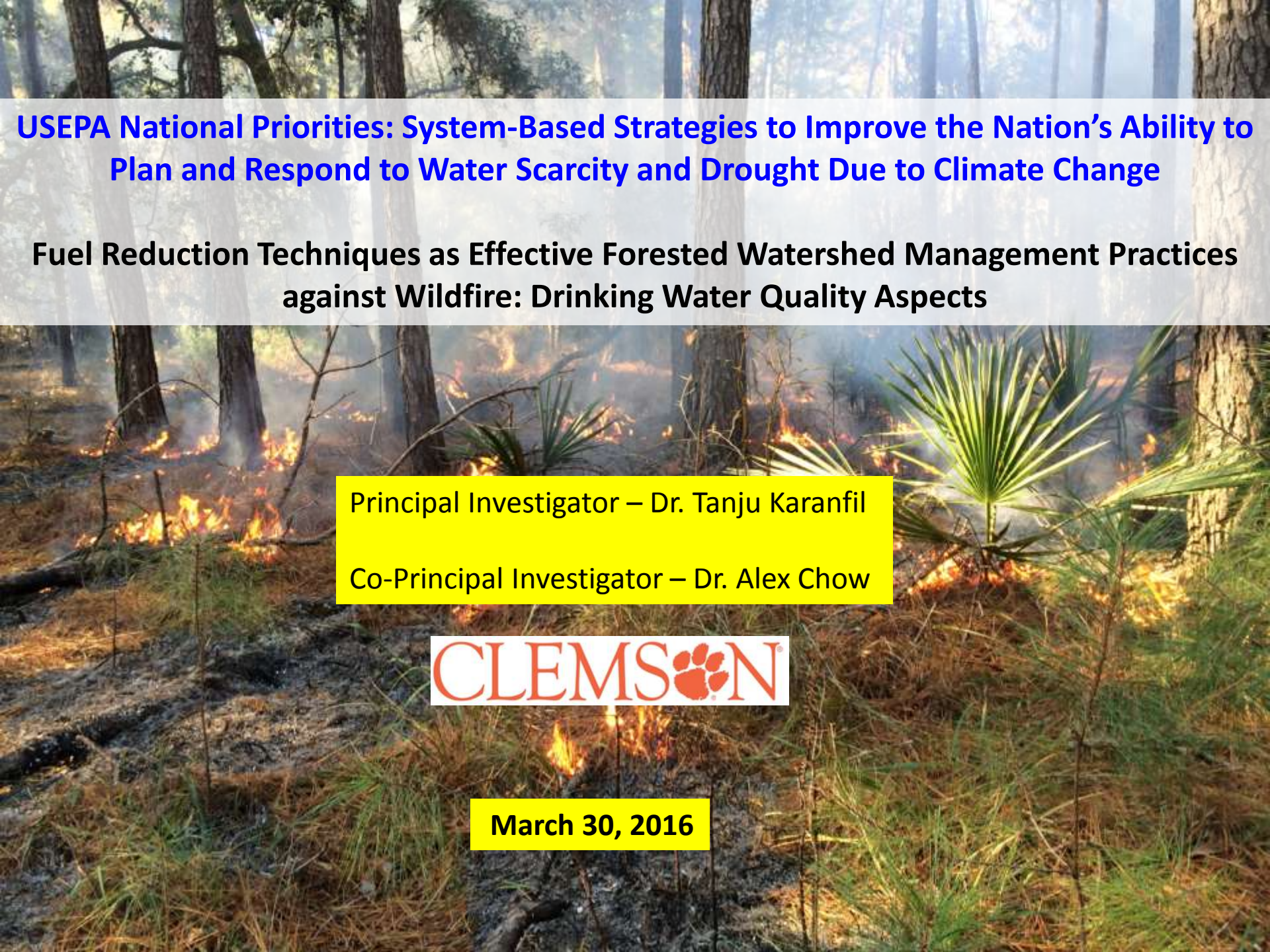


USEPA National Priorities: System-Based Strategies to Improve the Nation's Ability to Plan and Respond to Water Scarcity and Drought Due to Climate Change

Fuel Reduction Techniques as Effective Forested Watershed Management Practices against Wildfire: Drinking Water Quality Aspects

Principal Investigator – Dr. Tanju Karanfil

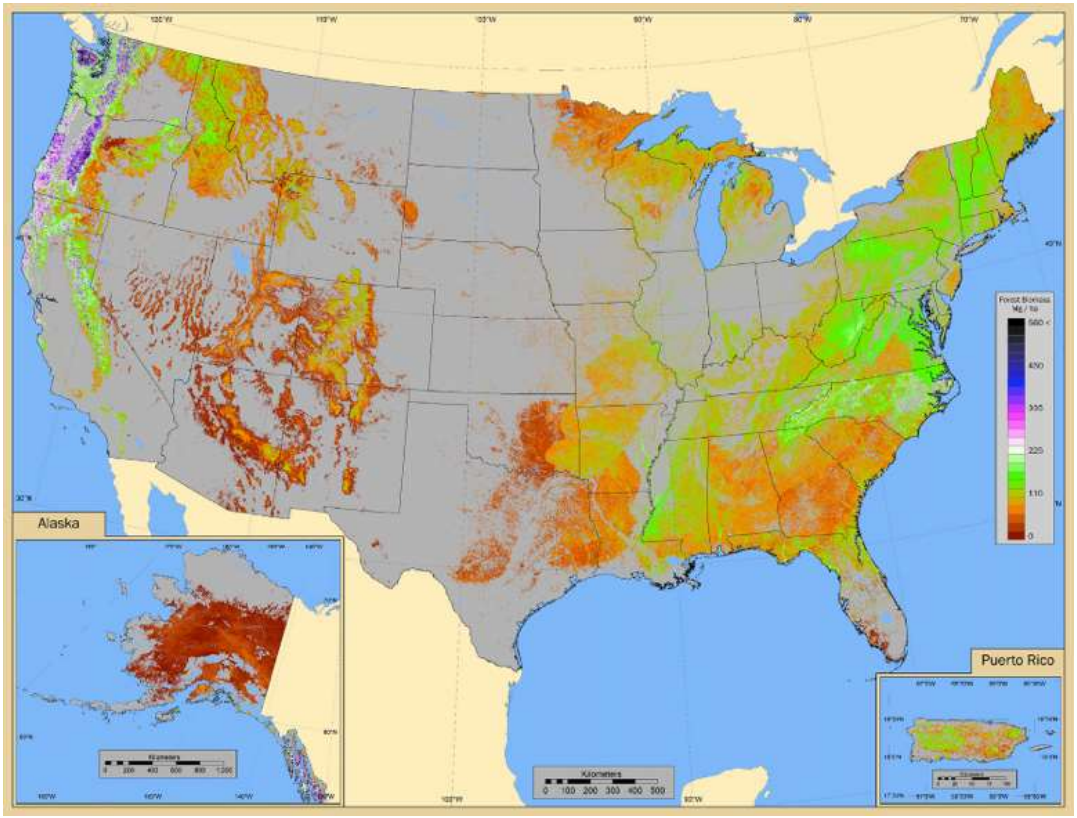
Co-Principal Investigator – Dr. Alex Chow

CLEMSON

March 30, 2016

Forest Land ⟷ Source Waters

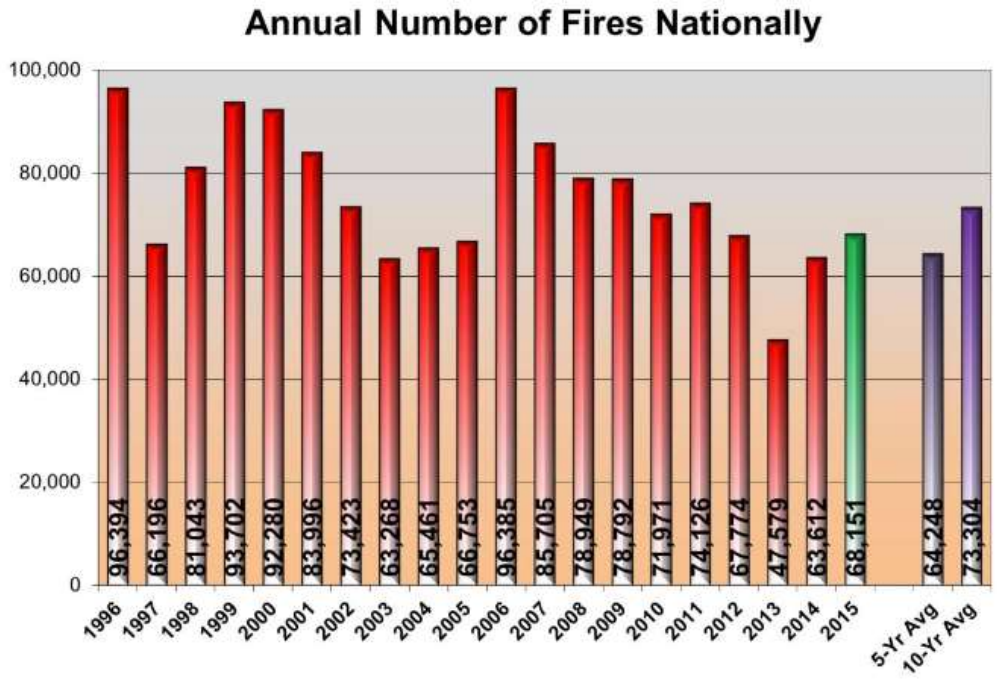
Forest land comprises 766 million acres, or 33% of the total land area of the United States



About 53% of the sources for water supply in the US surrounded by forest land

Sources: 1) Blackard et al. 2008. Remote Sensing of Environment 112(4): 1658-1677. 2) US Forest Resource Facts and Historical Trends, 2012.

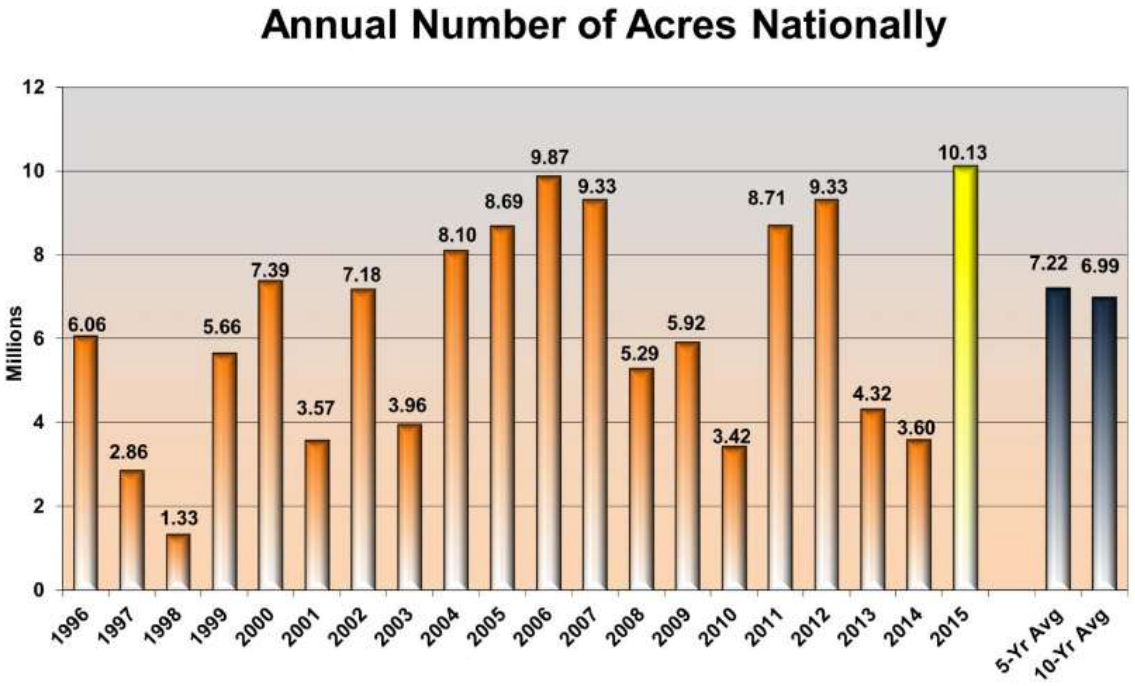
Source: 2015 Statistics and Summary
National Interagency Coordination Center



The 10 year average is 73,304 fires / per year

An average of 7 million acres are burnt each year

~The size of Massachusetts



Detritus in Forested Watersheds

Forest detritus is an ignition source and the main fuel of forest fires.

