ISSN 2632-4067

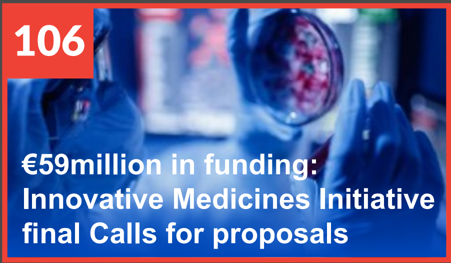
The PROJECT REPOSITORY journal

VOLUME 6 | JULY 2020

Future Tech Week
page 124

A NEW ERA OF PROJECT DISSEMINATION

CONTENT FOCUS



Disseminate – Communicate – Educate

edma EUROPEAN DISSEMINATION MEDIA AGENCY

Modelling complexity within agriculture using a dynamic sustainability assessment tool

Lelde Timma - Project Lead, Troels Kristensen and Marie Trydeman Knudsen - Supervisors, Aarhus University
Elina Dace - Co-Author, University of Latvia

Sustainability remains a disputable topic, even when researchers agree on one common definition of sustainability since different sustainability aspects can be evaluated differently. Based on the International Energy Agency's definition, the goal of biorefinery corresponds to the same goal of the conventional refinery of crude oil—to maximise the product yield per one unit of input (IEA, 2009). In contrast to conventional biorefineries, the 'green' biorefineries can have a wider variety of final product streams.

In this work by Timma et al. (2020), a novel, dynamic sustainability assessment tool is presented and validated in a case study. This tool combines two methods—system dynamics (SD) and temporal soil carbon modelling. The case study for sustainability analysis of Danish agriculture and green biorefineries supply chains is used. Thus, the model covers significant feed flows for animals and animal production, as well as limiting factors in the system, such as the ecosystem's carrying capacity, total available land area, normative regulations, and time delays in decision-making. The development of the Danish agriculture sector is simulated and assessed in relation to the ecosystem's carrying capacity until 2050, defined as 1.4 livestock units per hectare (Figure 1).

The general representation of the concept for the 'Ecosystem's carrying capacity' is given in Figure 1b). An impact of an innovation in agricultural practices on 'exploitation of the ecosystem' is given in Figure 1 a). When the exploitation of

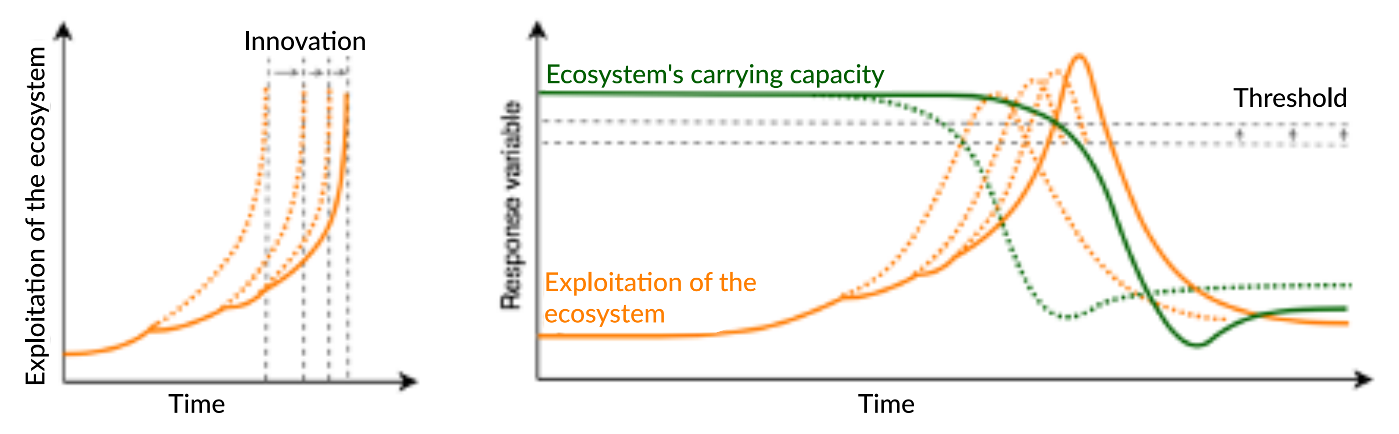


Figure 1: Representation of (a) the effect of innovation on the response variable, (b) the 'Exploitation of the ecosystem' reaching the 'Ecosystem's carrying capacity' after several innovations. Figure adapted from Rockström et al., 2009; Bettencourt et al., 2007; and Sterman, 2000.

the ecosystem reaches the Ecosystem's carrying capacity, firstly, degradation of the ecosystem's carrying capacity occurs. While the ecosystem's carrying capacity is degraded, the exploitation of the ecosystem is still developing by inertia, and growing "beyond" the ecosystem's carrying capacity. As the ecosystem's carrying capacity collapses, it triggers a collapse in the exploitation of the ecosystem as well. Later, a new equilibrium state is achieved, but the new level of the ecosystem's carrying capacity might never return to the initial level of the planetary boundary. In our model, the maximum number of livestock units per hectare (LSU/ha) is used as a major limiting factor and as a proxy for the carrying capacity of the ecosystem.

