Biochar derived from pyrolysis of common agricultural waste feedstocks and co-pyrolysis with low-density polyethylene mulch film

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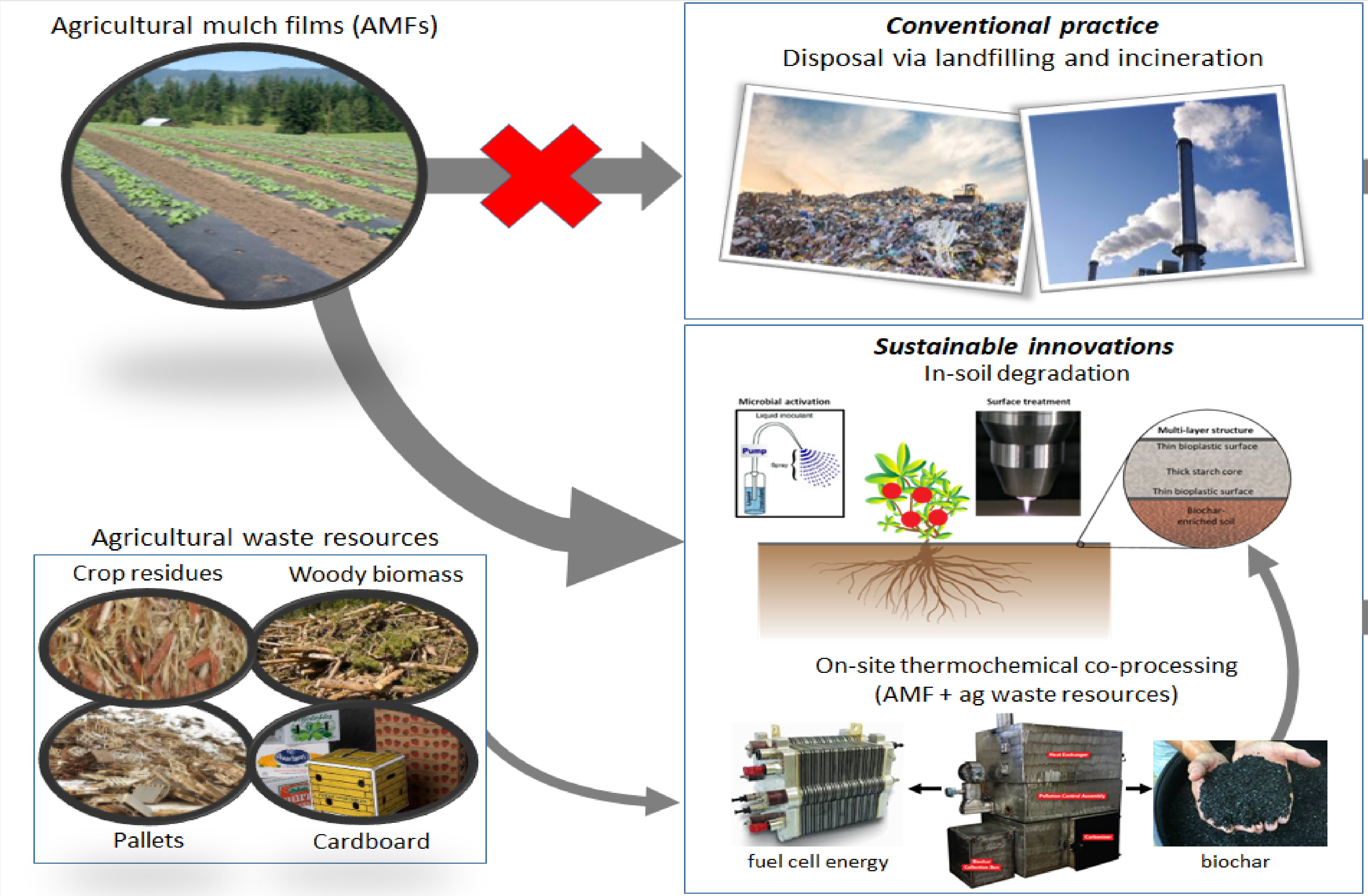
Background

- Different types of biomass-based waste streams available on farms are not converted into value-added products.
- Plastic agricultural mulch film (AMF) is used for many row crops, to control weeds, insects and soil moisture. However, at the end of the growing season, AMF is typically collected and disposed of via landfilling or incineration
- Pyrolysis may offer a more sustainable option by transforming mixed agricultural wastes into biochar.

