Biodegradable Plastic Mulch

USDA SCRI Project No. 2014-51181-22382

Douglas Hayes (PD), Annette Wszelaki, Jennifer DeBruyn, Markus Flury, Eric Belasco, Sean Schaeffer, Arnold Saxton, Susan Schexnayder, Margarita Velandia, Larry Wadsworth, Mark Fly, Carol Miles, Debra Inglis, Thomas Marsh, Jessica Goldberger, Suzette Galinato, Chris Benedict, Jeremy Cowan, Peter Tozer, Andy Bary, Lydia Tymon, Courtney Lyons, Jennifer Moore, Amy Salamone, Babette Gunderson, Ed Scheenstra, Jacky King, Marie English, Sreejata Bandopadhyay, Nurul Farhana Omar, Shuresh Ghimire, Henry Sintim, Kuan Chen

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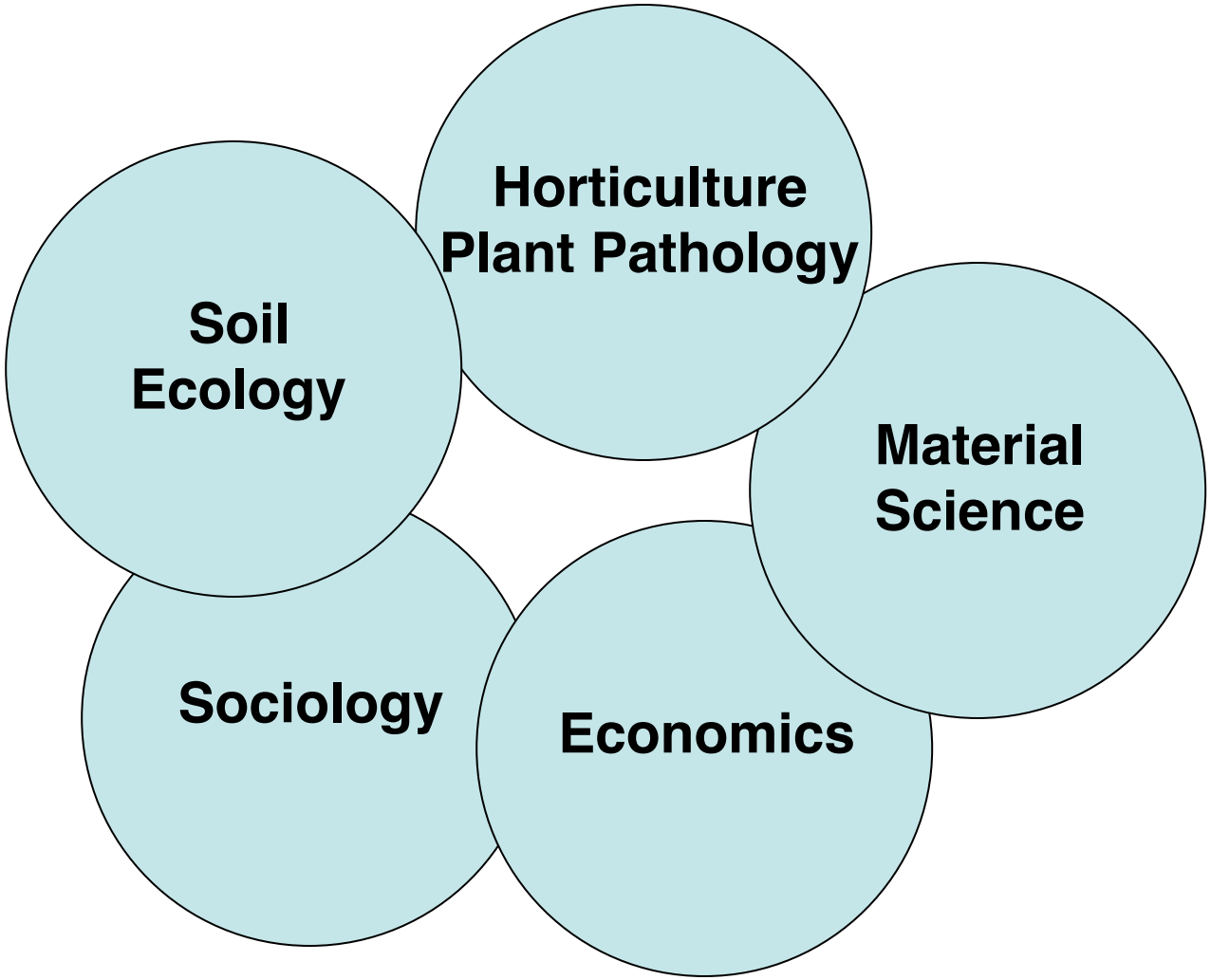
Overall Research Project



