

Life cycle sustainability assessment of plantain-based biorefineries in emerging industrial countries: The Colombia case study

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RECONSTRUCCIÓN DEL TEJIDO SOCIAL EN
ZONAS DE POSCONFLICTO EN COLOMBIA



UNIVERSIDAD NACIONAL DE COLOMBIA
SEDE MANIZALES

Content

1. **Introduction**
2. **Problem statement & Research Objective**
3. **Methodology**
4. **Results**
5. **Conclusions**
6. **Acknowledgments**
7. **References**

1. Introduction

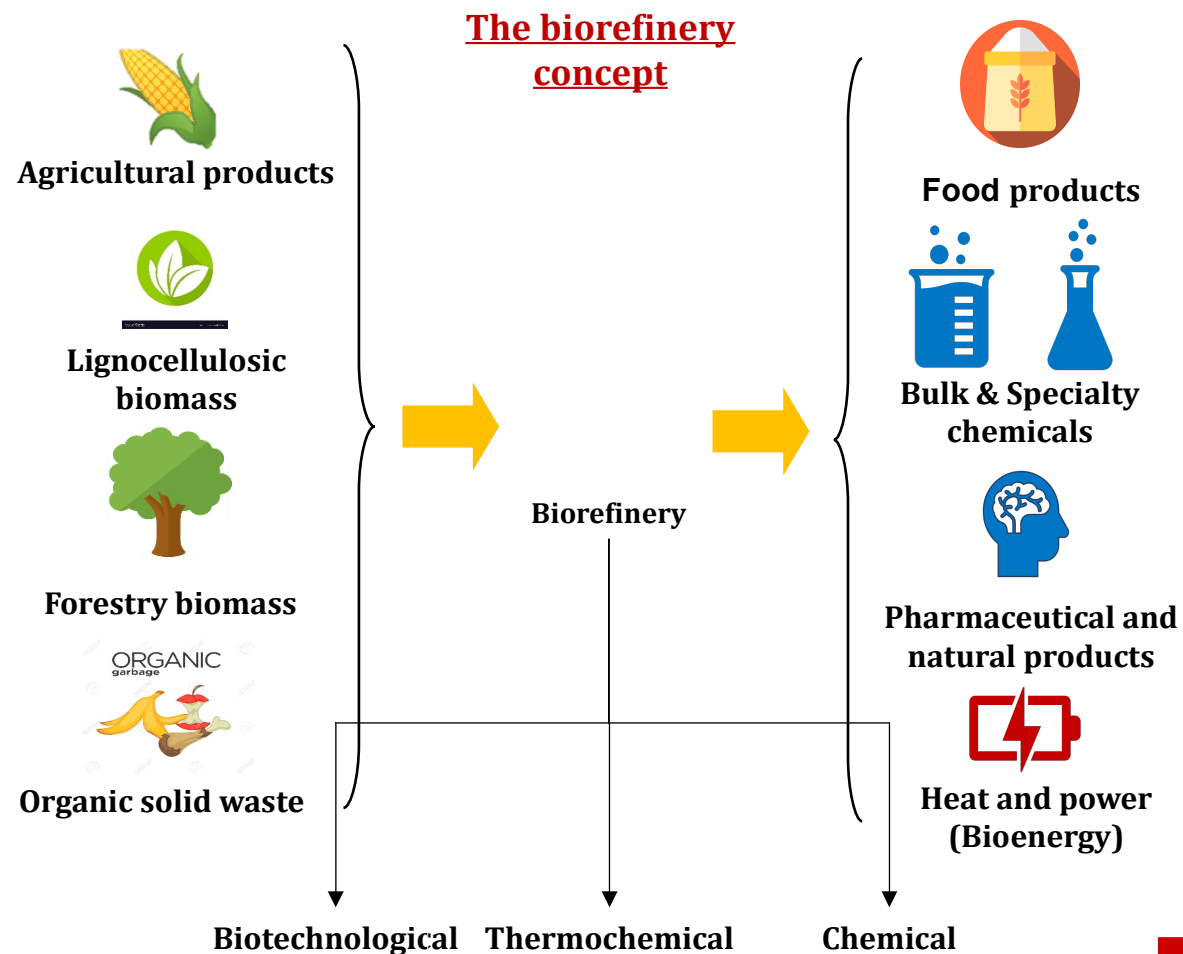
Bioeconomy & Biorefineries



Bioeconomy has been defined as “knowledge-based production and utilization of biological resources, biological processes, and principles to sustainably provide goods and services across all economic sectors” (GBS, 2015)

Advantages.

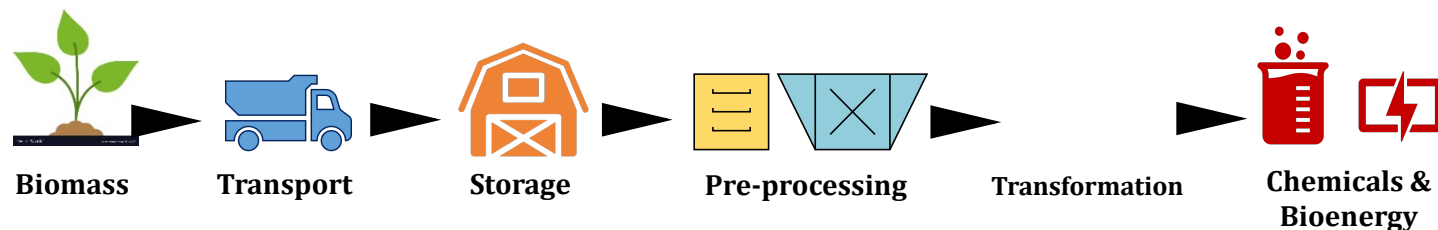
- ✓ New green industries
- ✓ Less oil-based products
- ✓ Climate change mitigation
- ✓ New business opportunities (especially in rural areas)
- ✓ Sustainable production