Foundation for Food & Agriculture Research (FFAR) project “*Degradable mulch films for sustainable agriculture*”



Costs to society

- Tipping fees and transport costs for growers
- Degraded soil health
- Emissions to land, air and water

Benefits to society

- Reduced farm operating costs
- Improved soil health
- Reduced emissions to land, air and water
- Minimize petroleum-based plastic use
- Carbon sequestration
- Renewable energy production

Research Questions

1. What are the properties of biochar produced by pyrolysis of common agricultural biomass wastes?

2. How do these properties change when biomass wastes are co-pyrolyzed with low-density polyethylene (LDPE) agricultural mulch film [$(C_2H_4)_n$]?

3. Is biochar generated from co-pyrolysis of agricultural residues and LDPE suitable for soil amendment?

4. What are the potential economic benefits of farm-based system for converting agricultural residues into biochar with and without the addition of AMF material.

Method: Biochar Production

Biomass wastes

LDPE mulch Film

500 to 800^{o}C

Blend ratios
100:0
95:5
75:25

High temperature furnace

Biochar

International Biochar Initiative (IBI) protocol Control Laboratories (Watsonville, California, USA)

- Physical properties: Moisture content, bulk density, hydrogen-to-carbon ratio (H:C), total ash, total N, pH, electrical conductivity (EC), specific surface area via butane activity.

- Basic soil enhancement properties: Volatile matter, organic nitrogen (Org-N), phosphorus (P), potassium (K), nitrate (NO_3), ammonia (NH_4)

- Metal composition: Arsenic, cadmium, copper, mercury, zinc, chlorine, sodium, iron, manganese, etc.

Selected physical properties and yield of biochar derived from pyrolysis of waste biomass materials

[WP = wood pellets; HB = hammer milled box board; PW = pallet wood]

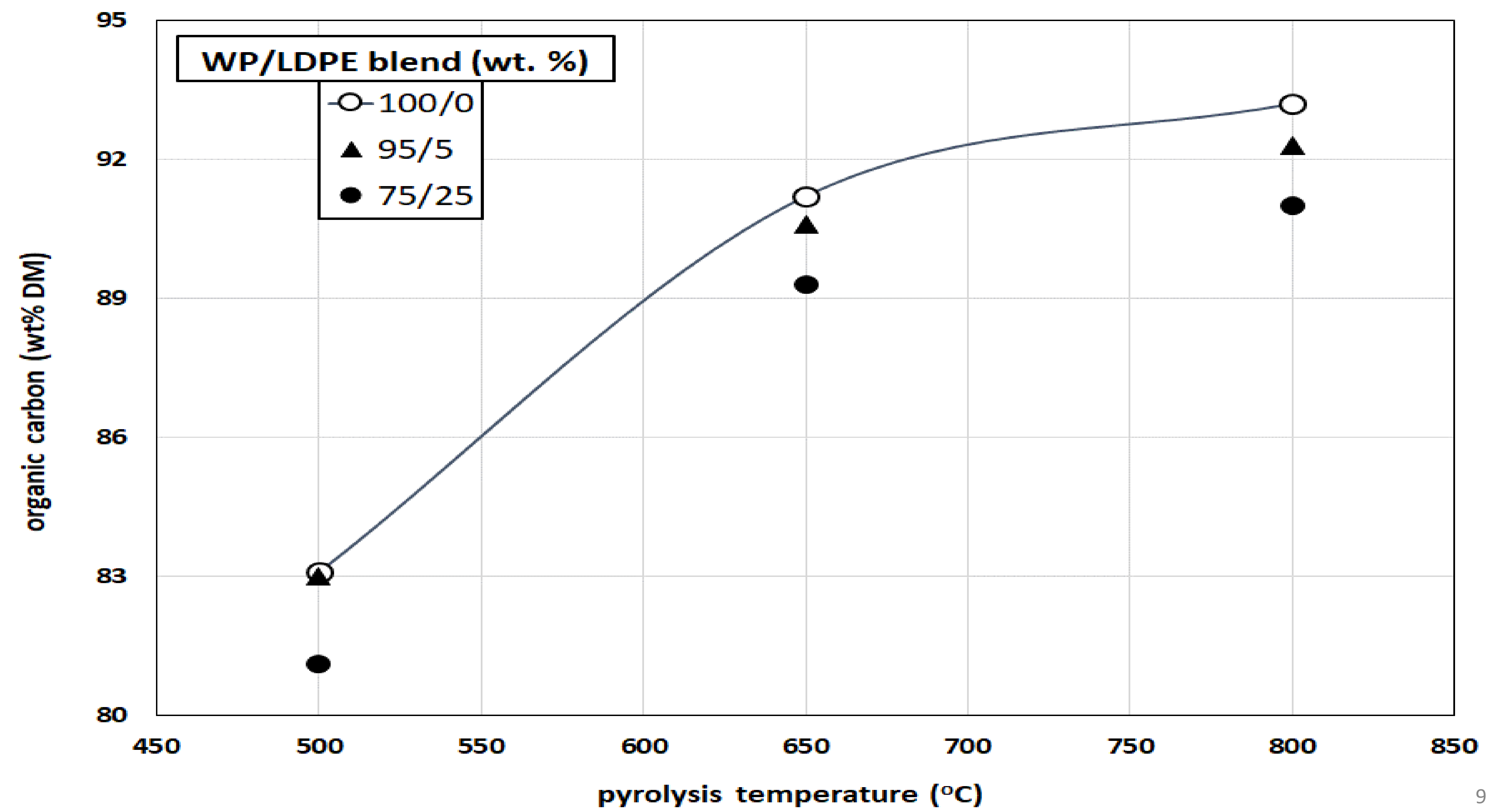
Feedstock	Temp (°C)	Average yield (%)	Total ash (%)	Bulk density (kg/m^3)	H:C	pH	EC (dS/m)	SSA (m^2/g dry)
Raw WP	-	-	0.6	346.0	1.43	12.37	0.11	154
WP	500	27.6	1.4	233.9	0.56	4.40	0.11	207
WP	800	21.9	1.6	249.9	0.23	5.93	0.49	118
Raw HB	-	-	3.7	49.7	2.35	7.91	0.34	203
HB	500	28.0	2.2	126.5	0.66	7.24	0.10	205
HB	800	22.0	16.0	40.0	0.40	12.0	6.52	215
PW	500	28.0	2.2	126.5	0.66	7.24	0.10	205
PW	800	25.0	3.8	152.2	0.26	11.3	1.38	149