Forest Litter = Fuel

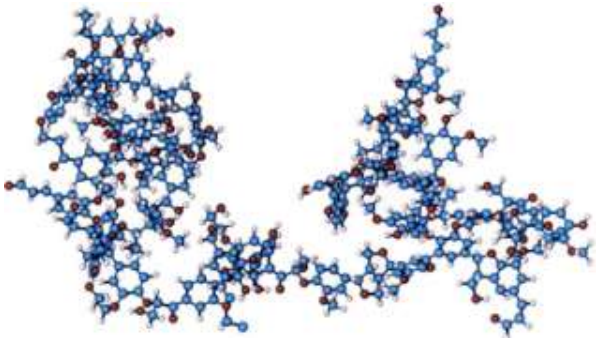


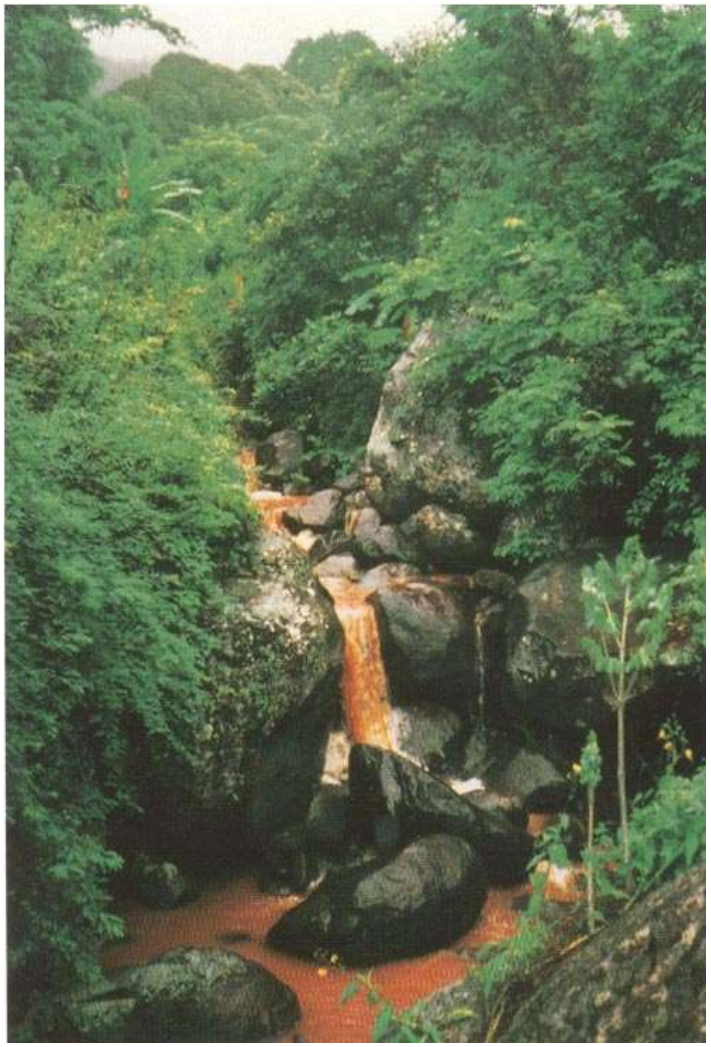
Forest detritus is also one of the major terrestrial sources of natural organic matter (DOM) in source waters. DOM is a precursor of disinfection byproducts (DBP), with increase risk of adverse health effects, during drinking water treatment.

Forest Litter = Sources of DBP Precursors

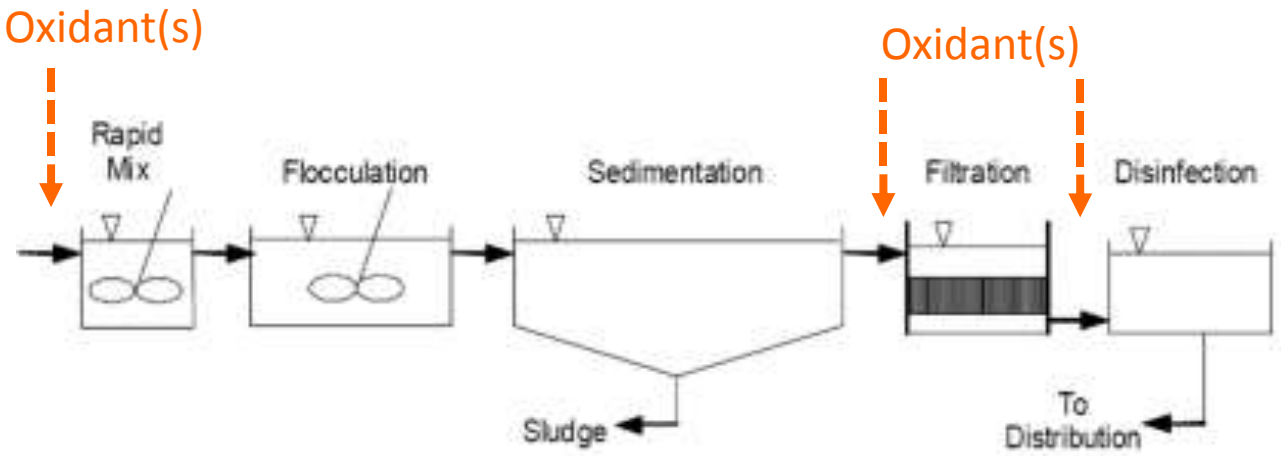
Challenges of DOM in Water

- Aesthetic problems in water
- Binding pollutants
- Effect photochemical reactions
- Increasing chemical (e.g., coagulants and oxidants) demands
- Membrane / activated carbon fouling
- Nutrients for biological growth
- Precursor of Disinfection Byproducts





Formation of Disinfection By-products (DBPs) during Water Treatment



- Control
  - Iron & manganese
  - Biological activity
  - Taste and odor control
- Disinfection

Precursor(s) + **Oxidant(s)** → *Factors* → **DBPs**

- Natural organic matter (NOM)
- Algal organic matter
- Effluent organic matter (EfoM)
- Br^- & I^-
- Others

- Cl_2
- ClO_2
- O_3

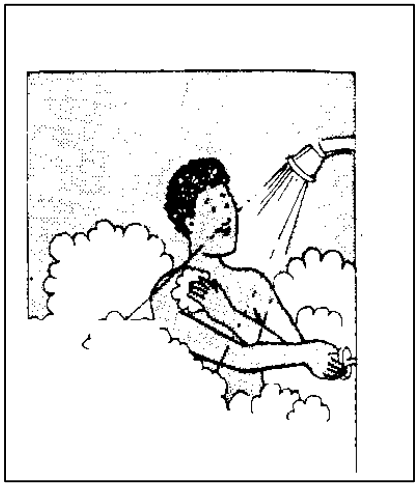
- pH
- Temperature
- Time
- Oxidant Dose

~ 600^+

Regulated DBPs in US: THM_4, ClO_2^-, BrO_3^- HAA_5

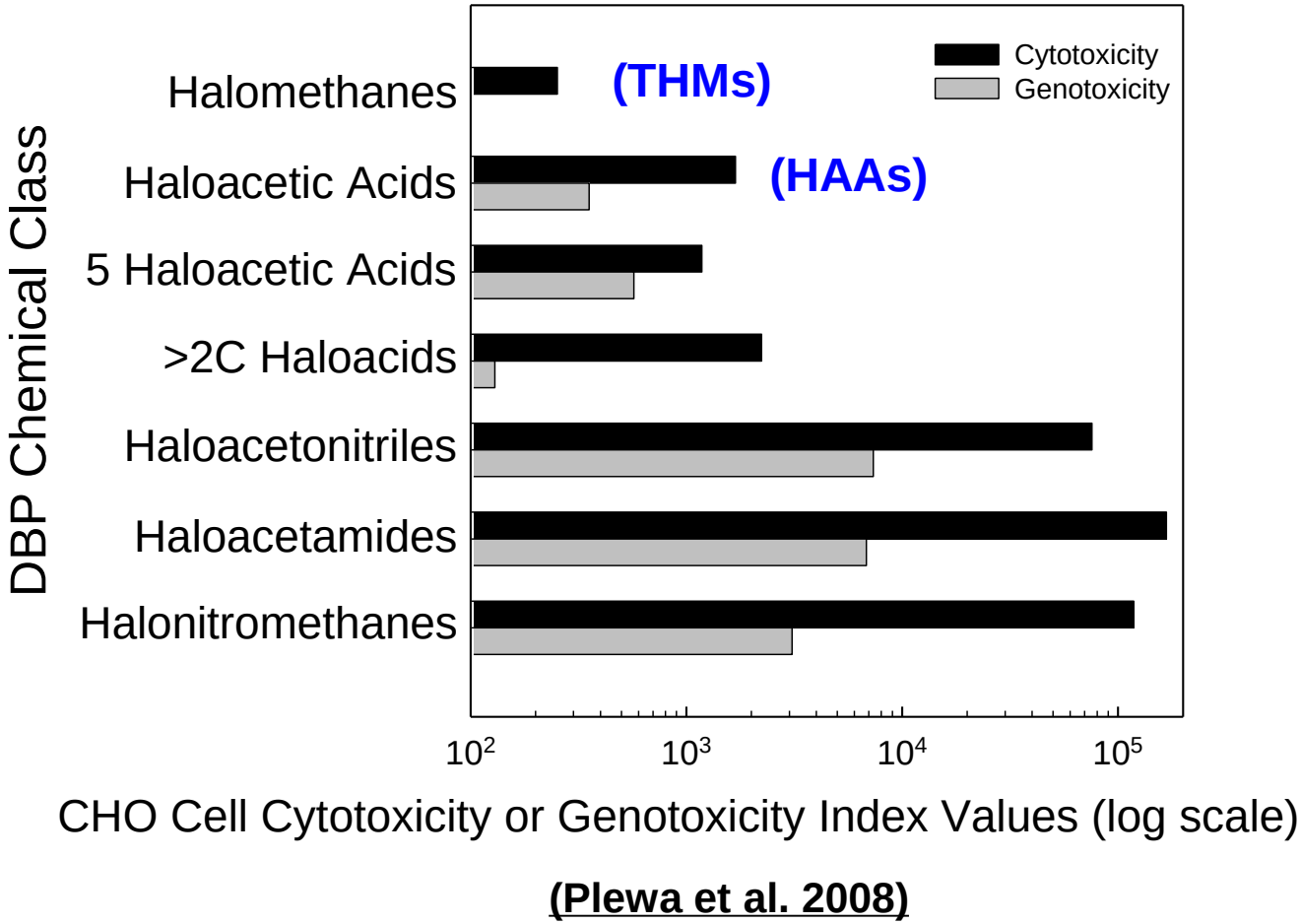
Health Concerns of DBP Exposure

- Some of the identified DBPs are possible carcinogen
- Brominated DBPs are much more toxic than other forms
- DBP exposure through dermal adsorption, ingestion, and/or inhalation



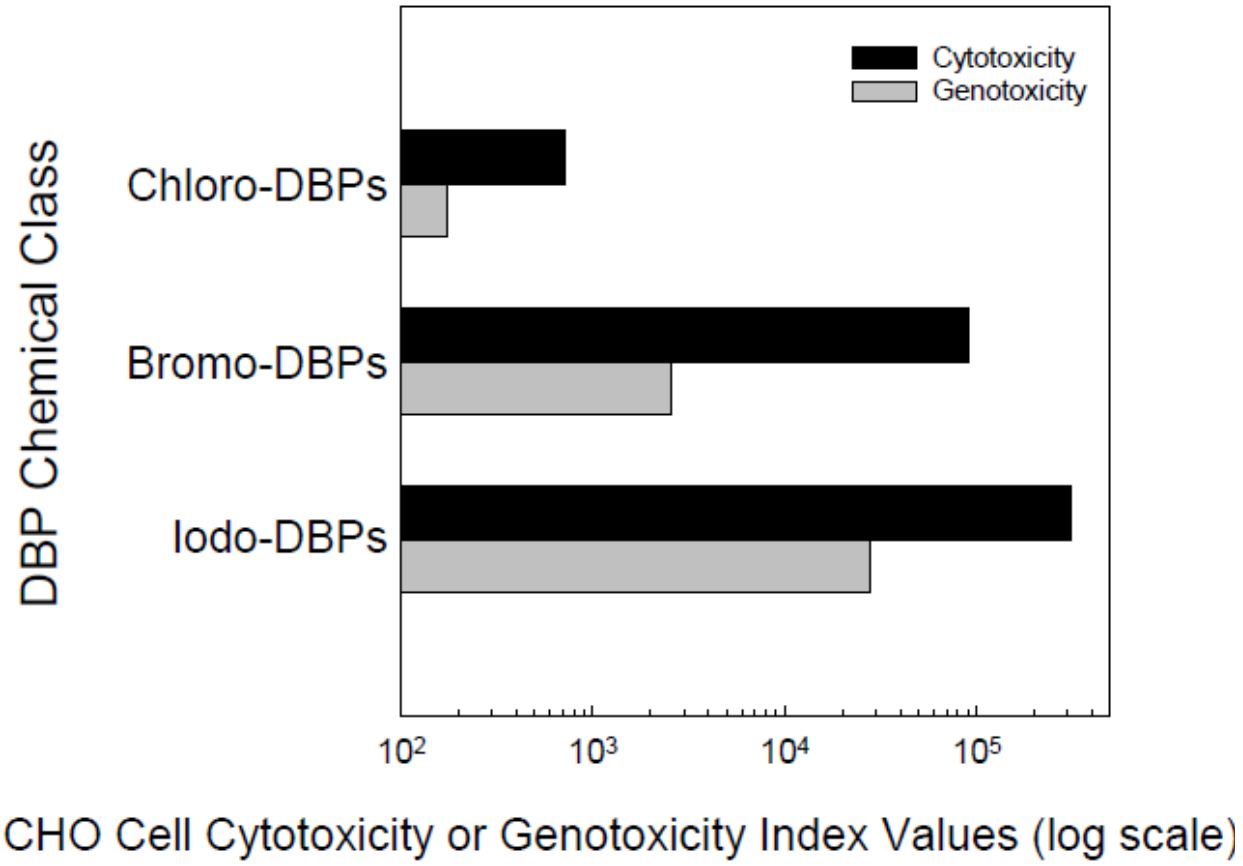
- Blood THM concentrations increase simply due to showering, bathing, swimming, and hand dishwashing