1. Introduction

Large & small scale biorefineries

Large-scale biorefineries

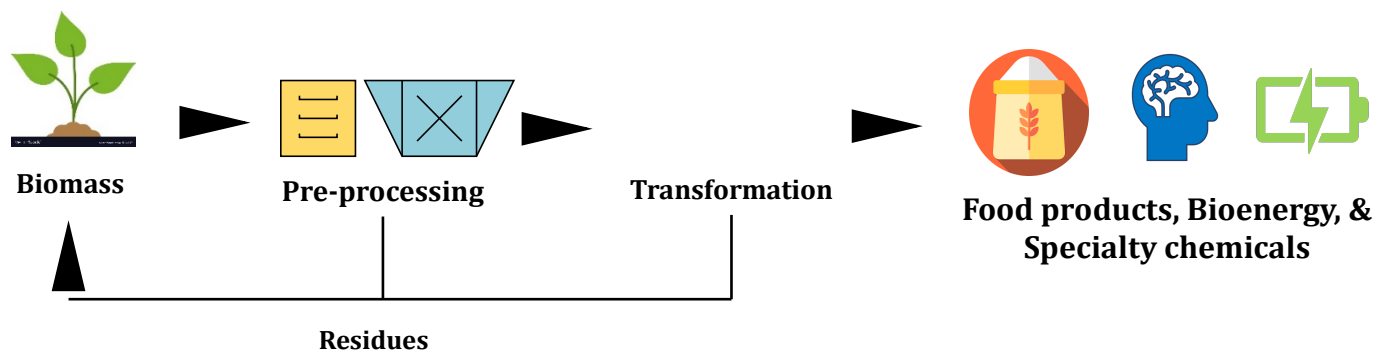


✓✗ Low costs on R&D ✓✗ Low unit costs ✓✗ High transportation and storage costs

Stakeholders with benefits

- ✓ Government (taxes)
- ✓ Shareholders
- ✓ Suppliers
- ✓ Traders

Small-scale biorefineries



✓✗ Versatile & Modular ✓✗ Low transportation and storage costs ✓✗ No-economy of scale

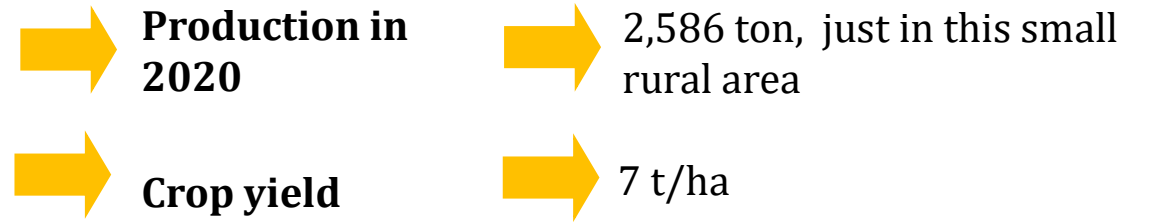
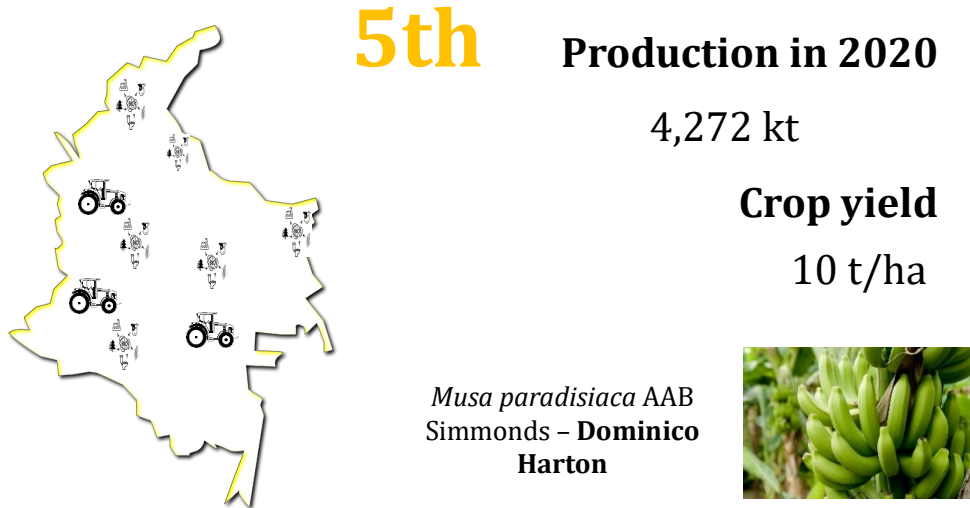
Stakeholders with some benefits

- ✓ Farmers
- ✓ Local communities
- ✓ Society
- ✓ Workers

1. Introduction

Plantain: a potential crop in Colombia

Plantain in Post-conflict zones (Montes de Maria)



