. Cash Receipts from Farming)

U.S. Cattle and Beef Operations and Inventory



There are many beef cattle operations in the U.S., but most are small in the numbers of animals that they produce. A similar trend is shown with beef cow operations.

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Products from Beef Production

Typically, we think of beef cattle being produced only for meat production for human consumption. Obviously, the meat is processed into many nutritious products, including, steaks, roasts, hamburger, sausages, etc. However, there are several valuable byproducts from the beef animal that also serve mankind. These include leather goods, fertilizers, cosmetics, drugs, hair products, perfumes, gelatin products, glues and animal feed byproducts, to name a few.

Byproducts from each 1,000 lbs steer are worth $96 ($3.4 billion annually for the U.S.) and benefits the consumer with health, clothing and nutritional products.

Segments of the Beef Industry

The beef industry encompasses all segments from conception of the animal to the delivery of food to the consumer's table. The cow-calf production sector involves breeding of cows with bulls or artificial insemination, conception, gestation, birth of the calf and lactation periods until weaning of the calf from the cow. The calf is weaned at approximately 500 to 600 lbs. live weight or about 6 to 8 months of age. From this age, the calves are usually fed on grassland until they weigh approximately 750 to 800 lbs. live weight when they are called stocker cattle. Stocker calves are placed in a confinement feedlot for approximately 90 to 120 days until they reach a live weight of 1100 to 1250 lbs. On some farms, depending on the availability of feed, weaned calves may be placed directly into a confinement feedlot for growing and finishing, skipping the grassland phase.

In today's specialized beef industry, one producer may operate a cow-calf business producing weaned calves, another producer may background the calves on forage or pastureland, and still another may finish the stocker cattle in the feedlot. Some cattle businesses manage all three sectors of beef production; however, these are typically relatively small production units. Often, several large producers from the various phases form alliances to enhance the flow of cattle through the process. Also, there are specialized heifer replacement operations with the objective of producing genetically superior females to be placed into breeding herds to supply better calves for beef production.

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Production Phases

Life cycle of beef cattle

After a calf is weaned from the cow at about 6 to 8 months of age, bull calves are typically castrated and ultimately, fed until market weight. Genetically superior bull calves are separated out for use in breeding programs. Heifers that will be kept in the herd reach sexual maturity by 15-months of age and are bred to deliver their first calf when they are 24-months of age. The gestation period for beef cattle is 9 months. Following the first calf, the female, now a cow, is rebred after a two to three month period and another calf delivered 9 months later. The goal is a 12-month calving interval. The average cow will stay productive in a breeding herd for 7 to 9 years if no disease or physical problems develop.

Feeding beef cattle

Beef cattle, like other ruminants, possess a digestive system that includes a multi-compartment stomach that can digest fibrous materials such as grass, corn stalks, cottonseeds, alfalfa and grass hays, etc. Bacteria and protozoa that reside in cattle's stomach make it possible to release nutrients from fibrous feeds that can be utilized by the animal. Unlike most other animals, cattle can consume byproduct feeds like corn gluten, distiller's grains, brewer's grains, potato chips, soybean hulls, citrus pulp and other products that are considered waste products. Cattle are also fed protein sources, such as soybean meal, canola meal, alfalfa and urea, and cereal grains such as corn, sorghum, barley, wheat, and oats. Generally, feedlot cattle are fed predominantly high quality fibrous diets early in their growth periods and high-energy cereal grain diets during the finishing periods. The breeding herd commonly grazes fibrous forages from pastureland, rangeland and from field residues, such as corn stalks. A mature cow consumes about 5 tons of fibrous feed (forages) per year.

Beef cattle consume feeds that range from high quality cereal grains such as corn, soybeans, wheat, barley, sorghum, etc. called concentrates to high and low quality fibrous feeds such as legume hays, i.e., alfalfa, clover, birdsfoot trefoil, soybeans, etc.; grass hays, i.e., brome, timothy, fescue, blue grass, coastal bermuda, etc.; mixtures of legumes and grasses; corn stalk residue, soybean residue, winter wheat, and other forages. The quality of forages can vary greatly depending upon the maturity and time of harvest, fertilization practices, method of harvest and preservation. Formulating a diet to meet specific animal needs requires knowing the nutrient content of the forage and balancing the diet with appropriate grains, minerals and vitamins. Forages can be preserved dry as hay in the form of large round bales or small rectangular bales, or fermented in the absence of oxygen by chopping the forage into smaller particle size and placed in storage structures called a silo. Silos can be upright above ground containers, horizontal concrete structures or horizontal plastic containers. All of these structures must be sealed for the anaerobic fermentation process to succeed in preserving the forage. Fermenting preserves the nutrient value of the feed so that it can be stored for a long time without spoilage. As mentioned before, beef cattle can consume fibrous feed sources and byproducts (waste products from other industries) that humans and non-ruminant animals (pigs and chickens) cannot consume. Thus, beef cattle provide a high quality, value-added protein source for humans from lower quality feed resources.

Feedlot cattle are commonly fed in open fence-line bunk feeders with the producer delivering the feed daily using a tractor and feed wagon, or by mechanical feed delivery systems to a stationary feed bunk. The cowherd normally obtains the majority of their diet from grazing, however, salt-mineral blocks (sometime fortified with protein and vitamins) and possibly a concentrate mix (predominantly cereal grains and protein) are fed during the winter or drought seasons when the quality of the pasture is poor. Generally, crop residues, such as corn stalks, require supplemental grains or protein and minerals at certain times of the life cycle (especially late in pregnancy and during early lactation) of the breeding herd.

Housing

Slotted Floor
Source: Purdue University

Housing systems for beef cattle in confinement feedlots vary, depending on the climate in the area and topography of the site. They include total confinement buildings, open sheds and lots or open lots with windbreaks and/or shades. The lots are usually paved if located in humid climates to minimize mud problems. Beef cattle are hearty animals that tolerate a wide range of climatic conditions. Most buildings have open sidewalls and are naturally ventilated. Open sheds and lots are typically positioned to allow for protection from prevailing winds and maximize sun exposure during winter. In summer, shades and open areas allow for cooling and air movement. In arid climates, sprinkler systems are used in hot weather for cooling as well as for dust control.

In most confinement buildings or in a loafing sheds, with the shed and lot system, bedding on a solid floor is used to keep cattle dry. Some cattle are housed in a confinement building with total slotted floors where the manure drops into a storage container beneath the floor. However, this system in not commonly used today because of cost and potential feet and leg problems. In humid regions of the U.S. (Midwestern, Northeastern and Southeastern U.S.) cattle are often housed in a paved, or partially paved, feedlot with a loafing shed containing bedding for comfort of the cattle and a large fenced area for the cattle to use as an exercise area. In more arid areas (Western and Southwestern U.S.), cattle are reared in earthen lots with only windbreak fences and/or shades to protect the cattle during inclement weather.

The cowherd may also be housed in feedlots during the winter season or during calving season to facilitate closer observation of any calving problems. More typically, however, the breeding herd grazes pastures, rangeland or cornstalks and other crop residues after harvest. In most cases, the breeding herd is on the open range or pasture for 9 to 12 months of the year.

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Manure Management System

Solid manure being loaded into spreader

Beef cattle manure can be handled as a solid, semi-solid or a liquid. The bedding used in loafing sheds will form a manure pack with the manure incorporated into the bedding material. Common bedding materials include, straw, sand, wood shaving, sawdust, recycled newspaper print, and chopped corn stalks. Generally, the manure pack is removed once or twice a year and spread onto cropland or pastureland for use as a fertilizer resource. Solid manure scraped from open lots is usually applied to cropland after removal, or stockpiled in a solid manure storage facility near the feedlot. Solid manure storage is generally in a structure with a paved floor and walls on three sides to allow the material to be stacked. In humid areas, manure storage may need to be covered to keep the manure drier. Solid manure is surface applied to cropland with a box-type manure spreader or a flail-type manure spreader. Clean up-slope runoff water and roof water should be diverted around the manure storage to minimize the amount of storage needed.

Solid manure ready for transport to the field for application

Solid manure being surface applied with box spreader

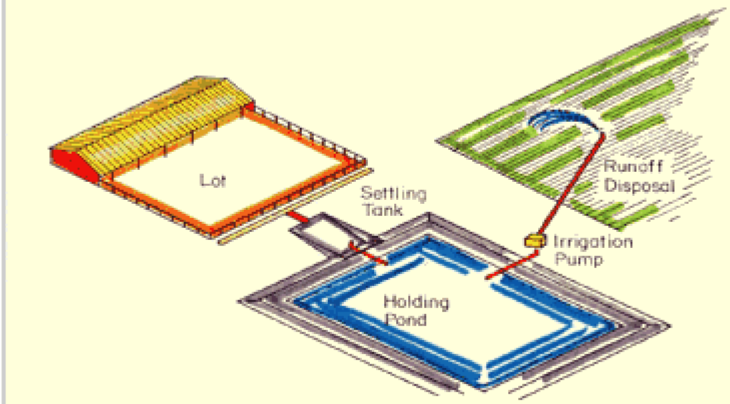
Manure in a liquid or semi-solid form (slurry) is generally stored for at least 180 days before removal and application to cropland or pastureland. Depending on the site, pumps, transfer pipes or channels may be required to move the manure from the animal housing areas to storage. Semi-solid manure is stored in either above ground concrete or steel tanks or below ground earthen or concrete tanks. Liquid manure may be stored in formed tanks, earthen storage, or in earthen lagoons that can consist of one cell or more cells. Lagoons provide treatment of the manure (by anaerobic, aerobic or a combination of aerobic and anaerobic processes) as well as storage. Composting is another option for solid manure management.

Solid manure being field applied with side slinging spreader

Shed and outside lot with runoff control

Manure scraped to sump and stored as a slurry

Runoff from open cattle lots must be controlled, especially during heavy rainfall events. Runoff control systems include settling basins (to remove manure solids) in combination with earthen detention ponds; transfer of runoff into a lagoon system; or for small feedlots, a settling basin in combination with grass infiltration areas.



Shed and outside lot with runoff control and irrigation of runoff holding pond

Equipment to transfer and apply manure to cropland includes tanker wagons and trucks that can spread manure on the surface or inject it directly beneath the soil surface or irrigation systems with stationary or moving delivery systems. Very dilute liquids can often be applied with irrigation systems.

[More Manure Images](#)

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Beef Production Study Questions

Identify the definition that best fits the following terms:

1. **Bull**
   - Uncastrated bovine male
   - Positive stock market
   - A China shop figurine
   - Strong-willed individual

   Feedback

2. **Beef consumption in the US is nearly ______ pounds per person per year**
   - 30
   - 70
   - 100
   - 15

   Feedback

3. **In the US, the beef industry provides about $5 business activity for every $1 in cattle sales.**
   - True
   - False

   Feedback

4. **Backgrounding**
   - Providing a case history on each beef animal
   - Teaching each animal to back up in a straight line
   - Growing program for feeder cattle from weaning until finishing in a lot
   - Housing in a dirt feedlot

   Feedback

5. **Lagoon**
   - Plants that fix nitrogen and are a good protein source

- Excellent place to fish
- Contains concentrated slurry manure
- Earthen structure for storage and treatment of dilute manure

Feedback

6. **Ruminant**

- Animal with a multi-compartment stomach
- Microorganisms that biodegrade organic matter without oxygen
- General family grouping of cattle
- Unique specie of ants

Feedback

7. **Stocker**

- Person who places inventory on the shelves at retail stores
- Cattle buyer who purchases live finished cattle for harvesting
- Equipment to place hay in piles for storage before feeding
- Weaned cattle fed high-roughage diets before finishing in feedlot

Feedback

8. **Feedlot**

- Storage area for feeds
- Open area where forages are grown, cattle can roam and graze
- Structure for collection and storage of manure
- Enterprise and housing system for finishing cattle with grain and concentrates

Feedback

9. **Common examples of byproducts from the cattle industry are**

- Leather goods
- Cosmetics
- Perfumes
- Hair products
- All of the above

Feedback

10. **Byproduct feeds that cattle can consume include :**

- Corn gluten
- Distiller's grains
- Potato chips
- Citrus pulp
- Soybean hulls
- Cottonseed hulls
- All of the above
- None of the above

Feedback

11. **A typical cow will consume about 5 tons of fibrous feed (forages) per year.**

- True
- False

Feedback

12. **A beef cow will stay productive in the herd for about**

- 2 to 3 years
- 5 to 6 years
- 7 to 9 years
- 12 to 14 years

Feedback

13. **Cattle have the unique capability of providing protein for human consumption from byproduct feeds and highly fibrous forages that humans do not consume**

- True
- False

Feedback

14. **Silo**

- Structures for storing high moisture fermented feeds in anaerobic conditions
- Structure for storing slurry manure
- Housing system for pigs

Feedback

15. **Cattle manure can be stored in the following forms**

- Solid with bedding
- Liquid slurry in tanks
- Liquid slurry in earthen storage
- Dilute liquid waste water in earthen lagoons or detention ponds
- All of the above
- None of the above

Feedback

16. **Concentrate**

- Serious thought process
- Feed with high energy, low fiber and highly digestible
- Grazed feed in the open range

Feedback

See Results RESET

Score in Percentage:	

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Beef Glossary

Aerobic - Microorganisms that require free oxygen to biodegrade organic matter.

Anaerobic - Microorganisms that biodegrade organic matter without free oxygen.

Artificial Insemination (AI) - Placing semen into the female reproductive tract (usually the cervix or uterus) by means other than natural service.

Average Daily Gain - Pounds of live weight gained per day.

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Backgrounding - Growing program for feeder cattle from the time calves are weaned until they are on a finishing ration in the feedlot. Backgrounding is the management process of feeding the stocker animal.

Beef - Meat from cattle (bovine species) other than calves. Meat from calves is called veal.

Bovine - Refers to a general family grouping of cattle.

Breed - Cattle of common origin and having characteristics that distinguish them from other groups within the same species.

Bull - Bovine male. The term usually denoted animals of breeding age.

Bullock - Young bull, typically less than 20 months of age.

Byproduct - Product of considerably less value than the major product. For example, the hide and offal are byproducts while beef is the major product.

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Calf - Young male or female bovine animal under 1 year of age.

Calve - Giving birth to a calf. Same as parturition.

Concentrate - Feed that is high in energy, low in fiber content, and highly digestible.

Cow - Sexually mature female bovine animal that has usually produced a calf.

Cow-Calf Operation - Management unit that maintains a breeding herd and produces weaned calves.