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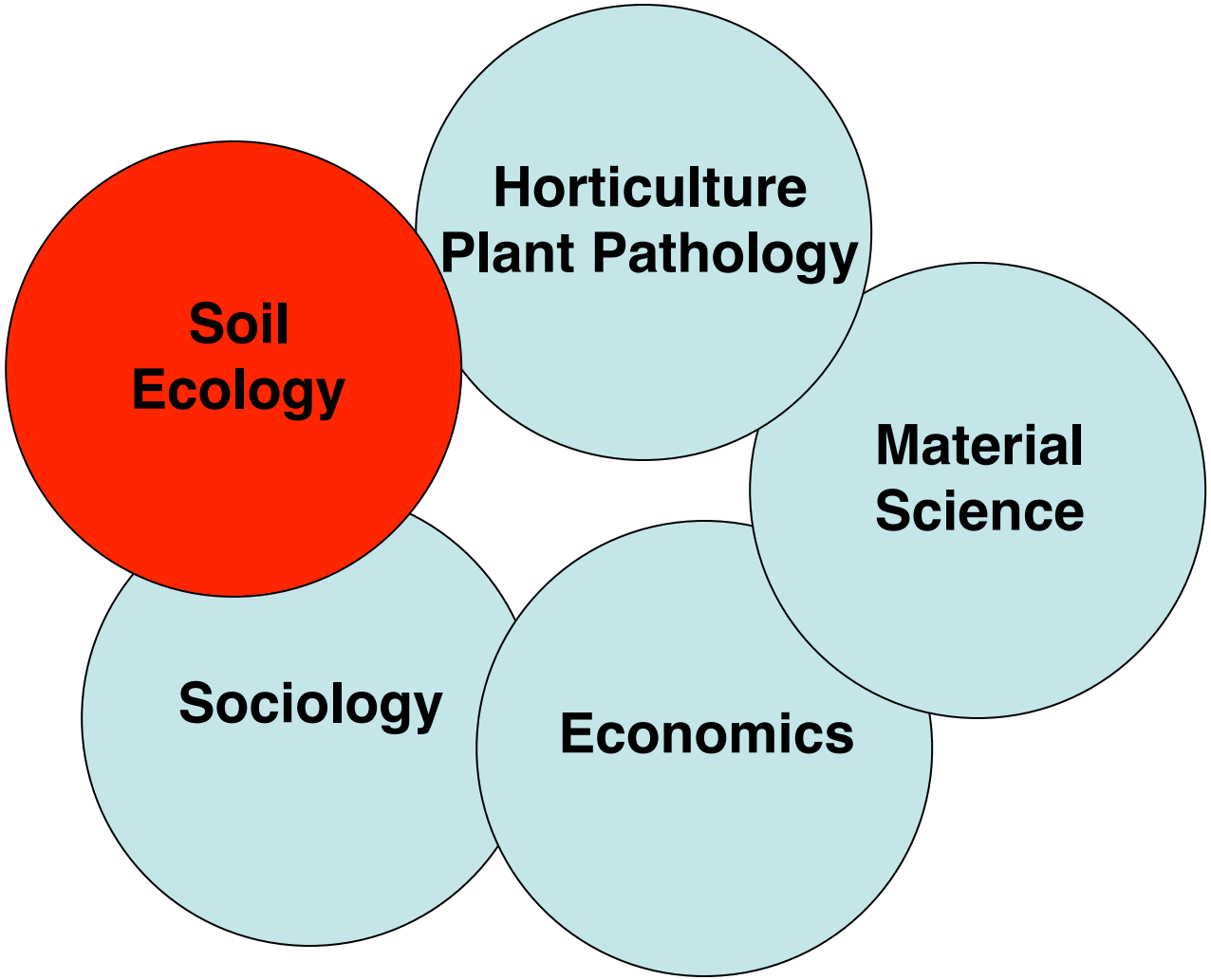

Field Experiment

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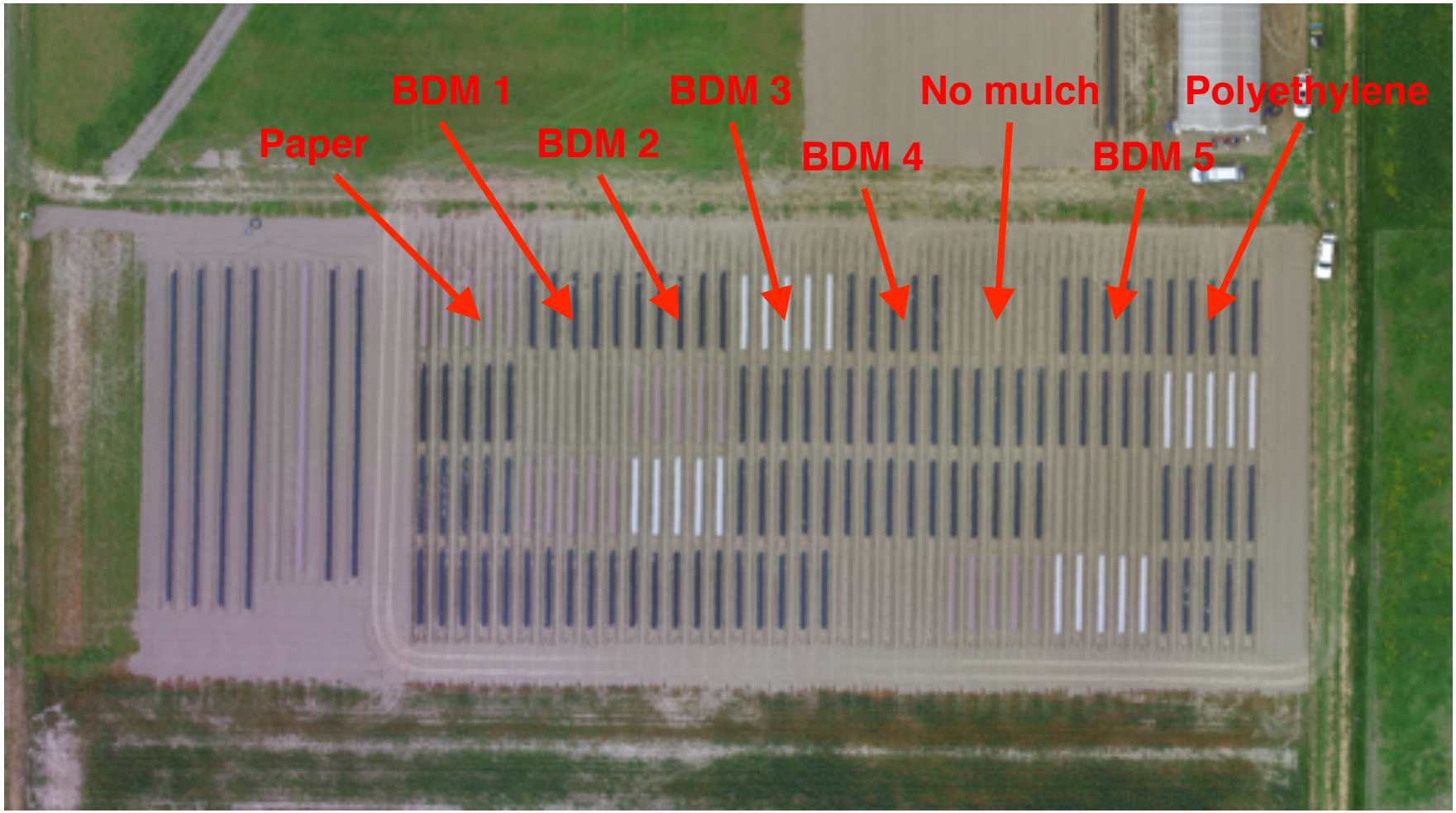