Plantain residues

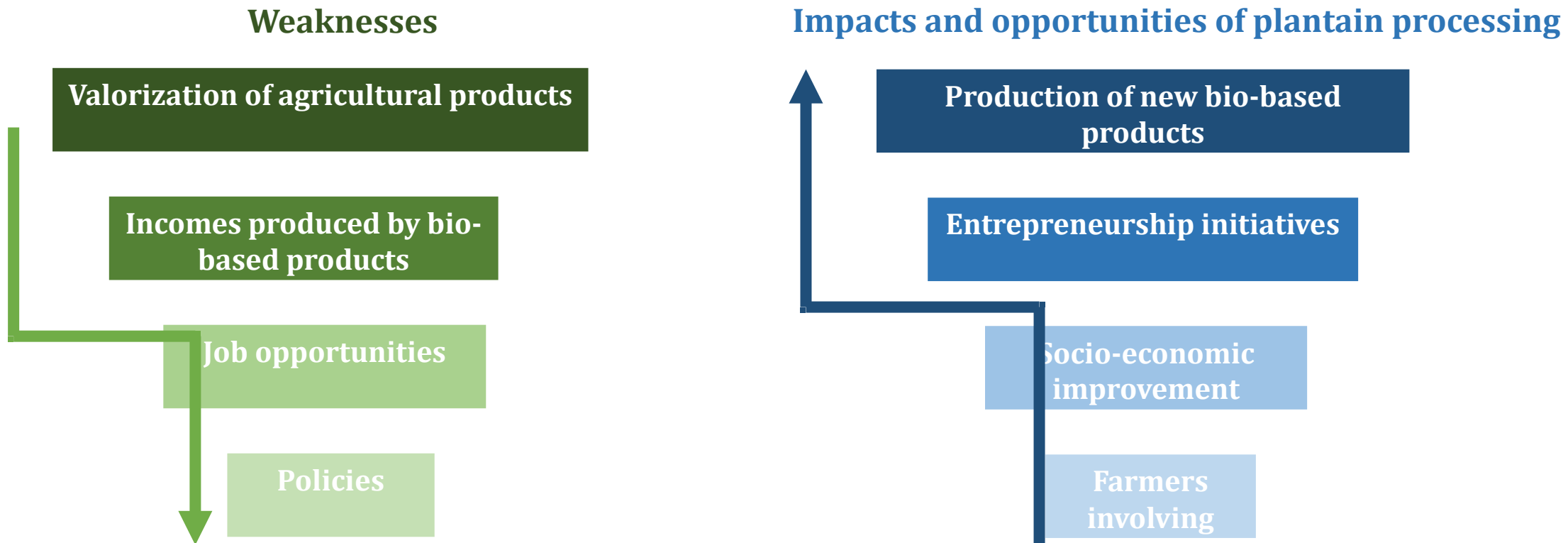
Institutional strategy for peace and post-conflict

- Social and economic development of rural areas for territorial peace.
- Conservation and sustainable use of biomass sources.

How?

- ✓ Creation of entrepreneurship alternatives using biomass as the main source of income.
- ✓ Study of the potential applications of agricultural products through the context of biorefinery at different levels.

2. Problem statement



The direct commercialization of agricultural products and low valorization of residues do not have a real impact in rural zones since traders, suppliers, and shareholders receive more economic benefits than farmers

2. Research objective

This research work assess the economic and environmental performance of different small-scale biorefinery configurations to produce marketable products and energy vectors using plantain as raw material from small producers communities.

This assessment is contextualized in rural zones in emerging industrial countries like Colombia.

3. Methodology

01

02

03

04

Process design

Involves conceptual design of the process.

Process simulation

Involves the use of the Aspen Plus simulation tools based on experimental results.

Economic and environmental evaluation

Involves the process evaluation considering economic, social, and environmental aspects

Results and discussion

Involves the analysis of the obtained data in the simulation and evaluation stages

3. Methodology



Montes de María



Chalán & Ovejas municipalities
Sucre, Colombia 5 km²

Figure 1. The Montes de María region in Colombia

Process contextualization



Plantain
(*Musa Paradisiaca AAB Simmonds*)

Total production in 2020

2,586 ton

5% → Self-consumption

95% → Commercialization

Share of plantain production used to propose the biorefineries

35%*

Biorefineries processing scale
2.6 ton/day

*Assumed value as starting point to propose the small scale biorefineries

3. Methodology

Process design and simulation

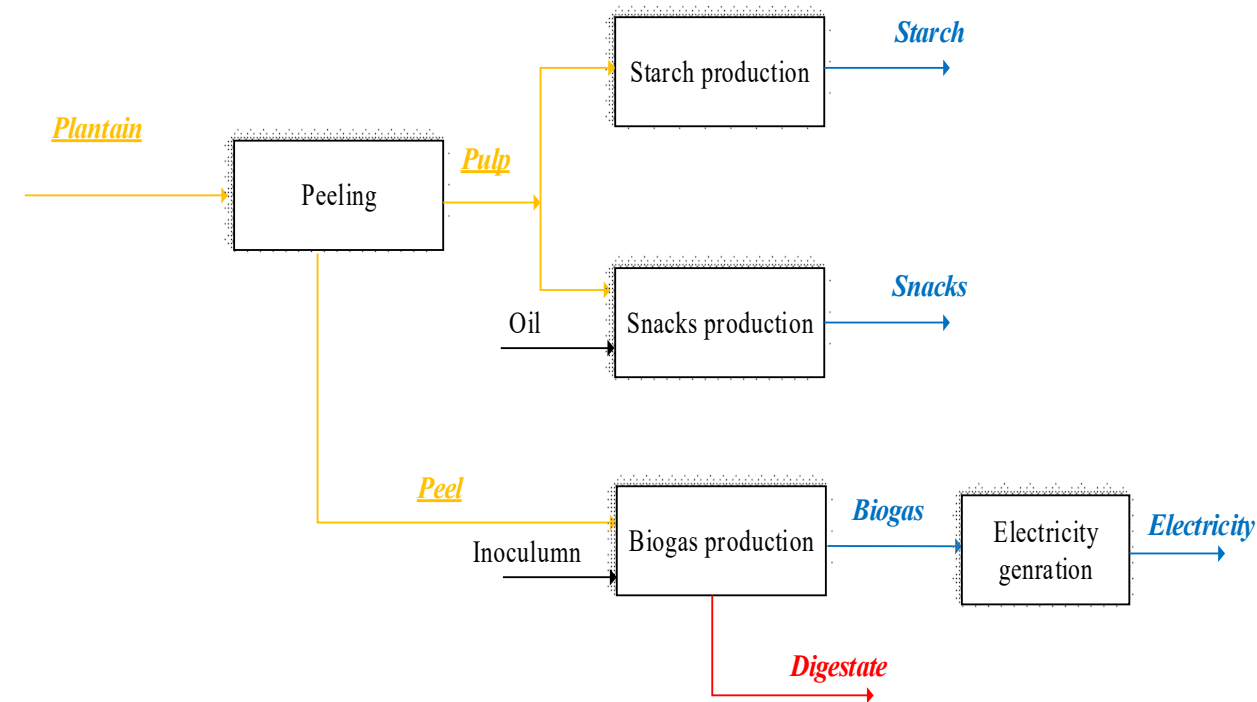


Figure 2. First small-scale biorefinery (Snacks + Starch).