DBP Toxicity



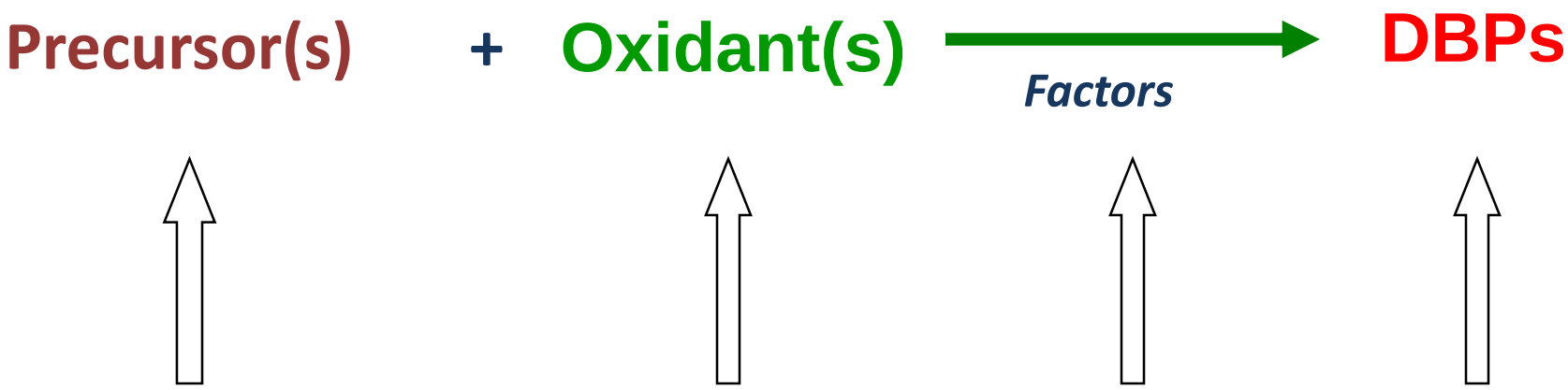
(Plewa et al. 2008)

Toxicity Index of DBP Classes: The Impact of Halogens



(Plewa et al. 2008)

Control of DBP Formation



Source Control and Management

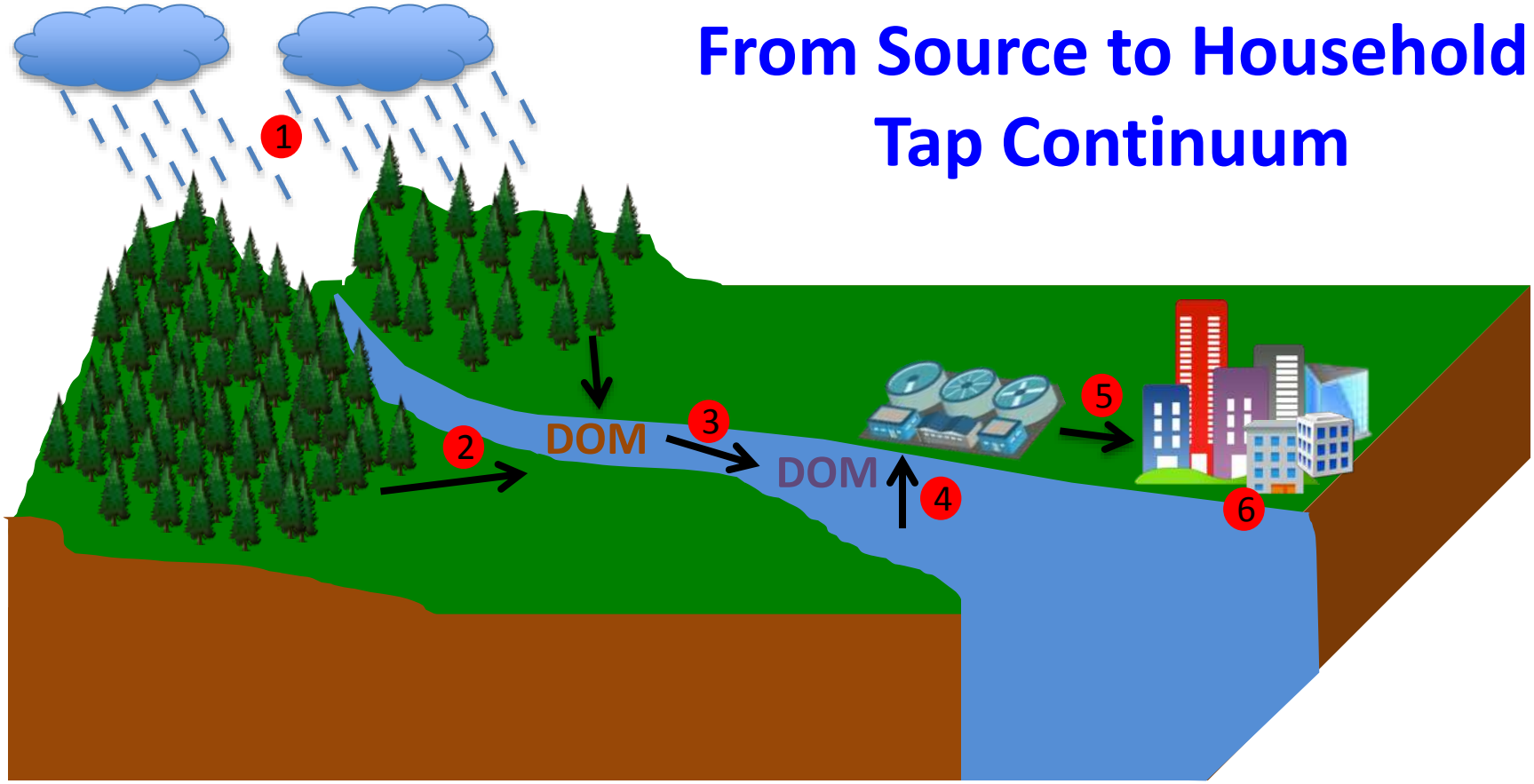
Remove Before Oxidant Addition

Use an Alternate

Manage

Remove After Formation

From Source to Household Tap Continuum



1) Droughts / Rainfalls
2) Runoffs / exports from forest watershed
3) Transformation of DOM in aquatic systems
4) Water intakes from treatment facilities / water treatment
5) Water distribution system
6) Tap waters in household

Detritus materials in forest floor

Management

Reduce

Mass of litter & duff per unit area

Reduce

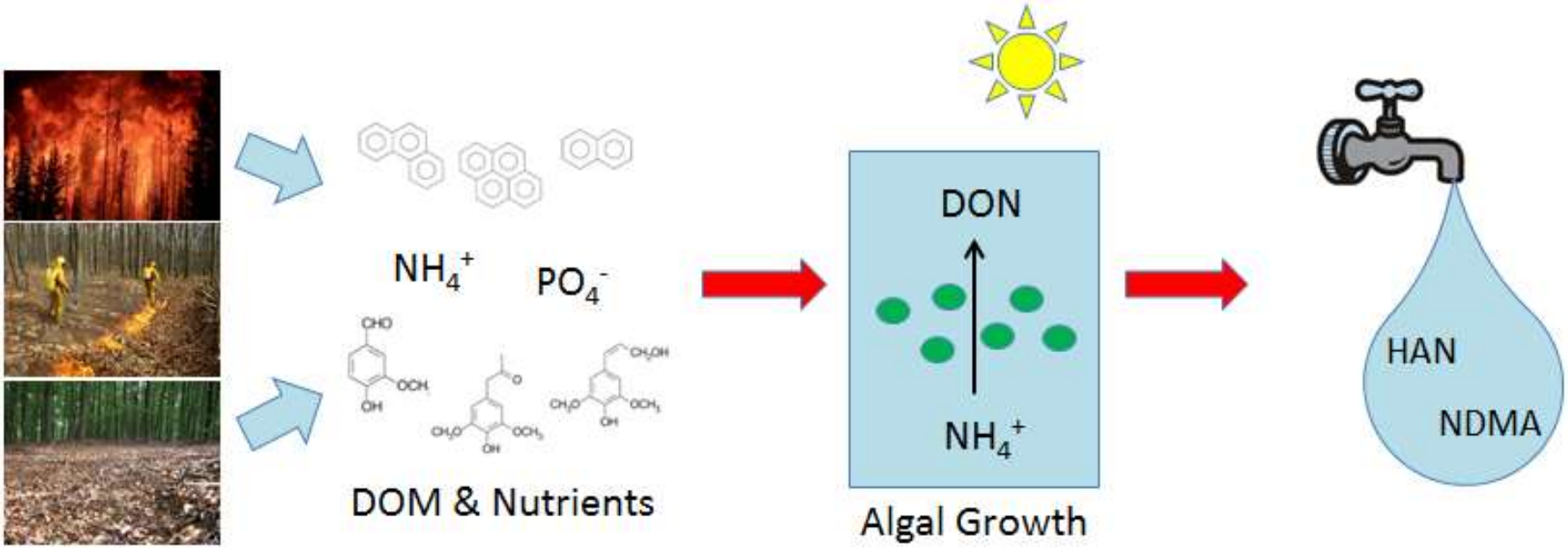
DOM Exports from Watersheds

Reduce

DBP Precursor in Source Water

Project Objectives

The goal of this project is to develop adaptive management strategies and innovative, cost-effective technologies to reduce the risks of forest fires and their impact on the source water quality, mainly the concentrations and characteristics of dissolved organic matter (DOM) and the formation of regulated and emerging disinfection byproducts (DBPs).



Project Approach



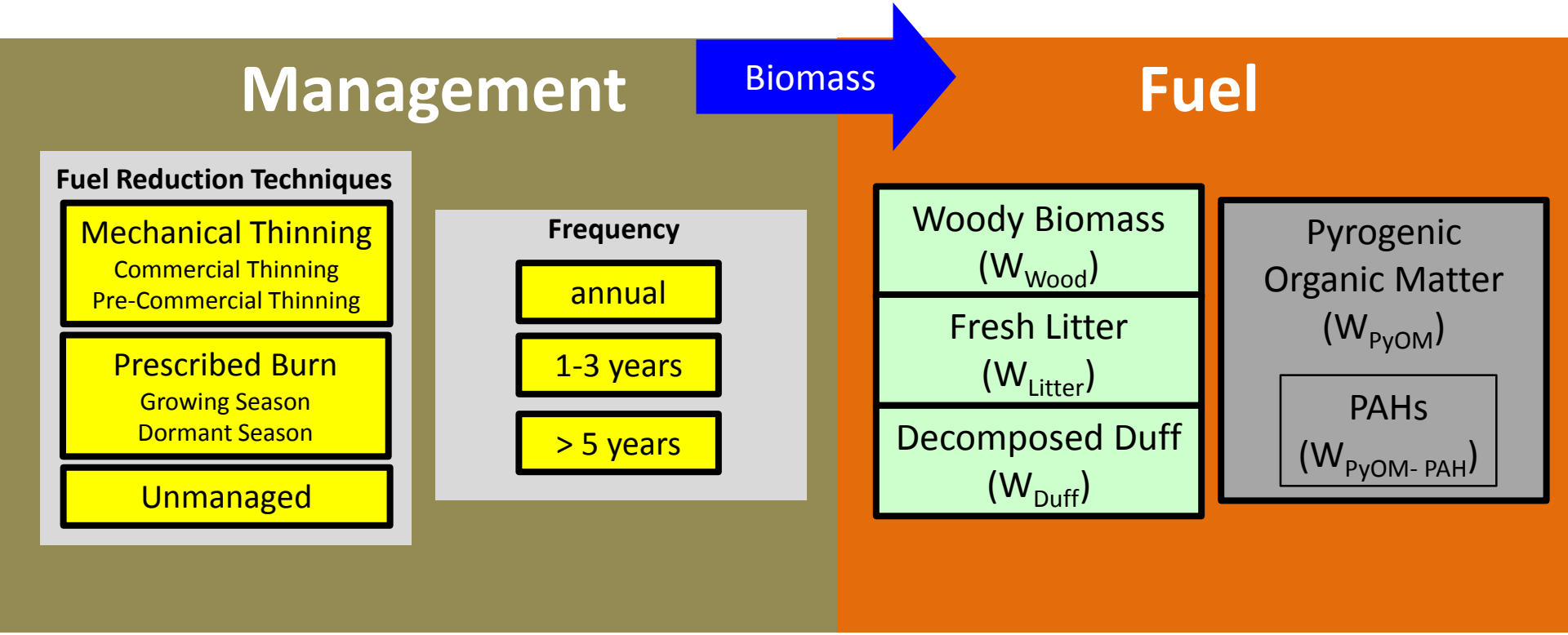
I. Management Practices
- Prescribed Burn versus Mechanical Thinning
- Frequency versus Season