Biodegradable Plastic

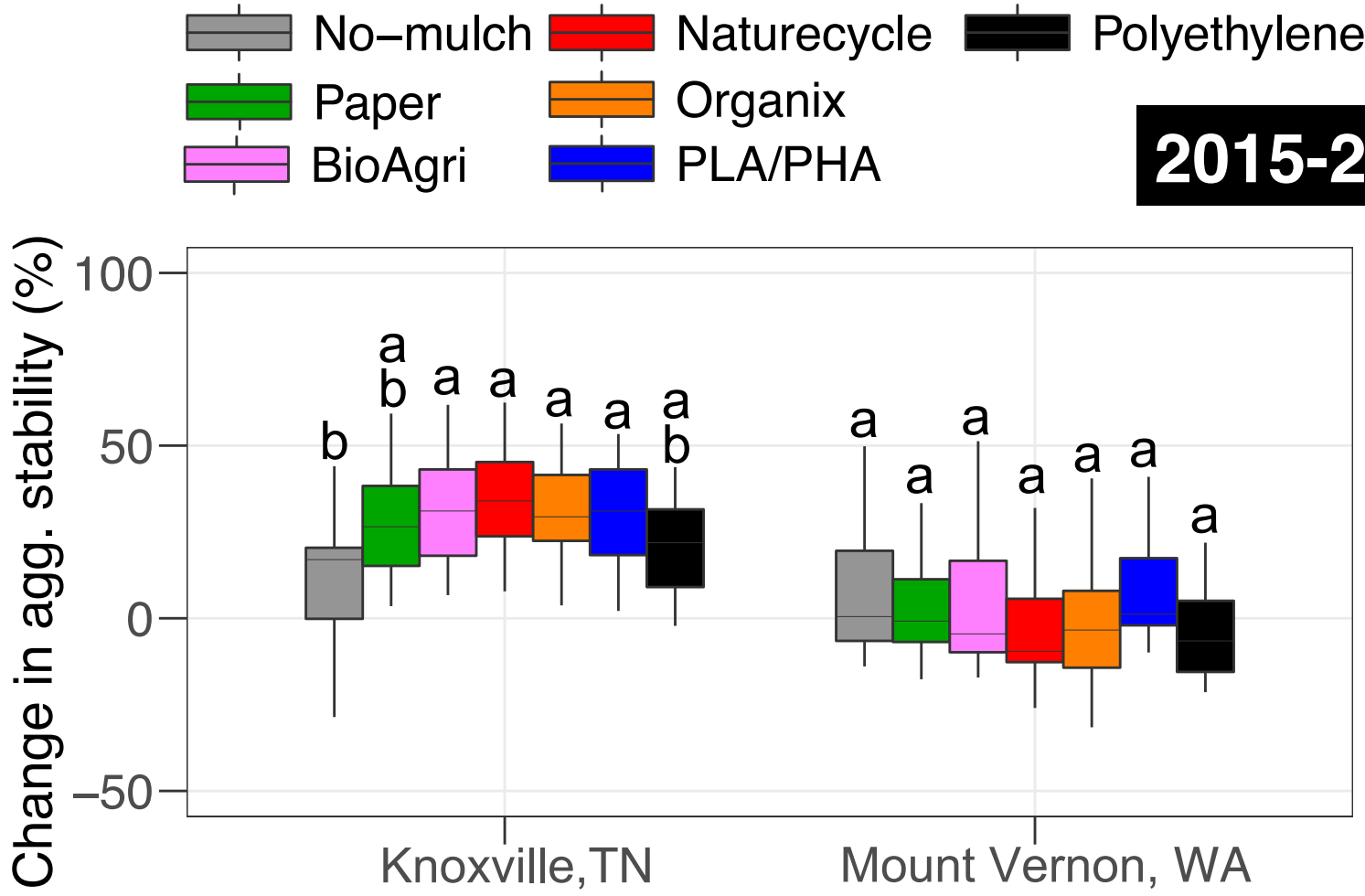
Questions:

