BIO4Africa life cycle assessments

The green biorefinery in Uganda: the environmental life cycle assessment explained

Introduction

Life cycle assessments (LCAs) are a critical task in the BIO4Africa project to evaluate potential positive and negative aspects of introducing the selected bio-based technologies to African farming communities. This paper provides an overview of the initial environmental LCA (E-LCA) of the green biorefinery located at Kabarole Research & Resource Centre (KRC) in Uganda. DRAXIS has conducted the E-LCA using data and knowledge provided by GRASSA.

Two E-LCA scenarios had been assessed at the time of writing:

- The environmental impact of producing one tonne of animal feed protein, present in the three biorefinery products: green protein concentrate, press cake and whey juice
- The environmental impact of producing the same amount of protein when four plausible fertilisation strategies are applied during feedstock cultivation

Identification of indicators

As LCA lead in the BIO4Africa project, DRAXIS has used the Environmental Footprint 3.1 method developed by the European Commission to score the performance of the green biorefinery across 16 environmental indicators. The eight highest-scoring indicators were selected as the most important impact categories, based on their collective normalised and weighted contribution of more than 80% to the total environmental impact.

Impact category	Brief description	Unit of measurement
Climate change (CC)	Emission of GHG gasses from the system, e.g. CO2, CH4, N20. Aggregated in terms of their potential contribution to global warming over 100 years	Kg CO_2 equivalents
Resource use, minerals and metals (RUmm)	Mineral and metal depletion caused by the system	Kg antimony (Sb) equivalents
Resource use, fossil fuels (RUf)	Fossil fuel depletion caused by the system	Number of fossil fuel-derived Megajoules deprived
Particulate matter (PM)	Particulate matter emissions from the system (e.g. NOx and SOx) with the potential to compromise human health.	Number of disease incidents
Acidification (AC)	Aggregated acidifying emissions from the system (e.g. S02, N0x, NH3), known to cause acid rain and other issues.	Acidification potential of 1 mol hydrogen ion (H+)
Ecotoxicity, freshwater (EcF)	Emission of toxic substances from the system that can harm freshwater aquatic organisms.	Comparative toxic unit equivalents (CTUe)
Photochemical ozone formation, human health (POCP-HH)	Aggregated smog-producing emissions from the system (e.g.VOCs, NOx)	Smog-producing potential of 1kg non-methane volatile organic compounds (NMVOC)
Eutrophication, terrestrial (EuT)	Nutrient enrichment of terrestrial ecosystems due to aggregated emissions from the system (e.g. N, P).	Eutrophication potential of 1 mol nitrogen (N)

Table 1. The top eight indicators of environmental impact for the green biorefinery

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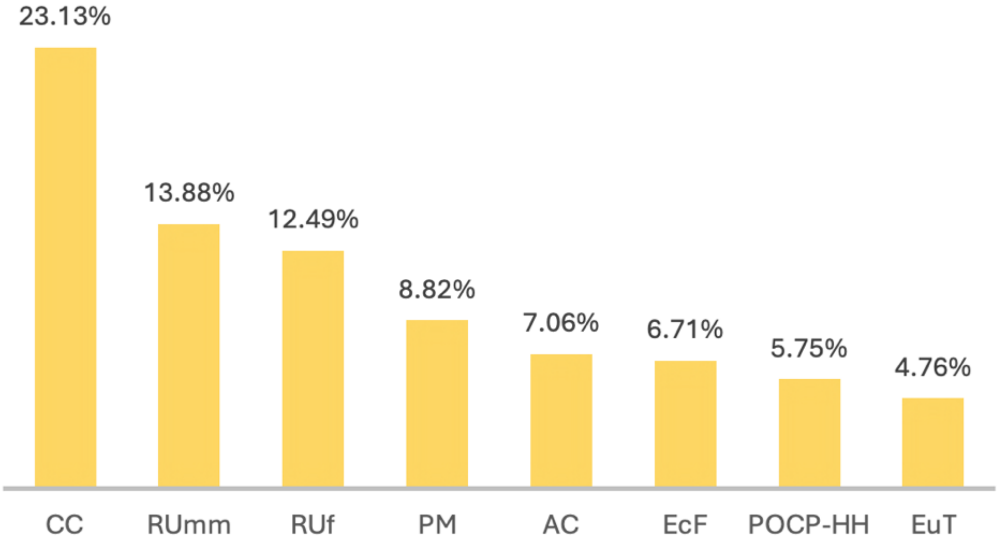


Figure 1. Normalised and weighted contribution of the top eight impact categories (described in table 1) to the total environmental score of the green biorefinery in Uganda per tonne of animal feed protein

Findings from the comparison of fertiliser strategies

The top eight impact indicators show that feedstock cultivation is the most important phase in the green protein lifecycle in terms of environmental impact – and that choice of fertiliser strategy can make a big difference.