II. Landscape Processes
- Trends, Yields, and Loads of DOM and DBP Precursors

III. Treatability
- Conventional Treatments on DOM removal
- DBP Formations

I. Management Practice – Controlled Field Studies

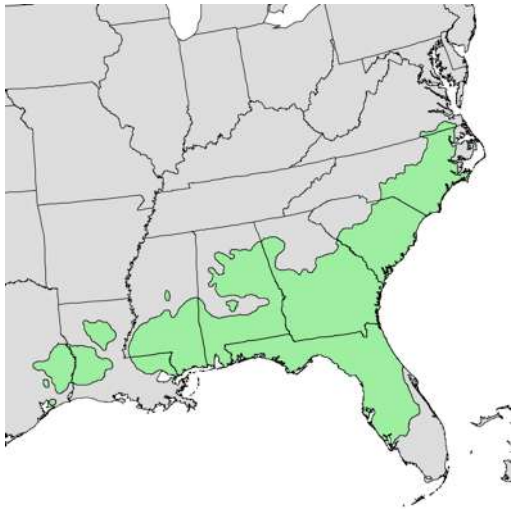
Task 1 – Establish experimental field plots with different forest management practices



I. Management Practice – Controlled Field Studies

Approach:

Longleaf Pine (*Pinus palustris*) Forest / Loblolly Pine (*Pinus taeda*)



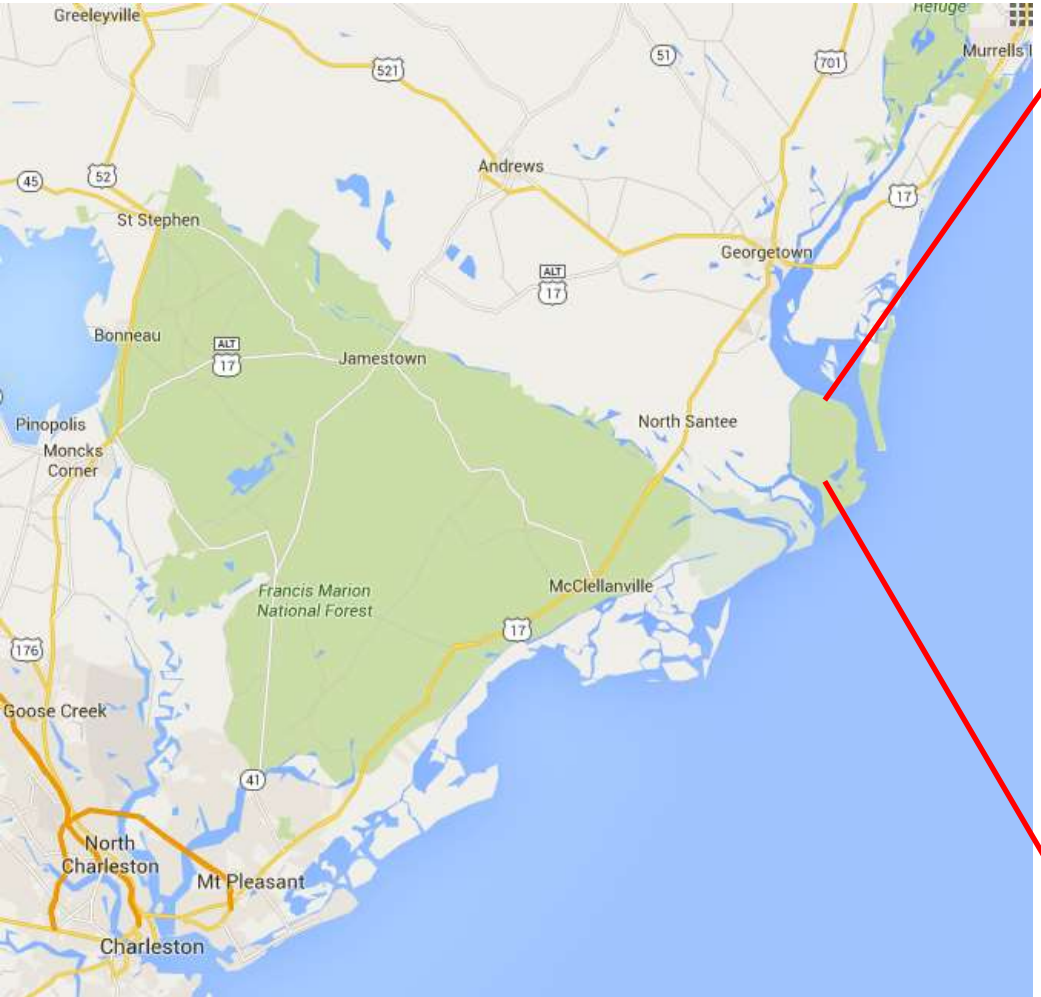
5 Mg/ha/yr litterfall in the longleaf pine
8 Mg/ha/yr litterfall in the Loblolly pine
(Gresham, 1982 – Forest Sci 28: 223-231)

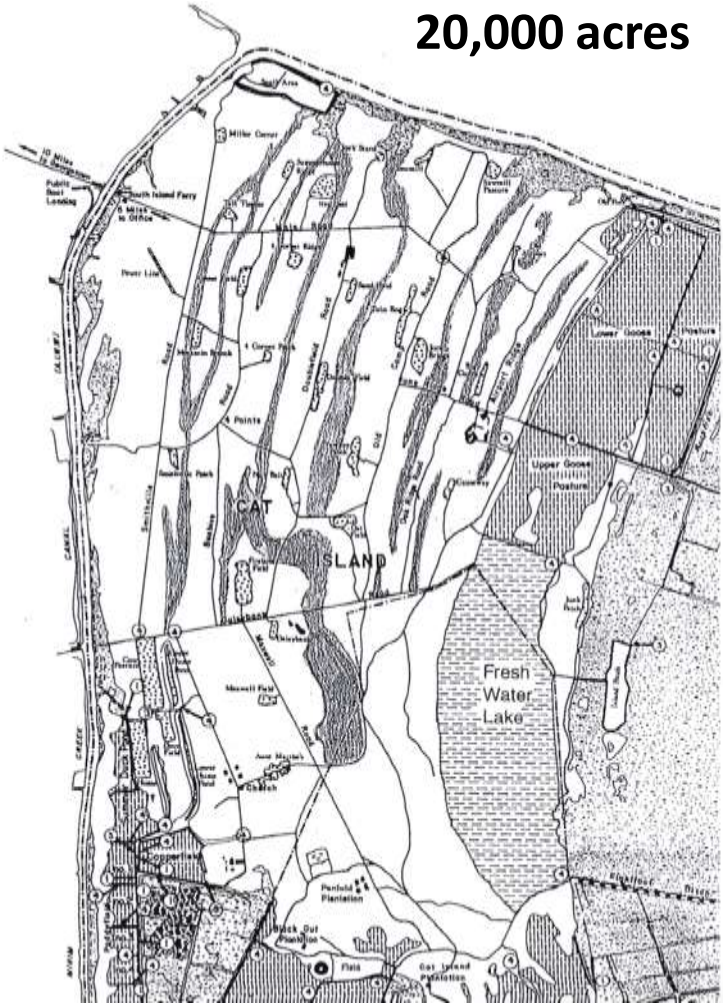
3-11 Mg/ha/yr litterfall from various ecosystems
(Zhang et al., 2014, Ecological Complexity)

I. Management Practice – Controlled Field Studies

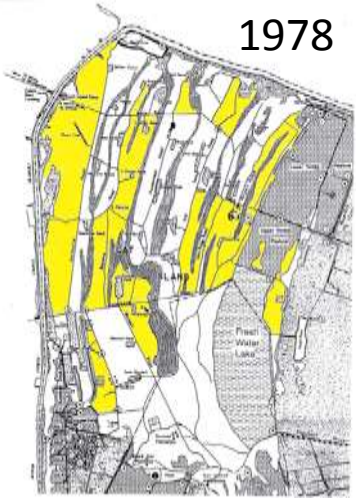
Approach:

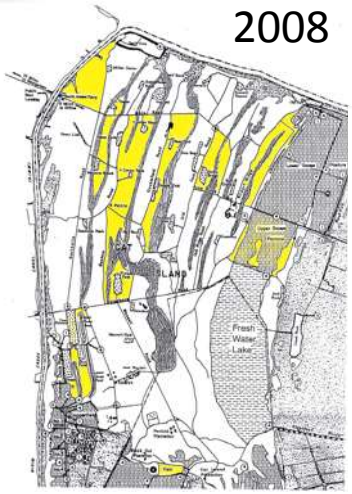
Forest plots in Yawkey Wildlife Center, Georgetown, South Carolina. SC Dept. of Natural Resources has implemented the prescribed fire practices since 1978's.

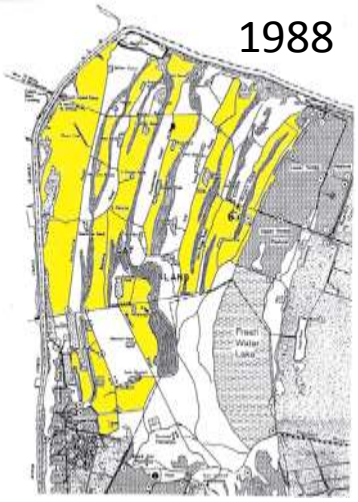




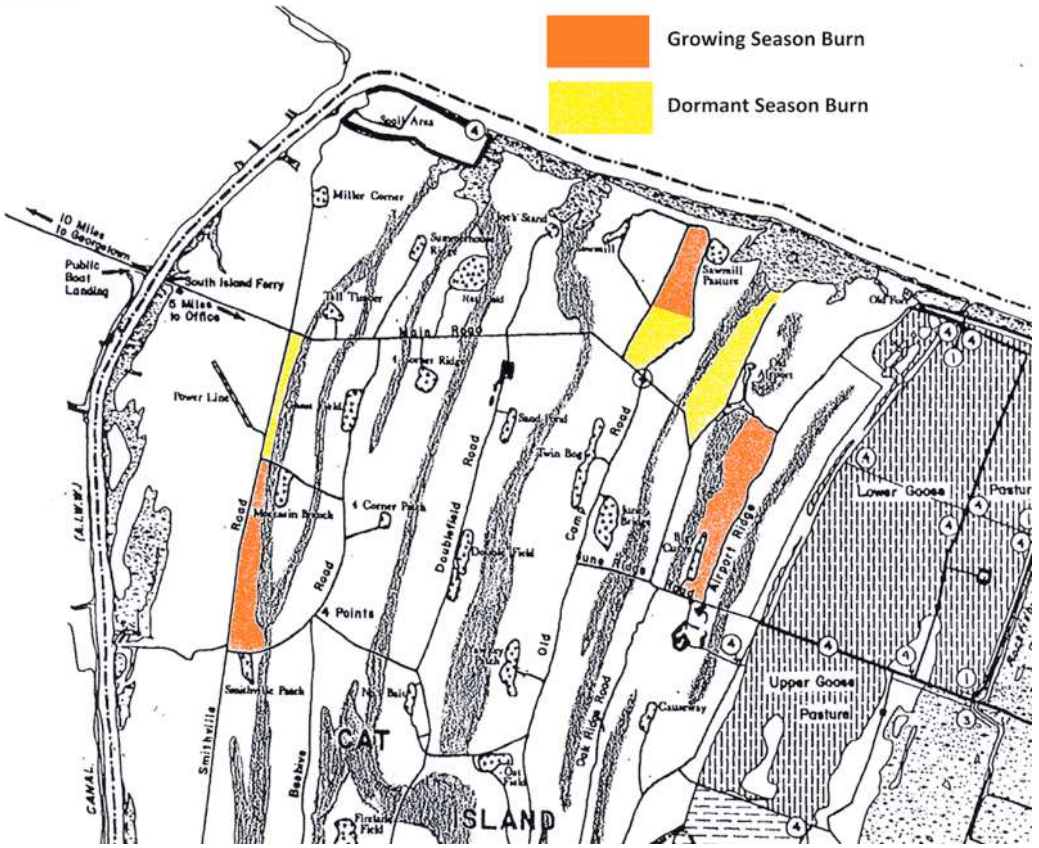
I. Management Practice – Controlled Field Studies







2015



- Growing season burn vs dormant season burn (Completed in 2015)
- Periodic vs annual season burn (Ongoing - 2016)

I. Management Practice – Controlled Field Studies

Approach:

Field Measurements:

1) Forest Structure
2) Fuel Thickness & Consumption
3) Fire Temperature & Heat Duration
4) Litter, soil, and ash collections

Laboratory Analyses :

1) Water Extractable Organic Matter
2) Nutrients
3) DOM Characterization
4) DBP-FP
5) Black carbon