1. Does biodegradable plastic affect soil health?

2. Does biodegradable plastic degrade completely in soil?

3. Are residues released during degradation?

Soil Health Assessment

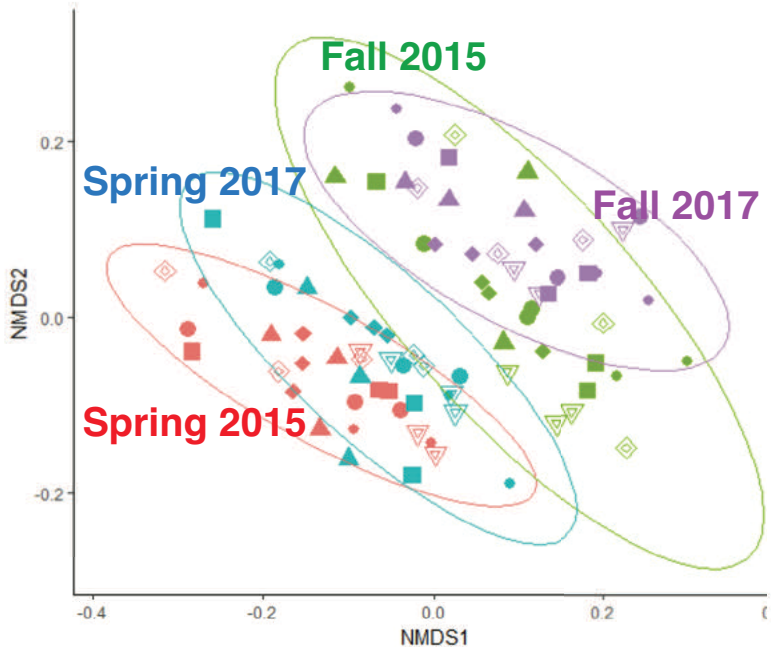


Aggregate Stability

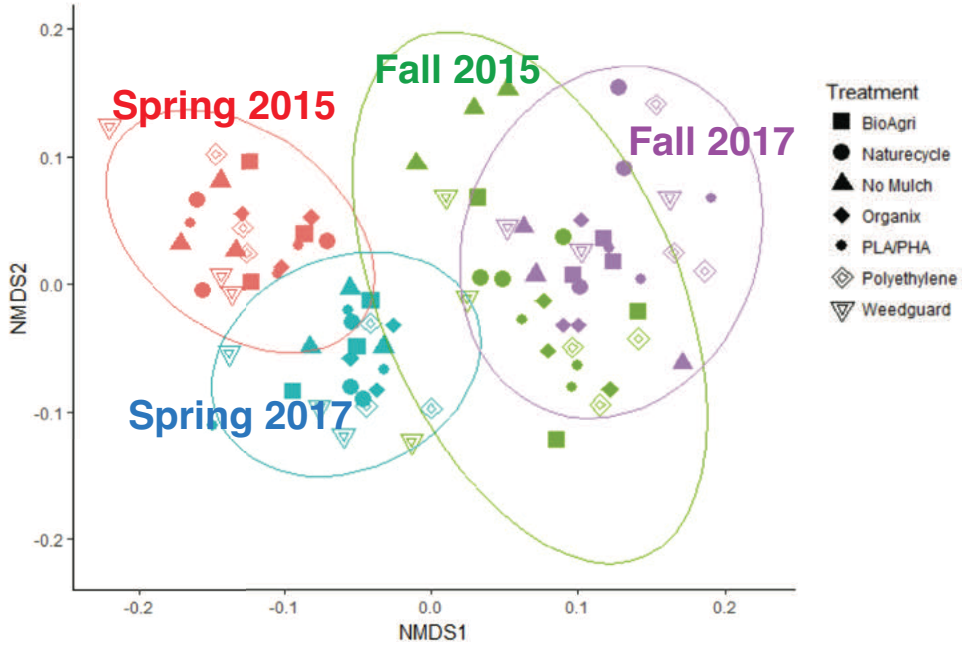
Soil Health Assessment

2015-2017

Tennessee



Washington



Microbial Communities

Biodegradable Plastic Mulches

1. Similar agronomic benefits
2. No short-term effects of mulches on soil health
3. Seasonal changes more pronounced than mulch effects
4. Soil health is a slow changing process

→ long-term study needed

Biodegradable Mulch Film Basics

Ramani Narayan (narayan@msu.edu)
MSU University Distinguished Professor

QUESTIONS

1. **What is the effect on overall soil health, including soil biology, when this material biodegrades**

2. **What is the cumulative effect of the continued use of this biodegradable biobased mulch film, on soil nutrient balance, soil biological life, and soil tilth, when used in the same area of the field for 3-5-10 years?**

3. **What effect does the breakdown of these polymers have on soil and plant life as well as livestock that would graze either crop residues or forages grown the subsequent year after this mulch film was used?**

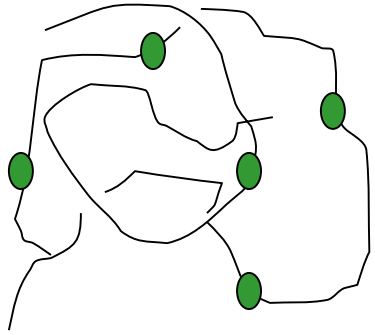
4. **Are there different cropping systems, climate, soil types or other factors that affect the decomposition rate (Examples would be long cold winters, or exceptionally dry conditions, such as found in a desert)?**

5. **Are there metabolites of these mulches that do not fully decompose, and if so, is there an effect upon soil health or biological life?**

6. **Can you provide information on the existence or development of biobased biodegradable mulch films that would meet the requirements of NOP policy memorandum 15-1?**

What does "Biodegradable" Mean?

Can the microorganisms in the target disposal system (composting, soil, anaerobic digestor) assimilate/utilize the carbon substrate as food source completely and in a short defined time period?

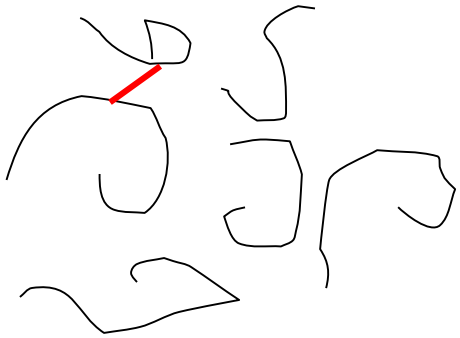


Polymer chains with susceptible linkages

Environment – soil, compost, waste water plant, marine

Hydrolytic
Oxidative
Enzymatic

STEP 1



Oligomers & polymer fragments

STEP 2

Complete microbial assimilaton

defined time frame, no residues

Biodegradation(Step 2): Only if all fragmented residues consumed by microorganisms as a food & energy source as measured by evolved CO_2 in defined time and disposal environment

$CO_2 + H_2O$ + Cell biomass

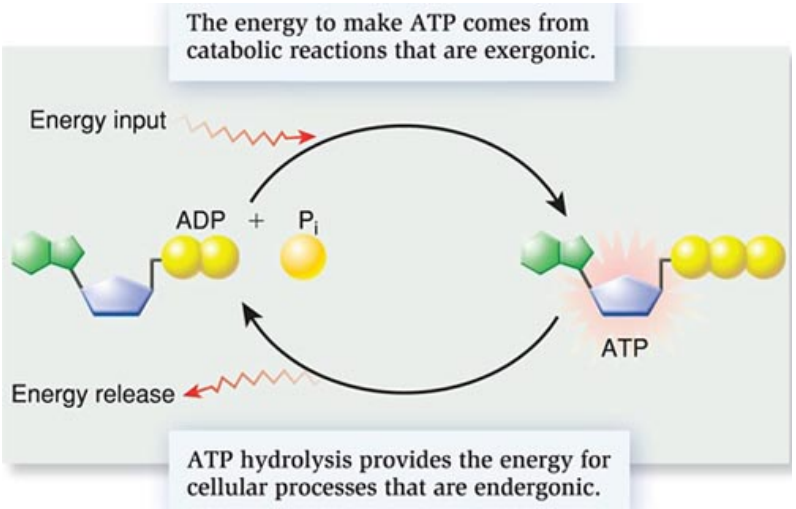
Basics of microbial utilization -- biodegradability