Note: Raw pallet wood (PW) was not characterized because of a lack of feedstock material.

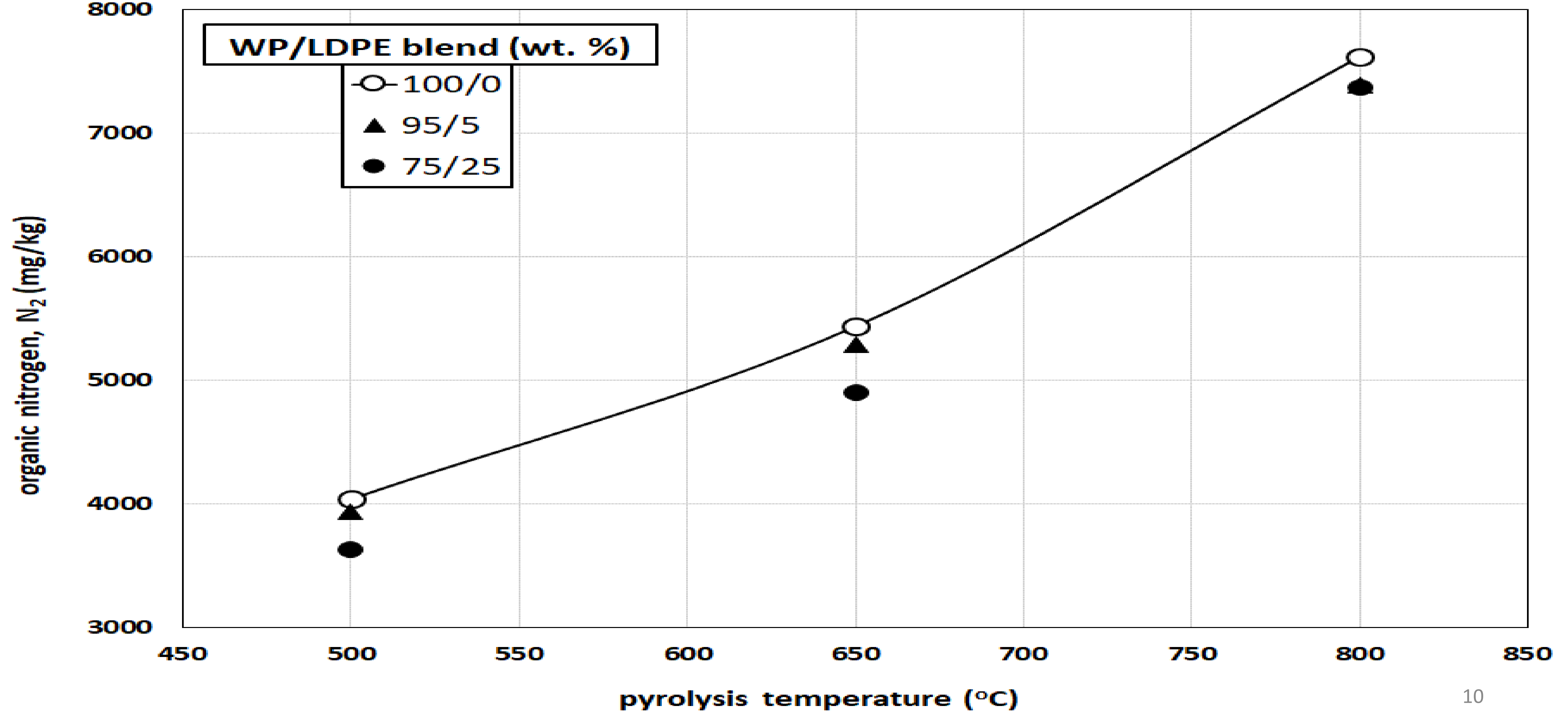
Selected physical properties and yield of biochar derived from co-pyrolysis of wood pellets (WP) with low-density polyethylene (LDPE) mulch film