Objective III

I. Management Practice – Controlled Field Studies

2015 / 2016 Prescribed Fire at Yawkey Wildlife Center

I. Management Practice – Controlled Field Studies

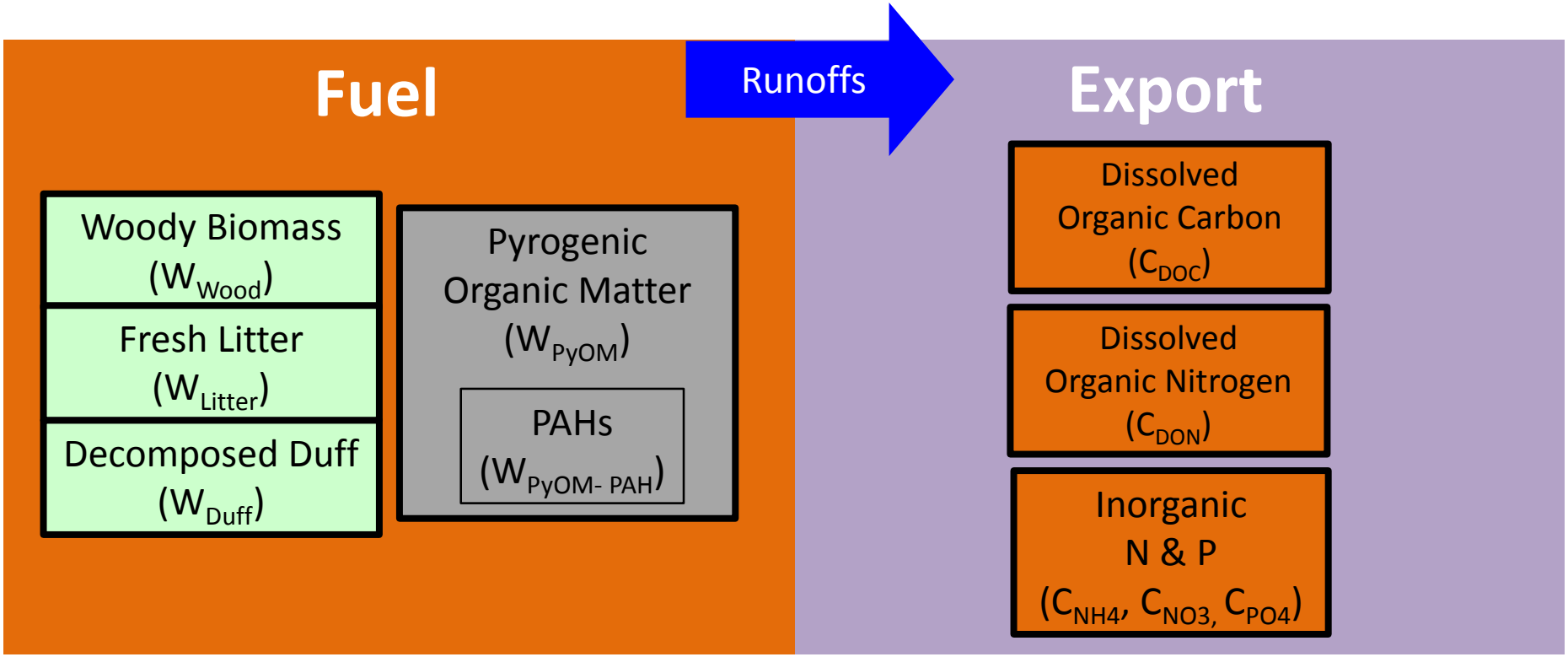
Before Fire

After Fire

I. Management Practice – Controlled Field Studies

I. Management Practice – Controlled Field Studies

Task 2 – Quantify and characterize DOM and nutrient exports from the detritus layers under different management practices



I. Management Practice – Controlled Field Studies

Approach:

Field Tray Incubation:

- One kg detritus materials from experimental plots (Task 1) will be placed into aluminum trays for one year.

- Water drained into the glass carboys underneath will be quantified for its selected water quality parameters and total volume.

I. Management Practice – Controlled Field Studies

Approach:

Treatments:

1) Empty Trays
2) Non-Burn Control (>30 years)
3) Before Burns
4) Annual Growing Season Burn
5) Annual Dormant Season Burn

Field Measurements:

1) Precipitation
2) Temperature
3) Sunlight Irradiation
4) Daily check on water collections

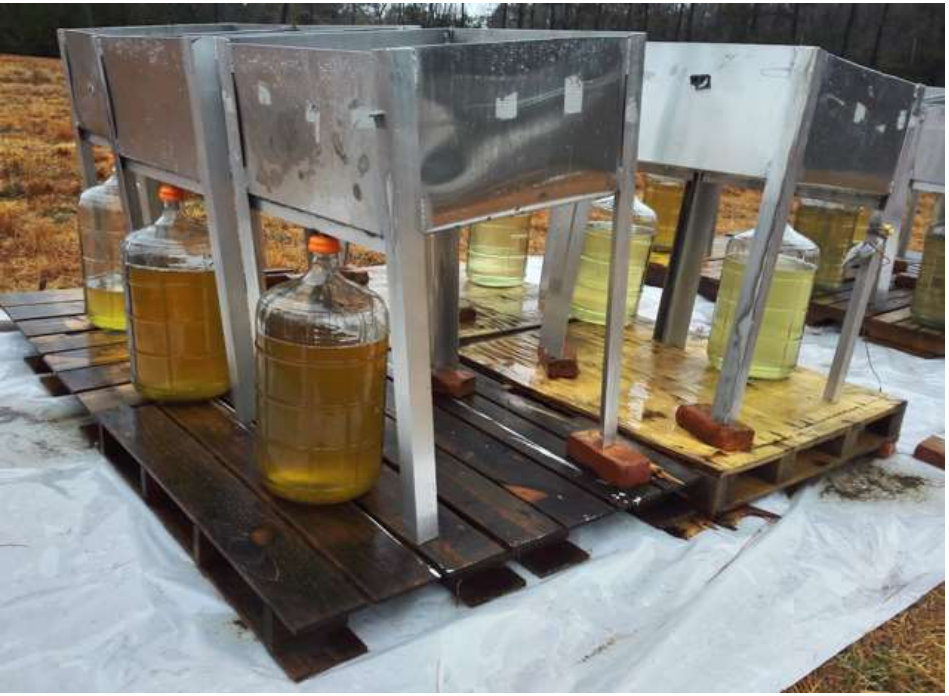
The field incubation started on Jan 2016

I. Management Practice – Controlled Field Studies

Laboratory Analyses

1) Detritus Decomposition
2) DOM & Nutrient
3) DOM Characterization
4) Treatability
5) DBP-FP

Objective III



I. Management Practice – Controlled Field Studies

Table 4. Maximum potential production of dissolved organic carbon (DOC), dissolved organic nitrogen (DON), trihalomethanes (THMs), and haloacetonitriles (HANs) from litter and duff cover types.

Sample	DOC	DON	THMs	HANs
	kg ha^{-1}			
		Litter		
Live oak	2.8	0.01	0.08	0.01
Blue oak	74	0.28	2.1	0.38
Foothill pine	2.7	0.02	0.06	0.01
Annual grass	31	0.32	0.93	0.09
		Duff		
Live oak	3.5	0.05	0.11	0.01
Blue oak	300	4.9	9.9	1.2
Foothill pine	6.0	0.07	0.16	0.02
Annual grass	24	0.38	0.45	0.06
Total yield†	445	6.0	14	1.8

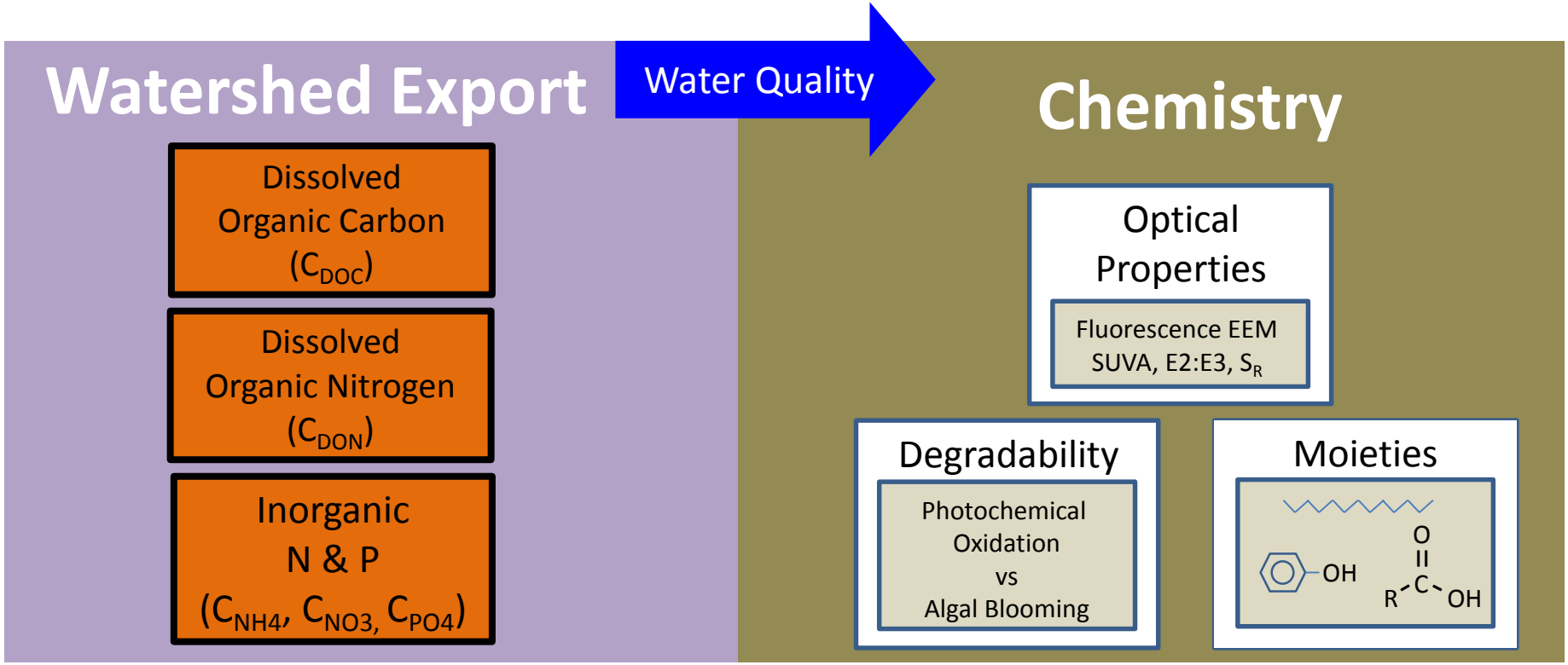
† The total yield was calculated by the following equation:

$$\text{Total yield} = \sum_{i=1}^{4}\left([\text{Constituent}]_i \times [\text{Detrital Mass}]_i \times [\text{Coverage}]_i\right) + \sum_{i=1}^{3}\left([\text{Constituent}]_4 \times [\text{Grass Understory Detrital Mass}]_i \times [\text{Coverage}]_i\right)$$

Chow et al. 2009. Litter contributions to dissolved organic matter and disinfection byproduct precursors in California oak woodland watersheds. Journal of Environmental Quality 38(6): 2334-2343.

I. Management Practice – Controlled Field Studies

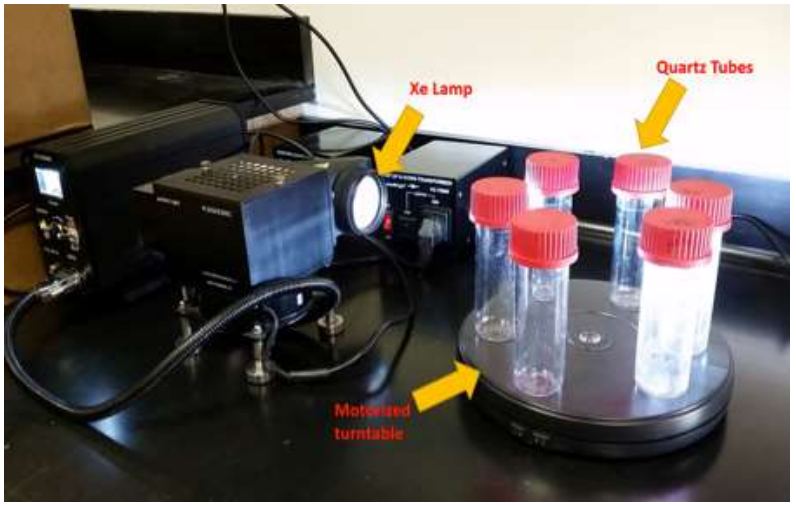
Task 3 – Examine selected biogeochemical processes under laboratory conditions to examine changes in concentrations of DOM & nutrient species in surface water



I. Management Practice – Controlled Field Studies

Approach:

- ***Algal Study*** – Inoculate algae into waters leaching from burnt detritus materials; two species (*Selenastrum capricornutum* and *Microcystis aeruginosa*) will be examined
- ***Sunlight Impact*** – Exposed DOM to simulate sunlight in the laboratory environments