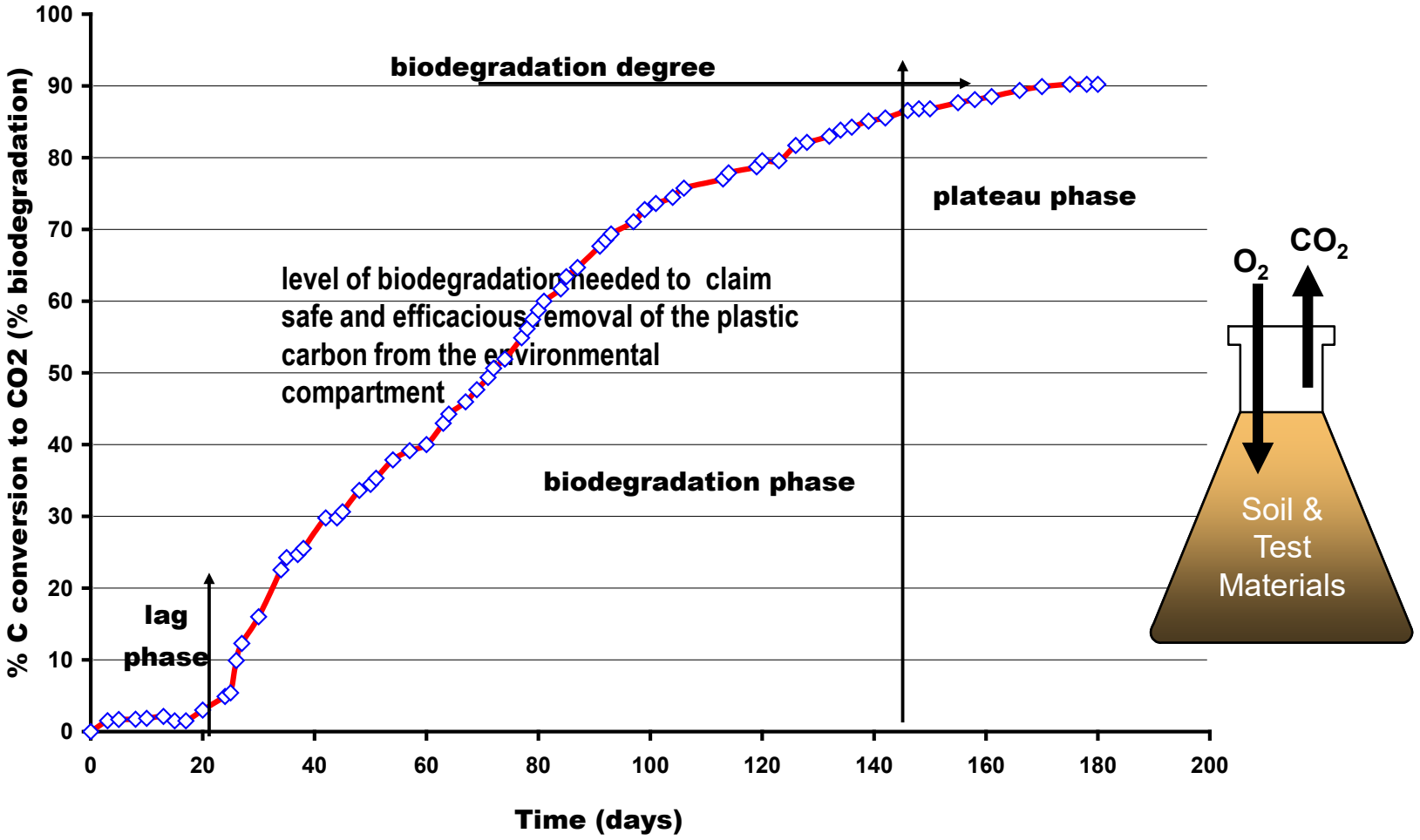
- Microorganisms utilize carbon substrates as "food" to extract chemical energy for their life processes.
- They do so by transporting the C-substrate inside their cells and:
- Under aerobic conditions, the carbon is biologically oxidized to CO_2 releasing energy that is harnessed by the microorganisms for its life processes. Under anaerobic conditions, CO_2+CH_4 are produced.
- Thus, a measure of the rate and amount of CO_2 or CO_2+CH_4 evolved as a function of total carbon input to the process is a direct measure of the amount of carbon substrate being utilized by the microorganism (percent biodegradation)

Glucose/C-bioplastic + 6 O_2 ⟶ 6 CO_2↑ + 6 H_2O; $\Delta G^{0'}$ = -686 kcal/mol

Glucose/C-bioplastic ⟶ 2 lactate; $\Delta G^{0'}$ = -47 kcal/mol

2 lactate ⟶ CO_2 + CH_4↑





ASTM D5988; ISO 17556 -- Soil biodegradability test method

EN 17033 – soil biodegradability specifications for biodegradable mulch film

CAUTION!!!

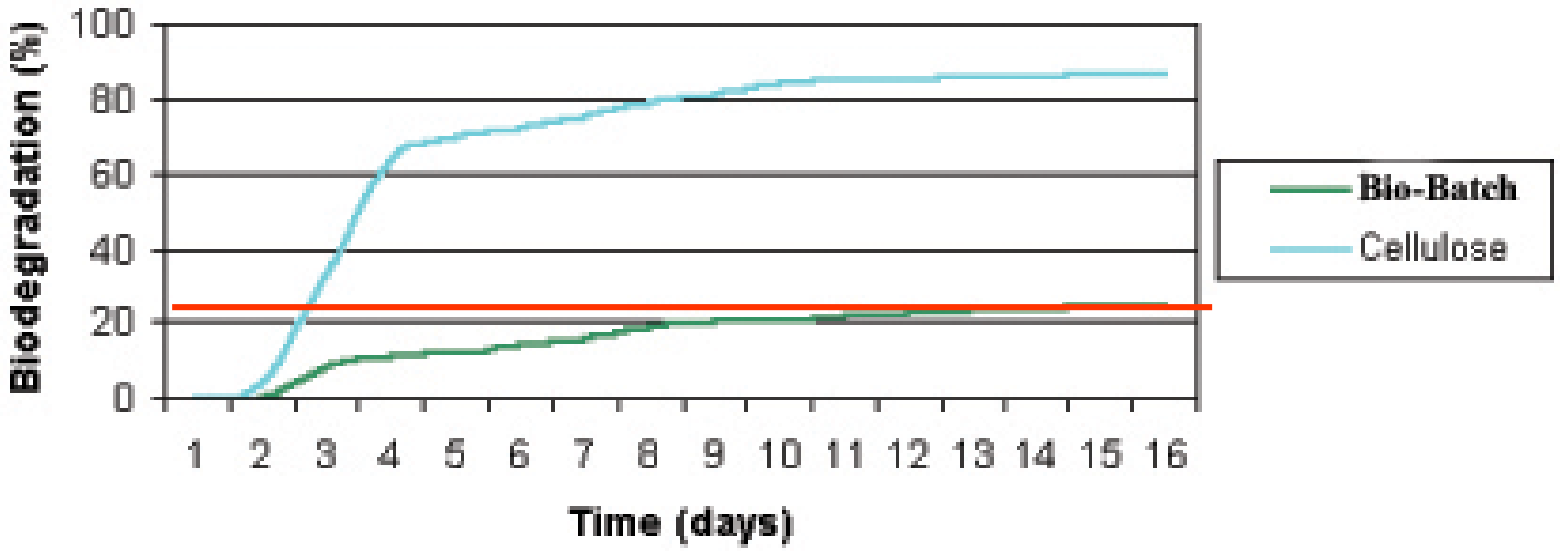
Unqualified use of the term "biodegradable" is wrong, misleading, and deceptive. It violates the law in the State of California and U.S. Federal Trade Commission (FTC) green guides **& in Australia too**

