Pesticide Program Dialogue Committee
Emerging Agricultural Technologies Working Group
Final Report

Contents

Executive Summary..2

Chapter One: Recitation of Emerging Technologies (Appendix 1: Technologies List)..5

UAVs (Drones)/Aerial Technology..5

a. Use of drones for data collection..5

b. Use of drones for focused crop applications of pesticides..11

Chapter Two: Issues Unique to Emerging Technologies Regarding Human and Environmental Impacts..12

Chapter Three: Recommendations for EPA (Appendix 3: Feedback from Individual Organizations)..12

Future Research Needed..17

Conclusion..19

Appendix 1: Emerging Technologies List..20

Appendix 2: OECD Analysis..25

Appendix 3: Workgroup Member Feedback..26

Executive Summary

Over the last half-century, agriculture has delivered unprecedented improvements in productivity fueled by technologies such as improved seed quality, precision agriculture equipment, plant breeding including the introduction of novel traits, and crop protection products. Worldwide demands for better quality diets while delivering on global sustainability and climate change needs will require that agricultural production and improved agronomic practices continue to increase over the next half century. Emergingtechnologies such as drones, sensors, and robotics are already being adopted by farmers globally to optimize agronomic inputs and increase efficiency while maintaining or improving protection of human health and the environment. Such optimization and the introduction of other components of precision farming like the use of data science to guide agronomic decisions should lead to changes in the regulatory approach utilized by Environmental Protection Agency Office of Pesticide Programs (EPA OPP); in particular, EPA should adopt more realistic exposure and risk assessments—moving from assessments that use multiple "worst-case" assumptions to ones that incorporate localized, and ultimately more precise, exposure estimates. Additionally, the EPA OPP policy and practice should be adapted for the adoption of autonomous machine application of crop protection products. A key component of ensuring that emerging technologies that enable precision agriculture and deliver on the goals of a more sustainable agriculture meet their full potential is their integration into the regulatory processes as an additional option for the farmer, providing access to a wide range of solutions while protecting human health and the environment.

In this context, the EPA (the Agency) began work on this topic formally through a Pesticide Programs Dialogue Committee (PPDC) Emerging Technologies Working Group in Fall of 2020 with key stakeholder groups (Figure 1) with two charge questions:

1.) How should EPA obtain a greater understanding of how the use of emerging agricultural technologies leads to reduced or increased risks that differ from those resulting from current methods?

2.) What changes to EPA's approach to pesticide labels, if any, are needed to accommodate? emerging technologies?

An important first step towards answering these charge questions is to increase awareness andalignment of the evolving landscape of emerging technologies. The group, through a review of existing publicly available information, constructed a Technologies List (see Appendix 1) consisting of 7 main categories —Aerial Robots, Data, Ground Robots, Operations, Remote Sensing, Robotic Manipulators, and Spray/Nozzle Configurations—along with examples, descriptions for each, and regulatory considerations.

As a second step, it was then decided by the group to outline potential unique issues related toemerging technologies that may not be accounted for in current human and environmental health risk assessments.

Thirdly, other similar efforts were considered, and the work by the Organisation for Economic Co-operation and Development (OECD) in 2019, namely the *OECD Risk Reduction Seminar* *on Evolving Digital and Mechanical Technologies for Pesticides and Pest Management*[1] and the work of the OECD Working Party on Pesticide (WPP) Drone/UAV Subgroup was cross-referenced for potential similarities, differences, and overall understanding of the EPA's fit within a global context.

- **Manojit "Mano" Basu**, CropLife America (Co-chair)
- **Ed Messina**, EPA/OPP (Co-chair)
- **Ruben Arroyo**, Riverside County Department of Agriculture and Measurements Standards
- **Dan Cederberg,** Teejet
- **Gilbert Del Rosario**, Corteva Agriscience
- **Adam Finch**, BASF
- **Josh Friell**, The Toro Company
- **Brad Fritz,** USDA, ARS
- **Rebecca "Becca" Haynie**, Syngenta
- **Ramon Leon**, North Carolina State University
- **Lauren Lurkins**, Illinois Farm Bureau
- **Daniel Markowski**, Vector Disease Control International
- **Dan Martin,** USDA, ARS
- **Jacob Moore**, ADAMA
- **Robby Personette**, Wisconsin Department of Agriculture
- **Damon Reabe**, National Agricultural Aviation Association
- **Karen Reardon**, RISE (Responsible Industry for a Sound Environment)
- **Margaret Reeves**, Pesticide Action Network
- **Scott Shearer**, Ohio State University
- **Bryan Sanders**, HSE-UAV
- **Christina Stucker-Gassi**, Northwest Center for Alternatives to Pesticides
- **Nick Tindall**, Association of Equipment Manufacturers
- **Anne Turnbough**, AMVAC Chemical
- **Greg Watson**, Bayer

Figure 1: PPDC Emerging Agricultural Technologies Workgroup: Roster, October 2021

Before going into more detail on the recommendations to the PPDC, we would like to urge EPA to consider the implementation of our recommendations as an opportunity to be an even more important stakeholder in shaping the future of US agriculture. While the continued adoption of emerging technologies in US agriculture is nothing new (e.g., the Morrill Act establishing the land grant university system became law in 1862 during the Lincoln presidency) the current intersection of demographic trends (e.g., the average age of a farmer in the US is 57.5 years and is increasing; (https://www.nass.usda.gov/Publications/Highlights/2019/2017Census_Farm_Producers.pdf) while only ~1.3% of the US population lives on farms (http://jaysonlusk.com/blog/2016/6/26/the-evolution-of-american-agriculture)) and the increased digital and other technological capacity that is driving 'the internet of things' will likely continue to drive the adoption of emerging technologies in US agriculture. While this trend toward digital / precision agriculture will likely continue, the shape and speed of the adoption will be influenced by the decisions that EPA will make in considering the recommendations in this report; hence, we urge EPA to view the regulation of relevant emerging technologies as a potentially historic opportunity to improve US agriculture.

Though this field is actively evolving, and the development of technology and its potential benefits will no doubt continue for the foreseeable future, we have identified several areas of recommendations to the EPA with respect to the charge questions mentioned above. Specifically, and respectively,

---

[1] https://www.oecd.org/chemicalsafety/pesticides-biocides/seminar-on-pesticide-risk-reduction.htm

(1.) For the EPA to obtain a greater understanding of how the use of emerging agricultural technologies might potentially lead to exposures or risks that differ from those accounted for in currently employed methods (or Standard Operating Procedures) and policies used toderive exposure estimates and complete risk assessments: Overall, the group should recommend to the PPDC balancing a future-looking mindset for technologies not yet implemented, while supporting adoption of current technologies entering into use by farmers. Efforts such as the Technologies List provide an overview of the emerging technologies available to growers and give insight into options for specific technology categories to incorporate into existing regulatory frameworks given the current state of knowledge, while remaining open to incorporating future developments. For example, EPA OPP's initial focus should be on establishing regulatory equivalency related to pesticide application, registration, exposure, spray drift, and residue for drone/UAV technology and use of existing exposure estimates to reflect currently employed manned aerial application technology. Additionally, the group should recommend to the PPDC that EPA OPP remain connected to other initiatives (like the OECD efforts in emerging technologies) to maximize effectiveness and efficiency. Many stakeholders (nationally and internationally), from governmental, academic, Non-Governmental Organizations, and industry groups, are involved in these initiatives, and awareness of and collaboration with these stakeholders will increase coordination and efficient uptake of existing and new information.

(2.) To accommodate these emerging technologies, OPP's approach to pesticide labels must change. We recommend that PPDC advocate for and support a mindset of digital transformation, which supports digital labels that can be read and acted on by autonomous machines, including robots. OPP has taken small steps in label review to compare PDF files of labels, but more sophisticated capabilities are needed. Digitalization of agriculture needsto be enabled to fully implement the benefits of precision farming.

Additionally, continued progress toward improving digital functionalities of regulatory information, digital review of labels, and the submissions process for registrations (as has been done with the EPA OPP submissions portal) will be essential. Efforts here could leverage learnings from initiatives such as the VDC Pesticide Submissions Portal[2], EPA LEAN Management System (ELMS)[3], the OPP Electronic Label (OPPEL) Pilot[4], Web-Distributed Labels (WDL)[5], and the Endangered Species Bulletins Live[6]. While success of these initiativeshas varied, they provide opportunities to learn. Given the inevitable digitalization of agriculture, all avenues for forward progress must be explored.

Beyond a centralized IT function to support troubleshooting and hardware for divisions across the Office of Chemical Safety and Pollution Prevention (OCSPP), the Agency mustcultivate among its staff, contractors, and collaborators the digital competencies and knowledge to

---

[2] https://www.epa.gov/pesticides/pesticide-electronic-application-submission-portal-updated-new-features

[3] https://www.epa.gov/sites/default/files/2020-10/documents/1-opp-updates.pdf

[4] https://www.epa.gov/pesticide-registration/office-pesticide-program-electronic-label-oppel-pilot

[5] https://www.epa.gov/sites/default/files/2016-03/documents/pr2014-1.pdf

[6] https://www.epa.gov/endangered-species/endangered-species-protection-bulletins

accompany traditional expertise in agronomy, chemistry, and biology.

Joint efforts are needed among federal and state government agencies, industry, users of pesticide products, and customers of the agricultural products to digitalize regulatory information above and beyond electronic submissions of regulatory applications. Digital review of labels, recognition of electronically distributed labeling, and integration with pestmanagement by machines and robots are all essential elements of a new digital agriculturewhere EPA plays a key role.

As with charge question 1, many varied stakeholders are involved in this space. Broad-based collaboration with all of them by OPP is necessary for progress.

Chapter One: Recitation of Emerging Technologies (Appendix 1: Technologies List)

UAVs (Drones)/Aerial Technology

Unpiloted aerial vehicles (UAVs), also known as drones or unmanned aircraft systems (UASs), allow for efficient data collection in the field on soil moisture, crop health, and other useful information.Additionally, they can be used to apply pesticides and fertilizers precisely and only in areas where they are needed.

a. Use of drones for data collection.

For field monitoring purposes, drones generally carry high-resolution digital cameras with sensors designed to cover both the visible (red, green, blue – “RGB” – or VIS) and near-infrared (NIR) portions of the electromagnetic spectrum, at wavelengths of 400-700 nm and 750-1400 nm, respectively. Multispectral and hyperspectral sensors may be used to detect light in multiple discrete ranges within the NIR-VIS spectrum for specific monitoring tasks. (While most light reaching the sensors is due to reflectance, fluorescence generated by the action of ultraviolet (UV) radiation on plants sometimes provides a minor contribution to that light). Thermal sensors, which detect infrared radiationin the long-wavelength region (7.7-13 µm, or 7700-13,000 nm), may be used to measure the temperature of plant canopies and other objects, although the spatial resolution of these sensors is lower than that obtainable at shorter wavelengths. LIDAR (light-radar) sensors emit their own light in the form of a laser beam and measure the time for the light to be reflected at a surface and returned to the sensor; thus, they can generate accurate topographical data and can be used to estimate canopy volume by measuring the distance between canopy height and ground surface.

An algorithm known as the Normalized Difference Vegetation Index (NDVI) is frequently used forvegetation assessment and is derived as follows:

$$\mathrm{NDVI} = (\mathrm{NIR} - \mathrm{VIS}) / (\mathrm{NIR} + \mathrm{VIS})$$

The chlorophyll in the leaves of plants, unlike most non-plant objects, strongly reflects NIR light but absorbs red and blue in the VIS range. When the plant is dehydrated or otherwise stressed, the leaves reflect less NIR light but the same amount of visible light, thus changing the NDVI image. A higherNDVI value normally indicates more vigorous growth or a greater volume of vegetation.

In general, the information garnered from the analysis of reflected light at various wavelengths is primarily related to the composition of the soil surface and the uppermost exposed surfaces of the plants. The data may simply classify images into leaves, soil, etc., or may provide detailed information onthe form, structure, and physiology of the plants being surveyed, depending on the number and spectralranges of the sensors being used and the complexity of the data being generated and processed. Also, asa drone passes across a land surface, the reflectance of light from an object such as a leaf will change as the angle between the sensor and the object changes, and this change becomes more pronounced the lower the drone is flying. Thus, the data from the sensors must be processed to compensate for these continuous changes[7].

Since the images recorded by a drone camera flying at a low altitude will suffer from geometrical distortion, especially when wide-angle lenses are used, the data that they generate must beprocessed to produce a geometrically corrected, seamless composite from which distances and areas can be accurately measured. This is commonly achieved using commercially available "orthomosaic" mapping software.

The following are some of the specific uses reported for drone-based remote sensing, togetherwith examples from the published literature. It should be noted that this technology can generate thematic maps to present data for any of the topics addressed below in visual format.

(i) Estimating soil and field conditions

Drone-based sensing has been used to detect soil erosion, drainage, salinity, acidity, nutrient deficiencies, and applied nutrient loss after flooding, and monitor drainage and fertility in general[8].