Fertilisation is necessary to restore nutrients depleted by cultivation and maintain soil quality. Drawing on data provided by GRASSA as biorefinery technology provider, DRAXIS has compared four fertilisation strategies (table 2) to highlight their influence on the top eight indicators of environmental impact when producing one tonne of protein.

The findings of the comparison indicate that fertiliser strategy S3, which includes manure and intercropping with nitrogen-binding legumes, has the lowest environmental impact across all indicators (figure 2). Use of chemical fertilisers alone (S1) has a significantly higher impact on all eight indicators.

However, it should be noted that the current E-LCA scenarios do not yet account for emissions from land use change or carbon sequestration balance. These factors are expected to have an influence when included.

Fertilisation strategy	Description
Baseline (S0)	Mix of chemical fertilisers and manure
Strategy 1 (S1)	Chemical fertilisers only
Strategy 2 (S2)	Chemical fertilisers and nitrogen-binding legumes
Strategy 3 (S3)	Chemical fertilisers, manure and nitrogen-binding legumes

Table 2. The four fertilisation strategies used for comparison of environmental impact

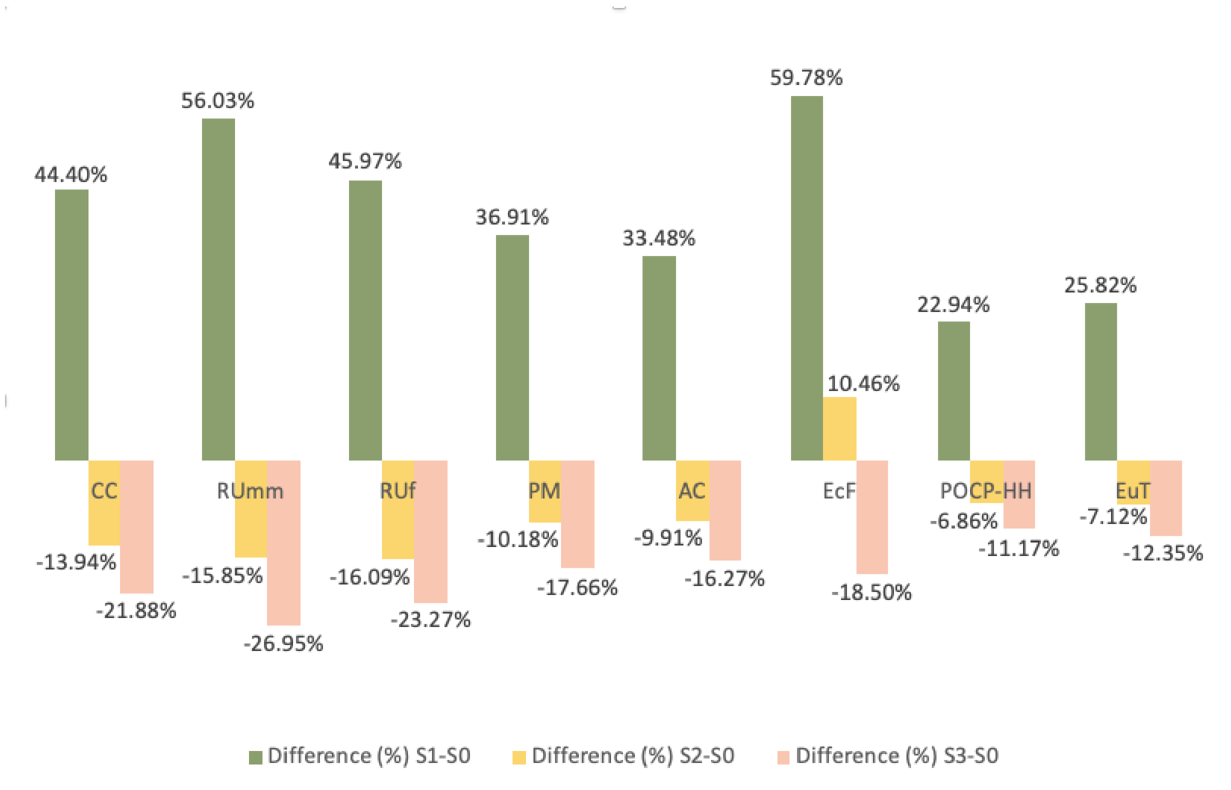


Figure 2. Assessed impact of the S1, S2 and S3 fertiliser strategies on the top eight indicators compared to baseline (S0) when producing a tonne of protein

Baseline data for the comparison

Biorefinery supplier GRASSA provided the baseline data and the model of circular mineral use for the fertiliser strategy comparison.