- **Need to define disposal environment, time/rate and extent of biodegradation – qualified biodegradability claim**
  - **Soil biodegradability (mulch films & ag products)**
  - **Compostable plastics -- enabler for food and organic waste diversion from landfills to composting**

- Need complete microbial assimilation and removal from the environmental compartment in a short time period otherwise may have environmental and health consequences
  - Degradable, partial biodegradable not acceptable – serious health and environmental consequences
    - Phil. Trans. Royal. Soc. (Biology) July 27, 2009; 364

Misleading (Green Washing) Claims -- Additive Technology

- ***"Plastic products with our additives at 1% levels will fully biodegrade in 9 months to 5 years wherever they are disposed like composting, or landfills under both aerobic and anaerobic conditions"***



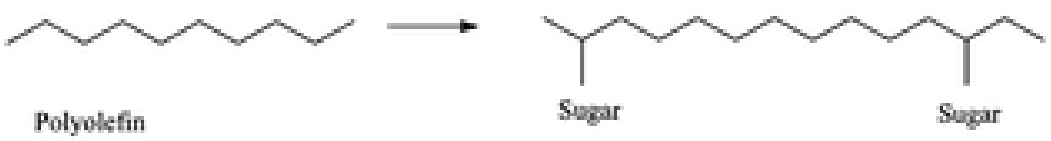
The 50% Bio-Batch film did not degrade as completely or as quickly as the cellulose. At the end of the test, 19% of the film had degraded.

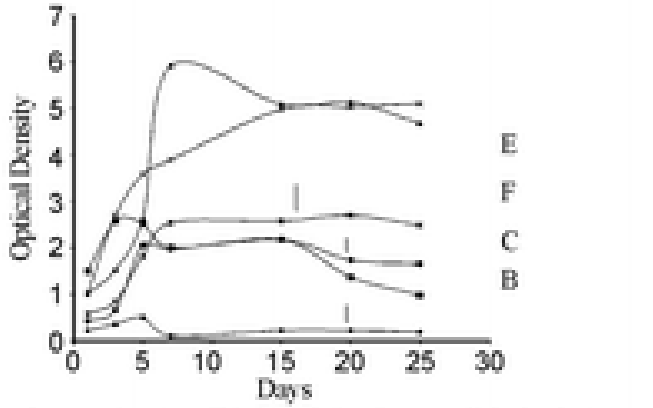
The results of the aerobic degradation tests indicate that, in time, plastics produced using Bio-Batch pellets will biodegrade in aerobic conditions.

DATA DOES NOT SUPPORT THE CONCLUSIONS!

MISUSE OF BIODEGRADABILITY CLAIMS

- ***Chem. Commun.***, 2002, (23), 2884 - 2885
  - A hypothesis was developed, and successfully tested, to greatly increase the rates of biodegradation of polyolefins, by anchoring minute quantities of glucose, sucrose or lactose, onto functionalized polystyrene (polystyrene-co-maleic anhydride copolymer) and measuring their rates of biodegradation, which were found to be significantly improved
- PRESS
  - **Sugar turns plastics biodegradable.** Bacteria make a meal of sweetened polythene and polystyrene.





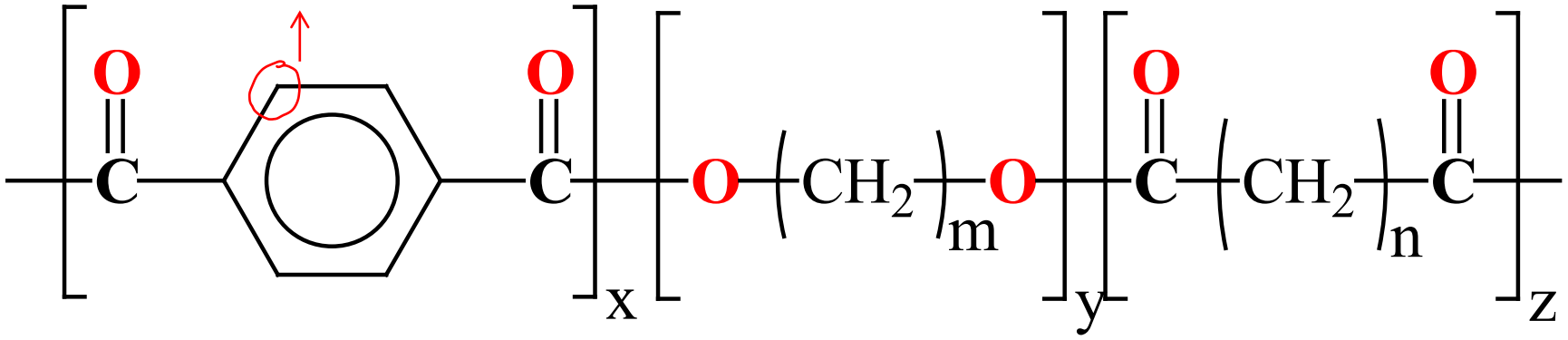
Increase in rates of biodegradation for sugar linked polystyrene

weight loss of only 2-12%,

Only sugar is being assimilated, PE chain intact – Is this a genuine example of biodegradable plastic?