Laboratory Analyses

- Algal Growth Rates
- DOC and Nutrient Dynamics
- DOM Characterization
- DBP FP

Objective III

Project Approach



I. Management Practices
- Prescribed Burn versus Mechanical Thinning
- Frequency versus Season

II. Landscape Processes
- Trends, Yields, and Loads of DOM and DBP Precursors

III. Treatability
- Conventional Treatments on DOM removal
- DBP Formations

II. Landscape Processes – Watershed Investigation

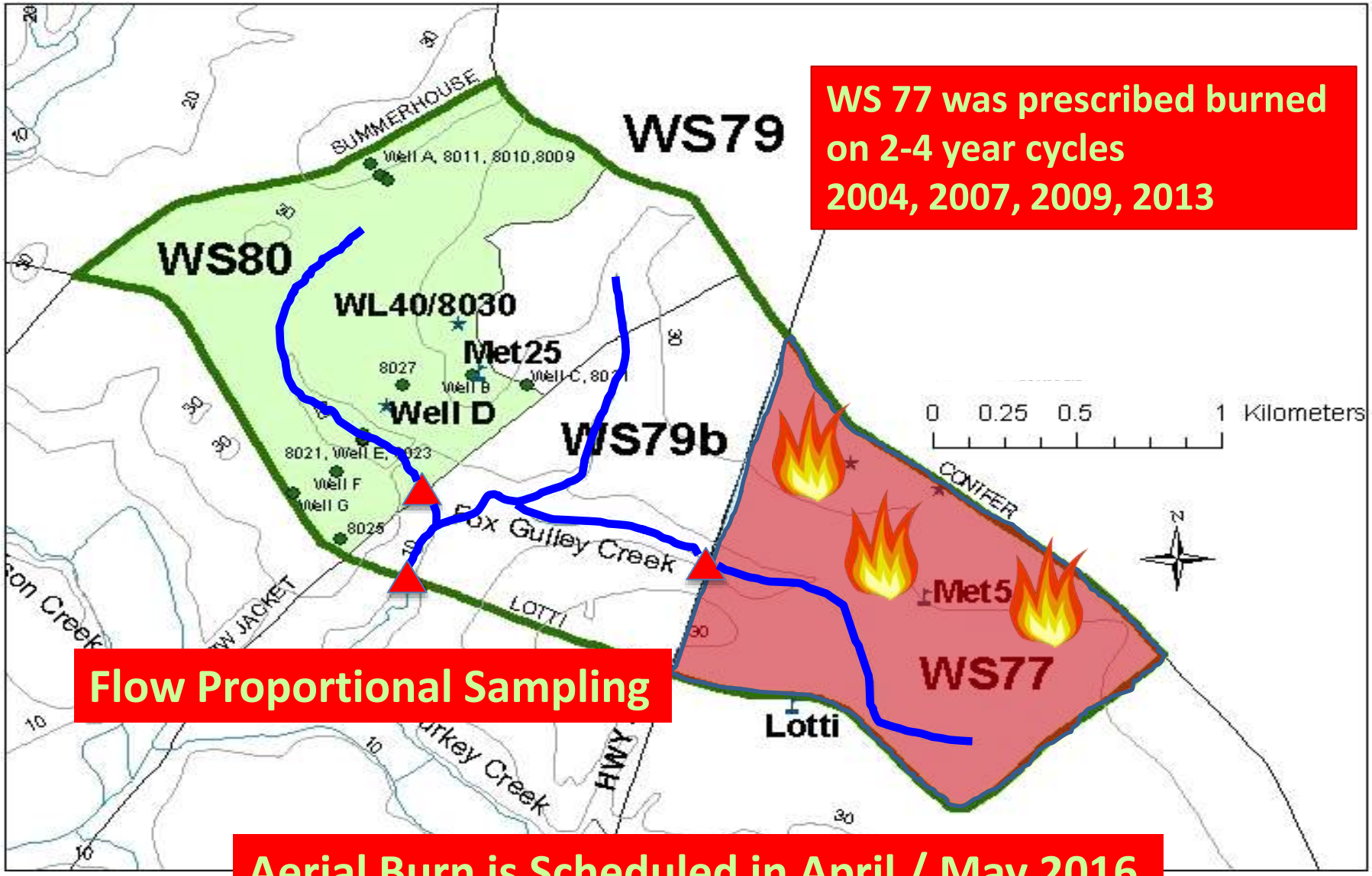
Experimental Watersheds:

1) Santee Experimental Forest – Aerial Burn at Spring 2016

2) Clemson Experimental Forest – Prescribed Burn and Mechanical Thinning at 2017

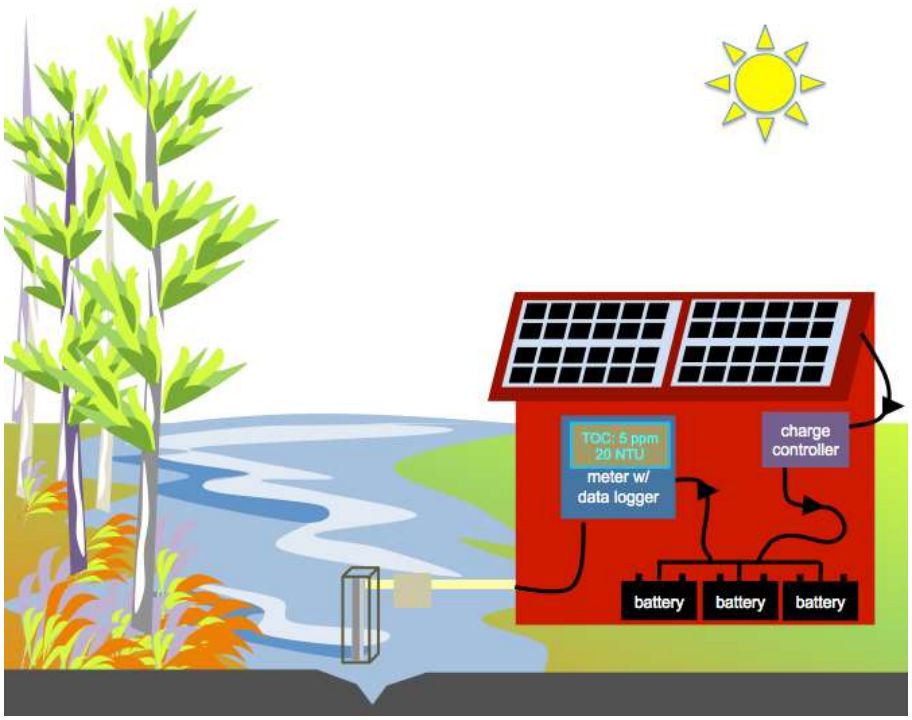
1) Santee Experimental Forest

Prescribed burned vs Unmanaged Watersheds



II. Landscape Processes – Watershed Investigation

Task 4 – Install in-situ field monitoring sensors and equipment to examine the temporal variation and movement of DOC in forested watersheds



II. Landscape Processes – Watershed Investigation

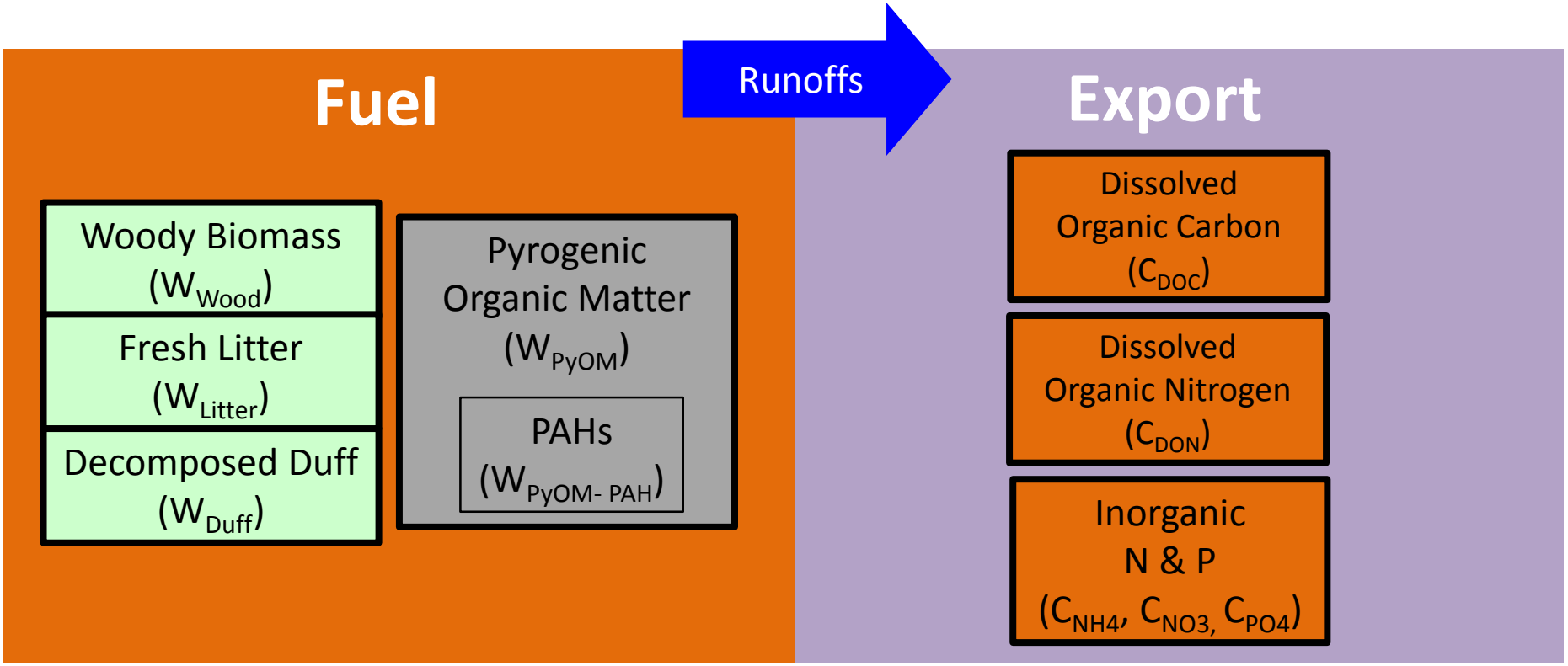
Approaches:

- Install DOC sensors at the three gauging stations for at least one-year monitoring
- Record reading every 15 minutes
- Recording TSS and TOC
- Up to 75 mg/L of TOC
- Compare with flow proportion samples

S::CAN - Carbo::lyzer

II. Landscape Processes – Watershed Investigation

Task 5 – Determine temporal variation and trends for DOC, DON, and nutrient exported from managed and unmanaged watersheds



II. Landscape Processes – Watershed Investigation

Approach:

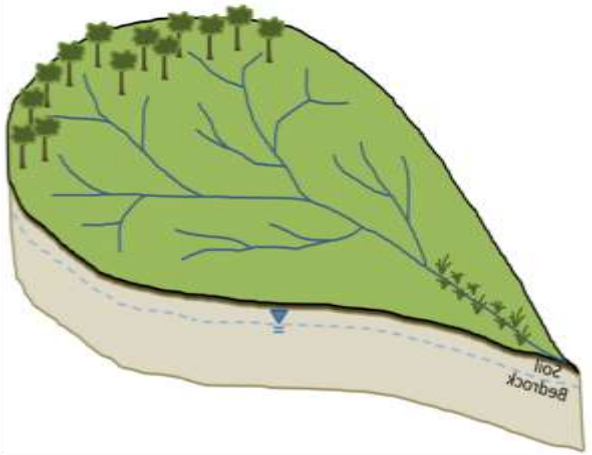
1) Flow-proportion sampling by ISCO samplers
2) In-situ DOC sensors
3) Grab samples in every two weeks

II. Landscape Processes – Watershed Investigation

Task 6 – Determine the loads and yields of DOC, DON, and nutrient exported from managed and unmanaged watersheds

Approaches:

1) Fuel loading surveys before and after prescribed fire
2) Obtaining hydrological data to determine the fluxes, nutrients and DBP precursor budgets

