DEVELOPMENT OF A BIODIVERSITY ASSESSMENT METHOD WITH FOCUS ON CROP CULTIVATION FOR INNOVATIVE AND MODERN VEGETABLE AND ANIMAL-BASED FOOD PRODUCTS

DÉVELOPPEMENT D'UNE MÉTHODE D'ÉVALUATION DE LA BIODIVERSITÉ CENTRÉE SUR LA CULTURE DE PLANTES POUR LA PRODUCTION DE PRODUITS ALIMENTAIRES VÉGÉTARIENS A LA FOIS MODERNES ET INNOVATIVES OU D'ORIGINE ANIMALE

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To support the transition from animal-based to protein-rich plant-based food products, the EU funded project PROTEIN2FOOD (P2F) (www.protein2food.eu) was initiated early 2015. P2F seeks to produce innovative vegetarian products, such as vegetarian meat alternatives (VMA) or protein rich plant-based milk, with a positive sustainability impact on an EU and global scale. The novelty of these products makes it crucial to examine the environmental performance through a LCA and compare them to suitable traditional reference products.

Agriculture is the main driver of biodiversity loss in Europe and will be so for years to come. Therefore, a biodiversity assessment with focus on crop cultivation has been conducted in addition to the usual examined set of life cycle impact categories.

The contribution will address a newly developed biodiversity assessment approach using the five pressure categories: (1) N-/P-related pollution, (2) Pesticides and other pollution, (3) Water balance, (4) Soil degradation and (5) Landscape structure. These pressure categories and the related influencing factors have been identified as appropriate to make a semi-qualitative assessments based on the crop specific, but non-spatial, cultivation data.

Furthermore, selected biodiversity assessment results for several innovative, modern and traditional food products out of the product lines fiber-like and spread-like vegetable meat alternatives (VMA), milk or burger will be discussed. The influence of crop yields on the biodiversity results of innovative food crops and highly industrialised feed crops might be a further interesting addition.

In the end, the contribution will highlight that the increased plant-based protein supply with innovative protein-rich foods developed within the P2F project would reduce the pressure of agriculture on biodiversity as well as on further environmental categories.

Keywords

Environmental assessment, plant-based food, biodiversity assessment, cultivation inventory data, protein-rich crops

INTRODUCTION

Protein supply is a key factor for food security, as 8 of 20 amino acids are essential for human nutrition. Presently, the main sources of proteins for human consumption in Europe are 'Meat' (29% of overall protein intake), 'Cereals' (27%) and 'Dairy' (23%) [6]. Many other plant-based food groups with high specific protein contents, such as pulses and oil crops, contribute presently not much to the overall protein intake, but might be important to meet the globally growing demand for high-quality, protein-rich food. Therefore, the EU-funded project PROTEIN2FOOD (P2F) (www.protein2food.eu) was initiated. P2F seeks to develop prototypes of plant-based innovative products through the application of new processes and the use of highly nutritious crops like quinoa, lentils or lupin.

The quality and quantity of proteins from selected seed crops and grain legumes shall be enhanced by using a multi-disciplinary approach, involving genetics, agronomy, and food-processing engineering. The challenge is furthermore to create innovative products with high consumer acceptance and a positive sustainability impact on an EU and global scale. Therefore, it is crucial to examine the potential environmental benefits through an environmental assessment. To give quantitative information on improvement potentials of the innovative food products (e.g. lupine and quinoa-based vegetable meat alternative (VMA)) as well as on the environmental advantages or disadvantages compared to suitable reference food products (e.g. chicken meat) a life cycle assessment (LCA) has been carried out.

As around 30% of the total human-induced global biodiversity loss among flora and fauna is related to livestock production [9], a biodiversity assessment with focus on crop cultivation has been conducted.

The following chapters contain the methodology description as well as the presentation of comparative biodiversity assessment results for vegetable versus traditional food products.

BIODIVERSITY ASSESSMENT: METHODOLOGICAL APPROACH

Methodological background

Agriculture is the main driver of biodiversity loss in Europe, but biodiversity provides the basis for all agricultural services [3]. The importance of assessing biodiversity within LCA is faced by unavailability of appropriate methods for biodiversity assessment of agricultural systems. Crop-specific differences are not yet represented in available methodology approaches addressing the impact of land use on biodiversity, e.g. Chaudhary et al. (2015) recommended by UNEP-SETAC. Some crop-specific aspects like nutrient leaching to ground water may be addressed by midpoint categories linked to biodiversity, e.g. Acidification or Eutrophication, as referred in [5].