Denitrification - The biochemical reduction of nitrate or nitrite to gaseous nitrogen, either as molecular nitrogen or as an oxide of nitrogen.

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Fed Cattle - Steers and heifers that have been fed concentrates, usually for 90-120 days in a feedlot.

Feeder

1. Cattle that need further feeding prior to slaughter.
2. Producer who feeds cattle.

Feedlot - Enterprise in which cattle are fed grain and other concentrates for usually 90-120 days. Feedlots range in size from less than 100-head capacity to many thousands.

Finished Cattle - Fed cattle whose time in the feedlot is completed and are now ready for slaughter.

Forage - Feedstuffs composed primarily of the whole plant, including stems and leaves that are utilized by cattle.

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Heifer - Young female bovine cow prior to the time that she has produced her first calf.

Herd - Group of cattle (usually cows) that are in a similar management program.

Hide - Skins from cattle.

Integration - Bringing together of two or more segments of beef productions and processing under one centrally organized unit.

Lagoon - Earthen storage structure with sufficient dilution water added to allow microorganisms to biodegrade and treat organic matter.

Legume - Any of thousands of plant species that have seed pods that split along both sides when ripe. Some of the more common legumes used for human consumption are beans, lentils, peanuts, peas, and soybeans. Others, such as clover and alfalfa, are used as animal feed. Legumes have a unique ability to obtain much or all of their nitrogen requirements from symbiotic nitrogen fixation.

Meat - Tissue of the animal body that are used for food.

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Nitrification - The biochemical oxidation of ammonium to nitrate, predominantly by autotrophic bacteria.

Ration - Feed fed to an animal during a 24-hour period.

Roughage - Feed that is high in fiber, low in digestible nutrients, and low in energy (e.g., hay, straw, silage, and pasture).

Ruminant - Mammal whose stomach has four parts-rumen, reticulum, omasum, and abomasum. Cattle, sheep, goats, deer, and elk are ruminants.

Steer - Bovine male castrated prior to puberty.

Stocker - Weaned cattle that are fed high-roughage diets (including grazing) before going into the feedlot.

Weaning (wean) - Separating young animals from their dams so that the offspring can no longer suckle.

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U.S. ENVIRONMENTAL PROTECTION AGENCY

Ag 101

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Beef Production

Beef cattle production is a strong animal industry within the United States and throughout the world. Since beef cattle can graze forages in the open range and pasturelands, they serve a unique role in providing high quality protein for human consumption from byproducts and forage sources that humans and non-ruminant animals do not consume. Considerable land in the U.S. and the world that will not support intensive crop production, can often times sustain grasses and forages that provide conservation of the land, and produce feeds that cattle can utilize. Beef cattle production is dispersed throughout the U.S., but a significant amount of beef is produced on the rangelands of the Western U.S. About 830,000 farms had beef cows in 2000 and almost 12 million cattle on feed annually.

Beef cattle production ranges from the beef cow herd that typically graze on pastureland or graze the remaining residue on the land after grain harvest to growing and finishing young cattle in feedlots. The feedlot-housing systems used in beef cattle production typically varies by climate and can range from open earthen lots with very little shelter to open shed and lot or an enclosed confinement building. Manure handling and storage ranges from solid manure with bedding included, and runoff water from open lots to liquid slurry and treatment lagoon systems. Due to the increasing size of beef operations, the large volume of manure production, collection, storage and application to the land has presented challenges.

This module will look at beef cattle production from a historical perspective, economic impact of the beef industry in the U.S., typical production practices and manure management systems used today.

Background of Beef Production in U.S.

Beef cattle production is an important industry in the United States and throughout the world. Since beef cattle can graze forages in the open range and pasturelands, they serve a unique role in providing high quality protein for human consumption from byproducts and forage sources that humans do not consume. Considerable land in the U.S. and the world that will not support intensive crop production, can often times sustain grasses and forages that conserve the land, and produce feeds that cattle can utilize. Beef cattle production is dispersed throughout the U.S., but a significant amount of beef is produced on the rangelands of the Western U.S.

Historical Background

The cattle used for beef production in the U.S. historically originated from two areas of the world. These include the *Bos taurus* cattle from Europe and the *Bos indicus* from tropical countries. *Bos taurus* were native to the temperate countries of the UK (Scotland, England and Wales), France, Belgium, Spain, Italy, Germany, Austria and Switzerland. These cattle were used primarily for meat and milk production with other byproducts such as hides tanned for leather. *Bos indicus* were native cattle in the tropical countries of SE Asia, and Africa. They have the characteristic "humped back" appearance, the capability to tolerate high temperature and humidity environments, disease resistance to ticks, mosquitoes and other tropical insects, and often were used for work, meat and milk production.

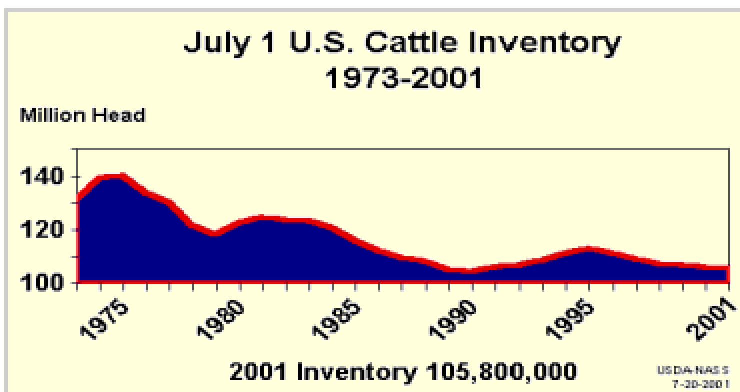
According to "The Science of Animal Husbandry" by Blakely and Bade, Second edition (1979) and "Animal Science" by Gillespie (1998), when Columbus came to America, there were no domestic type animals. Cattle etc., were brought on Columbus' second voyage in 1493. Small importations continued periodically with Vera Cruz bringing the Spanish type longhorn cattle from Spain into Mexico in 1521. These cattle later spread throughout the western U.S. as they were brought to Christian missions built by the Spanish. Herds of 424,000 cattle at two missions have been recorded. More cattle were brought to the New World by Portuguese traders in 1553. The English were the first to bring large numbers of cattle to the United States when they founded the Jamestown colony in 1611. Following the American Revolution, livestock moved westward, and by the early 1800s were distributed over most of the East, the South and the far West.

The animals imported from Europe were used mainly for milk, butter, hides and draft. With wild game plentiful, meat was not the citizen's main concern. These animals under the guiding hands of notables like George Washington and Thomas Jefferson multiplied and purebred herds developed in the East.

Cattle production today has become more specialized in the U.S. with concentrations of feedlot cattle in Texas, Colorado, Nebraska, Kansas, Iowa, California and Oklahoma and cow-calf operations in Missouri, South Dakota, North Dakota, Nebraska, Kansas, Kentucky, Montana, Tennessee, and Oklahoma. Today, the U.S. ranks fourth in the world in total cattle numbers.

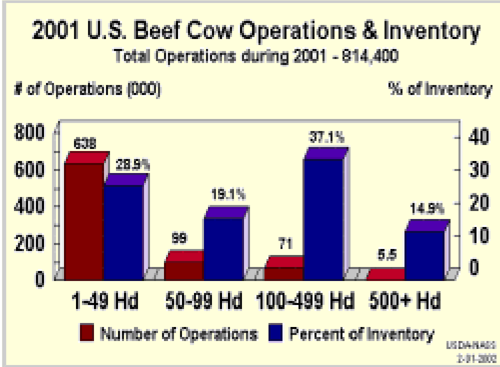
As the standard of living has increased throughout the world, protein consumption has increased and the overall quality of human diets has improved. Beef has become a significant protein source in the U.S. diet with nearly 70 lbs of beef consumed per person each year in the U.S. Beef is offered on the menus of most restaurants and consumption of beef is considered a status of wealth in many countries because it is usually a relatively expensive protein food source.

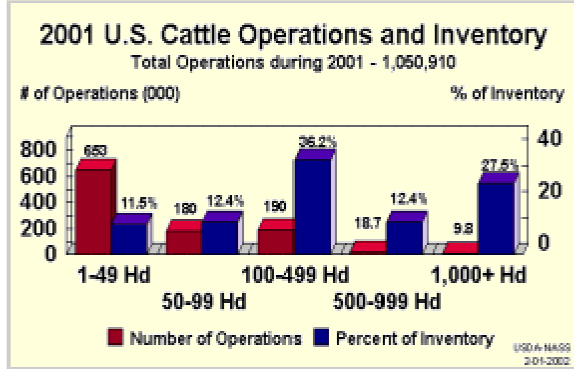
Industry size



The size of the beef industry in the U.S. has declined gradually over the last 15 years. There were 1.0 million beef cow operations in 1986, which had declined to 0.83 million operations in 2000. The numbers of beef cows, however, have remained stable at about 33 million head. The number of cattle produced for meat consumption has also remained steady with 11.9 million on feed in 1992 compared to 11.8 million in 2001. The current annual gross sale of feedlot cattle is $36.8 billion while the total value of our beef animal inventory is estimated at $70.6 billion. The beef industry provides more than one million jobs in the U.S., creating a ripple effect in the economy. For every dollar of cattle sales, there is approximately five dollars in additional business activity generated. During the 1990s, U.S. Beef production generated more than $30 billion annually in direct economic output, plus about five times that amount per year in related economic output.

There are many beef cattle





operations in the U.S., but most are small in the numbers of animals that they produce. A similar trend is shown with beef cow operations.

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Products from Beef Production

Typically, we think of beef cattle being produced only for meat production for human consumption. Obviously, the meat is processed into many nutritious products, including, steaks, roasts, hamburger, sausages, etc. However, there are several valuable byproducts from the beef animal that also serve mankind. These include leather goods, fertilizers, cosmetics, drugs, hair products, perfumes, gelatin products, glues and animal feed byproducts, to name a few.

Byproducts from each 1,000 lbs steer are worth $96 ($3.4 billion annually for the U.S.) and benefits the consumer with health, clothing and nutritional products.

Segments of the Beef Industry

The beef industry encompasses all segments from conception of the animal to the delivery of food to the consumer's table. The cow-calf production sector involves breeding of cows with bulls or artificial insemination, conception, gestation, birth of the calf and lactation periods until weaning of the calf from the cow. The calf is weaned at approximately 500 to 600 lbs. live weight or about 6 to 8 months of age. From this age, the calves are usually fed on grassland until they weigh approximately 750 to 800 lbs. live weight when they are called stocker cattle. Stocker calves are placed in a confinement feedlot for approximately 90 to 120 days until they reach a live weight of 1100 to 1250 lbs. On some farms, depending on the availability of feed, weaned calves may be placed directly into a confinement feedlot for growing and finishing, skipping the grassland phase.

In today's specialized beef industry, one producer may operate a cow-calf business producing weaned calves, another producer may background the calves on forage or pastureland, and still another may finish the stocker cattle in the feedlot. Some cattle businesses manage all three sectors of beef production; however, these are typically relatively small production units. Often, several large producers from the various phases form alliances to enhance the flow of cattle through the process. Also, there are specialized heifer replacement operations with the objective of producing genetically superior females to be placed into breeding herds to supply better calves for beef production.

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Production Phases

Life cycle of beef cattle

After a calf is weaned from the cow at about 6 to 8 months of age, bull calves are typically castrated and ultimately, fed until market weight. Genetically superior bull calves are separated out for use in breeding programs. Heifers that will be kept in the herd reach sexual maturity by 15-months of age and are bred to deliver their first calf when they are 24-months of age. The gestation period for beef cattle is 9 months. Following the first calf, the female, now a cow, is rebred after a two to three month period and another calf delivered 9 months later. The goal is a 12-month calving interval. The average cow will stay productive in a breeding herd for 7 to 9 years if no disease or physical problems develop.

Feeding beef cattle

Beef cattle, like other ruminants, possess a digestive system that includes a multi-compartment stomach that can digest fibrous materials such as grass, corn stalks, cottonseeds, alfalfa and grass hays, etc. Bacteria and protozoa that reside in cattle's stomach make it possible to release nutrients from fibrous feeds that can be utilized by the animal. Unlike most other animals, cattle can consume byproduct feeds like corn gluten, distiller's grains, brewer's grains, potato chips, soybean hulls, citrus pulp and other products that are considered waste products. Cattle are also fed protein sources, such as soybean meal, canola meal, alfalfa and urea, and cereal grains such as corn, sorghum, barley, wheat, and oats. Generally, feedlot cattle are fed predominantly high quality fibrous diets early in their growth periods and high-energy cereal grain diets during the finishing periods. The breeding herd commonly grazes fibrous forages from pastureland, rangeland and from field residues, such as corn stalks. A mature cow consumes about 5 tons of fibrous feed (forages) per year.

Beef cattle consume feeds that range from high quality cereal grains such as corn, soybeans, wheat, barley, sorghum, etc. called concentrates to high and low quality fibrous feeds such as legume hays, i.e., alfalfa, clover, birdsfoot trefoil, soybeans, etc.; grass hays, i.e., brome, timothy, fescue, blue grass, coastal bermuda, etc.; mixtures of legumes and grasses; corn stalk residue, soybean residue, winter wheat, and other forages. The quality of forages can vary greatly depending upon the maturity and time of harvest, fertilization practices, method of harvest and preservation. Formulating a diet to meet specific animal needs requires knowing the nutrient content of the forage and balancing the diet with appropriate grains, minerals and vitamins. Forages can be preserved dry as hay in the form of large round bales or small rectangular bales, or fermented in the absence of oxygen by chopping the forage into smaller particle size and placed in storage structures called a silo. Silos can be upright above ground containers, horizontal concrete structures or horizontal plastic containers. All of these structures must be sealed for the anaerobic fermentation process to succeed in preserving the forage. Fermenting preserves the nutrient value of the feed so that it can be stored for a long time without spoilage. As mentioned before, beef cattle can consume fibrous feed sources and byproducts (waste products from other industries) that humans and non-ruminant animals (pigs and chickens) cannot consume. Thus, beef cattle provide a high quality, value-added protein source for humans from lower quality feed resources.

Feedlot cattle are commonly fed in open fence-line bunk feeders with the producer delivering the feed daily using a tractor and feed wagon, or by mechanical feed delivery systems to a stationary feed bunk. The cowherd normally obtains the majority of their diet from grazing, however, salt-mineral blocks (sometime fortified with protein and vitamins) and possibly a concentrate mix (predominantly cereal grains and protein) are fed during the winter or drought seasons when the quality of the pasture is poor. Generally, crop residues, such as corn stalks, require supplemental grains or protein and minerals at certain times of the life cycle (especially late in pregnancy and during early lactation) of the breeding herd.