WP/LDPE ratio	Temp (°C)	Average yield (%)	Total ash (%)	Bulk density (kg/m^3)	H:C	pH	EC (dS/m)	SSA (m^2/g dry)
100/0 Biomass only	500	27.6	1.4	233.9	0.56	4.40	0.11	207
95/5	500	23.4	1.9	213.0	0.52	11.1	0.12	237
75/25	500	20.7	3.2	289.9	0.54	10.5	0.14	238
100/0 Biomass only	800	21.9	1.6	249.9	0.23	5.93	0.49	118
95/5	800	20.6	2.3	233.9	0.23	7.22	0.52	133
75/25	800	18.6	3.6	262.7	0.24	8.04	1.09	131

Effect of co-pyrolysis temperature on organic carbon content (wt% DM) for wood pellet (WP) feedstock with different LDPE blend ratios



Effect of co-pyrolysis temperature on organic nitrogen content (mg/kg) for wood pellet (WP) feedstock with different LDPE blend ratios



Techno Economic Analysis (TEA) of farm based co-pyrolysis system

Roberts et al. (2010) modeled the net profit of biochar production based on the functional unit of one dry tonne of biomass:

$$\pi = BC + E + Tip + Av - F - Trans - O - C - A - LS$$

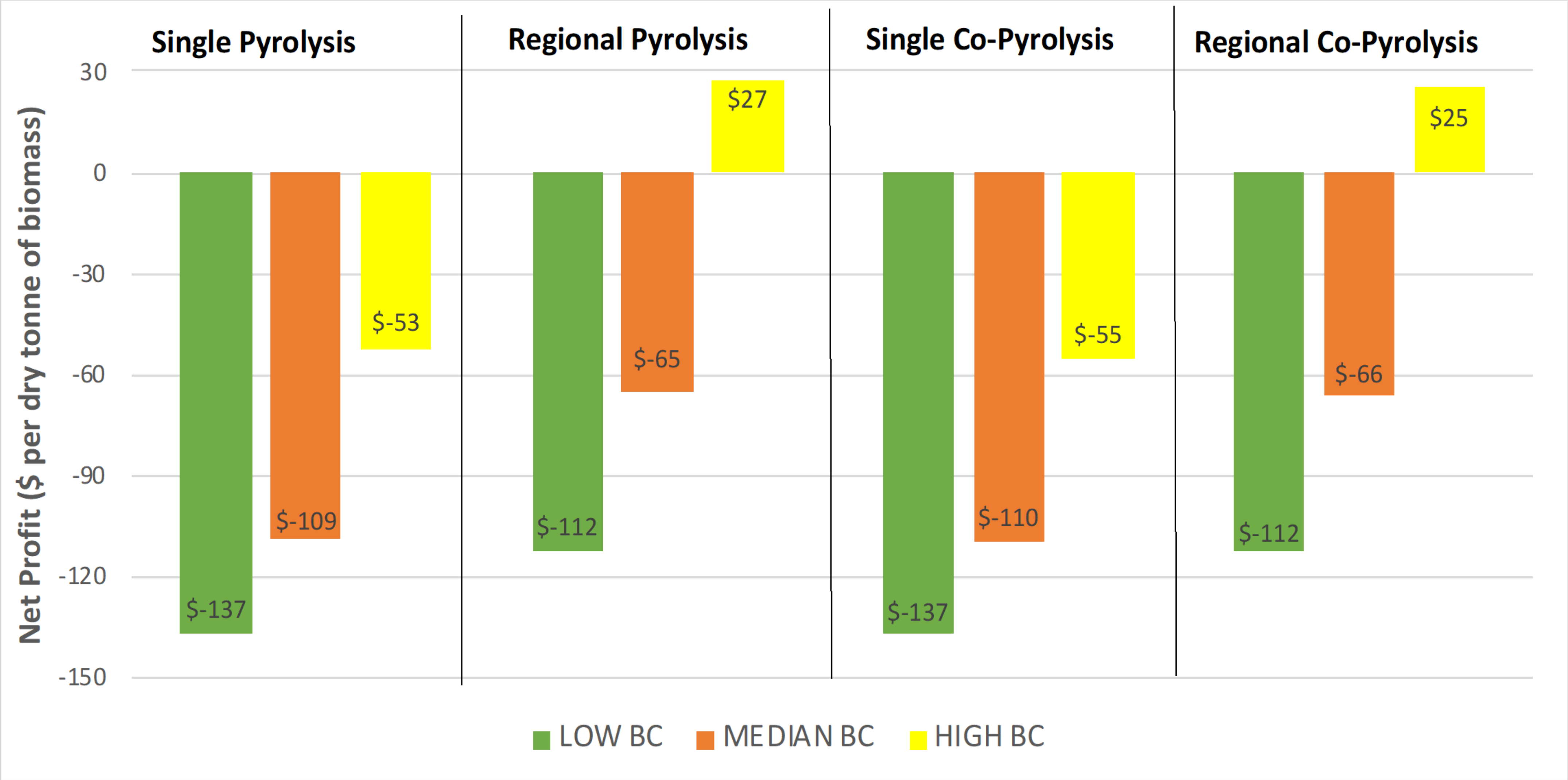
$$\pi = BC + DA - C - O$$

BC	=	Value derived from the biochar
DA	=	Disposal avoidance for landfilling of LDPE
C	=	Capital cost of equipment for processing a unit of the feedstock
O	=	Operating cost associated with processing the feedstock

Techno Economic Analysis: Model & Assumptions