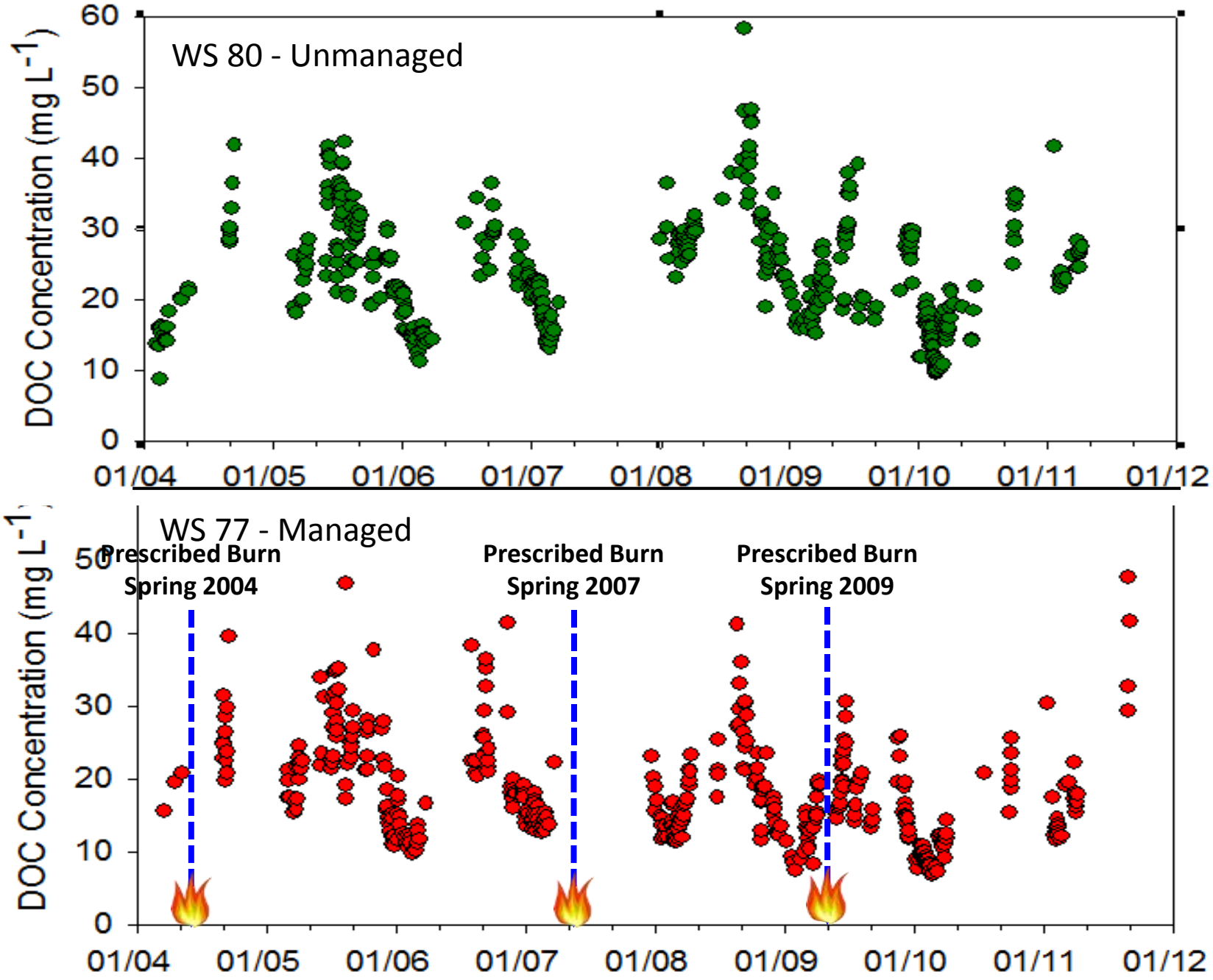


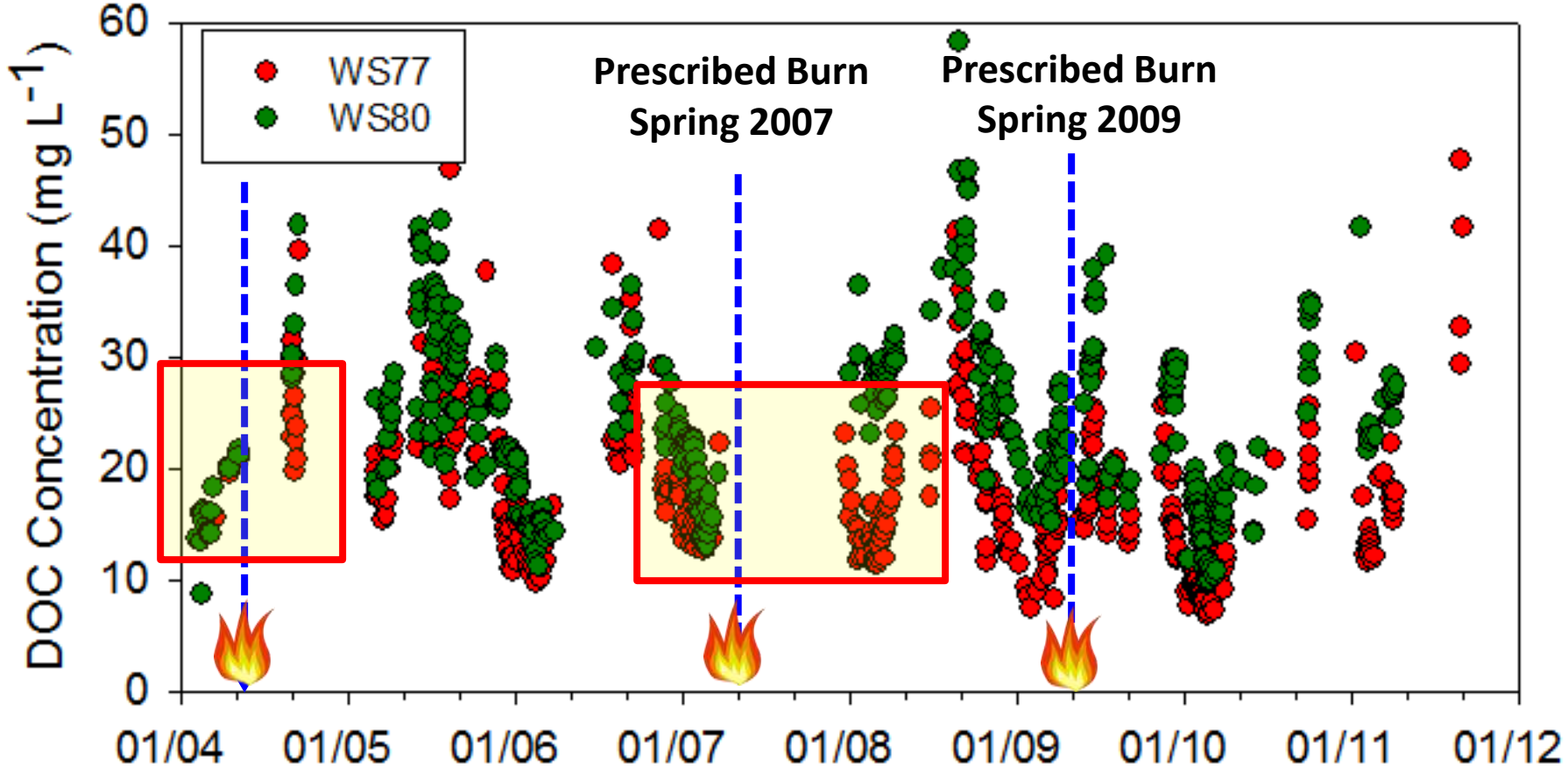
Concentration in water = mg / L

Yield per unit area = Mg / m^2

Load from a watershed= Mg / per year

Specific Objective: To evaluate the relationships between fuel (litter biomass) in forest floor and DOC exports

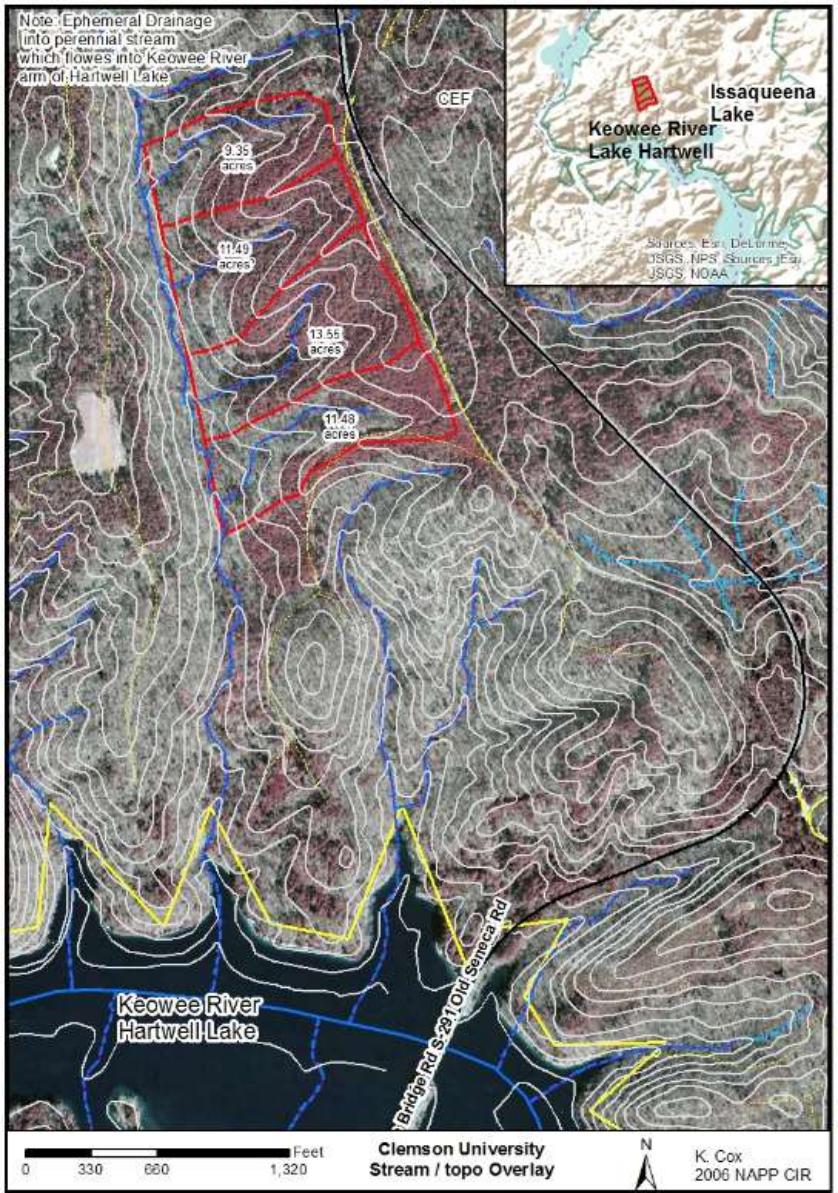

WS 80 - Unmanaged
DOC Concentration (mg L-1)
60
50
40
30
20
10
0
01/04
01/05
01/06
01/07
01/08
01/09
01/10
01/11
01/12
WS 77 - Managed
DOC Concentration (mg L-1)
Prescribed Burn
Spring 2004
Prescribed Burn
Spring 2007
Prescribed Burn
Spring 2009



DOC concentration exported from burned watershed < unburned watershed

2) Clemson Experimental Forest

Prescribed burned vs Mechanical thinning



Four adjacent small ephemeral watersheds ranging in size from 3.5 to 5.5 ha

Four Management Practices (2017):

- Control
- Prescribed Burn
- Commercial Mechanical Thinning
- Pre-commercial Mechanical Thinning

Project Approach



I. Management Practices
- Prescribed Burn versus Mechanical Thinning
- Frequency versus Season

II. Landscape Processes
- Trends, Yields, and Loads of DOM and DBP Precursors

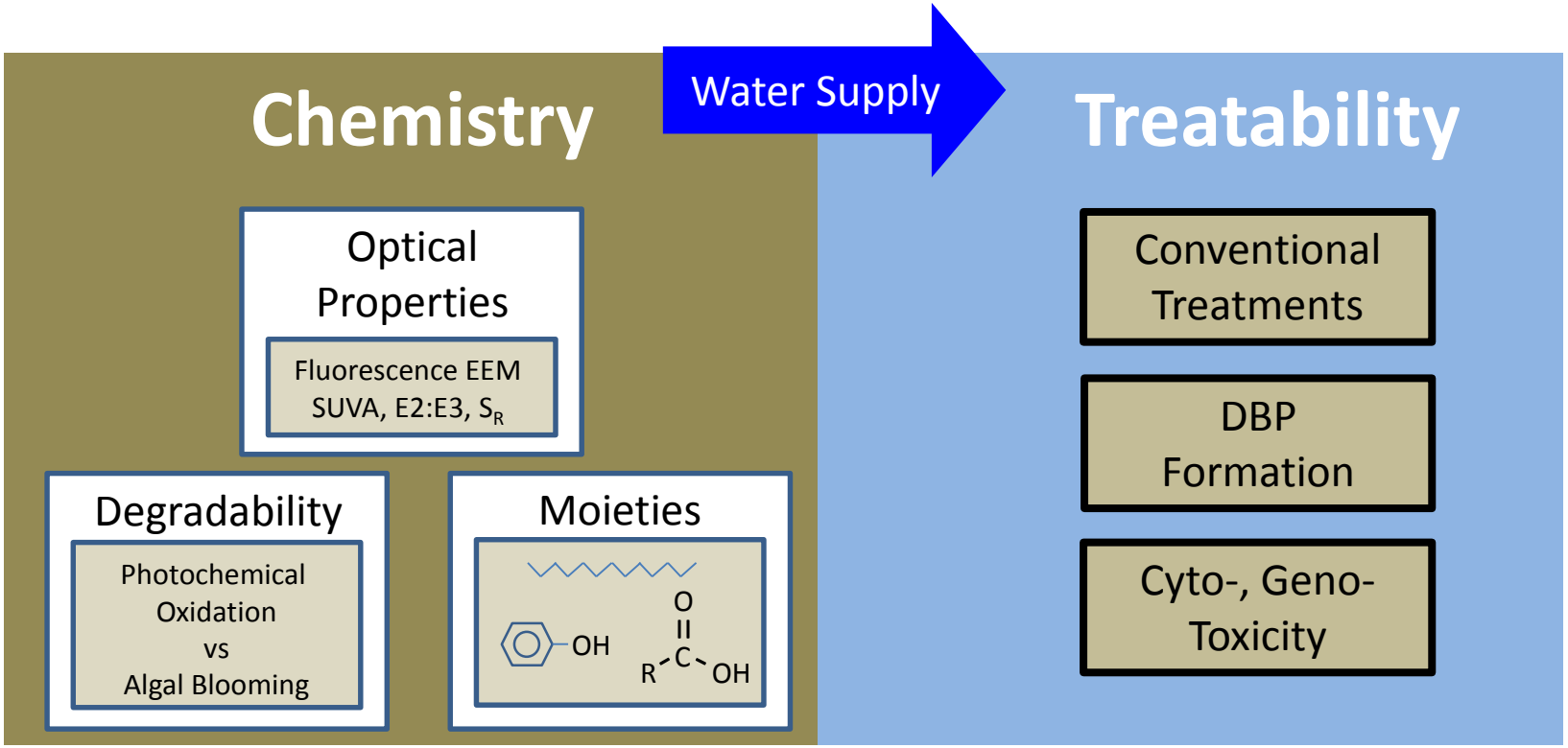
III. Treatability
- Conventional Treatments on DOM removal
- DBP Formations

III. Water Quality – Treatability

Task 7 – Quantify and characterize the removal of DBP precursors by conventional water treatment processes

Task 8 – Determine formation potentials and speciation of carbonaceous and nitrogenous DBPs upon chlorination and chloramination of DOM leachates

Task 9 – Calculate the change in the cyto- and geno-toxicity of source waters from different watershed management practices



III. Water Quality – Treatability

Approach:

Samples from above mentioned experiments will be fully characterized as follows:

General Water Quality

1) Electrical Conductivity, pH, Turbidity, etc.
2) Nutrients (e.g. nitrate, ammonia, etc.)
3) Cations (e.g. Na, K, Ca, Mg, etc.)
4) Anions (e.g. Cl, SO_4^{2-}, CO_3^{2-}, etc.)