Housing

Housing systems for beef cattle in confinement

Slotted Floor
Source: Purdue University

feedlots vary, depending on the climate in the area and topography of the site. They include total confinement buildings, open sheds and lots or open lots with windbreaks and/or shades. The lots are usually paved if located in humid climates to minimize mud problems. Beef cattle are hearty animals that tolerate a wide range of climatic conditions. Most buildings have open sidewalls and are naturally ventilated. Open sheds and lots are typically positioned to allow for protection from prevailing winds and maximize sun exposure during winter. In summer, shades and open areas allow for cooling and air movement. In arid climates, sprinkler systems are used in hot weather for cooling as well as for dust control.

In most confinement buildings or in a loafing sheds, with the shed and lot system, bedding on a solid floor is used to keep cattle dry. Some cattle are housed in a confinement building with total slotted floors where the manure drops into a storage container beneath the floor. However, this system in not commonly used today because of cost and potential feet and leg problems. In humid regions of the U.S. (Midwestern, Northeastern and Southeastern U.S.) cattle are often housed in a paved, or partially paved, feedlot with a loafing shed containing bedding for comfort of the cattle and a large fenced area for the cattle to use as an exercise area. In more arid areas (Western and Southwestern U.S.), cattle are reared in earthen lots with only windbreak fences and/or shades to protect the cattle during inclement weather.

The cowherd may also be housed in feedlots during the winter season or during calving season to facilitate closer observation of any calving problems. More typically, however, the breeding herd grazes pastures, rangeland or cornstalks and other crop residues after harvest. In most cases, the breeding herd is on the open range or pasture for 9 to 12 months of the year.

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Manure Management System

Solid manure being loaded into spreader

Beef cattle manure can be handled as a solid, semi-solid or a liquid. The bedding used in loafing sheds will form a manure pack with the manure incorporated into the bedding material. Common bedding materials include, straw, sand, wood shaving, sawdust, recycled newspaper print, and chopped corn stalks. Generally, the manure pack is removed once or twice a year and spread onto cropland or pastureland for use as a fertilizer resource. Solid manure scraped from open lots is usually applied to cropland after removal, or stockpiled in a solid manure storage facility near the feedlot. Solid manure storage is generally in a structure with a paved floor and walls on three sides to allow the material to be stacked. In humid areas, manure storages may need to be covered to keep the manure drier. Solid manure is surface applied to cropland with a box-type manure spreader or a flail-type manure spreader. Clean up-slope runoff water and roof water should be diverted around the manure storage to minimize the amount of storage needed.

Solid manure ready for transport to the field for application

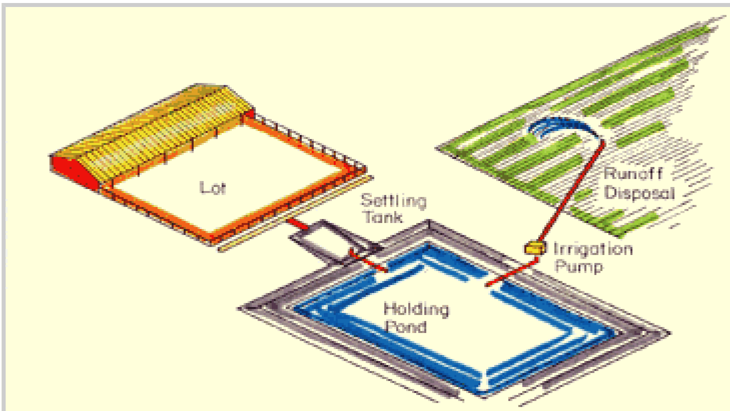
Solid manure being surface applied with box spreader

Manure in a liquid or semi-solid form (slurry) is generally stored for at least 180 days before removal and application to cropland or pastureland. Depending on the site, pumps, transfer pipes or channels may be required to move the manure from the animal housing areas to storage. Semi-solid manure is stored in either above ground concrete or steel tanks or below ground earthen or concrete tanks. Liquid manure may be stored in formed tanks, earthen storages, or in earthen lagoons that can consist of one cell or more cells. Lagoons provide treatment of the manure (by anaerobic, aerobic or a combination of aerobic and anaerobic processes) as well as storage. Composting is another option for solid manure management.

Solid manure being field applied with side slinging spreader

Shed and outside lot with runoff control

Manure scraped to sump and stored as a slurry



Shed and outside lot with runoff control and irrigation of runoff holding pond

Runoff from open cattle lots must be controlled, especially during heavy rainfall events. Runoff control systems include settling basins (to remove manure solids) in combination with earthen detention ponds; transfer of runoff into a lagoon system; or for small feedlots, a settling basin in combination with grass infiltration areas.

Equipment to transfer and apply manure to cropland includes tanker wagons and trucks that can spread manure on the surface or inject it directly beneath the soil surface or irrigation systems with stationary or moving delivery systems. Very dilute liquids can often be applied with irrigation systems.

More Manure Images

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Potential Environmental Impacts of Animal Feeding Operations

(Adapted in part from Livestock and Poultry Environmental Stewardship Curriculum, MidWest Plan Service; and Proposed US EPA Confined Feeding Rule.)

USEPA's 1998 *National Water Quality Inventory* indicates that agricultural operations, including animal feeding operations (AFOs), are a significant source of water pollution in the U.S. States estimate that agriculture contributes in part to the impairment of at least 170,750 river miles, 2,417,801 lake acres, and 1,827 estuary square miles (Table 1). Agriculture was reported to be the most common pollutant of rivers and streams.

However, one should not overlook the many positive environmental benefits of agriculture. For example, agricultural practices that conserve soil and increase productivity while improving soil quality also increase the amount of carbon-rich organic matter in soils, thereby providing a global depository for carbon dioxide drawn from the atmosphere by growing plants. The same farming practices that promote soil conservation also decrease the amount of carbon dioxide accumulating in the atmosphere and threatening global warming.

Other benefits compared to urban or industrial land use include greatly reduced storm runoff, groundwater recharge and water purification as infiltrating surface water filters through plant residue, roots and several feet of soil to reach groundwater.

In many watersheds, animal manures represent a significant portion of the total fertilizer nutrients added. In a few counties, with heavy concentrations of livestock and poultry, nutrients from confined animals exceed the uptake potential of non-legume harvested cropland and hayland. USDA estimates that recoverable manure nitrogen exceeds crop system needs in 266 of 3,141 counties in the U.S. (8%) and that recoverable manure phosphorus exceeds crop system needs in 485 counties (15%). It should be pointed out that while legumes are able to produce their own nitrogen, they will use applied nitrogen instead if it is available. The USDA analysis does not consider actual manure management practices used or transport of applied nutrients outside the county; however, it is a useful indicator of excess nutrients on a broad scale. Whole-farm nutrient balance is a very useful tool to identify potential areas of excess.

Air emissions from Animal Feeding Operations (AFO) can be odorous. Furthermore, volatilized ammonia can be redeposited on the earth and contribute to eutrophication of surface waters.

Animal manures are a valuable fertilizer and soil conditioner, if applied under proper conditions at crop nutrient requirements. Potential sources of manure pollution include open feedlots, pastures, treatment lagoons, manure stockpiles or storage, and land application fields. Oxygen-demanding substances, ammonia, nutrients (particularly nitrogen and phosphorus), solids, pathogens, and odorous compounds are the pollutants most commonly associated with manure. Manure is also a potential source of salts and trace metals, and to a lesser extent, antibiotics, pesticides and hormones. This problem has been magnified as poultry and livestock production has become more concentrated. AFO pollutants can impact surface water, groundwater, air, and soil. In surface water, manure's oxygen demand and ammonia content can result in fish kills and reduced biodiversity. Solids can increase turbidity and smother benthic organisms. Nitrogen and phosphorus can contribute to eutrophication and associated algae blooms which can produce negative aesthetic impacts and increase drinking water treatment costs. Turbidity from the blooms can reduce penetration of sunlight in the water column and thereby limit growth of seagrass beds and other submerged aquatic vegetation, which serve as critical habitat for fish, crabs, and other aquatic organisms. Decay of the algae (as well as night-time algal respiration) can lead to depressed oxygen levels, which can result in fish kills and reduced biodiversity. Eutrophication is also a factor in blooms of toxic algae and other toxic estuarine microorganisms, such as *Pfiesteria piscicida*. These organisms can impact human health as well as animal health. Human and animal health can also be impacted by pathogens and nitrogen in animal manure. Nitrogen is easily transformed into the nitrate form and if transported to drinking water sources can result in potentially fatal health risks to infants. Trace elements in manure may also present human and ecological risks. Salts can contribute to salinization and disruption of the ecosystem. Antibiotics, pesticides, and hormones may have low-level, long-term ecosystem effects.

In ground water, pathogens and nitrates from manure can impact human health via drinking water. Nitrate contamination is more prevalent in ground waters than surface waters. According to the U.S. EPA, nitrate is the most widespread agricultural contaminant in drinking water wells, and nearly 2% of our population (1.5 million people) is exposed to elevated nitrate levels from drinking water wells.

Table 1. Summary of U.S. Water Quality Impairment Survey

Total Quantity in US	Amount of Waters Surveyed	Quantity Impaired by All Sources	Quantity Impaired by Agriculture

Rivers 3,662,255 miles	23% of total 840,402 miles	36% of surveyed 248,028 miles	59% of impaired 170,750 miles
Lakes, Ponds, and Reservoirs 41,600,000 acres	42% of total 17,400,000 acres	39% of surveyed 6,541,060 acres	31% of impaired 2,417,801 acres
Estuaries 90,500 square miles	32% of total 28,889 square miles	38% of surveyed 11,025 square miles	15% of impaired 1,827 square miles

Reference: National Water Quality Inventory: 1998 Report to Congress (EPA, 2000a). AFOs are a subset of the agriculture category. Summaries of impairment by other sources are not presented here.

Table 2 lists the leading pollutants impairing surface water quality in the U.S. Agricultural production is a potential source of most of these.

Table 2. Five Leading Pollutants Causing Water Quality Impairment in the U.S.
(Percent of incidence of each pollutant is shown in parentheses. For example, siltation is listed as a cause of impairment in 38% of impaired river miles.)

Rank	Rivers	Lakes	Estuaries
1	Siltation (38%)	Nutrients (44%)	Pathogens (47%)
2	Pathogens (36%)	Metals (27%)	Oxygen-Depleting Substances (42%)
3	Nutrients (29%)	Siltation (15%)	Metals (23%)
4	Oxygen-Depleting Substances (23%)	Oxygen-Depleting Substances (14%)	Nutrients (23%)
5	Metals (21%)	Suspended Solids (10%)	Thermal Modifications (18%)

List of Contaminants in Animal Manure:

- Oxygen-Demanding Substances
- Nitrogen
- Ammonia
- Nitrate
- Phosphorus
- Pathogens
- Antibiotics, Pesticides, and Hormones
- Airborne Emissions from Animal Production Systems
- Comprehensive Nutrient Management Planning
- Study Questions

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Oxygen-Demanding Substances

When discharged to surface water, biodegradable material is decomposed by aquatic bacteria and other microorganisms. During this process, dissolved oxygen is consumed, reducing the amount available for aquatic animals. Severe depressions in dissolved oxygen levels can result in fish kills. There are numerous examples nationwide of fish kills resulting from manure discharges and runoff from various types of AFOs.

Manure may be deposited directly into surface waters by grazing animals. Manually-collected manure may also be introduced into surface waters. This is typically via storage structure failure, overflow, operator error, etc.

Manure can also enter surface waters via runoff if it is over-applied or misapplied to land. For example, manure application to saturated or frozen soils may result in a discharge to surface waters. Factors that promote runoff to surface waters are steep land slope, high rainfall, low soil porosity, and proximity to surface waters. Incorporation of the manure into the soil decreases runoff.

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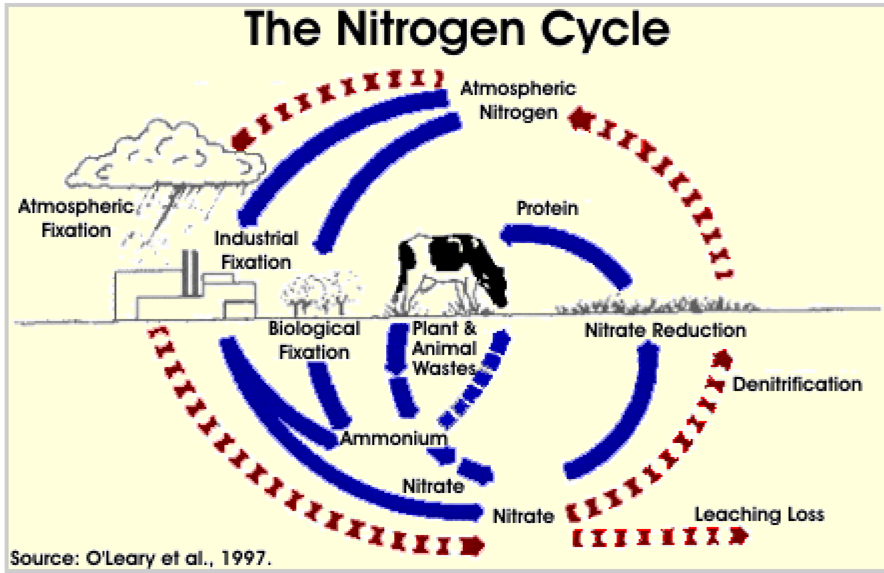
Nitrogen



Nitrogen (N) is an essential nutrient required by all living organisms. It is ubiquitous in the environment, accounting for 78 percent of the atmosphere as elemental nitrogen (N_2). This form of nitrogen is inert and does not impact environmental quality since it is not bioavailable to most organisms and therefore has no fertilizer value. Nitrogen can form other compounds, however, which are bioavailable, mobile, and potentially harmful to the environment. The nitrogen cycle shows the various forms of nitrogen and the processes by which they are transformed and lost to the environment.

Nitrogen in manure is primarily in the form of organic nitrogen and ammonia nitrogen compounds. In its organic form, nitrogen is unavailable to plants. However, organic nitrogen can be transformed into ammonium (NH_4^+) and nitrate (NO_3^-) forms, via microbial processes which are bioavailable and have fertilizer value. These forms can also produce negative environmental impacts when they are transported in the environment.