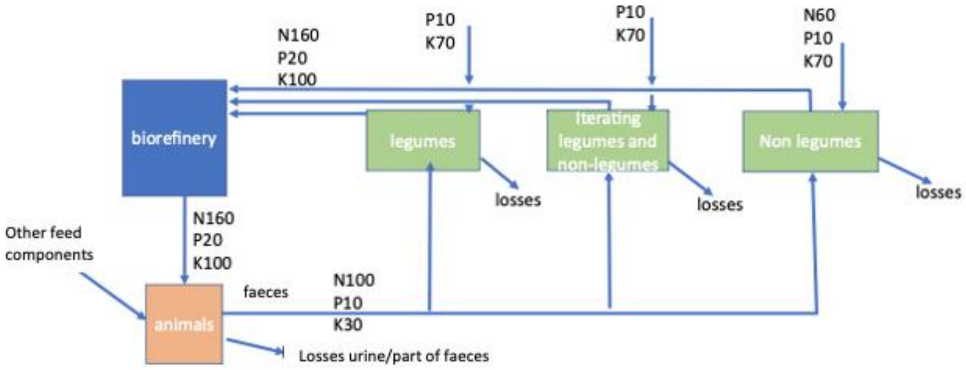
The baseline data are as follows and represent the minimum nutrients removed from the soil during feedstock cultivation (further mineral loss will occur due to leaching, for example):

- Five tonnes of fresh leaves are required to produce one tonne of protein in the biorefinery
- With every five tonnes of leaves, the following is removed from the soil:
  - 160kg of nitrogen
  - 20kg of phosphate
  - 100kg of potassium

GRASSA's model of circular mineral use depicts estimated mineral flows when fertilisation strategies are with or without manure (figure 3).

The model highlights the potential for returning minerals to the soil via manure from livestock that have consumed a green biorefinery product in their feed. S2 and S3 also include leguminous crops which capture and bind nitrogen from the air.

Estimated mineral flows with manure recycle (S0 and S3)*



Estimated mineral flows with no manure recycle (S1 and S2)*

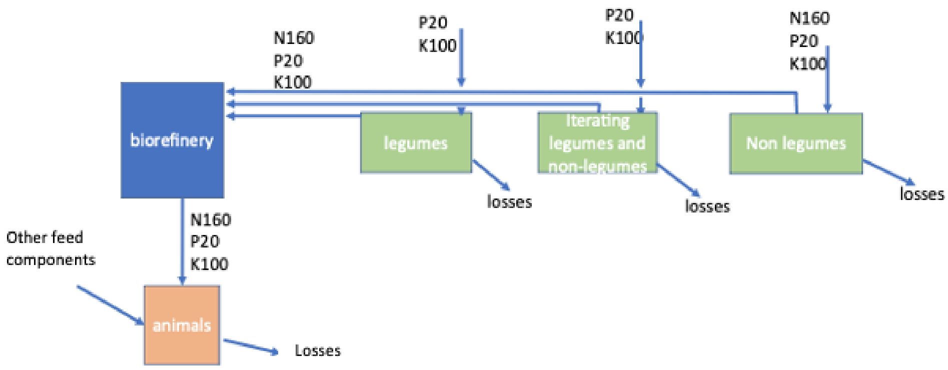


*Figure 3. The concept of circular mineral use developed by GRASSA. * All mineral numbers are per kg/hectare/year – N: nitrogen; P: phosphorus; K: potassium. Crop production is around five tonnes of dry matter per hectare, sufficient to produce one tonne of protein.*

Conclusion

Assessments of two E-LCA scenarios have found that feedstock cultivation is the biggest contributor to the overall environmental impact of protein produced by the biorefinery at KRC. Recycling of manure from livestock that have consumed a green biorefinery product and intercropping with nitrogen-binding legumes can reduce this environmental impact when included in the fertiliser mix. These findings provide an important indication of the sustainability of the green biorefinery technology and how it could support the transition to climate-resilient farming practices that generate more value for farmers.