Parameter	**Scenario 1**: Single farm pyrolysis	**Scenario 2**: Regional farms pyrolysis	**Scenario 3**: Single farm co-pyrolysis	**Scenario 4**: Regional farms co-pyrolysis
Available dry biomass (t)	230	2300	230	2300
Biochar available for sale (t)	42.9	710.7	41.8	700.3
Total capital cost ($)	312,000	2,519,000	312,000	2,519,000
Annual O&M ($)	9,060	90,660	9,060	90,660
Disposal Avoidance ($/year)	500			
Discount rate (%)	5			
Lifetime of equipment (years)	20			

Techno Economic Analysis: Results



Net profit ($ t^{-1} dry biomass) for the four scenarios, following method of Roberts et al. (2010). Low/Median/High value of biochar = $50, $200 and $500 $ t^{-1}.

Conclusions

- Most agricultural waste materials produced biochar with high organic carbon content (>80%), low hydrogen-to-carbon ratio (H:C), and low levels of heavy metals and other contaminants.

- Even when co-pyrolyzing woody biomass with LDPE mulch films at up to 25 wt%, the biochar properties were largely unchanged and still suitable for soil applications, despite the published guidance from biochar governing bodies that non-biomass feedstock should not be used.

- Economic viability is achievable only when processing a greater amount of waste feedstock in the regional scenario, and assuming a relatively high biochar value of $500/t that includes both commercial price and carbon credit value.


ANY
QUESTIONS?