Drone-based sensing can be particularly beneficial for:

1. Rapid assessment of field conditions after extreme weather events, such as flooding andlandslides.
2. Creation of 3D topographical maps that may be useful in planning seed-planting patterns.
3. Surveying fencing conditions.
4. Optimization of seed application

Since soil acidity can reduce crop yield, but current methods to identify and remediate acidic soils are expensive and time-consuming, Webb et al. (2021)[9] used spectral observations across a spring wheat field in Montana (which has extensive soil acidity problems) at 12 time points during the growing season to analyze a possible relationship between NDVI values and field measurements of soil pH and other parameters. The relationship was examined using two models, linear regression, and random forest. The linear regression models indicated that most of the variation in NDVI was indeed attributableto differences in soil pH and organic matter early in the season, but less so later in

---

[7] Van der Merwe D, Burchfield DR, Witt TD, Price KP, Sharda A. Drones in Agriculture. Advances in Agronomy.2020; 162: 1-30.

[8] Krishna KR. "Agricultural Drones. A Peaceful Pursuit." Apple Academic Press, Waretown, NJ, USA; 2018.

[9] Webb H, Barnes N, Powell S, Jones C. Does drone remote sensing accurately estimate soil pH in a spring wheat field in southwest Montana? Precision Agric. 2021; 22.

the season; the random forest model predicted soil pH with reasonable accuracy. Thus, this technique would enable land managers to easily identify and remediate acidic soils in a more cost-effective and timely manner ascompared to traditional methods.

(ii) Seedling emergence

High resolution drone mapping can be used to identify any areas of planting where crop emergence is delayed or not evident because of environmental conditions, thus allowing for possiblereplanting in the narrow time window available.

(iii) Crop monitoring

Benefits of drone use in crop monitoring include:

1. Real time assessment of vegetative stage, overall biomass, and ultimate yield
2. Optimization of fertilization
3. Assessment of damage resulting from storms, farm equipment, or malicious intrusion
4. Evaluation of different hybrids and cultivars in experimental plantings

Zhang et al. (2021)[10] have recently published a review of the extensive literature on the use of drone-based remote sensing in orchard management. They note that by mapping such geometric traitsas canopy area and crown volume, optimal pruning type, and intensity can be selected and applied.

Drone imagery can be used to estimate yield and productivity by providing counts of the flowers and/orfruit on trees, and to determine optimum harvest time by monitoring fruit ripeness.

Vega et al. (2015)[11] have reported on the use of a drone-based multispectral (R, G, NIR) sensor to generate the NDVI values for a sunflower crop and correlate them with grain yield, aerial biomass, and nitrogen content. Data acquired during the growing season allowed for early recognition of certain problems in the crop without having to wait until harvest, allowing the grower to tailor the extent of treatment (irrigation, or nitrogen or pesticide applications) to the specific needs of different areas withinthe crop field, and thus providing both economic and environmental benefits.

Herrmann et al. (2019)[12] used drone-based spectral imagery to predict yield and distinguish between different development stages and irrigation treatments for an experimental crop of 19 different maize (corn) hybrids. Similarly, Duan et al. (2017)[13] used multispectral imaging

---

[10] Zhang C, Valente J, Kooistra L, Guo L, Wang W. Orchard management with small unmanned aerial vehicles: a survey of sensing and analysis approaches. Precision Agric. 2021; 22D

[11] Vega FA, Ramirez FC, Saiz, MP, Rosua FO. Multi-temporal imaging using an unmanned aerial vehicle for monitoring a sunflower crop. Biosystems Eng. 2015; 132: 19-27.

[12] Herrmann I, Bdolach E, Montekyo Y, Rachmilevitch S, Townsend PA, Karnieli A. Assessment of maize yield and phenology by drone-mounted superspectral camera. Precision Agric. 2020; 21: 51–76.

[13] Duan T, Chapman SC, GuoY, Zheng B. Dynamic monitoring of NDVI in wheat agronomy and breeding trials usingan unmanned aerial vehicle. Field Crops Res. 2017; 210: 71-80.

to rapidly (1 ha/10 min) monitor NDVI values for multiple wheat cultivars and treatments (sowing, irrigation, nitrogen application) during the growing season. There was a strong correlation between NDVI valuesaround flowering time and final yields.

Drone-based monitoring has been shown to be particularly useful in assessing the status of so- called specialty crops like those grown in vineyards, orchard fruits, citrus trees, and olive trees. Campos et al. (2019)[14] report on the use of multispectral sensors to create a canopy vigor map of a vineyard, andfor using the map to reduce the existing pesticide spray application rate by 45%.

Red edge (RE) refers to the narrow spectral band at a wavelength of about 735 nm located between the red (R) and NIR bands. The Normalized Difference Red-Edge Index (NDRE) calculated as (NIR-RE)/(NIR+RE), has been correlated with nitrogen (N) uptake of plants. Argento et al. (2020)[15] acquired drone-based multispectral images of Swiss winter wheat fields and calculated both NDRE for N-uptake and NDVI, which correlates closely with canopy cover and biomass. They then used these data in combination with field measurements of existing available mineral N content prior to the growing season to calculate the required quantities of location-specific nitrogen fertilizer applications to be supplied in 3 splits that coincided with 3 growth stages. The value of the first split was based on the initial field measurement, while the second and third splits were adjusted for the latest NDRE index map. They monitored the crop throughout the growing season and compared the yields using this variable rate N application with yields using the standard, uniform application rate employed on many wheat farms. While the yields in all fields showed no significant differences between the variable rate and standard treatments, the reduction of applied N ranged from 5% to 40% with variable rate compared to standard rate. Overall, it was concluded that nitrogen use efficiency could be improved by about 10% using variable rate application and redistributing and reducing the amount of nitrogen fertilizer applied, based on NDRE values from drone-acquired remote sensing data. This reduction innitrogen fertilizer use also has significant environmental implications.

(iv) Crop health assessment

Monitoring for insect infestation and bacterial, viral, or fungal diseases, and designing precise pesticide applications (in terms of application rate and area covered) to treat them, can help minimize the amount of pesticide used. In contrast to weeds growing among crops, there is far more spectral contrast between healthy and diseased leaves; both hyperspectral sensing and fluorescence monitoringhave been used for this purpose. Monitoring by drone can allow for a rapid response to insect infestations that spread rapidly, like the Colorado potato beetle; the resulting defoliation is readily detectable.

---

[14] Campos J, Llop J, Gallart M, Garcia-Ruiz F, Gras A, Salcedo R, Gil E. Development of canopy vigour maps usingUAV for site-specific management during vineyard spraying process. Precision Agric. 2019; 20: 1136–1156.

[15] Argento, F, Anken T, Abt F, Vogelsanger E, Walter A, Liebisch F. Site-specific nitrogen management in winterwheat supported by low-altitude remote sensing and soil data. Precision Agric. 2021; 22: 364–386.

Crop diseases can be either biotic (causes by pathogens) or abiotic (resulting from environmental factors such as water pollution, overwatering, or extremes of sunlight or nutrients). In their recent review of the published literature on use of drones in orchard management, Zhang et al. (2021)[16] note that detection of either type of disease using drone imagery can provide orchard scoutingover a large area and is low-cost in terms of both time and equipment, although the complexity of disease diagnosis and the diversity of fruit species makes widespread application of the technology for orchards somewhat challenging. Nevertheless, use of hyperspectral and multispectral sensors has beenshown to distinguish between two different diseases (bacterial canker and citrus greening) in citrus trees, for example.

Yellow rust (YR), which often spreads to new and unexpected geographic locations, represents amajor threat to worldwide wheat production. Aharoni et al. (2021)[17] have derived a drone-based remotesensing system for detecting YR symptoms using the NIR-VIS reflectance spectrum and an algorithm thatclassifies YR at different stages of development and distinguishes it from typical defense responses in resistant wheat. The process yielded a true positive identification rate of about 86% for infected plants.

(v) Water management

Drone-based sensors can efficiently monitor water stress in crops on a timely basis and over large areas. The data generated can be used to fine-tune irrigation systems to optimize water delivery, increasing supply to areas under stress while avoiding unnecessary over-supply in other areas. Gago et al. (2015)[18] have reviewed much of the published literature on the use of drone-generated data to evaluate water stress and improve water stress management. They describe three main areas of drone-based sensing technology: reflectance indices, thermal indices, and chlorophyll fluorescence.

Reflectance indices include NDVI (described above); transformed chlorophyll absorption in reflectanceindex/optimized soil-adjusted vegetation index (TCARI/OSAVI); and normalized photochemical reflectance index (PRI_{norm}). TCARI/OSAVI and PRI_{norm} are derived from composites of reflectance at various spectral bands between 550 and 800 nm. TCARI/OSAVI is sensitive to chlorophyll content but insensitive to other factors that could affect canopy reflectance, such as the reflectance from the soil, angle of the sun and vigor of the plant, while PRI_{norm} considers changes in concentration of xanthophyll,chlorophyll content and canopy leaf area induced by water stress.

Stomata are microscopic pores on the leaf epidermis that regulate transpiration/CO_2 uptake byleaves. Drone-based thermal imagery is widely used to detect water stress in several crops, since drought increases stomatal closure, thereby reducing transpiration and evaporative cooling, which in turn increases leaf temperature.

---

[16] Zhang C, Valente J, Kooistra L, Guo L, Wang W. Orchard management with small unmanned aerial vehicles: a survey of sensing and analysis approaches. Precision Agric. 2021; 22.

[17] Aharoni R, Klymiuk V, Sarusi B, Young S, Fahima T, Fishbain B, Kendler S. Spectral light-reflection data dimensionality reduction for timely detection of yellow rust. Precision Agric. 2021; 22: 267–286.

[18] Gago J, Douthe C, Coopman RE, Gallego PP, Ribas-Carbo M, Flexas J, Escalona J, Medrano H. UAVs challenge to assess water stress for sustainable agriculture. Agr Water Manag. 2015; 153: 9-19.

Chlorophyll fluorescence, induced by ultraviolet radiation in sunlight, has been shown to be a direct indicator of photosynthesis. One fluorescence parameter strongly correlates with net CO_2 assimilation and accurately tracks water stress-induced reduction in photosynthesis. Drones that can flyextremely close to plants are ideally suited for measuring leaf fluorescence.

(vi) Weed detection

Multispectral sensors are most utilized for generating images that distinguish between weeds and crops (although some weeds may appear so visually similar to the crops that distinction is not possible). When visual separation is successful, the images may be used to optimize herbicide treatment, thus limiting both herbicide quantity to be applied and areas to be treated. Actualweed identification, if possible, is less important when using broad-spectrum herbicides like glyphosate rather than more specific products like 2, 4-D. For example, Rasmussen et al. (2019)[19] used a process called Thistle Tool, involving off-the-shelf drones armed with RGB cameras, to map outbreaks of the green weed *Cirsium arvense* (a common species of flowering thistle) among cereal crops like wheat andbarley, thus allowing for pre-harvest spraying with glyphosate.

Rozenberg at al. (2021)[20] used another off-the-shelf drone to weed map 11 dry onion (*Allium cepa* L.) commercial fields. The process involved both classification of late-season weeds and investigation of spatial patterns. Multiple weed maps were generated and evaluated. The classification processes showed the maps to be highly accurate; they demonstrated patchy weed coverage throughout the fields, varying from 1 to 79% between fields. These findings represent an important stepin developing precise weed control, and thus limiting herbicide application, in such fields.

Colchicum autumnale are plants with purple flowers that bloom in the autumn and grow in large meadows and pastures. All parts of the plant are toxic and can lead to respiratory paralysis and death in animals that consume them. Animals normally avoid them when they are simply growing in the pastures, but if the grass is harvested for hay and silage the toxic leaves and seeds pose a significant threat. Current treatment involves mulching of the grassland in the spring, but that has resulted in significant ecological damage and a negative effect on the growth of the grass crop. Petrich et al. (2020)[21] have used drone mapping in the visible spectrum of the grasslands in the autumn (when the purple flowers are present) and sophisticated processing of the data to map the presence of the weed with an 88% accuracy, allowing for treatment with non-chemical automated tools the following spring.

(vii) Livestock monitoring

Drones with visible light sensors can be used for real-time surveillance of the location, number,and behavior of livestock, and for confirming the adequacy of pasture fencing and gates,

---

[19] Rasmussen J, Nielsen J, Streibig JC, Jensen JE, Pedersen KS, Olsen SI. Pre-harvest weed mapping of Cirsiumarvense in wheat and barley with off-the-shelf UAVs. Precision Agric. 2019; 20: 983–999.

[20] Rozenberg G, Kent R, Blank L. Consumer-grade UAV utilized for detecting and analyzing late-season weed spatialdistribution patterns in commercial onion fields. Precision Agric 2021; 22: 1317–1332.

[21] Petrich L, Lohrmann G, Neumann M, Martin F, Frey A, Stoll A, Schmidt V. Detection of Colchicum autumnale indrone images, using a machine-learning approach. Precision Agric. 2020; 21:1291–1303.

water supply, feed troughs etc. High resolution thermal sensors can be used to remotely monitor body temperature (far more challenging at ground level) and thus screen for heat stress, diseases and even injuries with localized inflammation.

b. Use of drones for focused crop applications of pesticides.

Drones are garnering worldwide interest as an application technique for plant protection products (PPP). The need to produce significantly more food and feed while using fewer PPPs coupledwith harvest losses and shrinking agricultural land has accelerated innovation in the drone realm.