However, for a comprehensive picture of impacts on biodiversity from livestock production, further crop-specific parameters have to be considered. The difficulty here is that the assessment within the P2F project is performed at generic - rather than site-specific – level and should highlight differences in crop species. The Agri-Environmental Schemes targeting the improvement of benefits and mitigation of agricultural pressure on biodiversity [5] and the assessment of pressures per bioenergy crop developed by the European Environment Agency [4] provided useful methodological elements for the methodical development. The latter is based on a qualitative analysis of pressures exerted on the environment by different crops and builds on an ecological prioritisation study of energy crops for German conditions [8].

It has to be noted, that the method described here addresses only the cropping stage of the food supply chain. Additional potential negative impacts from husbandry are not taken into account.

Categories, indicators and metrics

Based on Agri-Environmental Schemes targeting the mitigation of agricultural pressure on biodiversity [5], five pressure categories have been identified in [6]: (1) N-/P-related pollution, (2) Pesticides and other pollution, (3) Water balance, (4) Soil degradation and (5) Landscape structure. The pressure categories were assigned to relevant and measurable influencing factors based on [5], [4] (see table 1).

Table 2: Factors targeting the improvement of benefits and mitigation of agricultural pressures on biodiversity based on Agri-Environment Schemes compiled by [5] (source: [6])

Pressure category	Influencing factor
(1) N-/P-related pollution	A) Partial replacement of N-fertilizer input by including legumes in crop rotation B) Nutrient leaching to ground and surface water: • Acidification & Aquatic and terrestrial eutrophication
(2) Pesticides and other pollution	C) Reduction of pesticide treatments D) Reduction of stratospheric ozone depletion E) Reduction of photochemical ozone formation
(3) Water balance	F) Reduction of water demand
(4) Soil degradation	G) Reduced soil compaction due to mechanical field work H) Increase of soil organic matter
(5) Landscape structure	I) Diversifying crop rotations

The operationalisation of the biodiversity assessment is carried out with individual metrics per influencing factors. The results per metric are calculated for each crop and food product per functional unit.

The metrics B), D) and E) could be directly fed with LCA results and the metrics A), C), E) and G) could be measured based on cultivation inventories. Whereas, the influencing factors H) and I) are subject to additional data and new methodological approaches. In the following, the latter two metrics will be described in more detail.

The influencing factor ‘H) Increase of soil organic matter’ is expressed as “Humus equivalents (kg C/area used per fu)” with reference to the area used for production of the analyses food products. Humus equivalents based on [7] represent the increase or decrease of soil organic matter due to cultivation of crops. Table 2 gives an overview of humus equivalents for selected crops and crop types. In contrast to existing soil organic matter models for application in LCA, the chosen average humus equivalents per crop type make it possible to differentiate between crops, rather than only between land use types. Thus, the results of this metric may highlight humus-depleting crops like sunflower or maize.

Influencing factor ‘I) Diversifying crop rotations’ refers to the area cultivated with minor crops (m^2*a/area used per fu). Therefore, all crops are categorised into three classes (A, B and C) based on crop decline and their current share of cropped area. Crop decline or increase is determined by evaluation of crop area time series with figures from 1961 to 2016 published by FAOSTAT. According to tendencies in the time series, the crops are classified into A) crop area has declined, B) crop area has remained unchanged or C) crop area has increased. In combination with the current crop share based on EuroStat crop production of the years 2014-2016, the crops are classified into following classes:

- A = decrease in cropped area and < 5 % of European cultivation area (value 1)
- B = decrease in cropped area and > 5 % of European cultivation area or cropped area remained unchanged and 5-20 % of European cultivation area (value 0.5)
- C = increase in cropped area and > 5 % of European cultivation area value 0)

To get area-related results, the area per crop is multiplied by the given values and divided by the total agricultural area occupied per functional unit.

The description of all metrics per influencing factor is published in [2].