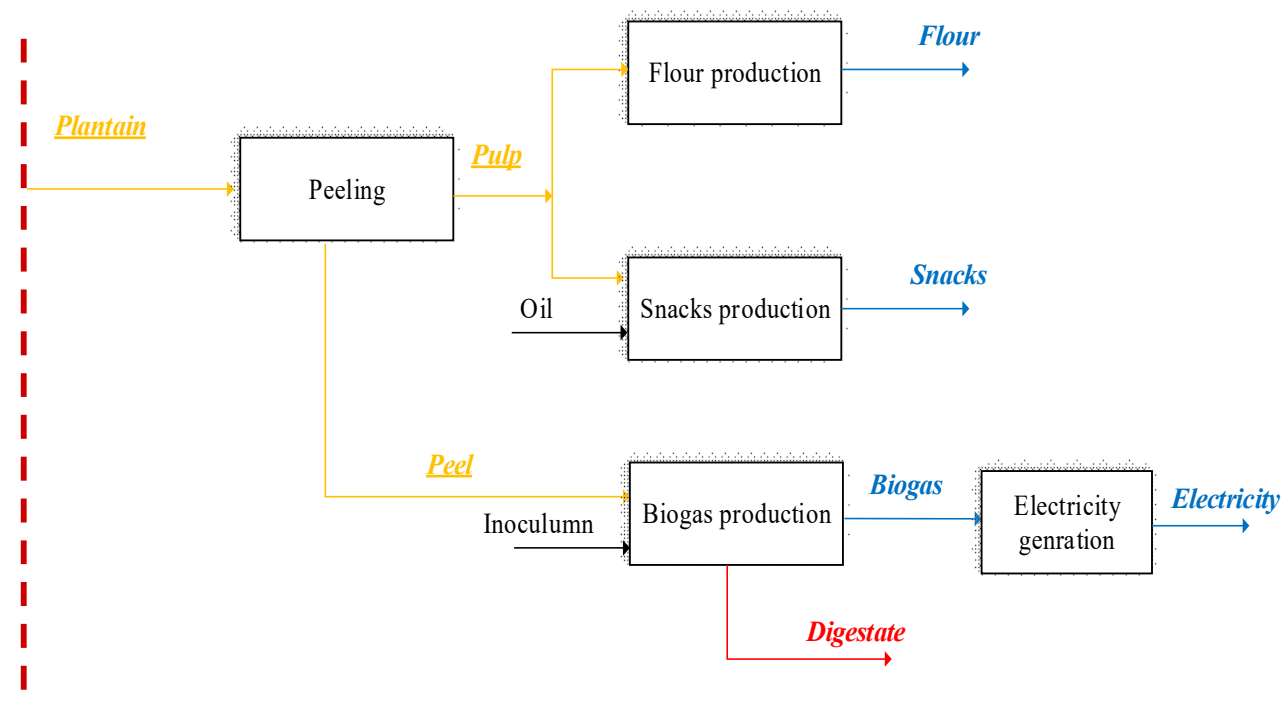
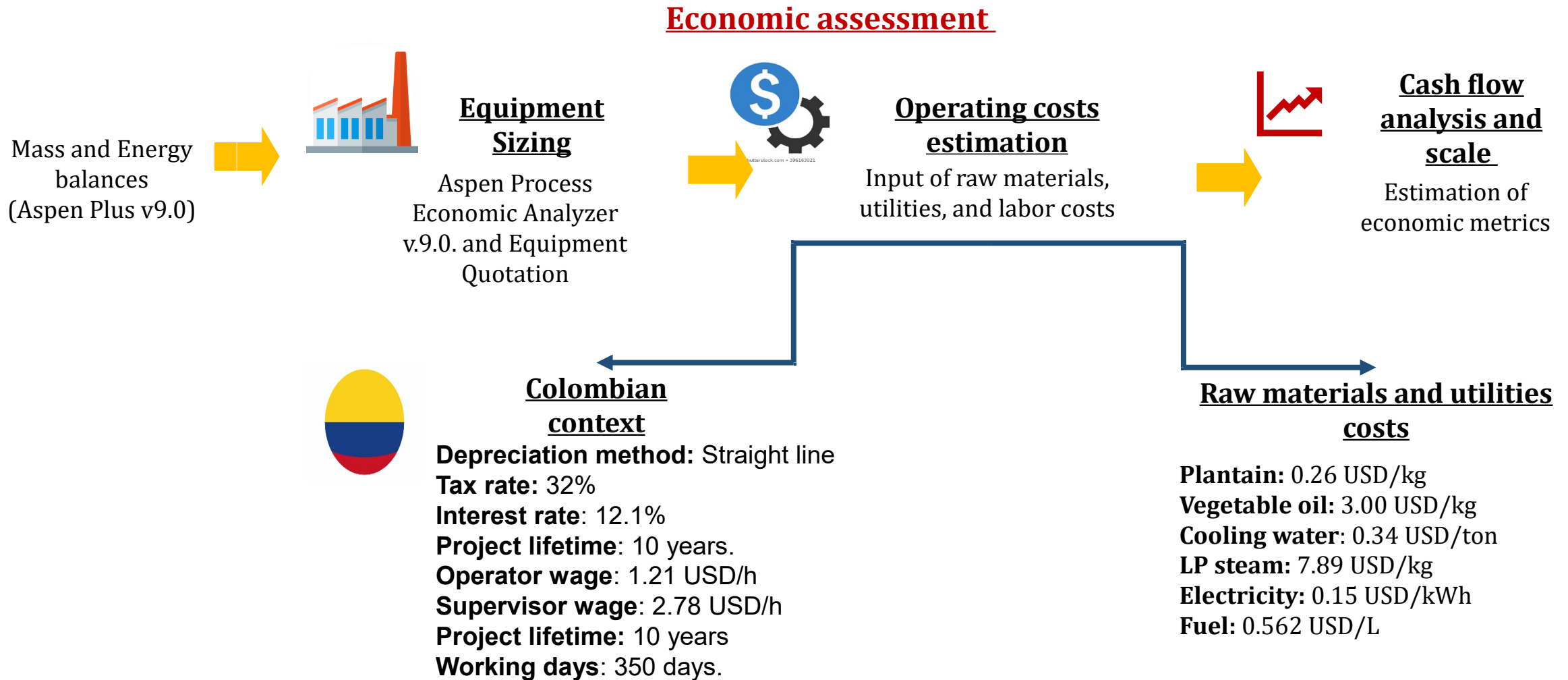