Drones are an important component of precision agriculture and have the potential to assist with achieving sustainable agricultural goals. Increased digital solutions such as satellite-driven technology, big data analytics, autonomous vehicles, and artificial intelligence are helping farmers to make better, more informed, and more efficient crop-growing decisions. The precision agriculture sector has responded to increased demand and there is now a wide array of drones available. This increased availability lends itself to many different application types from small acreage - high value crops, such asvineyards and orchards, to larger tracts with traditional row-crops, with the advent of drone swarms.

Given access-limiting growing conditions, such as muddy fields and/or areas with physical impediments such as power lines, drones offer a complimentary approach to, rather than a replacement of, conventional methods of PPP application such as manned aerial and ground applications. Additionally, when compared to larger traditional application equipment, and with business models such as spray-as-a-service, drones offer an affordable option for crop protection, increasing the availability of digital technologies to even small operations. Besides crop protection, drones are also used in vector control and industrial vegetation management, each of which often require application to remote and/or difficult-to-access terrain.

While these UAV systems have been widely employed in Asia for over 30 years and have been recently approved in Europe for specific applications on sloped vineyards and orchards (i.e., Germany and Switzerland), increased use in other geographies has created a need to establish a regulatory baseline of known information so that data gaps can be assessed and progressed upon. Although similar in many aspects to traditional aerial and precision PPP applications, there are variables that may need further understanding for drone-based pesticide applications.

The increased interest in drone technology and the need to further explore potential differencesin drone technology compared to existing application techniques has led to formation of several workinggroups. Most notably, in 2019 the OECD WPP created a team to consider the application of pesticides bydrone (OECD Drone Sub-Group). In 2020, the OECD Drone Sub-Group commissioned a critical literature review to summarize current knowledge around drones and assess data gaps present in approaching aregulatory framework for drone use of PPPs. The information from the review provides a current stateof the science and identifies key data gaps of operator exposure, efficacy, crop residue, and offsite movement (OECD, 2021). Additionally, efforts are underway that will establish a United States-based Task Force to take up these recommendations for data generation and will leverage the expertiseof the OECD group for guidance. Also, Crop Life America (CLA) established a Drones Working Group (DWG) in Fall of 2020. The Working Group's mission is to evaluate existing data used to assess, or generated by, aerial and/or traditional pesticide application methods to identify equivalencies and potential gaps in the context of drone applications. The CLA DWG has aligned closely with EPA in this effort, as well as with other working groups involved with various aspects of drone technology.

It should be noted that many of the above technologies' utilization are not limited to unmanned systems. For example, weed detection is likely to first appear on manned sprayers both as an aftermarket retrofit to existing units and fully incorporated in new models. EPA OPP must ensure regulations allow for the deployment of these tools across a broad-spectrum platform.

Chapter Two: Issues Unique to Emerging Technologies Regarding Human and Environmental Impacts

There are several potential benefits in using emerging technology for pesticide applications. For example, there could be potentially less worker exposure to pesticides and time/labor savings particularly in areas where hand application is needed. Additionally, there is an opportunity to use this technology in tough and difficult conditions (e.g., cliff sides) where traditional application methods may not be feasible or present additional hazards. Also, there is the potential to reduce environmental loading of pesticide/fertilizer/water as spot or partial field applications may become more viable. Depending on equipment type, reduced fuel use / emissions and a lower cost to entry may be realized in many scenarios. Benefits may be over-stated early in development and roll-out and therefore quantifying benefits as technologies evolve is very important.

While there are potential benefits, there are several potentially unique challenges that are also present regarding safety, implementation, and regulatory compliance. What difference does this technology present in terms of offsite movement that may impact applicators, bystanders, and/or wildlife that may be different than conventional application methods? Also, are there differences in the applications that may impact pesticide efficacy and/or tolerances or result in crop injury? Are there additional considerations regarding applicator training or safety? What additional label language may need to be considered to ensure it is clear to better ensure compliance? Reliance of many technologies on the internet may also present data hacking and privacy concerns as well as unequal access to technologies (for example, poor broadband internet access may not allow all consumers equal access to certain technologies). To gain a better understanding of the questions presented above, it will be important to determine what additional data (i.e., drift, worker exposure, efficacy) might be needed to test current assumptions or modeling already in place for conventional application methods as it relates to emerging technology.

Chapter Three: Recommendations for EPA (Appendix 3: Feedback from Individual Organizations)

Section 1: Greater Understanding for EPA (Charge question 1: How should EPA obtain a greater understanding of how the use of emerging agricultural technologies leads to reduced or increased risksthat differ from those resulting from current methods?)

For the EPA to obtain a greater understanding of how the use of emerging agricultural technologies potentially leads to exposures or risks that differ from those accounted for using current exposure estimate and risk assessment approaches, the group should recommend to the PPDC a balance between a future-looking mindset for technologies yet to be implemented, and support for adoption of current technologies entering into use by farmers. Efforts such as the Technologies List provide an overview of the emerging technologies available and give insight into options for specific categories to incorporate into existing regulatory frameworks given the current state of knowledge, while remaining open to incorporating future developments. For example, EPA OPP's initial focus should be on establishing regulatory equivalency related to pesticide application, registration, exposure, spray drift, and residue for drone/UAV technology and use of existing exposure estimates to reflect currently employed mannedaerial application technology.

Aerial Robots/Drone/UAV Technology

Drone/UAV technology is a precision tool that current regulatory frameworks should be adapted to incorporate. For the United States specifically, drones offer a compelling addition to existing application tools. Benefits for sustainability and the environment, safety, cost, and flexibility are just some of the potential values that this technology can offer. While commercial drone applications are currently operating under the manned aerial regulatory framework, UAV technology is sufficiently different to require that new data should be generated, analyzed, and assessed for its relevance and fit into current regulatory frameworks. Additionally, models like AgDRIFT® and AgDISP™ used for manned aerial applications have not been updated to reflect many best management practices and newer technologiesutilized today in that industry and should be revisited to reflect the state of the science more accurately.The current position of the EPA to enable UAV/drone technologies' commercial use is directionally correct, knowing that further data generation will facilitate their incorporation into the regulatory risk assessment process. Given these technologies' continued evolution, it is important that the agency seek to understand the spectrum of possibilities and then approach some type of standardization (for example based on rotor number) so that the effort put forth now can withstand the test of time andfurther advancement of the technology.

Additionally, the group recommends that the PPDC connect to other relevant initiatives to maximize effectiveness & efficiency. We recommend that EPA convene a workshop, or series of workshops, in order to familiarize itself with drone technology and the published literature on the application of the technology, and to identify any potential data gaps. Many stakeholders are involved in the UAV/drone space (nationally and internationally), from governmental, academic, and industry groups, and awareness of and collaboration with these stakeholders will increase coordination and efficient uptakeof existing and new information.

For example, in December 2020, the Center of Excellence for Regulatory Science in Agriculture (CERSA)held an Unmanned Application System (UAS) workshop[22] involving multiple

---

[22] https://cersauas.wordpress.ncsu.edu/

stakeholders across the public and private sectors from academia, government, research organizations, industry sectors, and other key groups, focused on advancing the science around regulation of pesticide drift from both UASand manned aerial applications. There was agreement among the stakeholders that:

1.) "We promote the implementation of UAS platforms in a complementary manner to conventional aerial and ground application equipment rather than a replacement for traditional application methods that may have the potential to expand application capacityin specific use conditions.
2.) We recognize the need for the development of public-domain regulatory models, supportedby high quality data, for the predictions of performance, drift and exposure from the use of UAS.
3.) We commit to continuing the conversation on how to keep drift modeling for manned aircraft up to date, whether by revising default inputs or expanding assessments to considerhigher tier simulations.
4.) We further support continued research into the effect of pesticide droplet size on efficacy for all application platforms."

In addition to the CERSA stakeholder group, the OECD UAV/Drone Subgroup commissioned a critical literature review to summarize current knowledge on UAVs and assess data gaps present in approachinga regulatory framework for drone application of pesticides. The information from the review provides a current state of the science, identifies key data gaps and recommends next steps for data generation with respect to operator exposure, efficacy, crop residue, and offsite movement. Current efforts are underway to form a Task Force, that while based in the U.S., will have a global focus on generating data to meet these outstanding needs, utilizing the OECD UAV/Drone Subgroup as a sounding board.

Coordination with stakeholders and efforts such as those mentioned above for UAV/drones will increaseefficiency and effectiveness for incorporating this emerging technology into regulatory systems.

Autonomous Ground Application Robots

Autonomous ground robots for application are very similar to manned ground application machinery. The difference is the location of the person either operating the equipment remotely or having pre-planned a course of action. Otherwise, they are performing the same task. The primary focus of EPA current regulations regarding manned tractors revolves around emissions standards, which is outside ofthe purview of OPP; therefore, along with existing training framework for safe and compliant operations, regulatory precedent exists to incorporate these technologies. Additionally, with the future of autonomous tractors likely to utilize alternative power sources such as electric or hydrogen fuel cells, they would theoretically have an equivalent or better (even zero)emissions profile, which justifies further support of this technology towards climate health goals.

Robotic Manipulators

Most of the Emerging Technologies described in the Technologies list do not require EPA registration, according to the guidance by the Agency[23], but are regulated by the EPA and are required to be manufactured in an EPA-registered establishment. Examples include mechanical, laser, and electrical weeding devices and any device that "works by physical means (such as electricity, light or mechanics) and does not contain a substance or mixture of substances to perform its intended pesticidal purpose."As described, these devices must have sound data to back claims and must not contain false or misleading claims regarding the safety or effectiveness of the device. Therefore, frameworks already exist to incorporate these technologies into current regulations and no further modification is needed.

General Considerations

Keeping an eye to the future, there are Emerging Technologies which warrant an occasional "pulsecheck" but, in the current state, do not need to be incorporated into EPA regulatory framework. Atpresent, these warrant experts in the field, such as University Extension agents, taking the lead. If regulatory concerns arise, they will need to be evaluated at that point. Examples that fall into these categories include, but are not limited to, spot application, variable rate technology, sensors for pest pressure, and digital prediction systems. A non-digital equivalent can be used as an example, with University Extension programs recommending specific Integrated Pest Management practices. Whereas each pesticide product used is regulated, and the pesticide use complies with label requirements, the overall recommendation, which could include non-pesticidal practices, remains flexible for use by the farmer based on localized needs.

Section 2: Approaches to Labels (Charge Question 2: What changes to EPA's approach to pesticidelabels, if any, are needed to accommodate emerging technologies?)

Drones/UAVs

As drone technology continues to evolve, we encourage the Agency to enable regulation ofpesticide application via unmanned aerial/ground vehicles under the current FIFRA framework.

Compliance through EPA will allow EPA to focus on regulation of the pesticide products, application, risk, etc. instead of operation of the drone. Following a similar approach to the current regulations of aerial applications through rotary or fixed-wing aircrafts, in conjunction with an expanded risk assessment that includes drone technologies, will help build support for the view that EPA can address drone applications under existing FIFRA regulations. Continuous collaboration with all stakeholders under a familiar framework with developed guidelines, such as FIFRA, will ensure that Best ManagementPractices are utilized. Following the EPA assessments of unmanned application technologies, if additional label language is required, continuous collaboration to streamline the process of label reviewsis imperative. It is suggested that the overall use pattern be considered, and that label language be consistent and standardized, thereby eliminating the need for a product-by-product evaluation by EPA.Expedited label reviews will allow for those end-users who may not be familiar with or accustomed to drone technology use in agriculture and public

---

[23] https://www.epa.gov/safepestcontrol/pesticide-devices-guide-consumers#1

health to have access to product use information that they can have confidence in.

It is also important that EPA considers expanding the scope of the teams currently working on digital label initiatives to incorporate innovations such as drones. Additionally, with the advancement and automation of application technologies, digitized labels should be considered for direct input into drones. The ability to do so could increase consistency in product use and adherence to label directionsand precautions, while taking advantage of automation features of drone technology. This type of project would require input from several stakeholders, including state authorities and drone manufacturers.

Digital Labels

Further connection to digital tools from farm equipment and devices placed into agricultural and vectorcontrol sites is on the rise, as are the scientific advances in enabling precision agriculture—as with GPS technology, environmental and crop sensors, and machines capable of acting on digital instructions.

Given these advancements, thought should be given to what this future state looks like, how it adds value to all stakeholders involved, and to a transition plan for incorporating this technology into existingregulatory frameworks. Automation and digitization of expert activities such as surveilling the crop or treatment area, applying crop protection and vector control products, following pesticide label restrictions and use directions, and measuring weather conditions, are examples of the many possibilities for these new innovations that can save time, expense, and labor. This also allows for site- and application-specific risk assessment and, where necessary, mitigation, thereby providing confidenceto regulators and society that use of these technologies under the specific conditions at the time of the application meets the governing safety standards.

To accommodate these emerging technologies, OPP's approach to pesticide labels must change. We recommend that PPDC advocate for and support digital transformation, including development and adoption of digital labels that can be read and acted on by autonomous machines, including robots. OPPhas taken small steps in label review to compare PDF files of labels, but more sophisticated capabilities are needed. Digitalization of agriculture needs to be enabled in order to fully implement the benefits of precision farming.