Table 2: Humus equivalents for selected arable crop types (source: based on [2])

Arable crop types	Humus equivalents (kg C/ha*a) based on [7]		
	min	max	average
Feed (legumes, pasture)/legumes gr.4	600	800	700
Nurse crop (e.g. buckwheat)	200	300	250
Grain legumes	160	240	200
Cereals/oilseeds/legumes gr.3	-400	-280	-340
Maize (silo, grain)/vegetable gr.2	-800	-560	-680
Potatoes/vegetables gr.1	-1000	-760	-700
Sugar/fodder beets	-1300	-760	-1030

Evaluation methodology

The above described first evaluation step covers the calculation of the metrics for all examined food products per functional unit.

In a second step, the results per influencing factor of the innovative products are compared relatively with the traditional food products. The single metrics are not aggregated to a single biodiversity score. Rather, the food products are classified as more or less favourable compared to the competing ones (see figure 1). In the end, these semi-quantitative results serve as indications for qualitative conclusions.

The classification of the differences into more or less favourable is always based on the definition of a significance threshold. For the biodiversity assessment with the chosen metrics, an estimated significance threshold of 20 % is chosen as pragmatic approach. This means that all differences ≤ 20 % are considered as insignificant. This threshold is chosen with respect to the variability of generic cultivation data and especially regarding the new developed non-LCIA metrics.

BIODIVERSITY ASSESSMENT RESULTS

The biodiversity assessment has been carried out for following product lines:

- VMA-fiber prototype versus chicken meat (low and high impact variant)
- VMA-spread prototype versus pork based Leberwurst (Liver Pâté) (low and high impact variant)
- Vegetable milk (innovative and modern) versus cow milk (low and high impact variant)
- Vegetable burger (innovative and modern) versus beef burger

Traditional food products show huge bandwidths due to the different farming practices in Europe. In order to make these effects visible in the environmental impact results, high- and low-impact scenarios were created for the animal based food products.

The qualitative result evaluation below shows the comparison of vegetable innovative and modern vegetable milk alternatives and low-impact and high-impact traditional cow milk. Figure 1 displays the comparative results for the influencing factors addressing pressure on biodiversity.