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Ammonia

"Ammonia-nitrogen" includes the ionized form (ammonium, NH_4^+) and the un-ionized form (ammonia, NH_3). Ammonium is produced when microorganisms break down organic nitrogen products such as urea and proteins in manure. This decomposition occurs in both aerobic and anaerobic environments. In solution, ammonium is in chemical equilibrium with ammonia.

Ammonia exerts a direct biochemical oxygen demand (BOD) on the receiving water since dissolved oxygen is consumed as ammonia is oxidized. Moderate depressions of dissolved oxygen are associated with reduced species diversity, while more severe depressions can produce fish kills.

Additionally, ammonia can lead to eutrophication, or nutrient over-enrichment, of surface waters. While nutrients are necessary for a healthy ecosystem, the overabundance of nutrients (particularly nitrogen and phosphorus) can lead to nuisance algae blooms.

Pfiesteria often lives as a nontoxic predatory animal, becoming toxic in response to fish excretions or secretions (NCSU, 1998). While nutrient-enriched conditions are not required for toxic outbreaks to occur, excessive nutrient loadings can help create an environment rich in microbial prey and organic matter that *Pfiesteria* uses as a food supply. By increasing the concentration of *Pfiesteria*, nutrient loads increase the likelihood of a toxic outbreak (Citizens *Pfiesteria* Action Commission, 1997).

The degree of ammonia volatilization is dependent on the manure management system. For example, losses are greater when manure remains on the land surface rather than being incorporated into the soil, and are particularly high when the manure is spray irrigated onto land. Environmental conditions also affect the extent of volatilization. For example, losses are greater at higher pH levels, warmer temperatures and drier conditions, and in soils with low cation exchange capacity, such as sands. Losses are decreased by the presence of growing plants. (Follett, 1995)

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Nitrate

Nitrifying bacteria can oxidize ammonium to nitrite (NO_2^-) and then to nitrate (NO_3^-). Nitrite is toxic to most fish and other aquatic species, but it typically does not accumulate in the environment because it is rapidly transformed to nitrate in an aerobic environment. Alternatively, nitrite (and nitrate) can undergo bacterial denitrification in an anoxic environment. In denitrification, nitrate is converted to nitrite, and then further converted to gaseous forms of nitrogen - elemental nitrogen (N_2), nitrous oxide (N_2O), nitric oxide (NO), and/or other nitrogen oxide (NO_x) compounds. Nitrification occurs readily in the aerobic environments of receiving streams and dry soils while denitrification can be significant in anoxic bottom waters and saturated soils.

Nitrate is a useful form of nitrogen because it is biologically available to plants and is therefore a valuable fertilizer. However, excessive levels of nitrate in drinking water can produce negative health impacts on infant humans and animals. Nitrate poisoning affects infants by reducing the oxygen-carrying capacity of the blood. The resulting oxygen starvation can be fatal. Nitrate poisoning, or methemoglobinemia, is commonly referred to as "blue baby syndrome" because the lack of oxygen can cause the skin to appear bluish in color. To protect human health, EPA has set a drinking water Maximum Contaminant Level (MCL) of 10 mg/l for nitrate-nitrogen. Once a water source is contaminated, the costs of protecting consumers from nitrate exposure can be significant. Nitrate is not removed by conventional drinking water treatment processes; its removal requires additional, relatively expensive treatment units.

Nitrogen in livestock manure is almost always in the organic, ammonia or ammonium form but may become oxidized to nitrate after being diluted. It can reach surface waters via direct discharge of animal wastes. Lagoon leachate and land-applied manure can also contribute nitrogen to surface and ground waters. Nitrate is water soluble and moves freely through most soils. Nitrate contributions to surface water from agriculture are primarily from groundwater connections and other subsurface flows rather than overland runoff (Follett, 1995).

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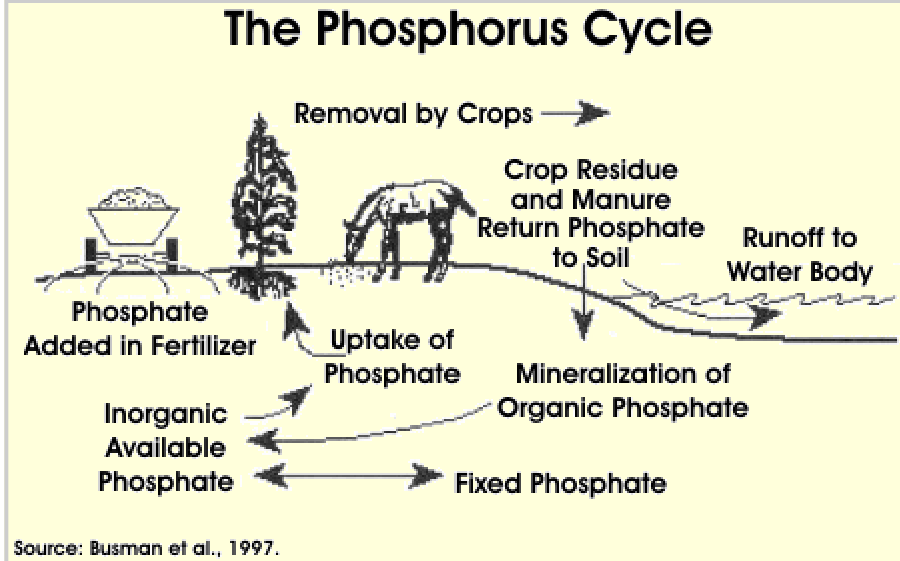
Phosphorus

Animal wastes contain both organic and inorganic forms of phosphorus (P). As with nitrogen, the organic form must mineralize to the inorganic form to become available to plants. This occurs as the manure ages and the organic P hydrolyzes to inorganic forms. The phosphorus cycle is much simpler than the nitrogen cycle because phosphorus lacks an atmospheric connection and is less subject to biological transformation.



Phosphorus is of concern in surface waters because it can lead to eutrophication. Phosphorus is also a concern because phosphate levels greater than 1.0 mg/l may interfere with coagulation in drinking water treatment plants (Bartenhagen et al., 1994). A number of research studies are currently underway to decrease the amount of P in livestock manure, primarily through enzymes and animal ration modifications that make phosphorous in the feed more available (and usable) by the animal. This means that less phosphorus must be fed to ensure an adequate amount for the animal and, as a result, less phosphorous is excreted in the manure.

Phosphorus predominantly reaches surface waters via direct discharge and runoff from land application of fertilizers and animal manure. Once in receiving waters, the phosphorus can become available to aquatic plants. Land-applied phosphorus is much less mobile than nitrogen since the mineralized form (inorganic Phosphate) is easily adsorbed to soil particles. For this reason, most agricultural phosphorus control measures have focused on soil erosion control to limit transport of particulate phosphorus. However, soils do not have infinite phosphate adsorption capacity and with long-term over-application, inorganic phosphates can eventually enter waterways even if soil erosion is controlled.

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Pathogens

Both manure and animal carcasses contain pathogens (disease-causing organisms) which can impact human health, other livestock, aquatic life, and wildlife when introduced into the environment. Several pathogenic organisms found in manure can infect humans.

Table 1. Some Diseases and Parasites Transmittable to Humans from Animal Manure

Disease	Responsible Organism	Symptoms
Bacteria		
Anthrax	*Bacillus anthracis*	Skin sores, fever, chills, lethargy, headache, nausea, vomiting, shortness of breath, cough, nose/throat congestion, pneumonia, joint stiffness, joint pain
Brucellosis	*Brucella abortus*, *Brucella melitensis*, *Brucella suis*	Weakness, lethargy, fever, chills, sweating, headache
Colibaciliosis	*Escherichia coli* (some serotypes)	Diarrhea, abdominal gas
Coliform mastitis-	*Escherichia coli* (some	Diarrhea, abdominal gas

metritis	serotypes)	
Erysipelas	*Erysipelothrix rhusiopathiae*	Skin inflammation, rash, facial swelling, fever, chills, sweating, joint stiffness, muscle aches, headache, nausea, vomiting
Leptospirosis	*Leptospira Pomona*	Abdominal pain, muscle pain, vomiting, fever
Listeriosis	*Listeria monocytogenes*	Fever, fatigue, nausea, vomiting, diarrhea
Salmonellosis	Salmonella species	Abdominal pain, diarrhea, nausea, chills, fever, headache
Tetanus	*Clostridium tetani*	Violent muscle spasms, “lockjaw” spasms of jaw muscles, difficulty breathing
Tuberculosis	*Mycobacterium tuberculosis, Mycobacterium avium*	Cough, fatigue, fever, pain in chest, back, and/or kidneys
Rickettsia		
Q fever	*Coxiella burneti*	Fever, headache, muscle pains, joint pain, dry cough, chest pain, abdominal pain, jaundice
Viruses		
Foot and Mouth	Virus	Rash, sore throat, fever
Hog Cholera	Virus	
New Castle	Virus	
Psittacosis	Virus	Pneumonia
Fungi		
Coccidioidycosis	*Coccidioides immitus*	Cough, chest pain, fever, chills, sweating, headache, muscle stiffness, joint stiffness, rash wheezing
Histoplasmosis	*Histoplasma capsulatum*	Fever, chills, muscle ache, muscle stiffness, cough, rash, joint pain, join stiffness
Ringworm	Various *microsporum* and *trichophyton*	Itching, rash
Protozoa		
Balantidiasis	*Balatidium coli*	
Coccidiosis	*Eimeria* species	Diarrhea, abdominal gas
Cryptosporidiosis	*Cryptosporidium* species	Watery diarrhea, dehydration, weakness, abdominal cramping
Giardiasis	*Giardia lamblia*	Diarrhea, abdominal pain, abdominal gas, nausea, vomiting, headache, fever
Toxoplasmosis	*Toxoplasma* species	Headache, lethargy, seizures, reduced cognitive function
Parasites / Metazoa		
Ascariasis	*Ascaris lumbricoides*	Worms in stool or vomit, fever, cough, abdominal pain, bloody sputum, wheezing, skin rash, shortness of breath
Sarcocystiasis	*Sarcosystis* species	Fever, diarrhea, abdominal pain

References: USDA, 1992 (for diseases and responsible organisms). Symptom descriptions were obtained from various medical and public health service Internet Web sites. Pathogens in animal manure are a potential source of disease in humans and other animals. This list represents a sampling of diseases that may be transmittable to humans.

The treatment of public water supplies reduces the risk of infection via drinking water. However, protecting source water is the best way to ensure safe drinking water. Cryptosporidium parvum, a protozoan that can produce gastrointestinal illness, is a concern, since it is resistant to conventional treatment. Healthy people typically recover relatively quickly from such illnesses. However, they can be fatal in people with weakened immune systems such as the elderly and small children.

Runoff from fields where manure has been applied can be a source of pathogen contamination, particularly if a rainfall event occurs soon after application. The natural filtering and adsorption action of soils typically strands microorganisms in land-applied manure near the soil surface (Crane et al., 1980). This protects underlying groundwater, but increases the likelihood of runoff losses to surface waters. Depending on soil type and operating conditions, however, subsurface flows can be a mechanism for pathogen transport.

Soil type, manure application rate, and soil pH are dominating factors in bacteria survival (Dazzo et al., 1973; Ellis and McCalla, 1976; Morrison and Martin, 1977; Van Donsel et al., 1967). Experiments on land-applied poultry manure have indicated that the population of fecal organisms decreases rapidly as the manure is heated, dried, or exposed to sunlight on the soil surface (Crane et al., 1980).

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Antibiotics, Pesticides, and Hormones

Antibiotics, pesticides, and hormones are organic compounds which are used in animal feeding operations and may pose risks if they enter the environment. For example, chronic toxicity may result from low-level discharges of antibiotics and pesticides. Estrogen hormones have been implicated in the reduction in sperm counts among Western men (Sharpe and Skakkebaek, 1993) and reproductive disorders in a variety of wildlife (Colburn et al., 1993). Other sources of antibiotics and hormones include municipal waste waters, septic tank leachate, and runoff from land-applied sewage sludge. Sources of pesticides include crop runoff and urban runoff.

Little information is available regarding the concentrations of these compounds in animal wastes, or their fate/transport behavior and bioavailability in waste-amended soils. These compounds may reach surface waters via runoff from land-application sites.

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Airborne Emissions from Animal Production Systems

With the trend toward larger, more concentrated production operations, odors and other airborne emissions are rapidly becoming an important issue for agricultural producers.

Whether there is a direct impact of airborne emissions from animal operations on human health is still being debated. There are anecdotal reports about health problems and quality-of-life factors for those living near animal facilities have been documented.

- Source of Airborne Emissions
- Emission Movement or Dispersion

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Source of Airborne Emissions

Odor emissions from animal production systems originate from three primary sources: manure storage facilities, animal housing, and land application of manure.

In an odor study in a United Kingdom county (Hardwick 1985), 50% of all odor complaints were

traced back to land application of manure, about 20% were from manure storage facilities, and another 25% were from animal production buildings. Other sources include feed production, processing centers, and silage storage. With the increased use of manure injection for land application, and longer manure storage times, there may be a higher percentage of complaints in the future associated with manure storage facilities and animal buildings and less from land application.

Animal wastes include manure (feces and urine), spilled feed and water, bedding materials (i.e., straw, sunflower hulls, wood shaving), wash water, and other wastes. This highly organic mixture includes carbohydrates, fats, proteins, and other nutrients that are readily degradable by microorganisms under a wide variety of suitable environments. Moisture content and temperature also affect the rate of microbial decomposition.

A large number of volatile compounds have been identified as byproducts of animal waste decomposition. O'Neill and Phillips (1992) compiled a list of 168 different gas compounds identified in swine and poultry wastes. Some of the gases (ammonia, methane, and carbon dioxide) also have implications for global warming and acid rain issues. It has been estimated that one third of the methane produced each year comes from industrial sources, one third from natural sources, and one third from agriculture (primarily animals and manure storage units). Although animals produce more carbon dioxide than methane, methane has as much as 15 times more impact on the greenhouse effect than carbon dioxide.

Dust, pathogens, and flies are from animal operations also airborne emission concerns. Dust, a combination of manure solids, dander, feathers, hair, and feed, is very difficult to eliminate from animal production units. It is typically more of a problem in buildings that have solid floors and use bedding as opposed to slotted floors and liquid manure. Concentrations inside animal buildings and near outdoor feedlots have been measured in a few studies; however, dust emission rates from animal production are mostly unknown.

Pathogens are another airborne emission concern. Although pathogens are present in buildings and manure storage units, they typically do not survive aerosolization well, but some may be transported by dust particles.