Additionally, continued progress toward improving digital functionalities of regulatory information, digital review of labels, and the submissions process for registrations (as has been done with the EPA OPP submissions portal) will be essential. Efforts here could leverage learnings from initiatives such as the VDC Pesticide Submissions Portal, EPA LEAN Management System (ELMS), the OPP Electronic Label (OPPEL) Pilot, Web-Distributed Labels (WDL), and the Endangered Species Bulletins Live. While successof these initiatives has been variable, they provide opportunities to learn. Given the inevitable digitalization of agriculture, all avenues must be explored.

Beyond a centralized IT function to support troubleshooting and hardware for divisions across OCSPP,the Agency must cultivate among its staff, contractors, and collaborators the digital competencies andknowledge to accompany traditional expertise in agronomy, chemistry, and biology.

Joint efforts are needed among federal and state government agencies, industry, users of pesticide products, and customers of the agricultural products to digitalize regulatory information above and beyond electronic submissions of regulatory applications. Digital review of labels, recognition and authorization of electronically distributed labeling, and integration with pest management by machinesand robots, are all essential elements of a new digital agriculture where EPA plays a key role.

Many varied stakeholders are involved in this space. Broad-based collaboration with all of them by OPPis necessary for progress.

Future Research Needed

In addition to the research and recommended areas for efforts outlined above, several emerging topicsare important to mention and to keep in mind.

Drones/UAVs

Further research is needed to quantify the benefits that drones provide to agriculture so they can be considered upon incorporation into the regulatory framework. Further understanding of the state of thetechnology will facilitate this. This includes, but is not limited to:

1.) USDA and Land Grant University focus areas:
    a. Investigating additional areas in which data collection by drone could benefit agriculture in such categories as:
        i. Evaluation of soil and field conditions
        ii. Monitoring of seedling emergence and crop development
        iii. Monitoring of crop health and disease emergence/identification
        iv. Monitoring of weed emergence
        v. Orchard management
        vi. Irrigation refinement and water use/loss minimization Livestock tracking and health monitoring
    b. Refining techniques (e.g., sensor selection) for each type of data collection application
        i. Development of use of drone swarms for treatment of large acreages of rowcrops
2.) USDA, Land Grant University, and EPA Biological and Economic Analysis Division of the Office of Pesticide Programs (OPP) focus areas:
    a. Quantification of benefits of drone use in terms of:
        i. Cost savings in inputs (pesticides, fertilizer, fuel, manpower, vehiclemaintenance)
        ii. Emissions reduction
        iii. Water use reduction
        iv. Nutrient runoff reduction
Improved soil health3.) EPA OPP focus areas:
    a. Equivalencies and potential differences in spray drift, operator exposure, crop

residues,and efficacy.

b. Development of drift modeling

New Stakeholders

It is worth pointing out that inherent to any "disruption" as is being seen now with the digitalization ofagriculture, new stakeholders will come with perspective and experience from other industries that could benefit agriculture. Stakeholders like Google, Amazon, and Microsoft, with experience in automation, sensors, machine learning, data analysis, and handling and storing of big data, could be important to consult or actively engage, depending on the topic. Examples can be seen of these stakeholders venturing into agriculture with "X"'s Mineral Project[24] (X is a venture of Alphabet, Google'sparent company) in "bring[ing] together diverse sources of information that until now were simply too complex or overwhelming to be useful". Given the diverse set competencies these new stakeholders bring, their participation could compliment on-going or new work regarding emerging technologies and increase coordination and thus efficiency and effectiveness. For future PPDC groups, it could be worth considering actively engaging these stakeholders if the subject matter is appropriate. It is also importantto mention that keeping up to date on advances in the technologies of established stakeholder industries will also be key to remain inclusive. It is critical that the "traditional" industries are not collateral damage during this transformative period of agriculture.

Climate Change and Sustainability

The current administration is keenly focused[25] on climate health and is looking to agriculture for opportunities related to greenhouse gas emissions and other sustainability contributions. Accordingly, focus areas for agricultural production will include management of soil fertility, soil loss, water use, land use, and agricultural inputs to minimize environmental impact while maximizing yields to feed a growingpopulation. It is, however, paramount that the policies and legislation surrounding emerging technologies offer tangible and measurable benefits to farmers, the environment, and society.

Fortunately, many of these practices are already being adopted and the current and potential futureresults are impressive.

For example, it was determined in one study that the need for an estimated 10.2 million acres of cropland, or an area equivalent to 4.5 Yellowstone National Parks, was avoided due to increases in yield as a result of precision farming (PF) practices. In another study, the use of an estimated 100 million gallons of fossil fuels was avoided through adoption of PF technologies, equivalent to taking an estimated 193,000 cars off the road annually or canceling 18,000 average flights. In another example, it was shown that the application of an estimated 30 million pounds of herbicide was avoided by adoption

---

[24] https://x.company/projects/mineral/

[25] https://climate21.org/

of PF technologies, with an estimated additional 48 million pounds of herbicide being avoided with broader adoption.

Looking to water use efficiency, one model demonstrated that the application of an estimated 750,000 Olympic swimming pools' worth of water was avoided by adoption of PF technologies.[26]

Federal regulatory efforts and guidance are underway in this space as well, for example with the USDA[27] on carbon reductions. Industry is responding[28] by working with growers to improve the carbon footprint of their operations and yields. Government support for efforts to enable climate and sustainability models that have the trust and buy-in from all stakeholders would be important for incorporating benefits of registered substances in a standardized, quantitative, and science-based way, and could enable possible future incorporation in the risk management framework. However, the carbon market inUS agriculture is finally organized, it is clear that digital tools for implementation of precision agriculture and for verification of carbon capture will be essential elements of this effort.

Conclusion

Emerging technologies will continue to arise during this dynamic and important time in agriculture. They are a central element to solving one of society's most pressing issues: feeding a growing populationwhile minimizing farming's impact on the environment and human health. Sustainable and climate-smart production will require this to be achieved by managing the economics as well as factors such as soil health, erosion, water use, and prudent use of agricultural inputs. Emerging technologies have surfaced as promising solutions in helping achieve these somewhat conflicting but interconnected objectives, and coordination among key stakeholders is necessary in any discussions on regulation. As with the adoption of any new technology, it will only be successful if it brings benefits to farmers, the environment, and society. The industry will continue with further research and innovation to enhance the competence and responsible use of emerging technologies. As these efforts progress, the industry iscommitted to work with governments within transparent, science-based, and flexible regulatory frameworks that can enable these technologies to continually evolve for the future of farming.

---

[26] https://soygrowers.com/wp-content/uploads/2021/02/Precision-Ag-Study.pdf and https://www.precisionfarmingdealer.com/blogs/1-from-the-virtual-terminal/post/4673-the-environment-and- farmers-reap-benefits-of-precision-ag-technology

[27] https://www.usda.gov/oce/energy-and-environment/markets/carbon

[28] https://www.usda.gov/oce/energy-and-environment/markets/carbon

Appendix 1: Emerging Technologies List

Category	Emerging Technology	Description	Regulatory Oversight/RA Changes Needed	References/ Additional Information
Aerial Robot	UAVs/drone/ aerial technology	Unpiloted aerial vehicles (UAVs), also known as drones, allow for efficient data collection in the field on soil moisture, crop health, and other useful information. Additionally, they could be used to apply pesticides more precisely in only areas where they are needed.	Establish regulatory equivalency (if any) related to pesticide application, registration, exposure, spray drift, and residue.	
Data	Digital Data	Many emerging technologies rely on use of digital data, collected on the farm and from other sources.	Joint effort between agencies and industry to digitalize regulatory information. Lack of laws and regulations around legal, social, and ethical considerations of agricultural data sharing is a concern.	
Data	Qualimetre	Statistical models that predict mycotoxin risk before harvesting based on climate conditions in a given year.		
Data	Fungicide Scripting Maps	Uses historical and forecasted weather data along with user-entered data on the growth stage in canola is analyzed to predict the growth stage and ideal timing for fungicide application.		
Data	Machine Mounted Weather Station	Mobile weather stations mounted directly on the sprayer. Allows for more accurate information to assist in mitigating spray drift.		

Category	Emerging Technology	Description	Regulatory Oversight/RA Changes Needed	References/ Additional Information
Ground Robot	ROMI/Robots for microfarms	Use of small and affordable robots on small market farms to assist farmers with physically demanding tasks, including weeding, phenotyping, and analyzing plant health.		https://romi-project.eu/
Ground Robot	Autonomous Tractor	Navigation and planning take place via cloud-based software that automatically generates path planning.		
Ground Robot	Autonomous sprayer (ground)	Targeted ground application of pesticides and fertilizer. It uses RtK, GPS, AI, and other technologies to spray weeds with micro-doses of pesticides.	Establish regulatory equivalency (if any) related to pesticide application, registration, exposure, spray drift, and residue.	
Ground Robot	Monitoring robot	Multisensory robots that monitor for weeds, soil health, gases, wildlife, and other metrics.		
Operations	Spot Farming	An agricultural area is classified into individual spots according to site specific characteristics. The spots are managed by an autonomous robot system on the individual plant level. The system manages high precision sowing, fertilization, pesticide application, and other needs.	Establish regulatory equivalency (if any) related to pesticide application, registration, exposure, spray drift, and residue.	Spot Farming
Operations	GPS Guidance	Tracks a machine's position in the field and enables other control technologies.		
Operations	Boundary Mapping	Ensures application is taking place in the intended area.		

Category	Emerging Technology	Description	Regulatory Oversight/RA Changes Needed	References/ Additional Information
Operations	Smart Guidance	Maintain consistent application speeds that help deliver consistent droplet size.		
Operations	Boom Height Control	Control with chassis roll compensation. Maintain correct boom height in relation to target will reduce off target movement.		
Operations	Rate Control	Provide correct rate of application for speed which will help produce the correct droplet size. Turn compensation to avoid over spraying while making turns.		
Operations	Section Control	Allow for partial boom shut off to ensure intended area is only being applied. Individual nozzle control.		
Remote Sensing	Subsurface Sensing	Sensors can now detect nematodes, microbial pest populations. Sensors can convert sound waves to light to give pictures of nematodes in the soil. Can cut weeks long process of sampling down to minutes of sensing.		
Robotic Manipulator	Robot for mechanical weed control	Guided by optical cameras and GPS to detect plant rows.		
Robotic Manipulator	Land care robot	Multi-purpose and heavy duty, land care robots can mow, haul, groom, plough snow, spray, till, hoe, and more. The machines use GPS and IMU and a topological probabilistic model to navigate. Some are designed more for specific tasks		

Category	Emerging Technology	Description	Regulatory Oversight/RA Changes Needed	References/ Additional Information
		(mechanical weeding) or for certain farms (small farms, orchards and vineyards).		
Robotic Manipulator	Bug vacuum	An autonomous vacuum used in lygus pest control, navigating reactively across the field.		
Robotic Manipulator	Tool-carrying robot	Can attach different implements generally used in vegetable cultivation.		
Spray/ Nozzle	New Ground Spraying Technology, ex. Pulse with Modulation (PWM)	Allows for on/off and rate control at the individual nozzle level, consistent droplet size, and plant-level application decisions, leading to reductions in pesticide use.	Plant protection labels to allow producers to utilize these technologies.	
Spray/ Nozzle	Direct Injection	Fully integrated system that allows for more efficient chemical use. Faster loading and safer cleaning.		
Spray/ Nozzle	PWM Compatible Nozzles	Reduces application in unwanted areas and provides more consistent droplet size due to positive shut off versus pressure drop.		
Spray/ Nozzle	Variable Rate Nozzles	Variable rate nozzles allow for more consistent drop size over a wider pressure range, eliminating the need of a combination of multiple nozzles. VR nozzles can include stacked (tiered) nozzles, and nozzles with a rubber metering orifice or spring to control flowrate.		

Category	Emerging Technology	Description	Regulatory Oversight/RA Changes Needed	References/ Additional Information
Spray/ Nozzle	Targeted Spray Technology	Distinguish difference between weeds and crops. Potential to reduce application by up to 90%. Works with pre and post emergence applications.		

Appendix 2: OECD Analysis

Organisation for Economic Co-operation and Development

ENV/JM/MONO(2020)3

Unclassified **English - Or. English**

22 January 2020

ENVIRONMENT DIRECTORATE
JOINT MEETING OF THE CHEMICALS COMMITTEE AND THE WORKING PARTY ON CHEMICALS, PESTICIDES AND BIOTECHNOLOGY

Cancels & replaces the same document of 22 January 2020

Report of the OECD Risk Reduction Seminar on Evolving Digital and Mechanical Technologies for Pesticides and Pest Management

Series on Pesticides
No. 102

JT03456966

OECD Environment, Health and Safety Publications
Series on Pesticides
No. 102

Report of the OECD Risk Reduction Seminar on Evolving Digital and Mechanical Technologies for Pesticides and Pest Management

26 June 2019
OECD Conference Centre
Paris, France

IOMC
INTER-ORGANIZATION PROGRAMME FOR THE SOUND MANAGEMENT OF CHEMICALS
A cooperative agreement among **FAO, ILO, UNDP, UNEP, UNIDO, UNITAR, WHO, World Bank and OECD**

Environment Directorate
ORGANISATION FOR ECONOMIC COOPERATION AND DEVELOPMENT
Paris 2020

About the OECD

The Organisation for Economic Co-operation and Development (OECD) is an intergovernmental organisation in which representatives of 36 industrialised countries in North and South America, Europe and the Asia and Pacific region, as well as the European Commission, meet to co-ordinate and harmonise policies, discuss issues of mutual concern, and work together to respond to international problems. Most of the OECD's work is carried out by more than 200 specialised committees and working groups composed of member country delegates. Observers from several countries with special status at the OECD, and from interested international organisations, attend many of the OECD's workshops and other meetings. Committees and working groups are served by the OECD Secretariat, located in Paris, France, which is organised into directorates and divisions.

