RAPPORT

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LCIA of Danish roughages

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1 INTRODUCTION

Given the widespread use of the GFLI database, this project aims to generate additional datasets with relevance for Denmark. The datasets are calculated according to the GFLI methodology, but they have not been externally reviewed yet (as required by GFLI for approval in their database).

The selected datasets come from a priority list made after a few meetings between SEGES Innovation P/S, DAKOFO and its members, where a few key Danish “raw feed ingredients” and “processed feed ingredients” were shortlisted. This report focuses on the production of the following roughages (“raw feed ingredients”), grown via conventional agriculture: maize silage, barley silage, grass silages, and fodder beets.

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2 WORKFLOW

A brief description of the workflow:

- Primary and improved secondary data on maize silage, barley silage, grass silages, and fodder beets cultivation in Denmark was collected by representatives from SEGES Innovation, using a broad list of data sources, using the GFLI data collection template for cultivations. Data collection followed the steps described in the project deliveries “Datainput til LCA” (in Danish).
- Primary and improved secondary data from SEGES overwrites the “default” data that is available in Agri-footprint 6.3 (AFP6.3), and missing data was filled in using the AFP6.3/GFLI methodology.
- Collected data was processed similarly as other silages that are in AFP6.3, with the only exceptions that crop specific parameters describing i) the ratio between below ground biomass (BGB) and above ground biomass (AGB), and ii) the N contents of below and above ground biomass were used instead of the default values from “non N-fixing forages”.
- Emission models describing emissions to air, soil and water are compliant with GFLI/AFP6.3 methodology.
- LCIA impacts of maize silage, barley silage, grass silages, and fodder beets were generated using ReCiPe 2016 Midpoint (H). See more details about the use of Recipe 2016 Midpoint (H) and EF3.1 in the supplementary material (“SM OpenLCA vs SimaPro”).

3 NOTES ON MODELLING

Key modelling parameters that require further specification (other than the well described AFP6.3 and GFLI methodology):

- The model uses AFP6.3 as the background LCI database

- Crop residue modelling parameters (unless otherwise specified, the data is based on IPCC (2019), Table 11.1A and 11.2):
  - Maize silage:
    Slope and intercept: “non N-fixing forages”

N contents in ABR and BGR: “maize”
Ratio of BGB to AGB: “maize”

- Barley silage:
  Slope and intercept: “non N-fixing forages”
  N contents in ABR and BGR: “barley”
  Ratio of BGB to AGB: “barley”

- Grass silage based on:
  Slope and intercept: “grass-clover mixtures”,
  N contents in ABR and BGR: “grass-clover mixtures”
  Ratio of BGB to AGB: “grass-clover mixtures”

- Fodder beet:
  Slope and intercept: “potatoes and tubers”
  N contents in ABR and BGR: “potatoes and tubers”
  Ratio of BGB to AGB: “potatoes and tubers”

- FRACremove = 0
  (fraction of above-ground residues of crop T removed annually for purposes such as feed, bedding and construction)

- Multifunctionality: there is only a single product that is generated from the cultivation of the individual roughages. In other words, there is no multifunctionality and no need for allocation in the foreground cultivation system.

- Heavy metal uptake by the crop based on Delahaye et al. (2003) (see AFP6.3 methodology, Table 3-10):
  - Maize silage: based on “maize”
  - Barley silage: based on “barley”
  - Grass silage: based on “grass silage (dm)”
  - Fodder beet: based on “fodder beet”

- Pasture renewal in the case of grass silage: every 3 years based on https://pure.au.dk/portal/files/219070968/Besvarelse_Mulighed_for_reduktion_af_n_ringsstoftab_i_gr_srige_s_dskifter.pdf

- The NPK content of Danish cattle manure, based on “Normtal for husdyrgødning” (average period 2020-2022), is 4.61 kg N /tonne, 0.73 kg P /tonne, 3.32 kg K /tonne.
  However, because of the lack of compositional values for heavy metals in Danish manure, the LCA model assumed a composition of the manure equal to the one in AFP6.3.
  Given the different N (but also PK) content of Danish manure and that there are some maximum amounts of N Danish farmers can apply on the field (depending on the cultivated crop), the amounts of manure used in the model were corrected (compared with the information contained in the “GFLI data collection template for cultivations”) to match the applied N amounts.

- High manure amounts in collected data, resulted in a high heavy metal deposition from manure.

- Types of fertilizers: calculated as in the GFLI database, i.e. based on IFAstat consumption data for Denmark over the period 2017-2021

- Start material modelled as in AFP6.3

- Drying:
    - The silages are dried onsite (at farm), in silage bunkers. The included “cultivation capital goods” are considered to be sufficient, and no additional use of material is included for the silage stage. There is no use of energy.