Flies are an additional concern from certain types of poultry and livestock operations. The housefly completes a cycle from egg to adult in 6 to 7 days when temperatures are 80 to 90°F. Females can produce 600 to 800 eggs, larvae can survive burial at depths up to 4 feet, and adults can fly up to 20 miles. Large populations of flies can be produced relatively quickly if the correct environment is provided. Flies tend to proliferate in moist animal production areas with low animal traffic.

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Emission Movement or Dispersion

The movement or dispersion of airborne emissions from animal production facilities is difficult to predict and is affected by many factors including topography, prevailing winds, and building orientation. Prevailing winds must be considered to minimize odor transport to close or sensitive neighbors. A number of dispersion models have been developed to Airborne Emission Regulations.

Most states and local units of government deal with agricultural air quality issues through zoning or land use ordinances. Setback distances may be required for a given size operation or for land application of manure. A few states (for example, Minnesota) have an ambient gas concentration (H_2S for Minnesota) standard at the property line. Gas and odor standards are difficult to enforce since on-site measurements of gases and especially odor are hard to do with any high degree of accuracy. Producers should be aware of odor- or dust-related emissions regulations applicable to their livestock operation.

Source: Lesson 40 of the LPES: Adapted from Livestock and Poultry Environmental Stewardship curriculum, lesson authored by Larry Jacobson, University of Minnesota; Jeff Lorimor, Iowa State University; Jose Bicudo, University of Kentucky; and David Schmidt, University of Minnesota, courtesy of MidWest Plan Service, Iowa State University, Ames, Iowa 50011-3080, Copyright (c) 2001.

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Environmental Impacts of Animal Feeding Operations Study Questions

Identify the definition that best fits the following terms:

1. **What are some of the positive environmental benefits of production agriculture?**

   - ○ Improved soil quality
   - ○ Carbon repository
   - ○ Reduced storm runoff
   - ○ Ground water recharge
   - ○ All of the above

   Feedback

2. **USDA estimates that manure phosphorous exceeds crop needs in what percent of U.S. countries?**

   - ○ 0%
   - ○ 15%
   - ○ 30%
   - ○ 45%

   Feedback

3. **What is the common name for the class of production agricultural plants that do not need commercial nitrogen fertilizer?**

   - ○ N Converters
   - ○ Maize
   - ○ Legumes
   - ○ Algae

Feedback

4. **If biodegradable organic matter is added to a stream, fish kills most often result from:**

- Lack of oxygen
- Turbulence
- Lack of visibility
- Build up of sludge deposits

Feedback

5. **Most manure spills that enter streams result from:**

- Pastured animals with stream access
- Rupture of manure storage
- Improper land application of manure
- Damage to manure transfer or irrigation pipes
- Feedlot runoff from animal area
- All of the above

Feedback

6. **Nitrogen gas (N_2) account for ___________ % of the atmosphere?**

- 0%
- 24%
- 62%
- 78%
- 92%

Feedback

7. **Nitrogen in manure can take many chemical forms. Which of the following is NOT included?**

- Nitrogen gas
- Organic nitrogen
- Catatonic nitrogen
- Ammonia
- Ammonium

Feedback

8. **Which nutrient in runoff from agricultural land has been blamed for the hypoxia problem in the Gulf of Mexico?**

- ○ Phosphorous
- ○ Chlorine
- ○ Sulfur
- ○ Nitrogen
- ○ Soil erosion

Feedback

9. **Which of the forms of nitrogen are volatile?**

- ○ NH_3
- ○ NO_3
- ○ NO_2
- ○ NH_4

Feedback

10. **High nitrate levels in drinking water can lead to the following serious condition in infants:**

- ○ "Green baby syndrome"
- ○ Headaches
- ○ Methemoglobinemia
- ○ Colic
- ○ Alzheimer's

Feedback

11. **The most important method of reducing phosphorous entering streams is:**

- ○ Placing riprap along edge of stream
- ○ Preventing soil erosion
- ○ Improving field drainage

Feedback

12. **Which of the following is NOT a significant source of air emissions around a livestock or animal production operation?**

- ○ Feed processing
- ○ Land application of manure
- ○ Animal production lots and buildings
- ○ Manure Storage

Feedback

See Results RESET

Score in Percentage:	

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Comprehensive Nutrient Management Planning

Recently, the concept of Comprehensive Nutrient Management Planning (CNMP) was introduced by the U. S. Environmental Protection Agency (EPA) and U.S. Department of Agriculture's (USDA's) Natural Resources Conservation Service (NRCS). It is anticipated that the CNMP will serve as a cornerstone of environmental plans assembled by animal feeding operations to address federal and state regulations. EPA and NRCS guidelines for CNMP are given in Table 1.

Table 1. Summary of Issues addressed by a CNMP as initially defined by EPA's Guidance

Planning components of CNMP	Issues addressed
A manure handling and storage plan	1. Diversion of clean water 2. Prevention of leakage storage plan 3. Adequate storage 4. Manure treatment 5. Management of mortality
Land application plan	1. Proper nutrient application rates to achieve a crop nutrient balance 2. Selection of timing and application methods to limit risk of runoff
Site management plan	Soil conservation practices that minimize movement of soil and manure components to surface and groundwater
Record keeping	Manure production, utilization, and export to off-farm users
Other utilization options	Alternative safe manure utilization strategies such as sale of manure, treatment technologies, or energy generation
Feed management plan	Alternative feed programs to minimize the nutrients in manure

Reference: USDA/EPA Unified National Strategy for Animal Feeding Operations (PDF) (34 pp, 404K)

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Beef Production Study Questions

Identify the definition that best fits the following terms:

1. **Bull**

   ○ Uncastrated bovine male

- ○ Positive stock market
- ○ A China shop figurine
- ○ Strong-willed individual

Feedback

2. **Beef consumption in the U.S. is nearly ______ pounds per person per year**

- ○ 30
- ○ 70
- ○ 100
- ○ 15

Feedback

3. **In the U.S., the beef industry provides about $5 business activity for every $1 in cattle sales.**

- ○ True
- ○ False

Feedback

4. **Backgrounding**

- ○ Providing a case history on each beef animal
- ○ Teaching each animal to back up in a straight line
- ○ Growing program for feeder cattle from weaning until finishing in a lot
- ○ Housing in a dirt feedlot

Feedback

5. **Lagoon**

- ○ Plants that fix nitrogen and are a good protein source
- ○ Excellent place to fish
- ○ Contains concentrated slurry manure
- ○ Earthen structure for storage and treatment of dilute manure

Feedback

6. **Ruminant**

- ○ Animal with a multi-compartment stomach
- ○ Microorganisms that biodegrade organic matter without oxygen
- ○ General family grouping of cattle

- Unique specie of ants

Feedback

7. **Stocker**

- Person who places inventory on the shelves at retail stores
- Cattle buyer who purchases live finished cattle for harvesting
- Equipment to place hay in piles for storage before feeding
- Weaned cattle fed high-roughage diets before finishing in feedlot

Feedback

8. **Feedlot**

- Storage area for feeds
- Open area where forages are grown, cattle can roam and graze
- Structure for collection and storage of manure
- Enterprise and housing system for finishing cattle with grain and concentrates

Feedback

9. **Common examples of byproducts from the cattle industry are**

- Leather goods
- Cosmetics
- Perfumes
- Hair products
- All of the above

Feedback

10. **Byproduct feeds that cattle can consume include :**

- Corn gluten
- Distiller's grains
- Potato chips
- Citrus pulp
- Soybean hulls
- Cottonseed hulls
- All of the above
- None of the above

Feedback

11. **A typical cow will consume about 5 tons of fibrous feed (forages) per year.**

- True
- False

Feedback

12. **A beef cow will stay productive in the herd for about**

- 2 to 3 years
- 5 to 6 years
- 7 to 9 years
- 12 to 14 years

Feedback

13. **Cattle have the unique capability of providing protein for human consumption from byproduct feeds and highly fibrous forages that humans do not consume**

- True
- False

Feedback

14. **Silo**

- Structures for storing high moisture fermented feeds in anaerobic conditions
- Structure for storing slurry manure
- Housing system for pigs

Feedback

15. **Cattle manure can be stored in the following forms**

- Solid with bedding
- Liquid slurry in tanks
- Liquid slurry in earthen storages
- Dilute liquid waste water in earthen lagoons or detention ponds
- All of the above
- None of the above

Feedback

16. **Concentrate**

- ◯ Serious thought process
- ◯ Feed with high energy, low fiber and highly digestible
- ◯ Grazed feed in the open range

Feedback

See Results RESET

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Fertilizer and Pesticide Storage

Summary of an Ideal Fertilizer and Pesticide Storage Facility

Properly designed facilities promote storage, handling and disposal practices that enhance worker safety and minimize the risk of point source contamination. An ideal facility incorporates safety features in all aspects of its design and provides:

- Secure storage of fertilizers away from pesticides.
- Secondary containment of day to day spills resulting from normal mixing/loading operations.
- Secondary containment of large, accidental spills or leaks (separate secondary containment for pesticides and fertilizers)
- Facilities for collecting, storing and recycling excess spray solutions and rinsates.
- A dry, secure, well managed area for storing empty containers and other waste prior to proper disposal.
- Office facilities for effective management and communications.
- Orderly, accessible storage for personal protection equipment (PPE) and emergency supplies.
- Worker convenience facilities: first-aid and training areas, restrooms, shower(s), laundry.

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Building a New Storage Facility

Building a new storage facility just for fertilizer storage may be expensive, but generally it will be safer than trying to modify areas meant for other purposes.

When selecting a site on which to build the facility, two basic criteria should be considered:

1. Human safety
2. Environmental safety

When designing and building a new fertilizer or pesticide storage facility, keep in mind a few simple principles of safe storage:

1. Check with your state Cooperative Extension Service or department of agriculture for design recommendations and requirements of a fertilizer or pesticide storage facility.
2. Check the local and state building codes and local zoning requirements before constructing the facility.
3. Have the site checked for background levels for potential soil and water contaminants.
4. Draw a facility site plan on which you locate and sketch important structures and activity areas using accurate dimensions and distances.
5. Locate the building downslope and away from your well. Separation from the well should be greater if the site has sandy soils or fractured bedrock near the soil surface. If the site must be upslope from the well, be sure to take precautions to have any spill contained to prevent it from moving into the water that supplies your well.

6. Surface water should drain to a retention area in the event of a fire.
7. The mixing and loading area should be close to your storage facility, to minimize the distance that chemicals are carried.
8. Maintain safe separation distances from your fertilizer or pesticide storage facility to other structures and activity areas.
9. The building foundation should be well drained and high above the water table. The finished grade should be 3 inches below the floor and sloped away from the building to prevent frost heave. The subsoil should have a low permeability.
10. Provide pallets to keep large drums or bags off the floor in order to keep them dry. Shelves for smaller containers should have a lip to keep the containers from sliding off easily. Steel shelves are easier to clean than wood if a spill occurs.
11. If you plan to store large tanks, provide a containment area capable of confining 110-125% of the volume of the largest container (check state regulations).
12. The building may need to be insulated and heated if fertilizer is to be stored over the winter. It may need to be air conditioned in the summer, depending on the type of fertilizers or pesticides stored.
13. Keep the building locked and clearly labeled as a fertilizer or pesticide storage area. Provide exterior illumination of the warning signs and of the building to identify it as a fertilizer or pesticide storage facility. Preventing unauthorized use of fertilizers or pesticides reduces the chance of accidental spills or theft. Labels on the windows and doors of the building give firefighters information about fertilizers and other products present during an emergency response to a fire or a spill. It is a good idea to keep a separate list of the chemicals and amounts stored. If a fire should occur, consider where the water used to fight the fire will go and where it might collect. For example, a curb around the floor can help confine contaminated water.
14. Provide adequate road access for deliveries and use, and in making the storage area secure, also make it accessible, to allow getting fertilizers and other chemicals out in a hurry.

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Modifying an Existing Facility

Some of the principles for safe fertilizer storage:

1. Provide pallets to keep large drums or bags off the floor. Shelves for smaller containers should have a lip to keep the containers from sliding off easily. Steel shelves are easier to clean than wood if a spill occurs.
2. If you plan to store large bulk tanks, provide a containment area large enough to confine 125 percent of the contents of the largest bulk container.
3. Keep the building locked and clearly labeled as a fertilizer storage area. Preventing unauthorized use of fertilizers reduces the chance of accidental spills or theft. Labels on the windows and doors of the building give firefighters information about fertilizers and other products present during an emergency response to a fire or a spill. It is a good idea to keep a separate list of the chemicals and amounts stored. If a fire should occur, consider where the water used to fight the fire will go and where it might collect. For example, a curb around the floor can help confine contaminated water.
4. Provide adequate road access for deliveries and use, and in making the storage area secure, also make it accessible, to allow getting fertilizers and other chemicals out in a hurry.
5. Never store fertilizers inside a wellhouse or a facility containing an abandoned well.

If you decide to improve your current storage building, applying the above principles can be expensive. However, compared to the cost of a major accident, fine or lawsuit, storage improvements can be a bargain! If that is not practical, consider how you can protect the fertilizers that you keep on hand.

Sound containers are your first line of defense against a spill or leak. If a container is accidentally ripped open or knocked off a shelf, the spill should be confined to the immediate area and promptly cleaned up. The building should have a solid floor and, for liquid fertilizers, a curb. The containment volume should be large enough to hold the contents of the largest full container.

Ideally, the fertilizer storage area should be separate from other activities. If the building must also serve as a machine shed or as livestock housing, you may find it difficult to meet all the requirements for safe storage.

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Fuel Storage Systems

Aboveground Storage Systems

In most states there are two major sets of regulations which impact the design, installation, use and management of aboveground storage tanks (ASTs) for motor fuel and waste oil:

1. Those related to fire, explosion and human safety; and
2. Those designed to protect the environment.

In addition, ASTs may also be subject to state "spill reporting" laws. For instance, Indiana's Spill Reporting Law requires that surface spills and releases of about 25 gallons or more "that enter or threaten the waters of the state" must be reported to the Emergency Response Section of the Indiana Department of Environmental Management within 24 hours, and appropriate corrective action must be initiated immediately. Check for similar laws in other states.

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Underground Storage Systems

Most states have adopted the federal regulations (or a stricter version of them) for underground storage tanks (USTs) greater than 1100 gallons. They may also have regulations for smaller USTs - check to be sure.