The Environment, Health and Safety Division publishes free-of-charge documents in eleven different series: **Testing and Assessment; Good Laboratory Practice and Compliance Monitoring; Pesticides; Biocides; Risk Management; Harmonisation of Regulatory Oversight in Biotechnology; Safety of Novel Foods and Feeds; Chemical Accidents; Pollutant Release and Transfer Registers; Emission Scenario Documents;** and **Safety of Manufactured Nanomaterials.** More information about the Environment, Health and Safety Programme and EHS publications is available on the OECD's World Wide Web site (www.oecd.org/chemicalsafety/).

This publication was developed in the IOMC context. The contents do not necessarily reflect the views or stated policies of individual IOMC Participating Organizations.

The Inter-Organisation Programme for the Sound Management of Chemicals (IOMC) was established in 1995 following recommendations made by the 1992 UN Conference on Environment and Development to strengthen co-operation and increase international co-ordination in the field of chemical safety. The Participating Organisations are FAO, ILO, UNDP, UNEP, UNIDO, UNITAR, WHO, World Bank and OECD. The purpose of the IOMC is to promote co-ordination of the policies and activities pursued by the Participating Organisations, jointly or separately, to achieve the sound management of chemicals in relation to human health and the environment.

This publication is available electronically, at no charge.

Also published in the Series on Pesticides: link

For this and many other Environment,
Health and Safety publications, consult the OECD's
World Wide Web site (www.oecd.org/chemicalsafety/)

or contact:

OECD Environment Directorate,
Environment, Health and Safety Division
2 rue André-Pascal
75775 Paris Cedex 16
France
Fax: (33-1) 44 30 61 80
E-mail: ehscont@oecd.org

Foreword

This report summarises the discussions and outcomes of the *OECD Risk Reduction Seminar on Evolving Digital and Mechanical Technologies for Pesticides and Pest Management*. The one-day seminar was held on 26 June 2019 at OECD headquarters in Paris, France, one day before the annual meeting of the OECD Working Group on Pesticides (WGP). The seminar was the fifteenth in a series of risk reduction seminars organised by the WGP.

The Seminar was chaired by Warren Hughes (New Zealand), Chairman of the WGP. Fifty-four experts participated, representing OECD member countries, the European Commission, partner countries, the Business and Industry Advisory Committee to the OECD, and research institutes/universities. The list of participants can be found at Annex 2.

The seminar was organised as governments are eager to understand the regulatory implications of new digital and mechanical technologies for the application of pesticides that have the potential to reduce human and environmental exposure to pesticides. These technologies include, for example, prediction and detection tools such as sensors and remote imaging, non-chemical weeding with electricity or lasers, and spraying via low flying drones rather than aircraft.

The seminar was organised by a steering group which included Warren Hughes, Eric Liégeois (European Commission), Peter Brander (Canada), Yukiko Yamada (Japan) and OECD Secretariat from the Environment Directorate and the Trade and Agriculture Directorate.

This document is being published under the responsibility of the Joint Meeting of the Chemicals Committee and the Working Party on Chemicals, Pesticides and Biotechnology, which has agreed that it be declassified and made available to the public.

Table of Contents

Introduction 8
Summary of Presentations and Discussions 9
1. Introduction 10
2. Overview 11
3. Mechanical Technologies 12
4. Digital Technologies 15
5. Stakeholder (e.g. farmers/growers/manufacturers) Views 19
6. Regulatory Views 23
Summary of Discussions, Ideas and Recommendations for Possible Future Work 26
Annex 1 - Seminar Programme 28
Annex 2 – List of Participants 31

Introduction

Background

The focus of the seminar was on evolving digital and mechanical technologies such as precision agriculture machinery, data collection, and data processing. These technologies will lead to more precise application of pesticides, offering alternatives to pesticides use. Expected positive consequences will be a reduction in pesticide use and/or a reduction in human and environmental exposure allowing farmers/growers to better manage their farm inputs.

These evolving technologies will assist the agricultural sector to not only become more productive, but also to minimise the use of pesticides by applying them more precisely when and where needed. Some of these technologies may pose challenges to pesticide regulatory agencies due to a lack of appropriate risk assessment methodologies and ad hoc management policies as regulators have a lack of knowledge and understanding of these technologies and whether they enhance risk reduction techniques or create additional problems.

Purpose and Structure of the Seminar

This Seminar provided an opportunity for experts in OECD governments and stakeholders (e.g., farmers and developers of new mechanical and digital technologies) to share their knowledge, experience and possible concerns associated with these evolving technologies.

The main objectives of this WGP Seminar were to:

- better understand these technologies and their strengths and weaknesses;
- identify the benefits and challenges to the agricultural sector from the use of these technologies;
- identify potential impacts on current regulatory systems for the management of pesticides;
- exchange information on countries' current activities in this area including from the perspective of regulators, industry, farmers/growers and other stakeholders; and
- make recommendations to the WGP for possible future work.

The seminar began with a series of presentations that focused on:

- describing the technologies and how they are employed;
- the experiences of stakeholders who develop or use these products, in terms of the benefits, challenges and problems encountered;
- new areas of research and development as well as for regulatory purposes; and
- the experiences of governments related to how they regulate such products, or plan to regulate such products.

There was a short discussion after each set of presentations and a more general discussion at the end of the seminar.

Summary of Presentations and Discussions

(Note: the PowerPoint presentations can be found at:

http://www.oecd.org/chemicalsafety/pesticides-biocides/seminar-on-pesticide-risk-reduction.htm**)**

1. Introduction

Opening and welcoming remarks

Richard Sigman, OECD Secretariat

The Secretariat gave an introductory presentation to provide background and context for the Seminar. He noted that OECD brings policy makers and stakeholders together to exchange ideas, share experiences and develop policy approaches to address common challenges. Such work is carried out by committees and working groups which include a broad range of perspectives due to the multidisciplinary approaches taken. For the OECD's work on chemicals, input is sought from and co-ordinated with government officials and the Secretariat who work with OECD committees in the areas of environment, agriculture, innovation, governance, and trade. The OECD's Environment, Health and Safety (EHS) Programme works to harmonise chemical safety tools and policies, focusing on pesticides industrial chemicals, biocides, manufactured nanomaterials, GMOs, testing and hazard/risk assessment, risk management and prevention of chemical accidents. Within the EHS Programme, the OECD Working Group on Pesticides (WGP) helps governments to co-operate in assessing and reducing the risks of agricultural pesticides by sharing the work of pesticide registration and developing tools to monitor and minimise risk to health and the environment. Such work focuses on: chemical and bio-pesticides as well as pesticides based on RNA interference; preventing the illegal trade of pesticides; the electronic exchange of pesticide data; assessing pesticide effects on insect pollinators; developing tools to assess pesticide residues; and addressing issues associated with minor use pesticides. Today's risk reduction seminar was organised by the WGP. As with all previous seminars, this seminar follows a similar structure: introduction and background to the topic; presentations by governments and stakeholders; group discussion; and conclusions and recommendations to the next WGP meeting. The seminar was organised by a Steering Group made up of New Zealand (Chair), the European Commission, Canada, Japan and the Secretariat.

Structure of the seminar

Warren Hughes (New Zealand), Seminar Chair

The Chair welcomed all attendees and invited speakers to the seminar. A brief oversight of the structure of the seminar was given – it has been structured into four sessions covering different topics, followed by a round table discussion. At the end of the seminar, there would be a closed session for regulators to reflect on the day. The Chair advised that this seminar was an opportunity for regulators to get ahead of the curve with these new technologies. Understanding of their implications in a regulatory context is important and thereby any regulatory oversight required would be fit for purpose. He concluded by hoping all attendees enjoy the seminar and gain insight and understanding of these new technologies.

2. Overview

Spot Farming – Giving sustainable intensification a face

Jens Karl Wegener (Julius Kühn-Institute (JKI)

Sustainable intensification is described as the desirable goal for agricultural production to increase agricultural productivity while using less input and without adverse environmental impacts. Increasing criticism on current agricultural production systems as well as demographic changes related with labour shortages in rural areas pose major challenges to agriculture all over the world. In this context, digitalization and autonomous machinery provide new opportunities to adapt agriculture to future demands. However, it is unknown what changes are necessary for a sustainable intensification of cropping systems and how future agriculture could look like under consideration of new technologies. Here we developed a concept for future cropping systems with focus on the requirements of crops and landscapes. In this concept, the agricultural area is classified into individual spots according to their site-specific characteristics. The resulting spot farming approach is completely managed by an autonomous robot system on the level of individual plants. High precision sowing, fertilization and pesticide application could reduce agronomic input and could increase yields. In addition, small robots contribute to soil protection. Furthermore, the spot farming approach considers landscape properties and has the potential for a higher biodiversity and more structural elements as well as an increased social acceptance. The evaluation of the concept according to agronomical, technical and economic aspects showed that the combination of modern technologies and a reorganisation of agricultural landscapes could contribute to the goal of sustainable intensification. More information: Wegener, J.-K.; Urso, L.-M.; von Hörsten, D.; Hegewald, H.; Minßen, T.-F.; Schattenberg, J.; Gaus, C.-C.; Witte, T.d.; Nieberg, H.; Isermeyer, F.; Frerichs, L.; Backhaus, G.F. (2019): Spot farming – an alternative for future plant production. Journal für Kulturpflanzen 71(4): 70-89. ISSN 1867-0911, DOI: 10.5073/JfK.2019.04.02

3. Mechanical Technologies

New ground spraying technologies supporting risk reduction

Chris Bursiek (John Deere Crop Care Platform)

The application of plant production products continues to evolve with the development of new technologies. Technology advancements allow for the reduction in the size of management zones, leading to application decisions moving from field to sub field level, all the way down to the plant level. One such technology is Pulse Width Modulation (PWM), that when incorporated into a nozzle body can allow for both on/off and rate control at the individual nozzle level. *See & Spray*™ technologies allow for plant-level application decisions. These types of systems can sense the plant, decide on treatment, and then act on the decision. Advancements in application technology allow for reductions in overall plant protection products applied while achieving similar pest control levels as conventional even application systems. For bush, tree and vine crop sprayers, technologies are available to sense the presence of the plant and density of the leaf mass, enabling to spray only the plants and not spacing between plants. As application technologies continue to enable the ability to transition from even application across a whole field to smaller site-specific applications, opportunities exist to evaluate current risk and toxicology assessments. When technology advancements come to market, the need for plant protection labels to allow producers to utilize such technologies is important, along with encouraging adoption of technologies.

Romi – Robotics for Microfarms

Peter Hanappe (Romi-Project; Sony CSL)

The ROMI robot is designed for small market farms that grow a wide variety of vegetables using agroecological methods (permaculture, bio-intensive agriculture). The primary objective of this platform is to help and assist farmers in physically demanding tasks. We are currently focusing on weeding as a first application. This task takes more than 25% of working time and is responsible for many musculoskeletal disorders. In the long term, we hope that the introduction of small and affordable robots will promote a sustainable local agriculture by making market farms more attractive.

The robot is inspired by the tools that can be found in FabLabs. The heart of the robot is a numerical control (CNC) that moves a mechanical weeding tool between crops. This CNC is installed on a motorized frame that moves along the vegetable beds. The robot divides the beds into zones of 80 x 80 cm. For each zone, it takes a photograph, discriminates between the crop and the weeds by relying on their development stage (weeds are less developed and smaller than the crop). It then hoes the soil surface while sparing the crop. Initial tests have shown that a weekly passage of the robot is sufficient to maintain the weed population under control.

In parallel to the weeding robot, the ROMI team is working on a 3D plant scanner for phenotyping. The objective is to install this tool the robot and use it in the fields for crop monitoring. The robot will analyse witness plants in 3D and inform the farmer of their health status. The project also develops aerial devices to obtain whole-farm views and compute health maps of the crops.

The ROMI robot aims to be an adaptable platform that users can modify according to their needs. That is why its hardware design and its software are released under free licenses.

Acknowledgments: This project has received funding from the European Union's Horizon 2020 research and innovation under grant agreement program No 773875. It project is developed in partnership with CNRS-ENS Lyon, Inria, Iaac-FabLab Barcelona-Noumena, Humboldt University in Berlin, Chatelain Maraîchage, France-Europe Innovations and Sony Computer Science Laboratories. https://romi-project.eu

Digital Agriculture: Producing more with less in a Sustainable Way

Janet Williams (Bayer Cropscience)

D. Schaefer[1], A.C. Chapple[1], S. Lauck-Birkel[1], C. Leake[1], P. A. Schmidt[1], R. Sur1, S. Van Wert[2], A. Zahlen[1]

Digital agriculture has emerged as one of the most promising technologies to enable sustainable use of resources while satisfying global demands for quantity and quality of food and feed. Digital tools, such as drones, sensors and robotics, are already used by farmers with both large and small-scale operations to reduce inputs and optimize yields.