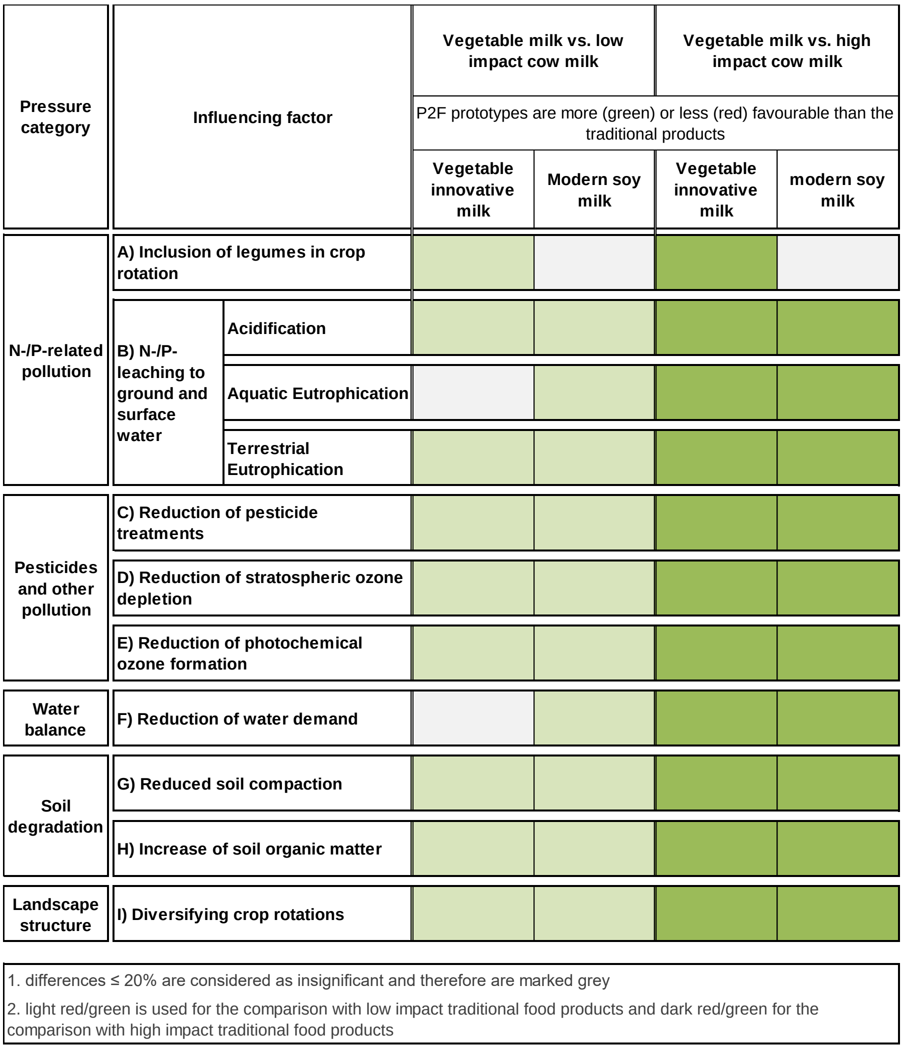

Figure 1: Comparison of results regarding influencing factors addressing pressure on biodiversity: vegetable innovative and modern milk versus low-impact and high-impact traditional milk (source: [2])

The results show, that the innovative milk prototype performs more favourable than the traditional low- and high-impact cow milk regarding all influencing factors except, in case of low-impact cow milk, for ‘F) Reduction of water demand’ and ‘aquatic eutrophication’.

The modern food product (soy milk) also performs more favourable than the high and low impact cow milk regarding most of the influencing factors, but shows no significant differences for ‘A) the inclusion of legumes in crop rotation’. As soy beans do not constantly fix nitrogen beyond their needs, the inclusion of legumes in crop rotation (influencing factor A) show no different results for the modern and traditional food products.

Thus, based on the chosen metrics, the biodiversity assessment indicates that the vegetable NOVEL and modern milk would potentially reduce the pressure of agriculture on biodiversity.

CONCLUSION

Given the lack of existing practical and operable methods for a fully quantitative biodiversity assessment, the new developed approach allows an initial assessment of potential pressure on biodiversity and, in this regard, a benchmarking of NOVEL protein rich products against animal based products.

The results show that the innovative products of all product lines are promising alternatives to animal-based products and would reduce the pressure of agriculture on biodiversity as well as on climate change [2].

REFERENCES

[1] Chaudhary, A., Verones, F., de Baan, L., & Hellweg, S. (2015). Quantifying Land Use Impacts on Biodiversity: Combining Species–Area Models and Vulnerability Indicators. Environmental science & technology, 49(16), 9987-9995.

[2] Detzel, A., Krüger, M., Busch, M., Drescher, A., Wriessnegger, C. L., Köppen, S. (2019). Deliverable 5.3 – Part I Report on the Life Cycle Assessment Results. Prepared for the P2F project (Protein to Food), funded by the European Union’s Horizon 2020 research and innovation programme under grant agreement No 635727 (the www.protein2food.eu), Heidelberg

[3] EC (2010). The CAP towards 2020: Meeting the food, natural resources and territorial challenges of the future. COM(2010) 672 final.

[4] EEA (2006). European Environmental Agency. 2006. How much bioenergy can Europe produce without harming the environment? EEA Report No. 7. 2006.

[5] FAO (2016). Teillard, F., Anton, A., Dumont, B., Finn, J.A., Henry, B., Souza, D.M., Manzano P., Milà i Canals, L., Phelps, C., Said, M., Vijn, S., White, S. 2016. A review of indicators and methods to assess biodiversity – Application to livestock production at global scale. Livestock Environmental Assessment and Performance (LEAP) Partnership. FAO, Rome, Italy.

[6] ifeu (2018). Deliverable 5.2 - Report on the methodology applied in this project for Life Cycle and Socio-Economic Assessment. Prepared for the P2F project (Protein to Food), funded by the European Union’s Horizon 2020 research and innovation programme under grant agreement No 635727 (the www.protein2food.eu), Heidelberg

[7] KTBL (2009). Faustzahlen für die Landwirtschaft. 14. Auflage. Herausgeber: Kuratorium für Technik und Bauwesen in der Landwirtschaft e.V. (KTBL), Darmstadt

[8] Reinhardt, G., Scheurlen, K. (2004). Naturschutzaspekte bei der Nutzung erneuerbarer Energien. Annex of report to the German Federal Agency for Nature Conservation. Leipzig

[9] Westhoek, H., Rood, T., van den Berg, M., Janse, J., Nijdam, D., Reudink, M., Stehfest, E. (2011). The Protein Puzzle - The consumption and production of meat, dairy and fish in the European Union, The Hague: PBL Netherlands Environmental Assessment Agency