State and local UST Regulatory Web sites

Whether regulated or not, all USTs deserve careful management with attention to preventing water pollution, including:

- Overfilling
- Pipe Leaks
- Tank Corrosion

There are many prudent measures to prevent contamination of water supplies, including:

- Secondary Containment Structures
- Catchment Basins
- Automatic Shutoff Devices
- Automatic Overfill Alarm
- Tank Relining
- Sacrificial Anodes for Corrosion Prevention

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Benefits of Pesticide Use

For many years, we have enjoyed the benefits of using pesticides to control weed, insect, fungus, parasitic, and rodent pests. Recently, both the public and the press have increasingly focused on the negative impacts of agricultural, urban industrial, and residential chemicals. However, there are also substantial benefits to society, including:

- Pesticides are the only effective means of controlling disease organisms, weeds, or insect pests in many circumstances.
- Consumers receive direct benefits from pesticides through wider selections and lower prices for food and clothing.
- Pesticides protect private, public, and commercial dwellings from structural damage associated with termite infestations.
- Pesticides contribute to enhanced human health by preventing disease outbreaks through the control of rodent and insect populations.
- Pesticides are used to sanitize our drinking and recreational water.
- Pesticides are used to disinfect indoor areas (e.g., kitchens, operating rooms, nursing homes) as well as dental and surgical instruments.
- The pesticide industry also provides benefits to society. For instance, local communities and state governments may be partially dependent upon the jobs and tax base that pesticide manufacturers, distributors, dealers, commercial applicators, and farmers provide.

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Risks of Pesticide Use

Within the last few decades, scientists have learned that some pesticides can leach through the soil and enter the groundwater below. While 50% of the nation depends upon groundwater for drinking water, almost 95% of the households in rural areas use groundwater as their primary source of drinking water. The impact of agricultural chemicals on surface and groundwater quality has become an issue of national importance.

EPA has responsibility under a variety of statutes to protect the quality of the nation's ground water as well as direct responsibility for regulating the availability and use of pesticide products.

Each pesticide product has inherent risks associated with it. Potentially detrimental impacts of pesticides include:

- Acute poisoning from a single or short-term exposure can result in death.
- Chronic impacts of long-term exposure to pesticides, including pesticide residues in food, could also result in death.
- Natural resources can be degraded when pesticide residues in storm water runoff enter streams or leach into groundwater.
- Pesticides that drift from the site of application can harm or kill nontarget plants, birds, fish, or other wildlife.
- The mishandling of pesticides in storage facilities and in mixing and loading areas can contribute to soil and water contamination.

The risk associated with a given pesticide or pesticide product depends on the toxicity of the compound and the probability of exposure.

Source: University of Florida - IFAS

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Lethal Dosage (LD50) Values

An LD50 is a standard measurement of acute toxicity that is stated in milligrams (mg) of pesticide per kilogram (kg) of body weight. An LD50 represents the individual dose required to kill 50 percent of a population of test animals (e.g., rats, fish, mice, cockroaches). Because LD50 values are standard measurements, it is possible to compare relative toxicities among pesticides. The lower the LD50 dose, the more toxic the pesticide.

A pesticide with an LD50 value of 10 mg/kg is 10 times more toxic than a pesticide with an LD50 of 100 mg/kg.

The toxicity of a pesticide is related to the mode of entry of the chemical into an organism. Oral LD50 values are obtained when test subjects are fed pesticide-treated feed or water. Dermal LD50 values are obtained when the pesticide is applied to the skin of the animal. Inhalation LD50 values are obtained when the animal breathes the pesticide with a mask. Often the inhalation LD50 is lower (more toxic) than the oral LD50, which is in turn lower (more toxic) than the dermal LD50.

LD50 values are not always given on the pesticide label; rather, the relative toxicity of a pesticide product is reflected by one of three signal words: DANGER, WARNING, or CAUTION. The purpose of signal words is to alert the user to the level of toxicity of the product. The signal word is generally assigned based on the pesticide's inhalation, oral or dermal toxicity, whichever is the most toxic.

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Ever-Changing Laws and Regulations

Shortly after the EPA's Groundwater Protection Strategy was issued in August 1984, the Agency initiated an intensive review of existing information and scientific knowledge about the extent of pesticide contamination, its causes and potential health impacts, and statutory authorities and programs available to help address the problem. EPA supports state strategy development through grants under Section 106 of the Clean Water Act as a means for strengthening the capacity of state governments to protect groundwater quality.

Other regulations and programs such as the Safe Drinking Water Act and its amendments, a new Wellhead Protection Program, Clean Water Act, the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), and the new Non-point Source Management Program have all been initiated in an attempt to protect the nation's groundwater from contamination by all types of pollutants including pesticides. Since the early 1970s, the EPA's Office of Pesticide Programs has been evaluating the leaching potential of new and existing pesticides.

Because of potential environmental concerns associated with pesticide application, there are two federal laws that regulate pesticide use: FIFRA and FFDCA. Most of the states have also enacted their own pesticide legislation. All pesticide labels contain certain standard information, including the ingredients, directions for proper use, warning statements to protect users, the public, and nontarget species of plants and animals. All statements on the label must be adhered to by all users and sellers. All pesticides must be registered with the EPA to ensure that they will not cause unreasonable adverse effects on the environment.

Certain pesticides are classified as "Restricted-Use" and can only be used by or under the direct supervision of a trained Certified Applicator. Restricted-Use pesticides are those that have a greater chance of causing adverse impacts to humans and the environment. Certification is a way of ensuring that people who apply these restricted-use pesticides possess the knowledge to do so in a safe manner. It is illegal to make restricted use pesticides available to non-certified personnel.

The benefits and risks are periodically reassessed as new scientific information is discovered and to reflect changes in the views of society. This does not mean that decisions of today eventually will be proven wrong. Rather, the balance of benefits and risks is ever-changing because of improved science and the changing expectations of society.

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Formulation Selection Considerations

The importance of formulation type is generally overlooked. The decision to use a formulation for a given application should include an analysis of the following factors:

- Applicator safety. Different formulations present various degrees of hazard to the applicator. Some products are easily inhaled, while others readily penetrate skin, or cause injury when splashed in the eyes.
- Environmental concerns. Special precautions need to be taken with formulations that are prone to drift in air or move off-target into water. Wildlife can also be affected to varying degrees by different formulations. Birds may be attracted by granules, and fish or aquatic invertebrates can prove especially sensitive to specific pesticide formulations such as 2,4-D esters.
- Pest biology. The growth habits and survival strategies of a pest will often determine what formulation provides optimum contact between the active ingredient and the pest.
- Available application equipment. Some pesticide formulations require specialized application equipment. This includes safety equipment, spill control equipment and, in special cases, containment structures.
- Surfaces to be protected. Applicators should be aware that certain formulations can stain fabrics, discolor linoleum, dissolve plastic, or burn foliage.
- Cost. Product prices may vary substantially, based on the active ingredients present and the complexity of delivering active ingredients in specific formulations.

Individuals such as commercial pest control technicians or farm workers who may not be involved in the selection process but are responsible for the actual application should also be made aware of the type of formulation they are using, its dangers and of the safety measures needed. This choice of formulation type can have an impact on human health and the environment. Inattention to the type of formulation being used could mean the difference between a routine application and one that is the source of environmental contamination - or worse, a serious human exposure.

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Integrated Pest Management

Integrated pest management (IPM) is the control strategy of choice for homeowners, growers, and commercial applicators. IPM is an approach to pest management that blends all available management techniques - nonchemical and chemical - into one strategy: Monitor pest problems, use nonchemical pest control, and resort to pesticides **only** when pest damage exceeds an economic or aesthetic threshold.

Labels and regulations change and new products are introduced routinely. Therefore, the pesticide selection process should be conducted just prior to **each** growing season.

The selection of a pesticide requires planning and knowledge of the alternatives. Begin by developing a comprehensive list of available pesticides for a specific crop, turf, or home garden pest. Pesticide recommendations for controlling any insect, weed, or disease can be suggested by numerous sources: the Cooperative Extension Service; consultants; agrichemical and urban pesticide dealers; product manufacturers; garden and nursery centers; association newsletters; trade journals; and expert applicators. After developing a pesticide list, the user should obtain labels of all products under consideration so that their strengths and weaknesses can be analyzed on a product profile worksheet. Labels generally are available locally from retail outlets or their suppliers.

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Water Quality

Four factors influence groundwater vulnerability to pesticide contamination:

1. Chemical properties of the pesticide
   - Low soil adsorption
   - Persistence
2. Soil Types
   - Sandy or gravel texture
   - Low organic matter content
3. Site Characteristics
   - Shallow water table
   - Sinkholes
   - Abandoned wells
4. Management Practices
   - Improper chemical storage, handling, and use

Options for protecting surface water near application sites include:

- No-spray strips around surface water supplies, wells, or irrigation ditches
- Grass waterways and grass buffers to resist runoff
- Use of conservation practices on erodible lands
- Plow berms around sinkholes

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Soil / Water Adsorption Coefficient (Kd)

The Kd value is a measure of how tightly the pesticide binds or sticks to soil particles. The greater the Kd value, the less likely a chemical will leach or contribute to runoff. A very high value means it is strongly adsorbed onto soil and organic matter and does not move throughout the soil.

Higher is better. Pesticides are less likely to leach or occur as surface runoff when the Kd is greater than 5.

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Water Solubility

Solubility is a measure of how easily a chemical dissolves in water. The lower a chemical's solubility, the less likely it is to move with water through the soil.

Lower is better. Pesticides are less likely to leach when their water solubility is less than 30 parts per million.

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Half-Life

Half-life is a measure of how quickly a chemical breaks down in soil (soil half-life) or water (hydrolysis half-life). The longer a chemical remains in water or soil without breaking down, the more likely it is to leach through the soil.

Shorter is better. Pesticides are less likely to leach when their hydrolysis half-life is less than six months and their soil half-life is less than three weeks.

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Movement Off Target

Pesticide particle drift and volatilization pose risks to neighbors, field workers, and the environment. Keeping products on the target site increases the effectiveness of pest control while reducing injury to nontarget susceptible plants, domestic animals, and wildlife. The proximity of an application site to sensitive areas such as nursing homes, subdivisions, schools, day-care centers, parks, playgrounds and hospitals is a critical factor requiring extra safety precautions. Misapplication can endanger public health and violate the law.

Two options exist for the applicator who is concerned about drift:

- Alter routine spray practices
- Switch to products than can be more easily managed to prevent particle drift or volatilization

Management decisions that can help prevent off-target movement include:

- Allowing for buffer zones and planting setbacks
- Incorporating pesticides into the soil
- Slowing the speed of the equipment
- Altering application methods
- Applying sprays nearer the target pest
- Applying at lower pressure
- Altering the time of application.

Products may vary in their ability to move out of the target treatment area. Evaluate each product to determine the best choice for your site requirements.

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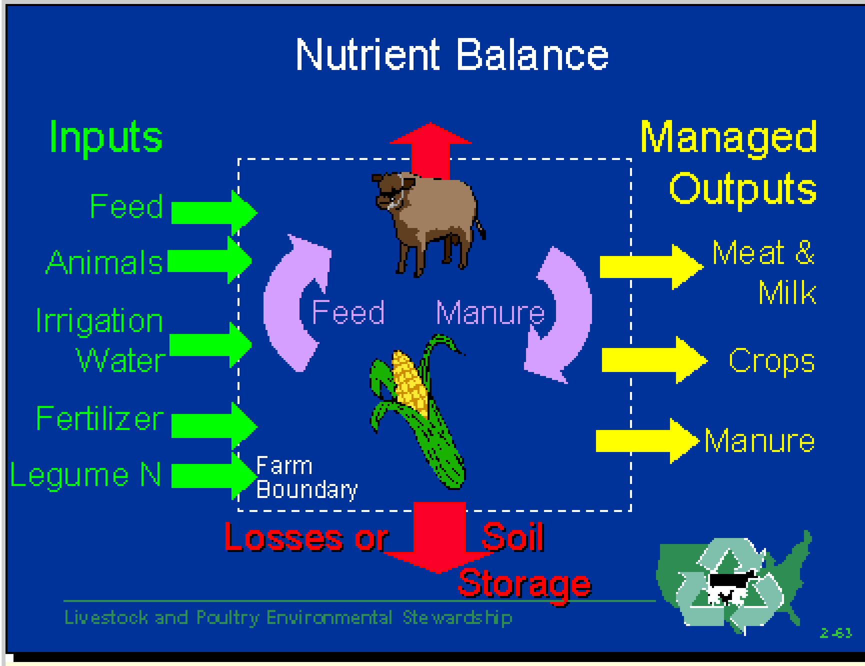
Whole-Farm Nutrient Balance



Source: Livestock and Poultry Environmental Stewardship

A "Whole Farm Nutrient Balance" evaluation is a tool that can be used to evaluate the potential for generation of excess nutrients on the farm and can form the basis for developing plans to deal with nutrient buildups. Nutrients are transported along multiple pathways and in a variety of forms in a livestock operation.

A picture of the flow of nutrients is presented in the above figure. Within the farm boundaries, nutrients are ideally "recycled" between the livestock and crop components. Manure nutrients are used for crop production and feed crop nutrients are in turn recycled as animal feed. Nutrients can enter a livestock operation as purchased products (fertilizer, animal feed, and purchased animals), nitrogen (N) fixed by legume crops, and nitrates in rain and irrigation water.

Most nutrients exit a livestock operation in the form of animals and crops sold and possibly other products moved off farm (e.g., manure sold or given to a neighboring crop producer). Ideally nutrients that exit the farm as losses to the environment (nitrates in groundwater, ammonia volatilized into the atmosphere, and N and phosphorus into surface water) should be minimal. Some nutrients (especially phosphorus) can accumulate in large quantities in the soil if over-applied over a period of several years. Although not a direct loss to the environment, an accumulation of nutrients in the soil can result in environmental losses in the future.

An "imbalance" is the difference between the Inputs and the Managed Outputs and represents either a direct environmental loss or the buildup of nutrients in the soil. Farm operations with a significant nutrient imbalance are at a greater risk to water quality. In contrast, operations that achieve a closer balance represent more sustainable production systems.

Size is a poor indicator of nutrient imbalance. A review of the whole farm nutrient balance for 33 Nebraska swine confinements and beef feedlots did not observe any connection between size and the extent of an imbalance. Some of the worst imbalances were observed for livestock operations with less than 1,000 animal units (1000 beef animals, 700 dairy cows, or 2500 hogs).

A P balance provides a good indicator of the risk to water quality. An imbalance in N does not distinguish between the relatively benign losses (e.g., denitrification of nitrate to N_2 gas) and the relatively harmful environmental losses (e.g., nitrate loss to water). In contrast, P losses impact water quality through increased soil P levels and greater concentration of P moving with surface runoff water.