Digital solutions also give new options for reducing plant protection product use per field, by providing more targeted, optimized and timely applications that further minimize potential human and environmental exposure, while maintaining product efficacy. Likewise, risk management measures can be adapted to local conditions such that vulnerable areas within and adjacent to the field are best protected. This can be achieved by a real-time, site-specific risk evaluation which uses digitalized equipment to diagnose crop status, current weather conditions, and relevant geographical and agronomical parameters (soil type, crop variety, distance to water body and non-target areas, topography of the field, nozzles etc.). The collected data may be used to ensure that the application meets the specified protection goals or to decide which mitigation measures must be implemented. Tailored mitigation options can be integrated into digital platforms and assist farmer’s in decision-making.

Digital solutions are able to document that applications were made with appropriate mitigation, as specified on the label. Since mitigation options are selected more efficiently and exactly where and when necessary, the flexibility for the farmer increases significantly. This, however, requires that digital solutions are evaluated and approved by regulatory authorities and become part of the labels of plant protection products. A joint regulatory authority and industry effort to digitalize regulatory information is fundamental to the implementation of digital farming solutions in the regulatory process. An industry standard for a machine-readable label format is a key enabler.

To make such an approach possible and sustainable, a shift is required from overall worst case risk assessment based on regional scenarios to a site-specific in-field risk evaluation integrating tailored risk mitigation measures.

------

[1]Bayer AG, Crop Science, Monheim am Rhein, Germany; [2] Bayer U.S. LLC, Research Triangle Park, North Carolina, USA; dieter.schaefer@bayer.com

4. Digital Technologies

Qualimetre®
A forecasting tool for mycotoxins for wheat and corn

Xavier Leprince, Syngenta

Mycotoxins are produced by several Fusarium species during cultivation of wheat and maize grain. In order to develop a predictive model in support of grower integrated pest management strategies that prevent or limit mycotoxin formation, Syngenta has organised large field surveys in France since 2000 capturing agronomic and climatic data. We have also taken grain samples for mycotoxin analysis. The importance of the agroclimatic factors and their interactions on the mycotoxin levels in grain has been assessed in detail. For example, it is clear that climate at the time of flower is the major factor for deoxynivalenol (DON) in wheat. The main agronomic criteria are residue management and the variety sensitivity to this mycotoxin. For DON, zearalenone and fumonisins in maize, the climate from flowering stage until harvest is more significant. Factors vary between each mycotoxin, however the main agronomic criteria are the harvest condition (date and grain moisture), corn borer infestation and the sensitivity of the plant variety to each of the mycotoxin forming fungi or moulds. Over the years, the database has been used to develop models that predict mycotoxin risk before harvesting based on climate conditions in a given year. Predictions are based on different agro-climatic statistical models specifically configured according to the different regions of production in France. This approach is called Qualimètre®. This mycotoxin level forecasting service started in France in 2004 for wheat and for maize in 2006.

A grid is now available to estimate the risk based on varietal susceptibility, previous crop and climate conditions. Forecasting has been shown to be accurate when compared with measured levels of mycotoxins over 17 years and with more than 17000 samples of wheat.

This tool helps farmers to decide if fungicide application is necessary at wheat earing and flowering stages in order to manage the risk as a component of integrated pest management strategies.

Digital Farming in Crop Protection

Roslyn Chua, Global Digital Product Lead, Crop Protection
Bayer AG / The Climate Corporation

Each cropping system has its unique challenges. In Wheat, yields have been relatively flat in the last 15 years in the United Kingdom, France, and Germany. This can be attributed to shorter rotations, increasing weed and disease resistances, and less investment in breeding/traits when compared to other field crops. Bayer experts' analysis estimates that 45% of the genetic potential of wheat is lost due to the sub-optimal weed and disease management. This represents a 1 ton/hectare opportunity for digital farming crop protection in Winter Wheat. In Corn, factors contributing to the yield potential are Weather (27%), Nitrogen (26%), Hybrid (19%), Previous crop (10%), Plant population (8%), Tillage (15%), and Growth regulators (4%). In summary, 2/3 of the contributors to yield variability in corn are predictable with the use of digital farming technologies.

Different cropping systems have different optimization potential. It is critical to find the critical parameters impacting productivity to create the most significant impact on the use of Digital Farming technologies. There is no one-size fit all solution in the digital farming landscape.

Because of the vast opportunities in different cropping systems, there is now a sea of offerings in Digital Farming – from Blockchain, food safety track and trace to crop and farm management software – farms today are spoilt with the universe these choices provide. While these tools offer vast potential for farms to select the best solution fitting their exact farm, they also represent a challenge in terms of onboarding and learning different tools.

Digital farming solutions allow outcomes to be measured and proven in each field or hectare. In practice, data[1] is only collected from farms when there is an opportunity to improve quantifiable results. Digital farming solutions follow four main steps, and most offerings in the market are categorized into these four main buckets – analyze data, visualize data, advice, and implement & measure outcomes. For example, in Canola in Canada, satellite maps are analyzed and visualized into Fungicide Scripting maps. Historical and forecasted weather along with user-entered data on the growth stage is analyzed to predict the growth stage and the ideal timing for the Fungicide application. The combination of growth stage and Fungicide Scripting maps are then aggregated into advice which hectare can be optimized with a Fungicide application and which hectare should not be sprayed with Fungicide. The return-on-investment on the application is then measured and compared at the end of the season, proving the value of the tool to farms. In Winter Wheat in Europe, data on seed varieties' disease susceptibilities, historical and forecasted weather, scouting results, and management practices are analyzed. Field-specific disease risks are then visualized informing the users the ideal time to spray a field, how many sprays are required, the dose rate of Fungicide to be used and in fields with high variability, a Fungicide scripting map is also provided to recommend the optimal distribution of dose rates in various zones in the field. The applications of Fungicide are then measured against the yield result as well as compliance with regulatory requirements.

---

[1] Data used for agronomic models are treated as personalized data. The use of this data is governed by European Union's requirements for General Data Protection Regulation (GDPR).

Digital farming tools today are now linking data and insights into actionable advice with measurable outcomes for each field. The field-specific result also takes into account different baseline scenarios comparing the impact of each agronomic practice as well as taking into account broad expectations in agriculture beyond yield or return or investment. More and more tools are quantifying crop quality, compliance with production system requirements, and carbon footprint impact in addition to measures of productivity. However, not all advice is experienced consistently in every field, every hectare, and every year. Currently most tools are focused on a single input decision and are not accurately predicting the whole system around the crop, a goal for future developments. Also, most conversations on digital farming are still centered on the technology rather than the results these technologies provide.

Bayer's approach in digital farming is to ensure that we are providing the best solution with a quantifiable outcome to our customers and also connecting the different components of the digital farming ecosystem. With Climate FieldView™, users can seamlessly collect, store, and visualize critical field data, monitor and measure the impact of their agronomic decisions on crop performance, and manage their field variability by building customized fertility and seeding plans to optimize yield and maximize profit. Also, Climate FieldView™ has 50+ partners who are leveraging the FieldView™ platform to bring their digital innovations to farms. With our collaborative approach with various partners, our users today have the convenience of only onboarding into a new system once.

Digital farming solutions are fit for purpose and adoption in the market is due to the measurable benefit in productivity and sustainability; these tools are targeted toward providing this potential benefit to each field and each farm. The digital farming industry thrives because of the quantifiable outcome it's contributing to farmers, stakeholders, society, industry, and the environment.

Legal Considerations arising from Digital Technologies and Agricultural Data

Leanne Wiseman, Griffith Law School, Griffith University; Australian Centre for Intellectual Property in Agriculture (ACIPA)

The digital transformation taking place on farms, and in agriculture more generally, and the enormous amounts of valuable farm and agronomic data now being generated, collected and shared brings with it untold potential for the future of agriculture. While much of the focus to date is on the benefits of Ag data sharing, little attention is being paid to the increasingly complex legal environment in which farmers find themselves when adopting digital farming technologies.

The lack of laws and regulations around the legal, social and ethical considerations of agricultural data sharing has left a gap for private actors to set the rules that govern agricultural data sharing. Currently, it is the data licences of the agricultural technology providers that regulate the way in which agricultural data is collected, managed and shared. An analysis of Australian farmers' attitudes to sharing agricultural data with a range of stakeholders (Wiseman, L., and Sanderson, J., The legal dimensions of digital agriculture in Australia: an examination of the current and future state of data rules dealing with ownership, access, privacy and trust) revealed a wide range of farmers' concerns (such as privacy and security; competition/market issues; surveillance and risk and liability). These concerns are common to farmers around the world.

While attempts have been made to encourage best practice in Ag data management through the adoption of voluntary principles and Industry codes of practice in the US, NZ and more recently in the EU, and with the extension of unfair terms legislation in Australia, farmers still have concerns in the way their data is being managed. There is a need for further efforts to expose and highlight the current data licensing practices, and the competition and privacy implications so that best practice can be developed. This in turn, will lead to the better management of farm and Ag data by agribusinesses, researchers and governments and thus earning farmers' trust and engagement in the future of smart farming.

5. Stakeholder (e.g. farmers/growers/manufacturers) Views

Evaluating Drone Application Technology in Crop Protection: FMC's Experience in China and USA

John T Andaloro, Xuan Li and Edward Lang FMC

Rarely in agriculture has a crop protection technology been so rapidly adopted in such a short period of time. In 2018, China's farmers placed their trust in unmanned aerial vehicle applicators (drones) at an extraordinary level to protect approximately 18 million hectares of cropland. This represents an unprecedented growth for a new application method in just a five-year period: almost twice the China hectarage sprayed compared to the prior year in 2017 but still less than the anticipated 30 million hectares predicted to be sprayed in 2019. The accelerated rise of drone technology in China agriculture has presented a complex dilemma: rapid adoption of unmanned aerial pest control provides partial alleviation to China's farm labor shortage but insufficient time to adequately research, develop, and deliver a refined product to the market that's undergone satisfactory quality control.

Certainly, aerial technology used to apply crop protection products has been commonly known for decades, with both fixed wing airplanes and single rotor helicopters. In addition, nozzle types and low/ultra-low spray volumes used in these traditional aerial spray systems that produce fine droplet sizes do not vary that much from that of the current drone application systems. However, leveraging the wealth of knowledge from a half century of fixed wing and single rotor copter experience to counter-rotating, multi-rotors on light weight drones is complex. Validated spray models that predict the path, dispersion, and eventual fate of a droplet under varying environmental conditions and spray system parameters are required to deliver a quality application with a comfortable understanding of potential off-target drift. Better integration of the drone and the spray system is imperative. Providing Best Management Practices that mitigate biological, environmental, chemical, and spray system variables are needed. The same effort dedicated to creating pesticide product label guidance for drift reduction for manned fixed-wing aircraft needs to be undertaken for multi-rotor drone use. Improvements in drone technology have proliferated (RTK, remote sensing, variable rate spraying, autonomous flight) over the past few years while minimal attention has been made to optimizing how the spray system mounted and integrated to various drone models can deliver a quality spray. Standardizing basic spray system components for the different multi-rotor drones such as length of fixed boom relative to rotor width, nozzle distance from rotors, drone height from canopy, spray pressure relative to drone speed, nozzle configuration, nozzle types, orifice size, etc., are fundamental to maximizing spray accuracy and uniform distribution of pest control products. The variation of these spray system configurations that exists in the market today is alarming and at times counter to achieving a quality pesticide application.

What is at stake? Depending on your view, ranging from the aggrandized to the pragmatic: ensuring food security in developing countries, reduced pesticide longevity by accelerating pest resistance, or just simply missing an astounding opportunity to implement a more efficient and safer step change in delivering crop protection. Traditional back pack spraying operation often requires the applicator to walk through freshly spayed foliage throughout the entire pesticide application process. Government subsidies through China's "Zero

Pesticide Growth" directive not only made this technology affordable to the consumer but very importantly also directly improved farmer safety. Developing an optimized drone spray system should offer excellent pest population control while minimizing applicator safety.

The use of drone technology for pest control in agriculture has the potential for delivering remarkable benefits to growers and the agricultural community. Overall, five years' experience in China, two years of grape pest control in California, and a growing library of observations from many other countries is convincing evidence that the use of unmanned aerial vehicles for pest control is not only very popular but also has great practical potential. The challenge is to ensure that iterative technical advancements in drone plus spray system optimization keep pace with the dramatic increase in drone use. The same challenge exists for creating parallel regulatory and operational guidance documents. Moreover, drone pilots and spray service providers need quality training and certification. Meeting the challenges above requires integrating the expertise of drone manufacturers, crop-protection agchem companies, country regulators, and academic experts. It also demands the coordination and alignment of current projects underway by a multitude of national and international agencies who are developing processes to guide the safe use and maximize the pest control capabilities of unmanned aerial vehicles as a new pesticide application method.