- Direct land use change impacts (on Climate Change) based on LUC Impact Tool (2023) from Blonk Sustainability
    - Maize silage: based on “maize” -> “insufficient data” -> assumption: dLUC = 0
      As shown in the LUC Impact Tool, there is no expansion of Danish crops that goes at the expense of forest or grassland (over the considered period 2000-2020). There is only a small contribution (in the crops that have expanded) between 0.01 and 0.08 tonne CO_{2eq} /ha (depending on the specific crop) that comes from the contraction of annual/ perennial crops. Given the “insufficient data”, and the relatively small dLUC impacts shown by the few Danish crops presenting dLUC impacts, the assumption of dLUC = 0 is considered to be acceptable.

    - Grass silage:
      “*In case of grassland management and roughages, data gaps from FAO statistics had to be solved. Since no grassland expansion was reported in the past 20 years by FAO statistics, no LUC impact was accounted for grassland management.*” (AFP6.3 methodology)
        - As in the AFP6.3 process “Grass, at farm {DK} Economic, U”, we assumed a dLUC = 0 for Danish grass silage.

    - Barley silage: based on “barley” (dLUC = 0)

    - Fodder beets: based on “sugar beet” (dLUC = 0)

- Peat soil oxidation:
    - Given the negligible crop-specific correction factor for Denmark (i.e. between 0.9991 – 1.0024), Danish peat soil oxidation values were modelled by using the country-level average value for all crops (i.e. 987 kg CO_2 /ha and 0 kg CH_4 /ha and 0.616 kg N_2O /ha) as calculated in AFP6.3.

4 LCIA RESULTS

Table 1 summarizes the LCIA results, using characterized impacts from ReCiPe 2016 Midpoint (H), for Danish maize silage, barley silage, grass silages, and fodder beets. Additional impact categories are added to comply with the GFLI format: climate change impacts from land use and land use change, and climate change impacts from peat oxidation.

The aggregated and weighted DQR of the four roughages is 1.29.

As mentioned in the methodology, there is only a single product that is generated from the cultivation of the individual roughages. Therefore, there is no allocation that must be carried out, and we present the results in a single table (that is valid for all allocation methods).

TABLE 1. LCIA results, expressed as characterized impacts, for maize silage, barley silage, grass silages, and fodder beets, per tonne of product (calculated via ReCiPe 2016 Midpoint (H)). Yields and dry matter are also reported, as additional information.

		1 tonne Maize silage, at farm {DK}	1 tonne Barley silage, at farm {DK}	1 tonne Grass silage, at farm {DK}	1 tonne Fodder beet, at farm {DK}
Yields, roughage	kg/ha	38700	18311	27648	69151
DM	-	34.9%	36.7%	35.2%	22.0%
Global warming - Including LUC & Peat	kg CO2 eq	103.3752	179.8798	144.2480	72.2316
Global warming - Excluding LUC & peat	kg CO2 eq	72.9452	115.3959	101.6745	55.2355
Global warming - LUC only	kg CO2 eq	0.0130	0.0227	0.0212	0.0070
Global warming - Peat only	kg CO2 eq	30.4169	64.4612	42.5522	16.9891
Stratospheric ozone depletion	kg CFC11 eq	0.0020	0.0033	0.0024	0.0016
Ionizing radiation	kBq Co-60 eq	0.6928	1.2757	1.2051	0.5279
Ozone formation, Human health	kg NOx eq	0.2934	0.4600	0.3483	0.1659
Fine particulate matter formation	kg PM2.5 eq	0.2552	0.3995	0.1422	0.1395
Ozone formation, Terrestrial ecosystems	kg NOx eq	0.5991	0.9317	0.5669	0.3595
Terrestrial acidification	kg SO2 eq	1.4793	2.3243	0.7181	0.8321
Freshwater eutrophication	kg P eq	0.1132	0.1374	0.0211	0.0444
Marine eutrophication	kg N eq	0.5315	0.8345	0.6369	0.4581
Terrestrial ecotoxicity	kg 1,4-DCB	96.7483	143.7889	100.0151	85.7712
Freshwater ecotoxicity	kg 1,4-DCB	1.9283	3.0824	1.3478	7.3715
Marine ecotoxicity	kg 1,4-DCB	1.4921	1.9403	1.7466	1.1845
Human carcinogenic toxicity	kg 1,4-DCB	1.1064	1.8931	1.8069	0.5554
Human non-carcinogenic toxicity	kg 1,4-DCB	21.4755	23.5538	24.8525	7.9540
Land use	m2a crop eq	259.3799	549.6004	199.7712	144.9064
Mineral resource scarcity	kg Cu eq	0.1278	0.1048	0.1343	0.0309
Fossil resource scarcity	kg oil eq	6.2301	9.5122	12.8017	3.7136
Water consumption	m3	0.1017	0.1527	0.1358	0.0507

5 SUPPLEMENTARY MATERIAL

Restricted access (only to reviewers):

- LCI from OpenLCA (JSON-LD file)
- LCI used in modelling (Microsoft Excel)
- “SM OpenLCA vs SimaPro” (Microsoft Word and Excel)