Purchased animal feeds are often the most significant source of the N and P inputs on livestock operations, with most of the rest coming from commercial fertilizer. In the Nebraska study, N inputs as feed varied from 33% to 77% of total N inputs for farms with less than 250 animal units and more than 2,500 animal units, respectively. Phosphorus inputs as feed was the largest nutrient source for most livestock and poultry farms. With the growing concentration of livestock and poultry, purchased animal feed is often the most significant source of nutrients even in regions that grow most animal feeds locally. (National Curriculum, MWPS) EXIT Disclaimer

Evaluating nutrient balance from a whole farm perspective provides a more complete picture of the driving forces behind nutrient-related environmental issues. The following four management strategies should help reduce nutrient imbalances:

1. Efficient use of nutrients in crop production can offset fertilizer nutrient inputs.
2. Alternative feed rations and efficient utilization of on-farm feeds can offset nutrient inputs as purchased feeds and forages.
3. Exporting of manure nutrients to off-farm users can increase managed nutrient outputs.
4. Manure treatments allow disposal of manure nutrients. Some treatment options enhance the value of manure nutrients and complement manure marketing efforts.

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Airborne Emissions from Animal Production Systems

With the trend toward larger, more concentrated production operations, odors and other airborne emissions are rapidly becoming an important issue for agricultural producers.

Whether there is a direct impact of airborne emissions from animal operations on human health is still being debated. There are anecdotal reports about health problems and quality-of-life factors for those living near animal facilities have been documented.

- Source of Airborne Emissions
- Emission Movement or Dispersion

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Source of Airborne Emissions

Odor emissions from animal production systems originate from three primary sources: manure storage facilities, animal housing, and land application of manure.

In an odor study in a United Kingdom county (Hardwick 1985), 50% of all odor complaints were traced back to land application of manure, about 20% were from manure storage facilities, and another 25% were from animal production buildings. Other sources include feed production, processing centers, and silage storage. With the increased use of manure injection for land application, and longer manure storage times, there may be a higher percentage of complaints in the future associated with manure storage facilities and animal buildings and less from land application.

Animal wastes include manure (feces and urine), spilled feed and water, bedding materials (i.e., straw, sunflower hulls, wood shaving), wash water, and other wastes. This highly organic mixture includes carbohydrates, fats, proteins, and other nutrients that are readily degradable by microorganisms under a wide variety of suitable environments. Moisture content and temperature also affect the rate of microbial decomposition.

A large number of volatile compounds have been identified as byproducts of animal waste decomposition. O'Neill and Phillips (1992) compiled a list of 168 different gas compounds identified in swine and poultry wastes. Some of the gases (ammonia, methane, and carbon dioxide) also have implications for global warming and acid rain issues. It has been estimated that one third of the methane produced each year comes from industrial sources, one third from natural sources, and one third from agriculture (primarily animals and manure storage units). Although animals produce more carbon dioxide than methane, methane has as much as 15 times more impact on the greenhouse effect than carbon dioxide.

Dust, pathogens, and flies are from animal operations also airborne emission concerns. Dust, a combination of manure solids, dander, feathers, hair, and feed, is very difficult to eliminate from animal production units. It is typically more of a problem in buildings that have solid floors and use bedding as opposed to slotted floors and liquid manure. Concentrations inside animal buildings and near outdoor feedlots have been measured in a few studies; however, dust emission rates from animal production are mostly unknown.

Pathogens are another airborne emission concern. Although pathogens are present in buildings and manure storage units, they typically do not survive aerosolization well, but some may be transported by dust particles.

Flies are an additional concern from certain types of poultry and livestock operations. The housefly completes a cycle from egg to adult in 6 to 7 days when temperatures are 80 to 90°F. Females can produce 600 to 800 eggs, larvae can survive burial at depths up to 4 feet, and adults can fly up to 20 miles. Large populations of flies can be produced relatively quickly if the correct environment is provided. Flies tend to proliferate in moist animal production areas with low animal traffic.

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Emission Movement or Dispersion

The movement or dispersion of airborne emissions from animal production facilities is difficult to predict and is affected by many factors including topography, prevailing winds, and building orientation. Prevailing winds must be considered to minimize odor transport to close or sensitive neighbors. A number of dispersion models have been developed to Airborne Emission Regulations.

Most states and local units of government deal with agricultural air quality issues through zoning or land use ordinances. Setback distances may be required for a given size operation or for land application of manure. A few states (for example, Minnesota) have an ambient gas concentration (H_2S for Minnesota) standard at the property line. Gas and odor standards are difficult to enforce since on-site measurements of gases and especially odor are hard to do with any high degree of accuracy. Producers should be aware of odor- or dust-related emissions regulations applicable to their livestock operation.

Source: Lesson 40 of the LPES: Adapted from Livestock and Poultry Environmental Stewardship curriculum, lesson authored by Larry Jacobson, University of Minnesota; Jeff Lorimor, Iowa State University; Jose Bicudo, University of Kentucky; and David Schmidt, University of Minnesota, courtesy of MidWest Plan Service, Iowa State University, Ames, Iowa 50011-3080, Copyright (c) 2001.

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Oxygen-Demanding Substances

When discharged to surface water, biodegradable material is decomposed by aquatic bacteria and other microorganisms. During this process, dissolved oxygen is consumed, reducing the amount available for aquatic animals. Severe depressions in dissolved oxygen levels can result in fish kills. There are numerous examples nationwide of fish kills resulting from manure discharges and runoff from various types of AFOs.

Manure may be deposited directly into surface waters by grazing animals. Manually-collected manure may also be introduced into surface waters. This is typically via storage structure failure, overflow, operator error, etc.

Manure can also enter surface waters via runoff if it is over-applied or misapplied to land. For example, manure application to saturated or frozen soils may result in a discharge to surface waters. Factors that promote runoff to surface waters are steep land slope, high rainfall, low soil porosity, and proximity to surface waters. Incorporation of the manure into the soil decreases runoff.

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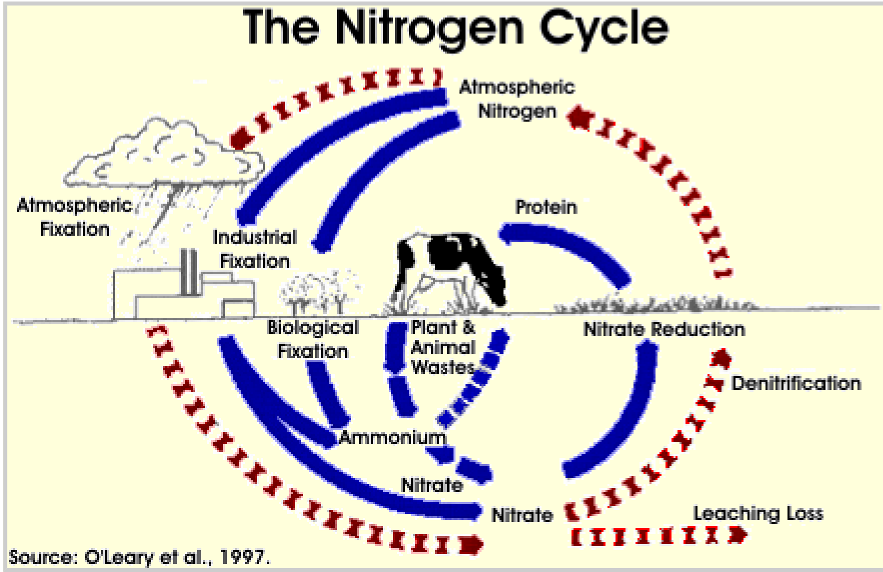
Nitrogen



Nitrogen (N) is an essential nutrient required by all living organisms. It is ubiquitous in the environment, accounting for 78 percent of the atmosphere as elemental nitrogen (N_2). This form of nitrogen is inert and does not impact environmental quality since it is not bioavailable to most organisms and therefore has no fertilizer value. Nitrogen can form other compounds, however, which are bioavailable, mobile, and potentially harmful to the environment. The nitrogen cycle shows the various forms of nitrogen and the processes by which they are transformed and lost to the environment.

Nitrogen in manure is primarily in the form of organic nitrogen and ammonia nitrogen compounds. In its organic form, nitrogen is unavailable to plants. However, organic nitrogen can be transformed into ammonium (NH_4^+) and nitrate (NO_3^-) forms, via microbial processes which are bioavailable and have fertilizer value. These forms can also produce negative environmental impacts when they are transported in the environment.

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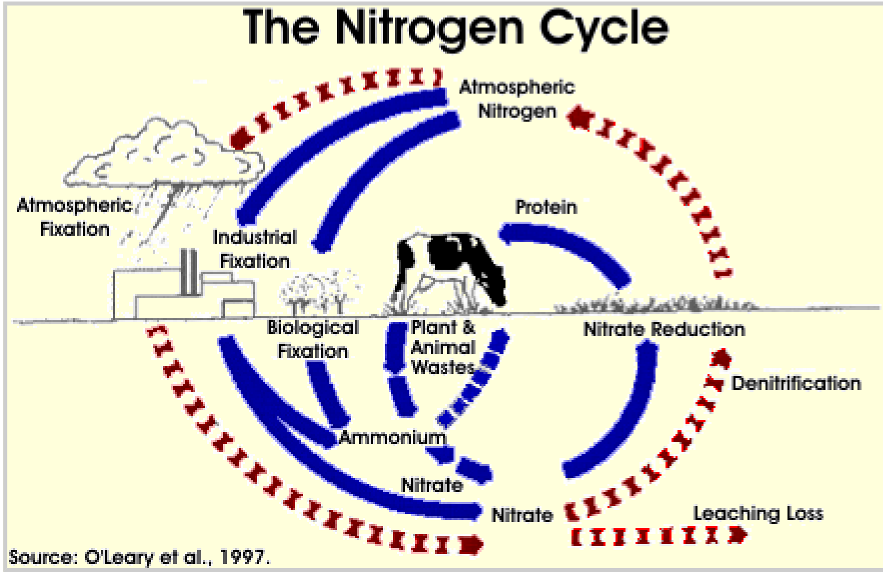
Ammonia



"Ammonia-nitrogen" includes the ionized form (ammonium, NH_4^+) and the un-ionized form (ammonia, NH_3). Ammonium is produced when microorganisms break down organic nitrogen products such as urea and proteins in manure. This decomposition occurs in both aerobic and anaerobic environments. In solution, ammonium is in chemical equilibrium with ammonia.

Ammonia exerts a direct biochemical oxygen demand (BOD) on the receiving water since dissolved oxygen is consumed as ammonia is oxidized. Moderate depressions of dissolved oxygen are associated with reduced species diversity, while more severe depressions can produce fish kills.

Additionally, ammonia can lead to eutrophication, or nutrient over-enrichment, of surface waters. While nutrients are necessary for a healthy ecosystem, the overabundance of nutrients (particularly nitrogen and phosphorus) can lead to nuisance algae blooms.

Pfiesteria often lives as a nontoxic predatory animal, becoming toxic in response to fish excretions or secretions (NCSU, 1998). While nutrient-enriched conditions are not required for toxic outbreaks to occur, excessive nutrient loadings can help create an environment rich in microbial prey and organic matter that *Pfiesteria* uses as a food supply. By increasing the concentration of *Pfiesteria*, nutrient loads increase the likelihood of a toxic outbreak (Citizens *Pfiesteria* Action Commission, 1997).

The degree of ammonia volatilization is dependent on the manure management system. For example, losses are greater when manure remains on the land surface rather than being incorporated into the soil, and are particularly high when the manure is spray irrigated onto land. Environmental conditions also affect the extent of volatilization. For example, losses are greater at higher pH levels, warmer temperatures and drier conditions, and in soils with low cation exchange capacity, such as sands. Losses are decreased by the presence of growing plants. (Follett, 1995)

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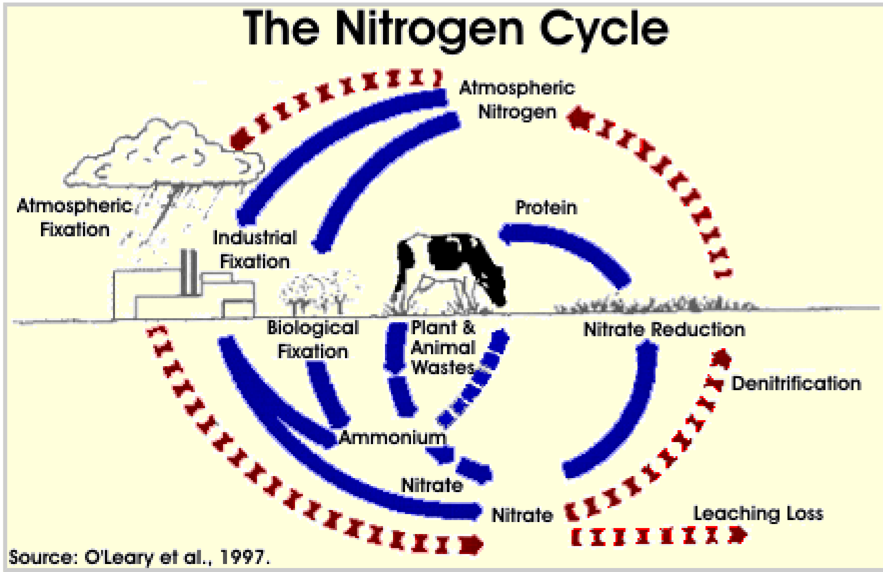
Nitrate



Nitrifying bacteria can oxidize ammonium to nitrite (NO_2^-) and then to nitrate (NO_3^-). Nitrite is toxic to most fish and other aquatic species, but it typically does not accumulate in the environment because it is rapidly transformed to nitrate in an aerobic environment. Alternatively, nitrite (and nitrate) can undergo bacterial denitrification in an anoxic environment. In denitrification, nitrate is converted to nitrite, and then further converted to gaseous forms of nitrogen - elemental nitrogen (N_2), nitrous oxide (N_2O), nitric oxide (NO), and/or other nitrogen oxide (NO_x) compounds. Nitrification occurs readily in the aerobic environments of receiving streams and dry soils while denitrification can be significant in anoxic bottom waters and saturated soils.