Figure 3. Second small-scale biorefinery (Snacks + Flour).

3. Methodology



3. Methodology

Environmental assessment

Goal of the study

1

The E-LCA aims to evaluate the environmental impact of different scenarios to upgrade plantain in the Montes de María region. A **cradle-to-gate approach** was conducted, starting at the germination of the plantain crop, and ending at the plantain valorization through the proposed small-scale biorefineries

2

Functional unit

The functional unit selected to perform the analysis and comparisons was **1 kg of unripe plantain**.

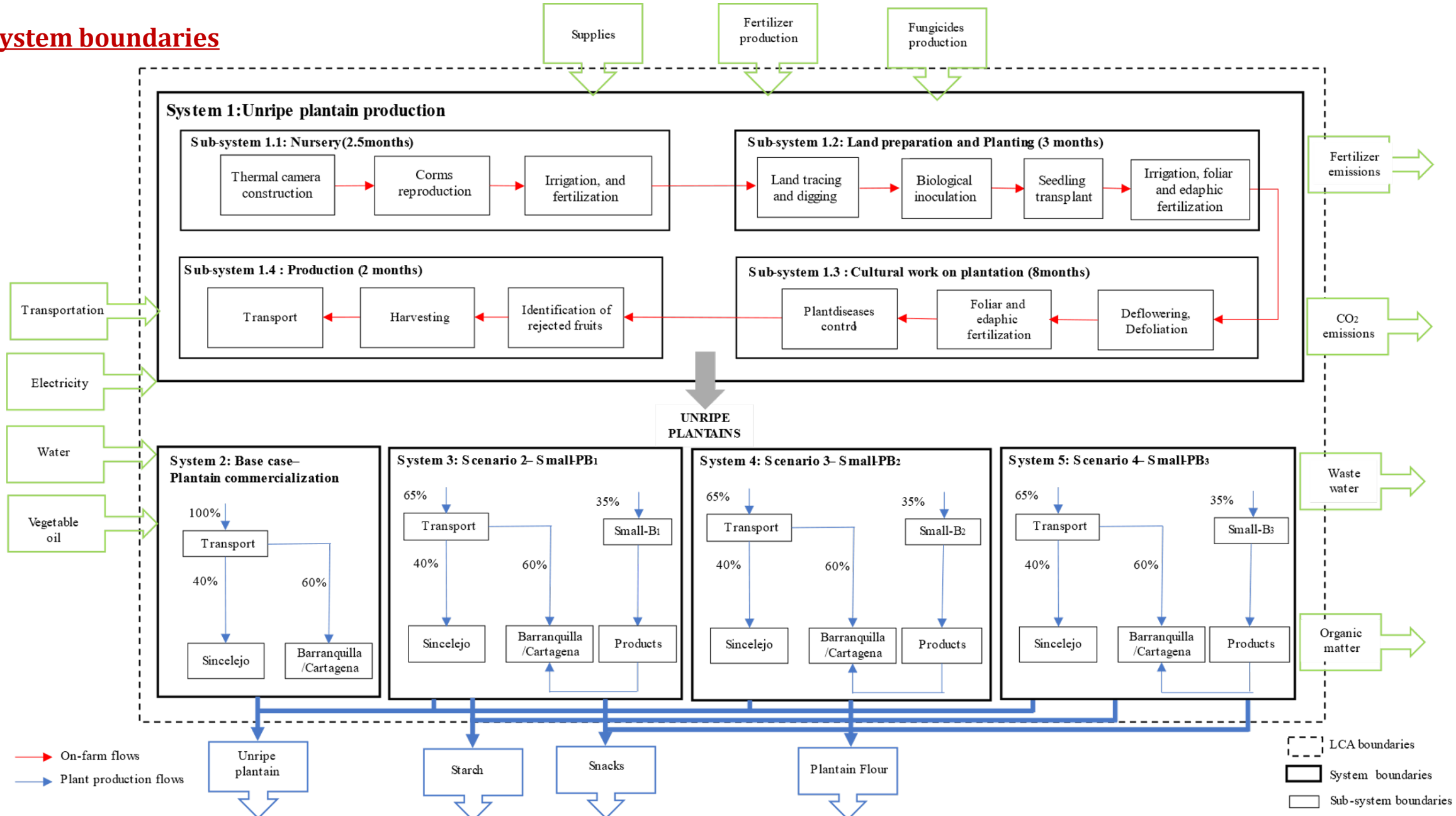
3

Life cycle inventory

The life cycle inventory was done by using **agronomic information** of the literature, information retrieved from **surveys** in the Montes de María region, and the **mass and energy balances** of the simulation

4

System boundaries



4. Results

Table 1. First small-scale biorefinery (Snacks + Starch).



Plantain Biorefinery I

Inlet	Mass Flow (kg/h)	Outlet	Mass Flow (kg/h)	Process Mass Intensity
Plantain	325	Snacks	26.41	9.81
Vegetable Oil	6.75	Starch	7.39	

Table 2. Second small-scale biorefinery (Snacks + Plantain Flour).