Digital and mechanical technologies addressing plant health – How to meet both farmer and consumer demands?

Marie-Cécile Damave (Agridées)

In France as in most developed countries, agricultural issues such as GMOs, water, pesticides, animal welfare and biodiversity have become societal issues. Driving forces in farming are changing from farmers and other upstream stakeholders to consumers, retailers and other downstream stakeholders. Agribusiness was techno-push, from farm to fork, and has no other choice than switching to market-pull, from fork to farm. Synthetic chemical pesticide use has become a major societal concern, pushing the Government of France to develop a national strategy to reduce it by 50 percent by 2025. Considering French agriculture is too dependent on these pesticides, many call for a “zero pesticide agriculture”. This pressures the farming community to explore alternatives. Precision agriculture brings solutions in this direction. It combines technologies and practices towards more efficient and environment-friendly farming. It belongs to wider concepts of sustainable agriculture, agroecology, and climate-smart agriculture.

AgTech and FoodTech are booming world wide, in Europe and in France in particular, with new startups and businesses as well as traditional groups developing new products and services specializing in Big Data and algorithms, artificial intelligence, robotics, machinery, imagery, digital platforms… Agridées has monitored these developments since 2014[2]. We found that digital is connecting multiple technologies used in farming and across the food chain, both in animal and plant production, questioning pre-existing business models and extension services. Precision farming is becoming a reality, as an increasing number of solutions are available for farmers to manage sanitary, weather and economic risks more accurately, more efficiently and more timely. Predictive models are now emerging. Precision farming includes breeding, animal and plant health solutions and monitoring, feed and nutrition, weather monitoring, machinery equipped with sensors, Internet of Things… they all converge to customized agriculture for each individual (plant and animal) to optimize production and market release. In addition to economic and environmental performance, digital farming also addresses societal performance: digital platforms better match supply and demand, and digital tools (such as block-chain) are developing to improve traceability, transparence and visibility across the food chain.

Trust is a key word in the success of the digital transition of agriculture: low tech and high-tech products and services are adopted if they are useful tools and not gadgets, with solid returns on investments, and accessible thanks to good connectivity and training. Data transparency and security needs to be addressed so that the farming community trusts digital tools. Transmitting the information that good practices are being used at all stages of the food chain has the potential to build trust among downstream stakeholders for food products. Recordings rather than claims on how and where food comes from and is produced and processed can reassure consumers in a society where “bashing” agricultural practices is becoming very popular. Smart agriculture practices and technology therefore

---

[2] Position paper (2017): “All actors of the digital transition of agriculture” (in French “Tous acteurs de la transition numérique agricole”) https://www.agridees.com/publication/acteurs-de-transition-numerique-agricole/

needs to be encouraged at each step of the value chain, and visible down to the consumer level. Farmer efforts can therefore be valued while consumer needs, concerns and preferences can be better understood and addressed.

6. Regulatory Views

Status of Unmanned Aerial Vehicles (UAVs/Drones) for Pesticide Application

Ed Messina (US Environmental Protection Agency)

The Environmental Protection Agency is responsible for developing and implementing national policy to complement the legal framework of pesticide use in the United States. As part of this responsibility, the EPA is in the process of updating its regulatory paradigm to account for pesticide applications made by unmanned aerial vehicles. To develop suitable national policy for this still relatively new technology, EPA is engaging stakeholders to fully understand the benefits, uncertainties, challenges, and issues associated with this currently limited and potentially expanding use.

Engagements to date have included discussions with other regulatory agencies such as the US Federal Aviation Administration to ensure regulatory alignment, aircraft companies to respond to requests for regulatory approval, pesticides companies to provide clear and consistent regulatory guidance, and state/tribal/International pesticide co-regulators to consider and address locality- and country-specific scenarios. Questions that remain to be answered include those associated with pesticide labeling, data needs for information risk assessments, adequacy of existing risk assessment exposure scenarios, pesticide drift, and user/by-stander safety.

Once a more complete set of information is available, EPA is confident that it will collaboratively identify a suitable approach that both ensures adequate protection and, where appropriate, continues to allow the use of a novel technology.

The challenges, regulatory and policy environment

Grant Stark (Health and Safety Executive, UK)

The presenter began by highlighting the need for regulators to view new technological developments within the wider political context. This included helping agricultural production addressing the challenges of: demographic change; working with a scarcity of resources; climate change; and minimising food waste. A combination of use of big data, artificial intelligence, robotics and automation, sensing technologies and genetics had the potential to revolutionise pesticide use, resulting in more precise applications. Regulators must ensure that their regimes do not impede/actively encourage the new technologies, whilst ensuring chemicals continued to be applied in a safe and sustainable fashion.

There was a need, however, to draw on the lessons from the introduction of new technologies elsewhere and identify whether there were any potential unintended adverse consequences (noting issues such as use of personal data, responsibility for automated decisions, etc). The need for a considered approach may create tensions in an environment of fast-moving technological development, and it may be unrealistic to expect that regulatory regimes are immediately able to embrace all new technologies. Regulators could reduce the risk of this occurring by engaging in horizon-scanning activities, understanding a different community of stakeholders and being prepared to consider whether their regimes should be adapted to ensure the new technologies can be controlled appropriately and deliver benefits for society.

Turning to the issue of drones, the presenter outlined a range of policy, legal and scientific issues that were being considered before authorisation could be granted for this method of application. Key issues included: configuration of the drone (number and power of rotors and position relative to nozzles) and its influence on vertical and horizontal spray drift and crop interception; handling, filling and cleaning practices (and the need for work protocols); and use of relatively low water volumes on product efficacy and worker protection. Work to date had demonstrated the importance of promoting collaborative activity amongst stakeholders and creating a welcoming regulatory environment by being prepared to offer elevated levels of support. The presenter also noted the need to ensure that users were trained appropriately in any unique risks that may be associated with this new method of application.

Risk Mitigation - Use of unmanned aircrafts for aerial application of pesticides in Japan

Hidetaka Kobayashi Ministry of Agriculture, Forestry and Fisheries, Japan

Dr Kobayashi gave a presentation concerning the new regulations of the aerial application of pesticides using unmanned aircraft, including helicopters and "drones" (multirotors), in Japan. For aerial application of pesticides, both manned and unmanned helicopters have been approved for a long time and some data have also been accumulated. Due to a labor shortage and ageing farmer populations, it is necessary to increase efficiency in agriculture including the application of pesticides. New regulations are necessary to increase efficiency of pesticide applications by adapting new technology including "drones".

Summary of Discussions, Ideas and Recommendations for Possible Future Work

Summary

Mechanical Technologies

There is a range of mechanical technologies being developed. New types of nozzles allow width modulation, rate of spray and finer spray resolution. Sensor technology can identify the weed or pest that allow for targeted application of a pesticide, instead of broadcast application of the pesticide. Then there are mechanical weeding technologies, which can reduce work pressure in particular for small farms.

These can all significantly reduce the amount of pesticides that need to be applied, as well as reduce pesticide exposure to humans and the environment. This has several advantages including reducing the potential for spray drift and worker exposure, reducing environmental loading and potential reducing costs to the farmer. However, further work is required on these technologies so that they can work in sub-optimal conditions. In relation to drones, rules need further development on qualifications of the drone operator, airspace, and understanding the differences between drones and standard aerial application including spray drift, residue and efficacy profiles.

Digital Technologies

Using digital technologies for better forecasting can help farmers determine when (and how) to spray to manage a pest/disease. Data on soil cultivation, varietal susceptibility sensitivity and weather conditions can be combined to provide information to support farmers' decisions on the optimal method, timing, place and amount of pesticides application thanks to data analyses and algorithms. There is a range of systems available to collect such information including, inter alia, sensors in the field and drone as well as satellite imaging.

Such technologies should lead to a quantitative reduction in spraying and a qualitative increase of pest management allowing farmers to move from calendar based spraying to target spraying based on an informed decision scheme. Some of the challenges or questions that arise from the use of these technologies include ownership of data, along with transparency, privacy and security of information: e.g., a farmer may have many years of agronomy-relevant information that may constitute his own farming practices that he/she would not like to share with commercial service providers like digital companies. A code of good practices could, in this sense, be very useful to protect farmers' interests/rights.

Stakeholder Views

New technologies need the “buy-in” from the consumers. This requires investment in communication efforts to explain the technologies, the benefits that arise from their use, and a description of how they fit within the wider ecosystem.

Regulator Views

Regulators fully support new technologies that reduce the risks of pesticides, but any reduction in exposure from the use of such technologies should be integrated into exposure estimates and models utilized in the regulatory risk assessment process. In order to increase the uptake of these technologies, the benefits should be sufficiently known and appropriately communicated. There is a significant focus by regulators on drone technologies as they might reduce operators’ exposure and applied quantities but they might also increase releases to certain environmental compartments. There are a number of challenges in part due to a lack of understanding of these technologies. These include spray drift, operator exposure, operator training, and formulation technology for drone-based applications. In addition, regulators need to know whether the risk profile for drone technologies is significantly different when compared to existing aerial technologies.

Conclusions / Recommendations

Sustainable agriculture and societal buy in are important drivers for new technologies. Robotic technologies allow for precision application of pesticides – reducing the carbon footprint, bringing environmental benefits and reducing pesticide use. Digital technologies allow for predicting the pest population and identifying pests and diseases. However, who owns the data generated for these technologies as well as how such data are used and shared are issues that need to be resolved. Drone use in certain countries or regions is expanding significantly and there is a rapid evolution in this area. While there are clear benefits to these technologies there are also challenges which will need to be addressed.

Recommendations:

Information exists that can support a better understanding and fill in gaps in exposure and risk assessments of these promising technologies. This information needs to be exchanged between all parties. A mechanism needs to be developed to support this exchange between regulators to validate assessment models and assumptions regarding equivalence between drones and more conventional application equipment as regards operators, consumers and environmental exposure.

The benefits and challenges of drones need to be identified, in part, for risk communication purposes.

Regulatory requirements (or guidance) should be developed to promote harmonisation across countries.

Annex 1 - Seminar Programme

ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

ORGANISATION DE COOPÉRATION ET DE DÉVELOPPEMENT ÉCONOMIQUES

OECD Pesticide risks reduction Seminar:

Evolving Digital and Mechanical Technologies for Pesticides and Pest

26 June 2019

OECD Conference Centre, 2 rue André-Pascal,
75016 Paris

Preliminary Draft Programme

Chair: Warren Hughes (New Zealand)

Time

9.00 am	**Introduction** • **Opening and welcoming remarks** – *OECD Secretariat* • **Structure of the seminar** – *Seminar Chair* • **Tour de table -** *participants*
9.25 am	**Presentations** **1) Overview** • **Overview presentation on the new technologies** - *Jens Karl Wegener (Julius Kühn-Institute (JKI)*
9h45 to 11h10	**2) Mechanical Technologies**

	- **Presentations about the technologies (e.g. in-field imaging robots/drones, mechanical/electrical/laser weeding, spraying UAVs) and their strengths and weaknesses** – *Chris Bursiek (John Deere Crop Care Platform)* – *Peter Hanappe (Romi-Project; Sony CSL)* – *Janet Williams (Bayer Cropscience)* **Coffee Break**
11h10 to 12h15	**3) Digital Technologies** - **Presentations about the technologies (e.g. prediction tools, image computing, data-driven decision making (artificial intelligence) and their strengths and weaknesses** – *Xavier Leprince (Syngenta)* – *Roslyn Chua (Bayer CropScience)* – *Leanne Wiseman (Griffith University, Australia)*
12h15 to 13h15	**Lunch**
13h15 to 14h00	**4) Stakeholder (e.g. farmers/growers/manufacturers) Views** **Presentations about impacts of technologies in their sectors** – *John Andaloro (FMC)* – *Marie-Cécile Damave (Agridées, France, part of International Farmer representative body)*
14h00 to 15h00	**5) Regulatory Views** Presentations about regulatory impacts – *Ed Messina (EPA, US)* – *Grant Stark (CRD, UK)* – *Hidetaka Kobayashi (MAFF, Japan)*
15h00 to 16h15	**Round-table Discussions and Coffee Break** The Seminar should aim to answer the following questions: i. What is the future of such technologies • What are the barriers to wider use of these technologies? • What relevant new technologies were not discussed during the presentations? ii. How will these technologies change existing practices:

	- What could be the benefits and drawbacks of such changes? (with focus on risk reduction) - What will be the impacts on industry practices? - What will be the Impacts on regulatory requirements? iii. Policies, procedures and regulations: - What regulatory requirements, guidance and processes are currently in place and apply to such technologies? - What are the gaps? - What are the differences between countries? - Are there opportunities for harmonization between regulators? iv. How could OECD support governments and stakeholders achieve greater risk reduction through the use of these technologies? **Coffee Break**
16h15 to 16h45	**Summary of the discussion and Ideas for follow-up** **Conclusions** The Seminar (Chair) will conclude on the roundtable discussions. **Recommendations**
16h45 to 17h30	**Closed Session – Regulators Only** Discussion regulatory challenges and issues
17h30	**Finish**

Annex 2 – List of Participants

Participants list for the OECD Pesticides Risk Reduction Seminar : Evolving Digital and Mechanical Technologies for Pesticides and Pest Management