Aliphatic-aromatic copolyester

C-14 label on aromatic carbon – the most recalcitrant component



Terephthalic acid Diol Aliphatic diacid

Copolyester

T_m ~ 110 -125 ^{0}C

Completely Biodegradable (microbial assimilation) under composting conditions

BASF
KingFa
Showa
Mitsubishi
Novamont

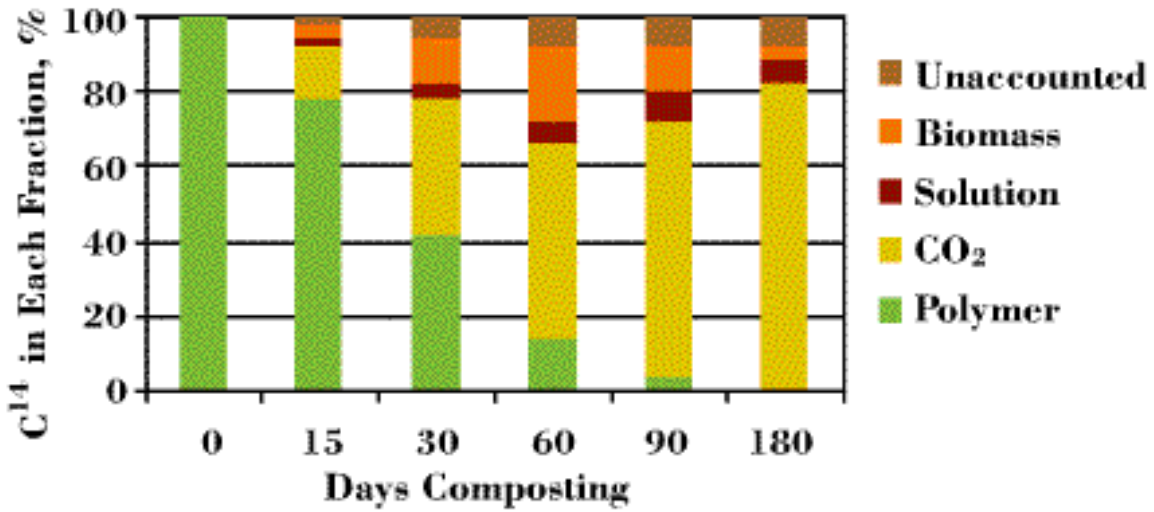
Biodegradability/Composting Data

Profile of BioPlast Film T-101

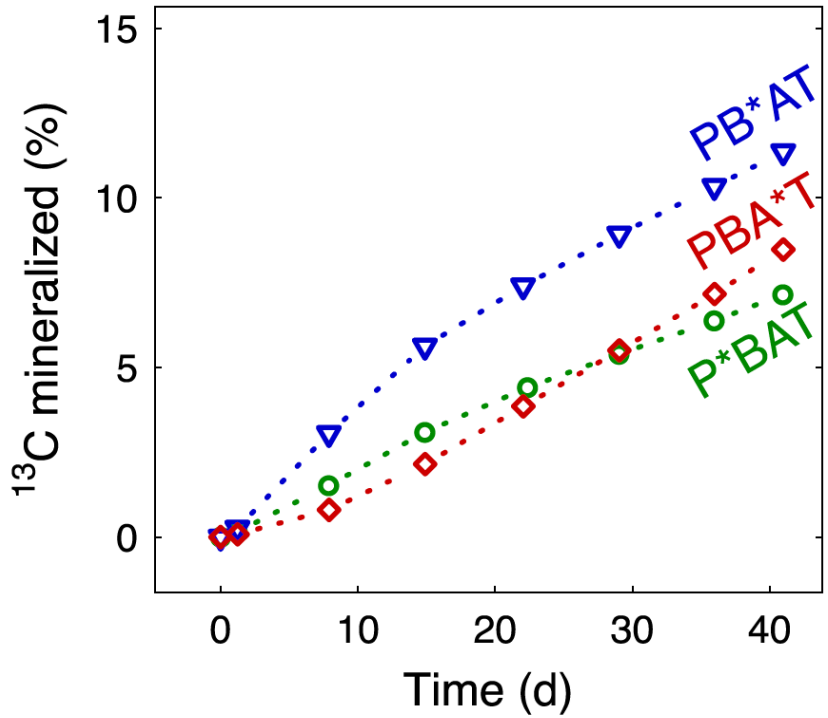
Aliphatic-aromatic copolyester

Carbon Balance

Using ASTM D6340 and Carbon^{14} techniques, very accurate collection of data and a carbon balance are possible for BioPlast Film T-101 . Standard respirometer methods may incorporate >20% "priming" error.

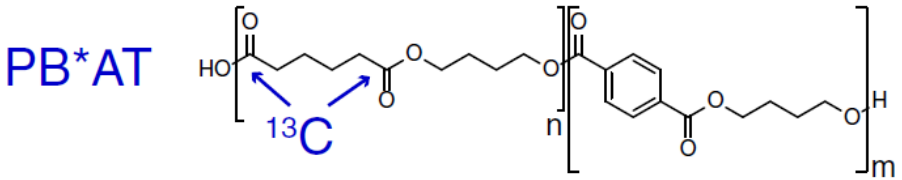


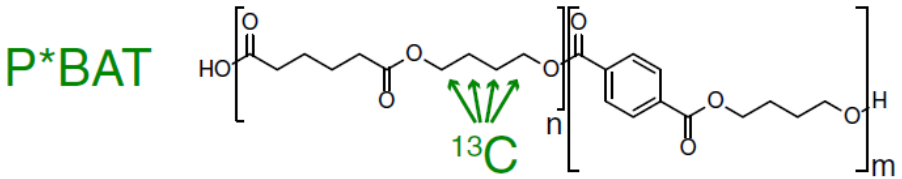
Aromatic ring carbons, the most recalcitrant component is assimilated by the compost microorganisms as seen by evolution of the C-14 carbon dioxide

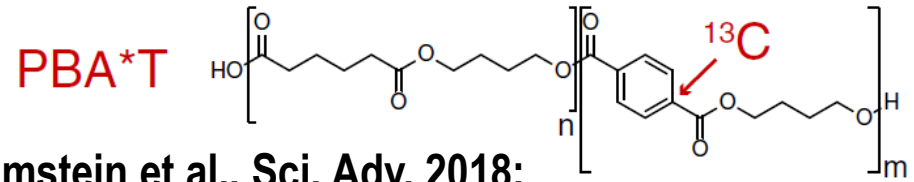


"Carbon from each monomer unit of PBAT was used by soil microorganisms, including filamentous fungi, to gain energy and to form biomass"