Plantain Biorefinery II

Inlet	Mass Flow (kg/h)	Outlet	Mass Flow (kg/h)	Process Mass Intensity
Plantain	325	Snacks	26.41	6.98
Vegetable Oil	6.75	Flour	21.13	

PMI values are better when are closer to one (1).

4. Results

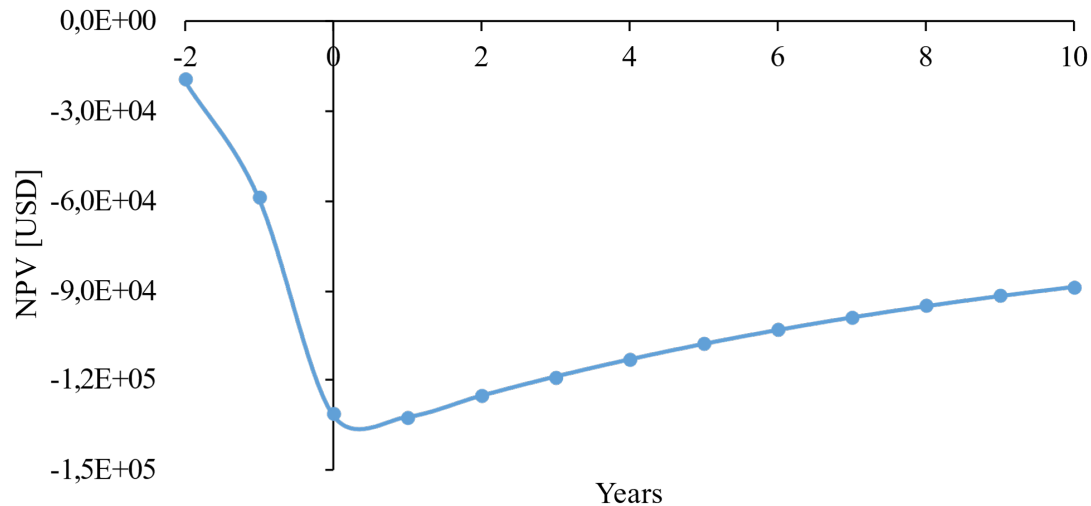


Figure 4. Net Present Value over the project lifetime (Snacks + Starch).

The Small-PB1 is not economic feasible since the NPV has a negative value

CapEx: 114,800 USD .

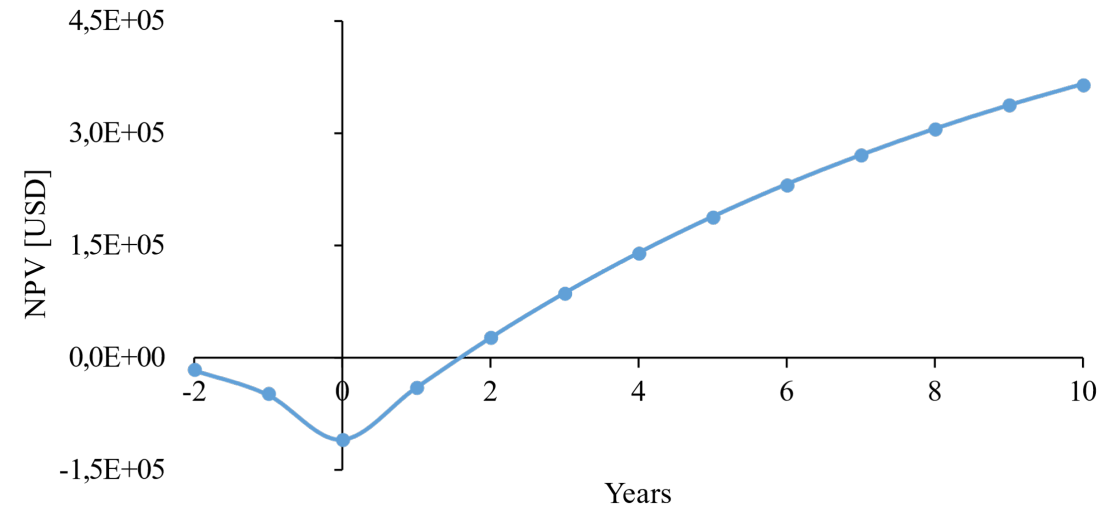


Figure 5. Net Present Value over the project lifetime (Snacks + Plantain Flour).

The Small-PB2 is economic feasible since the NPV has a positive value

CapEx: 95,300 USD.

4. Results

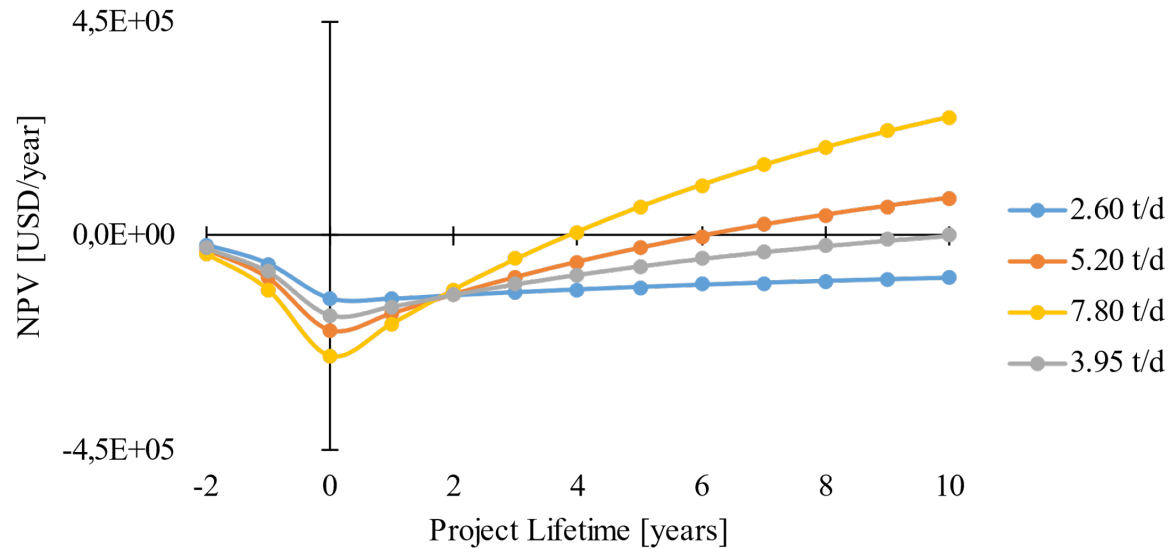


Figure 6. Sensitivity analysis of processing scale (Snacks + Starch) Small-PB1 .