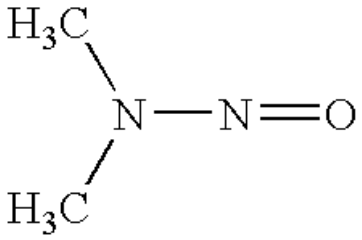
III. Water Quality – Treatability

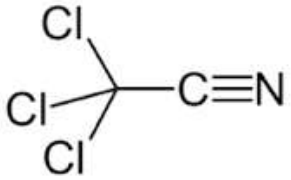
DBP Formation & Treatability

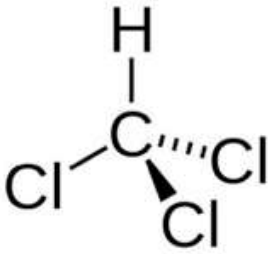
1) Al and Fe Coagulation
2) DBP Tests – UFC & Formation Potentials
3) Chlorination, Chloramination & Other Disinfection Processes

DBP Species

1) Trihalomethane (THM)
2) Haloacetic acid (HAA)
3) Haloacetonitrile (HAN)
4) Chloral Hydrate (CHD)
5) N-Nitrosodimethylamine (NDMA)
6) Total Organic Halide (TOX)



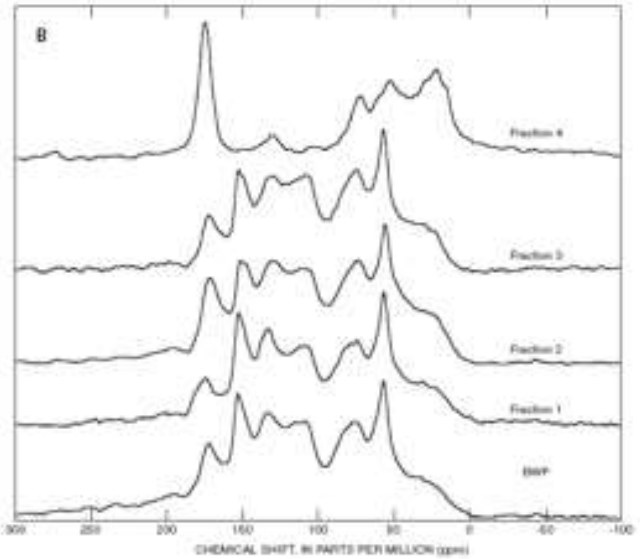


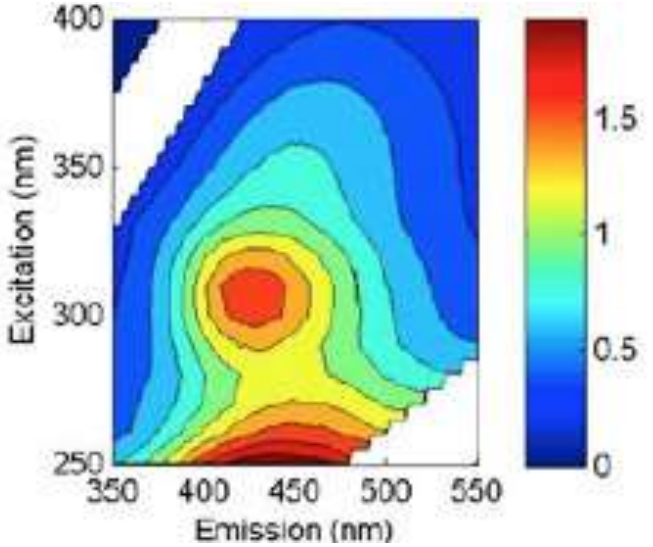


III. Water Quality – Treatability

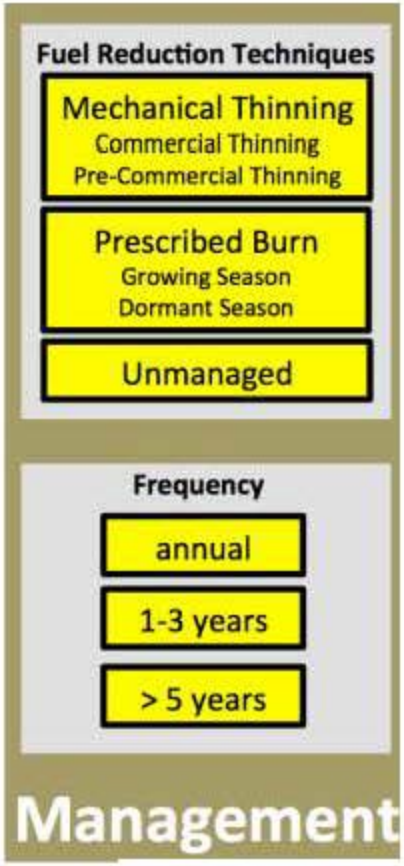
DOM Characterization

1) UV/VIS Absorbance
2) Fluorescence Emission-Excitation Matrix
3) Pyrolysis-Gas Chromatography-Mass Spectrometry
4) Fourier Transform Ion Cyclotron Resonance Mass Spectrometry (FT-ICR-MS)
5) Nuclear Magnetic Resonance (NMR)
6) Dissolved Black Carbon





Box Model


Fuel Reduction Techniques
Mechanical Thinning
Commercial Thinning
Pre-Commercial Thinning
Prescribed Burn
Growing Season
Dormant Season
Unmanaged
Frequency
annual
1-3 years
> 5 years
Management

Extension & Education

Extension Partners

Clemson Public Service Activities / Extension
Southern Fire Exchange
Water Research Foundation

Formats:

Web Pages & Fact Sheets
Workshops & Field Tours
Webinars
Continue Education Units

Target Audiences

Foresters & Forestry Technicians
Water Engineers & Treatment Operators
End Users & General Publics
Land Owners
State & Regulatory Agencies

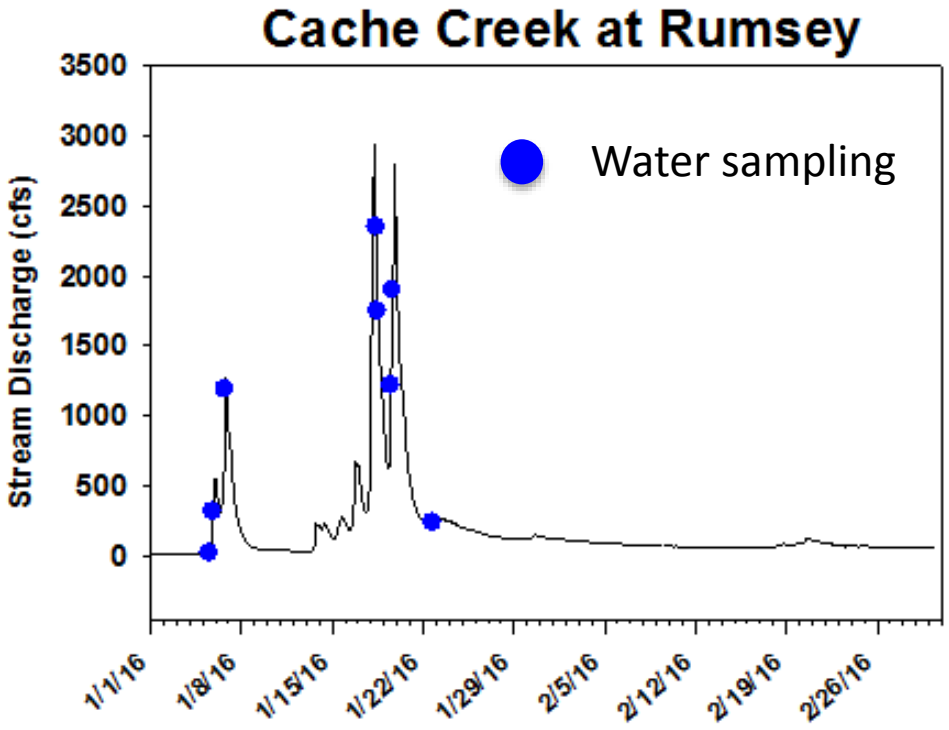
Field Demonstrations

1) Experimental plots at Yawkey Wildlife Center (Georgetown)
2) Experimental plots at Hobcaw Barony (Georgetown)
3) Experimental Watersheds at Francis Marion National Forest (Charleston)
4) Experimental Watersheds at Clemson Experimental Forest (Clemson)

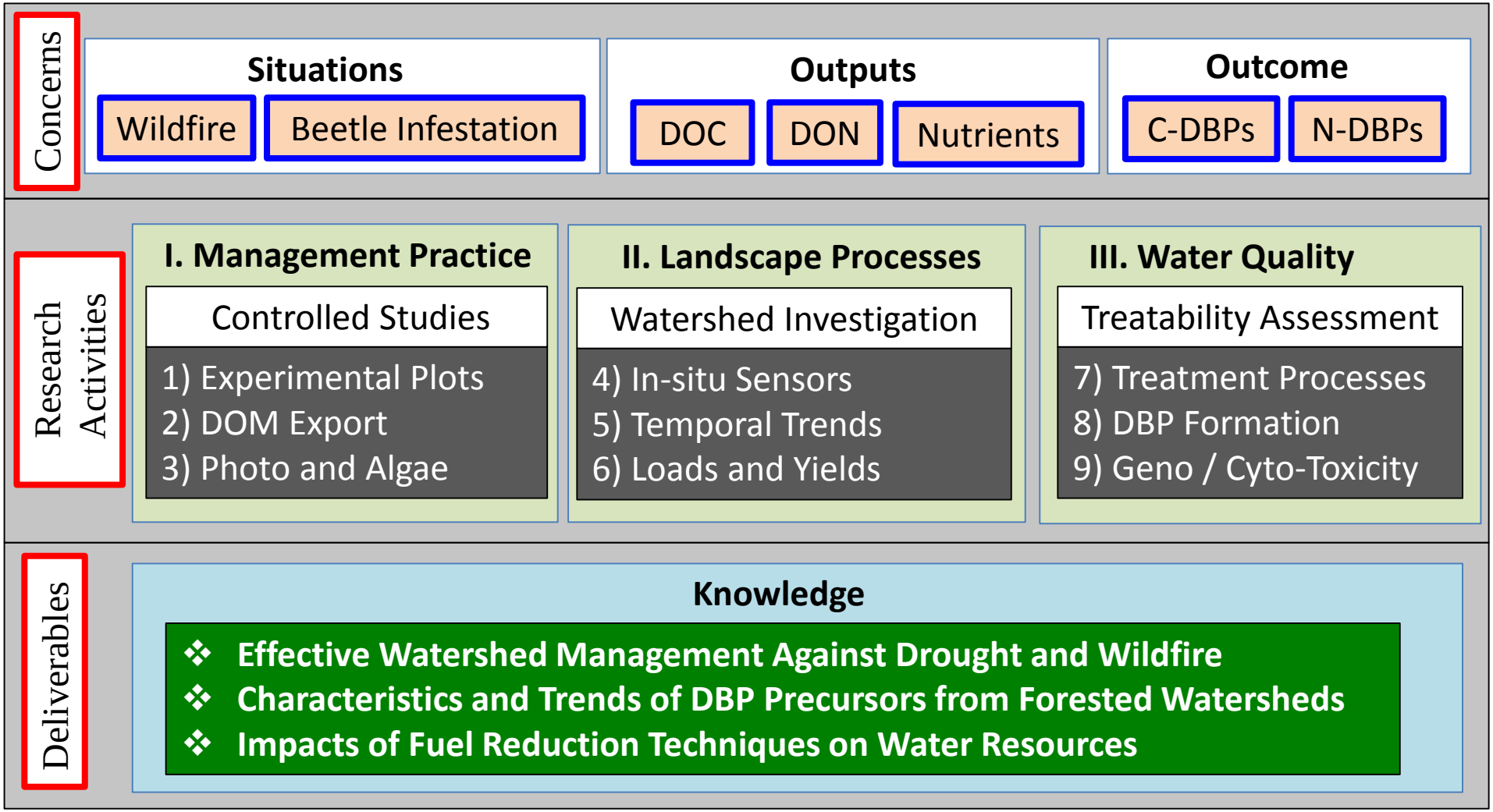
Other Related On-Going Researches

California Wildfire in Summer 2015

Wragg Fire Field Sampling



Project Overview



Acknowledgment

Randy Dahlgren
University of California, Davis

Jamie Dozier
SC Department of Natural Resources

Carl Trettin
US Forest Service

U.S. EPA National Priorities Extramural Research Grants Program

Grant # 83586401

Thank You!!

Questions?