Nitrate is a useful form of nitrogen because it is biologically available to plants and is therefore a valuable fertilizer. However, excessive levels of nitrate in drinking water can produce negative health impacts on infant humans and animals. Nitrate poisoning affects infants by reducing the oxygen-carrying capacity of the blood. The resulting oxygen starvation can be fatal. Nitrate poisoning, or methemoglobinemia, is commonly referred to as "blue baby syndrome" because the lack of oxygen can cause the skin to appear bluish in color. To protect human health, EPA has set a drinking water Maximum Contaminant Level (MCL) of 10 mg/l for nitrate-nitrogen. Once a water source is contaminated, the costs of protecting consumers from nitrate exposure can be significant. Nitrate is not removed by conventional drinking water treatment processes; its removal requires additional, relatively expensive treatment units.

Nitrogen in livestock manure is almost always in the organic, ammonia or ammonium form but may become oxidized to nitrate after being diluted. It can reach surface waters via direct discharge of animal wastes. Lagoon leachate and land-applied manure can also contribute nitrogen to surface and groundwaters. Nitrate is water soluble and moves freely through most soils. Nitrate contributions to surface water from agriculture are primarily from groundwater connections and other subsurface flows rather than overland runoff (Follett, 1995).

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http://www.epa.gov/agriculture/ag101/impactnitrate.html
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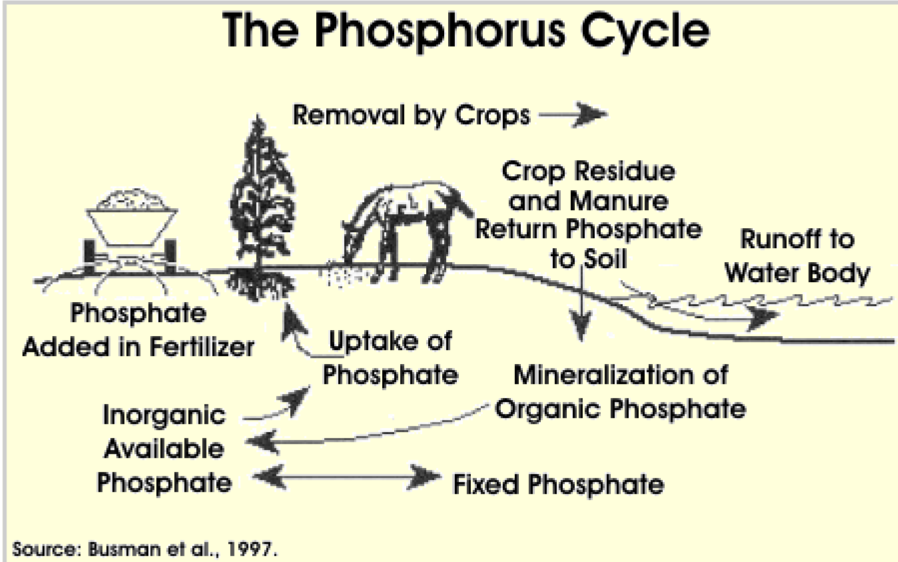
Phosphorus



Animal wastes contain both organic and inorganic forms of phosphorus (P). As with nitrogen, the organic form must mineralize to the inorganic form to become available to plants. This occurs as the manure ages and the organic P hydrolyzes to inorganic forms. The phosphorus cycle is much simpler than the nitrogen cycle because phosphorus lacks an atmospheric connection and is less subject to biological transformation.

Phosphorus is of concern in surface waters because it can lead to eutrophication. Phosphorus is also a concern because phosphate levels greater than 1.0 mg/l may interfere with coagulation in drinking water treatment plants (Bartenhagen et al., 1994). A number of research studies are currently underway to decrease the amount of P in livestock manure, primarily through enzymes and animal ration modifications that make phosphorous in the feed more available (and usable) by the animal. This means that less phosphorus must be fed to ensure an adequate amount for the animal and, as a result, less phosphorous is excreted in the manure.

Phosphorus predominantly reaches surface waters via direct discharge and runoff from land application of fertilizers and animal manure. Once in receiving waters, the phosphorus can become available to aquatic plants. Land-applied phosphorus is much less mobile than nitrogen since the mineralized form (inorganic Phosphate) is easily adsorbed to soil particles. For this reason, most agricultural phosphorus control measures have focused on soil erosion control to limit transport of particulate phosphorus. However, soils do not have infinite phosphate adsorption capacity and with long-term over-application, inorganic phosphates can eventually enter waterways even if soil erosion is controlled.

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Pathogens

Both manure and animal carcasses contain pathogens (disease-causing organisms) which can impact human health, other livestock, aquatic life, and wildlife when introduced into the environment. Several pathogenic organisms found in manure can infect humans.

Table 1. Some Diseases and Parasites Transmittable to Humans from Animal Manure

Disease	Responsible Organism	Symptoms
Bacteria		
Anthrax	*Bacillus anthracis*	Skin sores, fever, chills, lethargy, headache, nausea, vomiting, shortness of breath, cough, nose/throat congestion, pneumonia, joint stiffness, joint pain
Brucellosis	*Brucella abortus*, *Brucella melitensis*, *Brucella suis*	Weakness, lethargy, fever, chills, sweating, headache
Colibaciliosis	*Escherichia coli* (some serotypes)	Diarrhea, abdominal gas
Coliform mastitis-metritis	*Escherichia coli* (some serotypes)	Diarrhea, abdominal gas
Erysipelas	*Erysipelothrix rhusiopathiae*	Skin inflammation, rash, facial swelling, fever, chills, sweating, joint stiffness, muscle aches, headache, nausea, vomiting
Leptospirosis	*Leptospira Pomona*	Abdominal pain, muscle pain, vomiting, fever
Listeriosis	*Listeria monocytogenes*	Fever, fatigue, nausea, vomiting, diarrhea
Salmonellosis	Salmonella species	Abdominal pain, diarrhea, nausea, chills, fever, headache
Tetanus	*Clostridium tetani*	Violent muscle spasms, "lockjaw" spasms of jaw muscles, difficulty breathing
Tuberculosis	*Mycobacterium tuberculosis*, *Mycobacterium avium*	Cough, fatigue, fever, pain in chest, back, and/or kidneys
Rickettsia		
Q fever	*Coxiella burneti*	Fever, headache, muscle pains, joint pain, dry cough, chest pain, abdominal pain, jaundice
Viruses		
Foot and Mouth	Virus	Rash, sore throat, fever
Hog Cholera	Virus	
New Castle	Virus	
Psittacosis	Virus	Pneumonia
Fungi		
Coccidioidycosis	*Coccidioides immitus*	Cough, chest pain, fever, chills, sweating, headache, muscle stiffness, joint stiffness, rash wheezing
Histoplasmosis	*Histoplasma capsulatum*	Fever, chills, muscle ache, muscle stiffness, cough, rash, joint pain, join stiffness
Ringworm	Various *microsporum* and *trichophyton*	Itching, rash

Protozoa		
Balantidiasis	*Balatidium coli*	
Coccidiosis	*Eimeria* species	Diarrhea, abdominal gas
Cryptosporidiosis	*Cryptosporidium* species	Watery diarrhea, dehydration, weakness, abdominal cramping
Giardiasis	*Giardia lamblia*	Diarrhea, abdominal pain, abdominal gas, nausea, vomiting, headache, fever
Toxoplasmosis	*Toxoplasma* species	Headache, lethargy, seizures, reduced cognitive function
Parasites / Metazoa		
Ascariasis	*Ascaris lumbricoides*	Worms in stool or vomit, fever, cough, abdominal pain, bloody sputum, wheezing, skin rash, shortness of breath
Sarcocystiasis	*Sarcosystis* species	Fever, diarrhea, abdominal pain

References: USDA, 1992 (for diseases and responsible organisms). Symptom descriptions were obtained from various medical and public health service Internet Web sites. Pathogens in animal manure are a potential source of disease in humans and other animals. This list represents a sampling of diseases that may be transmittable to humans.

The treatment of public water supplies reduces the risk of infection via drinking water. However, protecting source water is the best way to ensure safe drinking water. Cryptosporidium parvum, a protozoan that can produce gastrointestinal illness, is a concern, since it is resistant to conventional treatment. Healthy people typically recover relatively quickly from such illnesses. However, they can be fatal in people with weakened immune systems such as the elderly and small children.

Runoff from fields where manure has been applied can be a source of pathogen contamination, particularly if a rainfall event occurs soon after application. The natural filtering and adsorption action of soils typically strands microorganisms in land-applied manure near the soil surface (Crane et al., 1980). This protects underlying groundwater, but increases the likelihood of runoff losses to surface waters. Depending on soil type and operating conditions, however, subsurface flows can be a mechanism for pathogen transport.

Soil type, manure application rate, and soil pH are dominating factors in bacteria survival (Dazzo et al., 1973; Ellis and McCalla, 1976; Morrison and Martin, 1977; Van Donsel et al., 1967). Experiments on land-applied poultry manure have indicated that the population of fecal organisms decreases rapidly as the manure is heated, dried, or exposed to sunlight on the soil surface (Crane et al., 1980).

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Antibiotics, Pesticides, and Hormones

Antibiotics, pesticides, and hormones are organic compounds which are used in animal feeding operations and may pose risks if they enter the environment. For example, chronic toxicity may result from low-level discharges of antibiotics and pesticides. Estrogen hormones have been implicated in the reduction in sperm counts among Western men (Sharpe and Skakkebaek, 1993) and reproductive disorders in a variety of wildlife (Colburn et al., 1993). Other sources of antibiotics and hormones include municipal wastewaters, septic tank leachate, and runoff from land-applied sewage sludge. Sources of pesticides include crop runoff and urban runoff.

Little information is available regarding the concentrations of these compounds in animal wastes, on their fate/transport behavior and bioavailability in waste-amended soils. These compounds may reach surface waters via runoff from land-application sites.

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Comprehensive Nutrient Management Planning

The concept of Comprehensive Nutrient Management Planning (CNMP) was introduced by the U. S. Environmental Protection Agency (EPA) and U.S. Department of Agriculture's (USDA's) Natural Resources Conservation Service (NRCS). It is anticipated that the CNMP will serve as a cornerstone of environmental plans assembled by animal feeding operations to address federal and state regulations. EPA and NRCS guidelines for CNMP are given in Table 1.

Table 1. Summary of Issues addressed by a CNMP as initially defined by EPA's Guidance

Planning components of CNMP	Issues addressed
A manure handling and storage plan	1. Diversion of clean water 2. Prevention of leakage storage plan 3. Adequate storage 4. Manure treatment 5. Management of mortality
Land application plan	1. Proper nutrient application rates to achieve a crop nutrient balance 2. Selection of timing and application methods to limit risk of runoff
Site management plan	Soil conservation practices that minimize movement of soil and manure components to surface and groundwater
Record keeping	Manure production, utilization, and export to off-farm users
Other utilization options	Alternative safe manure utilization strategies such as sale of manure, treatment technologies, or energy generation
Feed management plan	Alternative feed programs to minimize the nutrients in manure

Reference: USDA/EPA Unified National Strategy for Animal Feeding Operations (PDF) (34 pp, 404K)

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Environmental Impacts of Animal Feeding Operations Study Questions

Identify the definition that best fits the following terms:

1. **What are some of the positive environmental benefits of production agriculture?**

   - Improved soil quality
   - Carbon repository
   - Reduced storm runoff
   - Ground water recharge
   - All of the above

   Feedback

2. **USDA estimates that manure phosphorous exceeds crop needs in what percent of U.S. counties?**

   - 0%
   - 15%
   - 30%
   - 45%

   Feedback

3. **What is the common name for the class of production agricultural plants that do not need commercial nitrogen fertilizer?**

   - N Converters
   - Maize
   - Legumes
   - Algae

   Feedback

4. **If biodegradable organic matter is added to a stream, fish kills most often result from:**

   - Lack of oxygen
   - Turbulence
   - Lack of visibility

- Build up of sludge deposits

Feedback

5. **Most manure spills that enter streams result from:**

- Pastured animals with stream access
- Rupture of manure storage
- Improper land application of manure
- Damage to manure transfer or irrigation pipes
- Feedlot runoff from animal area
- All of the above

Feedback

6. **Nitrogen gas (N_2) account for ___________ % of the atmosphere?**

- 0%
- 24%
- 62%
- 78%
- 92%

Feedback

7. **Nitrogen in manure can take many chemical forms. Which of the following is NOT included?**

- Nitrogen gas
- Organic nitrogen
- Catatonic nitrogen
- Ammonia
- Ammonium

Feedback

8. **Which nutrient in runoff from agricultural land has been blamed for the hypoxia problem in the Gulf of Mexico?**

- Phosphorous
- Chlorine
- Sulfur
- Nitrogen
- Soil erosion

Feedback

9. **Which of the forms of nitrogen are volatile?**

- ○ NH_3
- ○ NO_3
- ○ NO_2
- ○ NH_4

Feedback

10. **High nitrate levels in drinking water can lead to the following serious condition in infants:**

- ○ "Green baby syndrome"
- ○ Headaches
- ○ Methemoglobinemia
- ○ Colic
- ○ Alzheimer's

Feedback

11. **The most important method of reducing phosphorous entering streams is:**

- ○ Placing riprap along edge of stream
- ○ Preventing soil erosion
- ○ Improving field drainage

Feedback

12. **Which of the following is NOT a significant source of air emissions around a livestock or animal production operation?**

- ○ Feed processing
- ○ Land application of manure
- ○ Animal production lots and buildings
- ○ Manure Storage

Feedback

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Other Airborne Emissions

Particulate emissions from AFOs include dried manure, feed, epithelial cells, hair, and feathers. This airborne "organic dust" can include endotoxins (the toxic protoplasm liberated when a microorganism dies and disintegrates), adsorbed gases, and possibly steroids. The main impact downwind appears to be respiratory irritation due to the inhalation of organic dusts.

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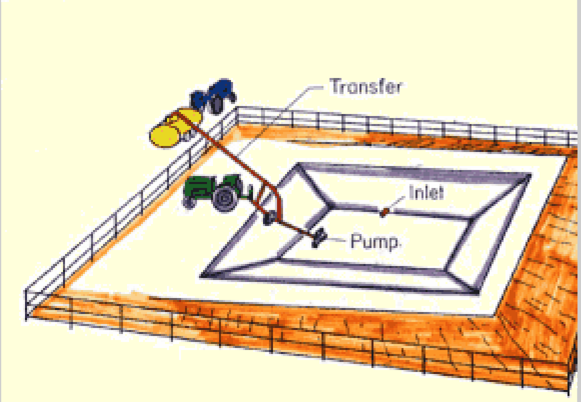

Slurry manure being agitated and hauled to field application

Slurry manure being injected below the soil surface

Manure treated and stored in a multi-cell lagoon before land application

Irrigation of lagoon effluent onto pasture

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