Biomass refers to cellular biomass – PBAT carbons incorporated into lipid molecules







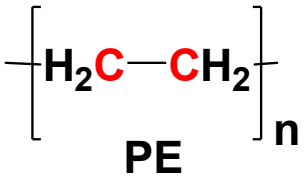
Zumstein et al., Sci. Adv. 2018;

Narayan

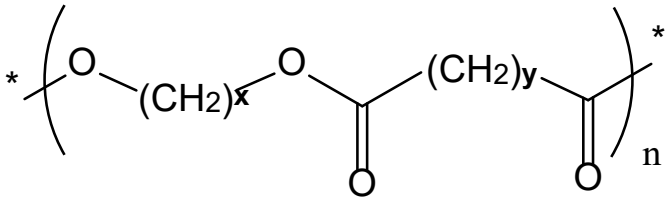
BASICS -- TERMINOLOGY

Biobased plastics/products refers to the "beginning of life"

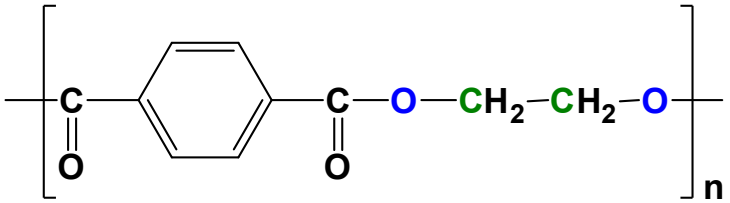
- **Origins of the carbon in the polymer**
- **Plant-biomass feedstock (biobased) vs petro-fossil feedstock**



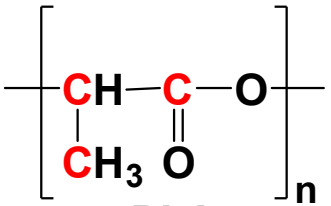
PE



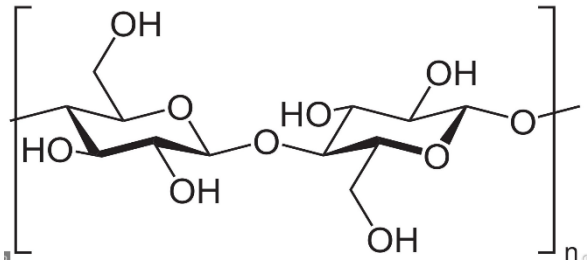
Biobased polyester



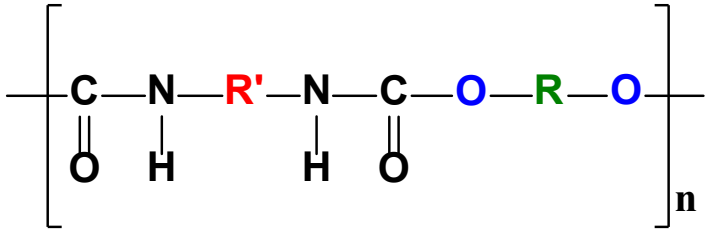
PET



PLA



Cellulose



Biobased polyurethane

WHY BIOBASED??

What are the benefits of replacing petro/fossil carbon with biocarbon?

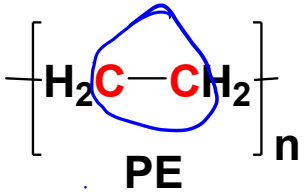
- **Reduced carbon footprint**
- **Food security and creating value for rural agrarian economy**
- **Create "wealth" in rural agriculture through value-added industrial products**

CAUTION:

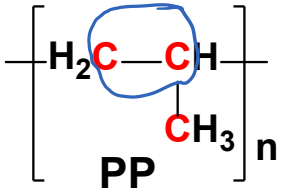
Need to still address the issue of end-of-life

mechanical, chemical, biological/organic recycling

Understanding "BIOBASED & BIODEGRADABILITY" at Molecular level



PE



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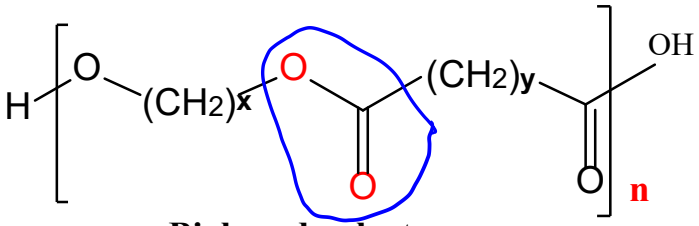
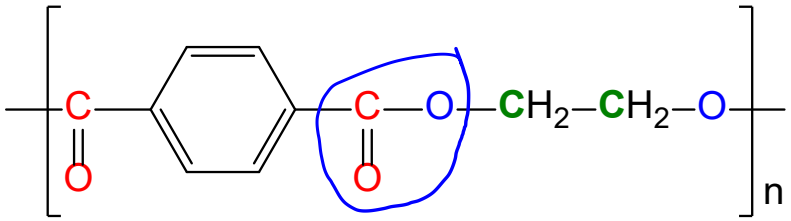
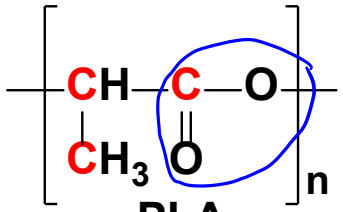


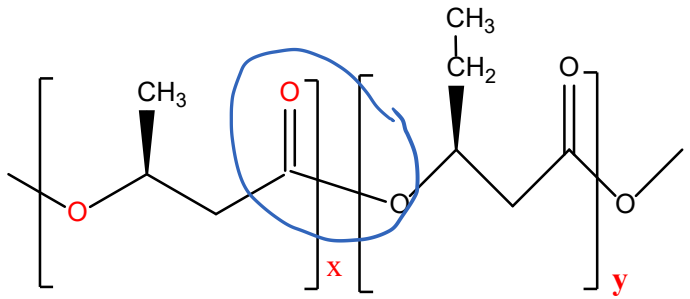
Biobased polyeter



BIO-PET



PLA



PHBV -- poly(3-hydroxybutyrate-co-3-hydroxyvalerate)

PHAs

Biobased Plastics are NOT necessarily biodegradable/compostable

Biodegradable-Compostable Plastics are NOT necessarily Biobased

Thank You