Higher scales than the initial flow rate requires to decrease the supply of unripe plantain for direct consumption . **Then, this option is not attractive.**

MPSEF: 3.95 t/d (55% of the current plantain production)

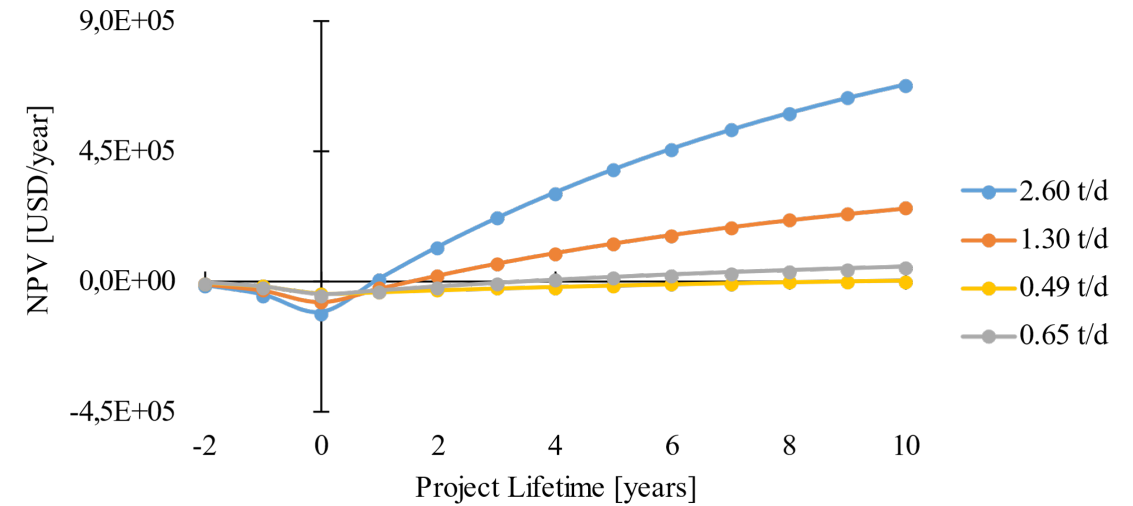


Figure 7. Sensitivity analysis of processing scale (Snacks + Starch). Small-PB2

Lower scales than the initial flow rate. The current productive chain is not affected.. **Then, this option is attractive.**

MPSEF: 0.65 t/d (8,79% of the current plantain production)

4. Results

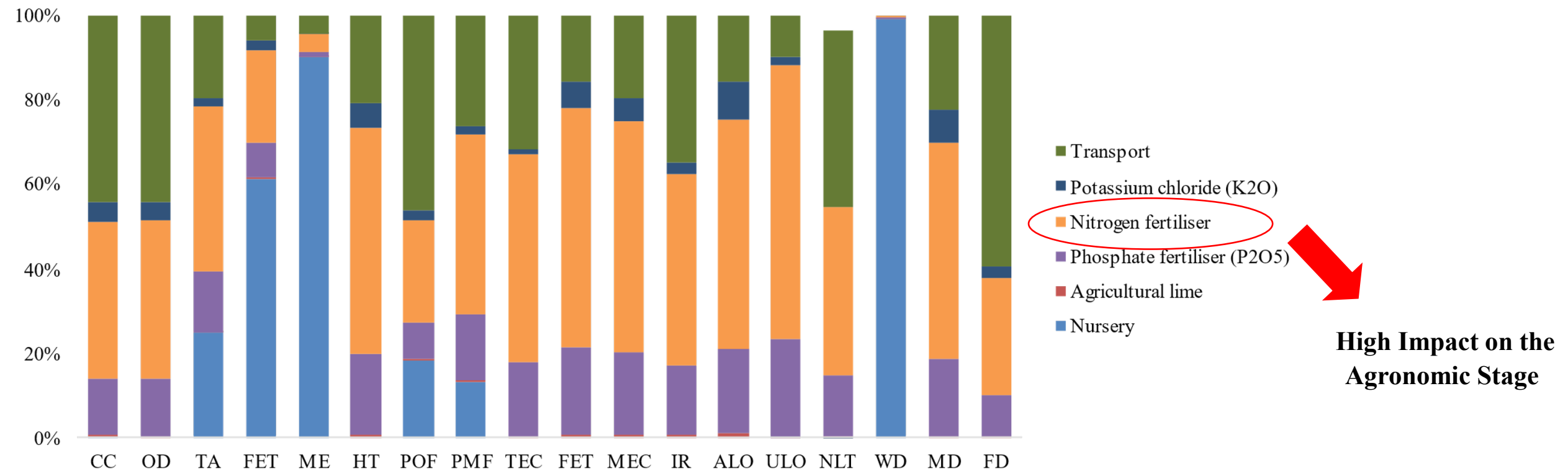
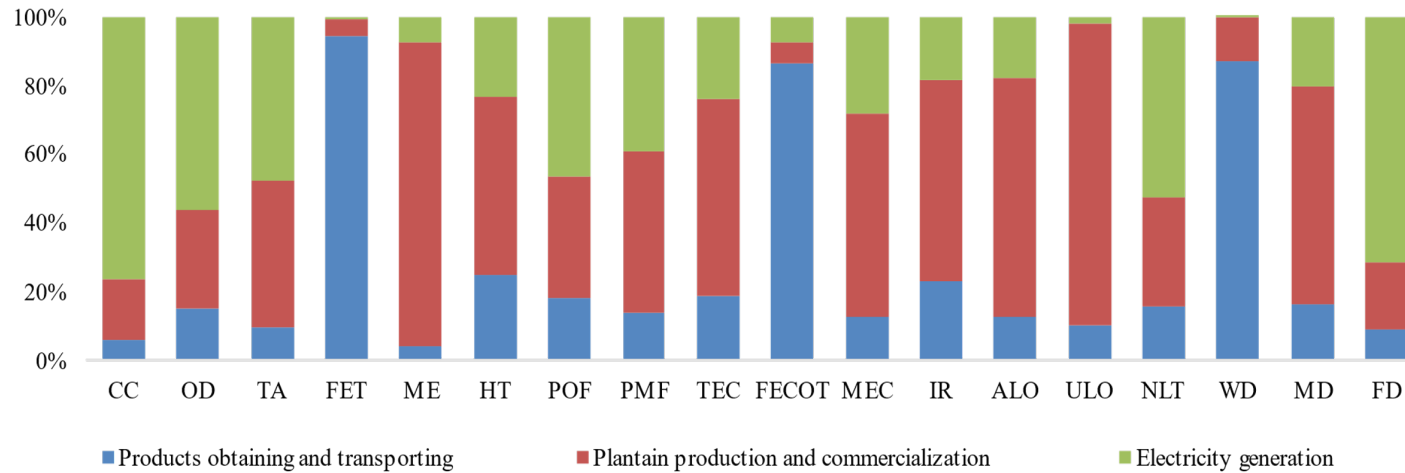