Allemagne/Germany

Dr. Jens Karl WEGENER
Director and Professor
Julius Kühn-Institut (JKI)

Australie/Australia

Mr. Alan NORDEN
Executive Director
Registration Management and Evaluation
Australian Pesticides and Veterinary Medicines Authority (APVMA)

Canada

Dr. Richard AUCOIN
Executive Director
Pest Management Regulatory Agency
Health Canada

Mr. Peter J. BRANDER
Chief Registrar and Director General
Pest Management and Regulatory Agency (PMRA)
Health Canada

Chili/Chile

Mr. Eduardo AYLWIN
Advisor
Chilean Food Safety Agency
Ministry of Agriculture

Corée/Korea

Professor HeeRa CHANG
Professor
Department of Applied Biotoxicology
Hoseo University
Environmental Chemistry, Department of Applied BioToxicology,

Dr. JaeHo OH
Senior Researcher
Food Safety Risk Assessment Division
NIFDS, Korea Ministry of Food and Drug Safety

	Dr. Sangsoon YUN Pesticide and Veterinary Drug Residues Division Ministry of Food and Drug Safety, Korea
États-Unis/United States	Mr. George HERNDON Deputy Director Field and External Affairs Division U.S. Environmental Protection Agency (EPA)
via WebEx	Mr. Edward MESSINA Deputy Director, Programs Office of Pesticide Programs US Environmental Protection Agency
Japon/Japan	Dr. Yukiko YAMADA Senior Advisor Ministry of Agriculture, Forestry and Fisheries
	Dr. Hidetaka KOBAYASHI Deputy Director Plant Products Safety Division, Food Safety and Consumer Affairs Bureau Ministry of Agriculture Forestry and Fisheries
Lettonie/Latvia	Mr. Vents EZERS Head of Unit Plant Protection Department State Plant Protection Service of Latvia
Lituanie/Lithuania	Ms. Raimonda GRIGAITE Adviser Plant Protection Products Authorisation Division The State Plant Service under the Ministry of Agriculture of the Republic of Lithuania
Nouvelle-Zélande/New Zealand	Mr. Warren HUGHES Principal Adviser ACVM Assurance Directorate Ministry for Primary Industries

	Ms. Sarah LESTER Adviser (Agricultural Chemicals) Assurance Directorate Ministry for Primary Industries
Pays Bas/The Netherlands	Mr. Rob VAN DRENT Policy Officer Board for the Authorisation of Plant Protection Products (Ctgb)
République slovaque/Slovak Republic	Ms. Bronislava SKARBOVA Senior Counsellor Department of Plant Production Ministry of Agriculture and Rural Development of the Slovak Republic
Royaume-Uni/United Kingdom	Mr. John DALE Team Leader Pesticide Active Substances and Operational Policy Health & Safety Executive
	Dr. Christine SNAITH Head, Plant Protection Products Chemicals Regulation Division Health and Safety Executive
	Mr. Grant STARK Chemicals Regulation Division Health and Safety Executive (HSE)
UE/EU	Mr. Eric LIEGEOIS Policy Officer Pesticides Unit E.4. Pesticides and Biocides DG Health and Consumers (SANCO)
	Mr. Jeroen MEEUSSEN Coordinator European Union Minor Uses Coordination Facility
Costa Rica	Mr. Roger RUIZ ZAPATA State Phytosanitary Service Ministry of Agriculture and Livestock

Comité consultatif économique et industriel (BIAC)/Business and Industry Advisory Committee (BIAC)	Mr. Craig DUNLOP Regulatory Policy Team Leader Syngenta Crop Protection AG Switzerland
	Mr. Marcello GIANNUZZI Global Product Stewardship Director FMC Corporation Switzerland
	Ms. Brenda HARRIS Regulatory & Government Affairs Leader Corteva Agriscience Canada
	Dr. Peter HORNE FMC Agricultural Solutions Stine-Haskell Research Center United States
	Dr. Ray MCALLISTER CropLife America United States
	Philipp-Andreas SCHMIDT Bayer AG Belgium
	Ms. Sara STERLING Director of Precision Agriculture FMC
	Dr. Greg WATSON Crop Protection Policy Lead Regulatory Scientific Affairs Bayer U.S.
International Biocontrol Manufacturers Association	Mr. David CARY Advisor International Biocontrol Manufacturers' Association Belgium
	Mr. Ulf HEILIG Regulatory Affairs Director Regulatory Affairs International Biocontrol Manufacturers Association (IBMA) Belgium

Organisation des Nations Unies pour l'alimentation et l'agriculture (FAO)/UN Food and Agricultural Organization (FAO)	Mr. Mario YARTO Agricultural Officer Secretariat of the Rotterdam Convention Food and Agriculture Organization of the United Nations (FAO) Italy
AGRIDEES	Ms. Marie-Cécile DAMAVE Head of innovation and markets AGRIDEES France
Bayer AG, Crop Science	Ms. Roslyn CHUA Digital Farming/Climate Corp. Crop Protection Domain Lead Bayer AG, Crop Science Germany
Bayer CropScience Limited	Ms. Janet WILLIAMS Head of Regulatory Science – UK & Ireland Bayer CropScience Limited United Kingdom
FMC Corporation	Dr. John ANDALORO Global Technical Product Manager Agriculural Solutions FMC Corporation United States
Griffith University	Dr. Leanne WISEMAN Associate Professor Griffith Law School Griffith University Australia
John Deere Crop Care Platform	Mr. Christopher BURSIEK Manager, Product Safety Standards engineering John Deere Crop Care Platform United States
Sony France	Dr. Peter HANAPPE Sony Computer Science Laboratories Sony France

Syngenta Company

Mr. Xavier LEPRINCE
Head of Business Sustainability EAME
Syngenta Company
Switzerland

OCDE/OECD

Ms. Francesca CASALINI
TAD/EPI
OECD
France

Ms. Gwendolen DEBOE
TAD/ARP
OECD
France

Mme Marie-Agnes JOUANJEAN
TAD/ARP
OECD
France

Ms. Christiana OLADINI-JAMES
ENV/EHS
OECD
France

Mr. Richard SIGMAN
ENV/EHS
OECD
France

Mr. Sebastian WEBER
TAD/ARP
OECD
France

Appendix 3: Workgroup Member Feedback

Feedback from Individual Organizations/Workgroup Member/Representatives

Section 1: Greater Understanding for EPA (Charge question 1: How should EPA obtain a greater understanding of how the use of emerging agricultural technologies leads to reduced or increased risks that differ from those resulting from current methods?)

AEM

Expand the current field day events that have been held in the past to be more interactive and demonstrate more technologies. There could be more targeted/regional type events that can talk specifically to a technology as it is used in that region. An example being orchard sprayers used in CA compared to a boom sprayer used in the Midwest. During these events it is important to make sure multiple manufacturers participate as not every sprayer or manufacturer has every type of technology. So, this might need to be a multi-color exercise that allows them to experience the full “toolbox” of things that are available to sprayer operators. A video library could also be put together by relevant stakeholders to help provide educational opportunities as well in between field days.

Syngenta

1. Various work groups have formed at US and international levels to assimilate, critically evaluate and summarize the state of science for pesticide application made by UAV and other emerging application technologies. It will be efficient for the agency to utilize these resources, which reference many peer-reviewed publications, when evaluating whether risks are increased or decreased by emerging technology relative to conventional methods.

2. EPA should continue to work with the various entities (registrants, academia, equipment manufacturers, etc.) to incorporate newly generated data into the risk assessment framework. Communication among all entities is crucial to developing a sound regulatory framework. Workshops and focused emerging technology sessions at industry meetings, will be an important venue for communication and idea-sharing.

3. Field visits are an excellent means to view and experience emerging technologies. The EPA should focus on these opportunities with the farmer and/or end user(s).

4. Because the technology and its use are rapidly evolving, the agency’s position should remain dynamic and responsive to internal and external change.

NAAA

1. For application platforms, evaluate and compare the drift potential of new technologies with existing technologies to see if new technology increases or decreases risk of drift. Determine typical droplet size and application height, but also evaluate other properties of

the application method that have the potential to reduce drift, such as shields on ground sprayers and air assistance such as on airblast sprayers and aircraft.

2. Use information from point 1 to determine if the risk to the environment and human health differs from existing technologies by using EPA's current registration review risk assessment process.

3. Determine if efficacy is expected to increase or decrease using the new technology. If it increases, it could result in fewer applications and/or lower use rates which would lower risks. If it decreases efficacy, determine if the extent of the reduction would force users to increase the number of applications and/or use rates, which would increase risk.
    4. For pesticide mixers and loaders, evaluate the new technology to determine if the exposure will be increased or decreased. Factors to consider include whether the new technology reduces exposure by using a closed loading system or other similar engineering controls. Capacity should also be considered, as the number of times an application system needs to be loaded to complete an application on a site will impact the risk to mixers and loaders. If the new technology increases the risks to mixers and loaders, determine if additional PPE can be used to bring the risks in line with existing technologies.

    5. For pesticide applicators, determine if the technology changes their risk compared to existing technologies. A key factor will be whether the technology has an enclosed cockpit or cab. If the new technology increases the risks to applicators, determine if additional PPE can be used to bring the risks in line with existing technologies.

PANNA/NCAP

1. The EPA should require robust data to back up any claims that new technologies result in risk reduction. New technologies without science backed claims should not be exempt from agency review.

2. Review of new technologies may require new criteria of evaluation. For example, aerial application of pesticides (including via drones) poses additional threats that ground applications do not. Quantification of drift, especially if there is anything unique to these technologies, is crucial.

3. Any drift analyses should take into consideration weather and climate, especially temperature and winds, and include volatilization drift as well as spray drift.

4. If risk analyses determine that additional PPE is required to protect applicators and workers on the ground, this should be done with a comprehensive approach that includes considerations of heat stress and any inherent challenges to safe use of PPE.

5. Given that approximately 85% of pesticide applications end up in the soil; all risk analyses should include the impacts of pesticides (hazard level, concentration, application method, weather conditions at application, etc.) on the structure and function of the soil ecosystem.

6. There is training for pesticide applicators using air blast sprayers, etc. There should be regulations for training for drone use.

PANNA/NCAP Question:

1. Advocates claim that drone technology can accurately and more efficiently identify pests. Can drones estimate pest population size -- a necessary element in determining economic threshold as justification for pesticide applications? Can drones, at the same time, sample for NE populations? Can they look for rates of parasitism or predation?

2. Does the opportunity to use drone technology create a disincentive to use these other important components of describing and quantifying the pest problem and actual 'need' for control?

3. What about drone malfunction? ex. what if a drone malfunctions and spills or drops or dumps pesticides rather than a regular application? What about other types of accidents? It is hit by something and breaks up? or falls to the groups for some reason? goes off course? I can think of various scenarios. How might these malfunctions affect the application and any people/workers that may be in the vicinity.

Section 2: Approaches to Labels (Charge Question 2: What changes to EPA's approach to pesticide labels, if any, are needed to accommodate emerging technologies?)

AEM

Chemical formulations change and label verbiage comes from some very targeted tests. Dicamba is a prime example where initially there was only one approved spray tip for this chemical which severely limited the operator even though there were other technologies on the market that would work. Somehow, there needs to be a push for wording that allows for the use of like products or technology that can meet the desired results. This may be a difficult task, but those who write the labels and provide the data used to create that language need to know what else is available to help meet those requirements. This includes both current technologies and ones that are emerging within the marketplace. An example being you don't want to write out see and treat technology because the label language is only specific to a broadcast application.

Better definition of terms, such as Spot Spray and other methods of application.

Clarity around rates listed on labels, i.e. Volume/acre - if only 1/10 of the acre is sprayed could a higher rate be used? (Question around number of passes – could additional passes be made if only parts of the field were sprayed on subsequent passes?)

Syngenta:

Initially, label changes needed to support application by emerging technologies may be formulation or equipment- specific and related to Directions for Use. Such label updates are currently managed through direct interaction with EPA via the Product Manager. As data generation and emerging technology adoption continues, additional label updates to other portions of the label may be necessary. To maximize efficiency and consistency, EPA should continue to engage with the registrants and end-users when developing label language.

NAAA

1. Evaluate the technology as described in section 1
2. Compare the results to existing technologies used on current labels
    i. Are the risks similar?
    ii. Are the application requirements, such as application height, droplet size, use rate, spray application rate, weather restrictions, and other application instructions like technologies already included on the label?

b. If the answers to 2a and 2b are yes, then EPA would likely be justified in considering the new technology to be a new version of existing technology that does not require modifying existing labels

c. If the answers to 2a and 2b are no, then the EPA will need to determine if the new technology will be allowed or prohibited. If allowed, a new label section should be created to address application requirements specific to the new technology. If prohibited, then the label should specifically state the technology is prohibited.

Future Research Needed

Syngenta

1. Assessment methodology. For example, what method should be used to quantify whether the emerging technology increases or decreases environmental exposure?
    a. Model development
2. Define SOPs or BMPs for application systems (e.g., UAVs, autonomous tractors, etc)
3. On-target delivery of pesticide products

Evaluate costs, to access and savings realized, of new technologies in context of the end user (e.g., small, mid-size, large farms).