Figure 8. E-LCA Midpoint results of plantain production and commercialization (Base case) in Colombia's Montes de Maria region.

High Impact on the Agronomic Stage

4. Results



Small-PB2 has a high impact on water related midpoint impact categories due to the disposition of frying oil. Nevertheless, the most contributing stage to most of the impact categories was the **Plantain Production and Commercialization Stage.**

Figure 9. E-LCA results of the second small-scale biorefinery (Snacks + Starch) involving plantain production and upgrading

Small-PB1 has a high impact on water related midpoint impact categories due to the high water consumption and high volume of wastewater produced in the process. Moreover, the disposition of frying oil also contributed to these impact categories

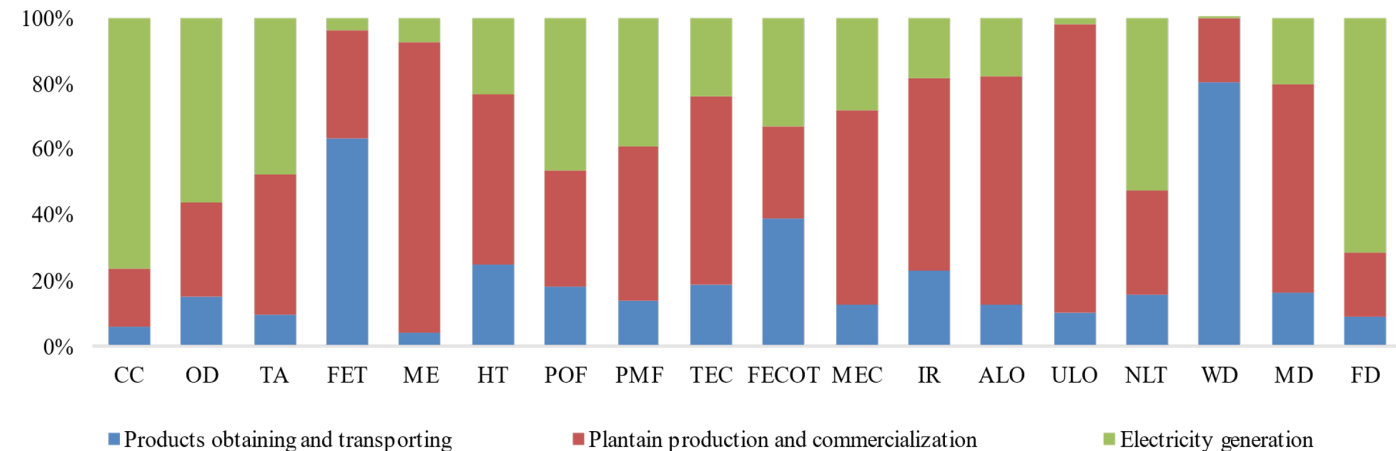


Figure 10. E-LCA results of the second small-scale biorefinery (Snacks + Plantain Flour) involving plantain production and upgrading.

5. Conclusions

- Plantain (*Musa Paradisiaca AAB Simmonds*) is a potential raw material to increase the economic development of rural regions in Colombia. Moreover, upgrading processes have a lower environmental impact since lower carbon dioxide emissions are released.
- Plantain upgrading can increase farmers incomes through the production of value-added products
- The production of snacks and plantain flour is the most suitable option since this process has a good economic performance and a low environmental impact.
- In general, biomass upgrading in biorefineries is a sustainable option to increase the sustainability of productive chains since allow increase economic value, social impact with low environmental loads.

6. Acknowledgments



“Thanks to the research program entitled “Reconstrucción del tejido social en zonas posconflicto en Colombia” SIGP code: 57579 with the project entitled “Competencias empresariales y de innovación para el desarrollo económico y la inclusión productiva de las regiones afectadas por el conflicto colombiano” SIGP code 58907. Contract number: FP44842-213-2018. Moreover, The call PROGRAMA NACIONAL PARA LAS MUJERES EN LA CIENCIA UNESCO’ORÉAL-MINCIENCIAS-ICETEX

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