Three scenarios are modelled: 1) the reference scenario shows the system's behaviour for the next 30 years under the initial set of data and without any policy intervention; 2) the carrying capacity scenario, where the development of the production of pigs and cows is limited by the defined carrying capacity of the ecosystem; and 3) the biorefinery scenario shows the area of agriculture land needed to substitute all demand of soy import and the available land that can be transformed into the production of green protein from alfalfa after the year 2025. The temporal soil carbon modelling is applied in this scenario. The developed model can be further expanded to include the influence of various policy tools or other sectors of the economy.

First, the reference scenario showed that under the current development, the agriculture sector would exploit the ecosystem beyond the carrying capacity shortly after 2030. Second, the scenario limiting the expansion of animal production to the level of carrying capacity indicated that the agriculture system will still exceed the carrying capacity due to development inertia and further decreasing agricultural area. Third, the biorefinery scenario tested an introduction of biorefineries within the carrying capacity limits to ensure local protein supply for animal feed instead of imported soybean meal. The results of the third scenario showed that due to the limited agricultural land area, the demand for protein could hardly be satisfied by local biorefineries, i.e. the land area available for alfalfa will be at least six times less than needed to supply protein locally. Thus, it can be concluded that other solutions will be needed to maintain the Danish animal production system within the ecosystem's carrying capacity.

In this paper, soil carbon gains were used as an example to demonstrate the difference in obtained results between using constant and temporal soil carbon modelling values. Moreover, the variable used for impact assessment also contained time dynamics derived from the SD model, thus showing the application for the developed dynamic sustainability assessment tool. It can be concluded that this dynamic sustainability assessment tool shows a more precise and less optimistic projection of future development than the assessment using constant soil carbon modelling values only. Therefore, the use of the temporal aspects in the impact assessment should be further developed and included in sustainability assessments to yield results with the representation of processes occurring in natural ecosystems.

References

Bettencourt, L., Lobo, J., Helbing, D., Kuhnert, C. and West, G. (2007) Growth, innovation, scaling, and the pace of life in cities. *Proceedings of the National Academy of Sciences*, 104(17), pp. 7301-7306.

IEA, International Energy Agency (2009) IEA Bioenergy Task 42 Biorefinery. IEA Bioenergy, [online]. Available at: <https://www.iea-bioenergy.task42-biorefineries.com/upload_mm/5/8/2/a47bd297-2ace-44d0-92bb-cb7cc02f75de_Brochure_Totaal_definitief_webs.pdf>.

Rockström, J., Steffen, W., Noone, K., Persson, Å., Chapin, F., Lambin, E., Lenton, T., Scheffer, M., Folke, C., Schellnhuber, H., Nykvist, B., de Wit, C., Hughes, T., van der Leeuw, S., Rodhe, H., Sörlin, S., Snyder, P., Costanza, R., Svedin, U., Falkenmark, M., Karlberg, L., Corell, R., Fabry, V., Hansen, J., Walker, B., Liverman, D., Richardson, K., Crutzen, P. and Foley, J. (2009) Planetary Boundaries: Exploring the Safe Operating Space for Humanity. *Ecology and Society*, 14(2).

Sterman, J. (2000) *Business Dynamics: Systems Thinking and Modeling for a Complex World*. Boston: Irwin/McGraw-Hill, p. 928.

Timma, L., Dace, E., Kristensen, T. and Knudsen, M. (2020), *Dynamic Sustainability Assessment Tool*. Case Study of Green Biorefineries in Danish Agriculture. Submitted for review to 'Sustainability', p. 21.

PROJECT SUMMARY

The SABIR project presents a novel, dynamic sustainability assessment tool. This tool combines temporal soil carbon modelling and greenhouse gas modelling with system dynamics models. The case studies of green biorefineries and the agriculture sector in Denmark and Latvia are used to formally approve this tool.

PROJECT LEAD PROFILE

Born in Kraslava, Latvia, **Dr Lelde Timma** received her doctorate in environmental engineering from Riga Technical University in 2017. She also studied in Sweden, Switzerland, Lithuania and the USA. Dr Timma has authored over 60 peer-reviewed articles, five monographs, assists as a reviewer in numerous internationally recognised scientific journals and as an external expert in the European Commission.

PROJECT PARTNERS

The project's host institution is the Research Section of Agricultural Systems and Sustainability, Department of Agroecology, Aarhus University, in Denmark. Collaboration partners in this project were from the Ralph E. Martin Department of Chemical Engineering, University of Arkansas, USA; the Institute of Microbiology and Biotechnology, University of Latvia; and Riga Stradins University, in Latvia.

CONTACT DETAILS

Lelde Timma

Computational Systems Biology Group,
University of Latvia, Jelgavas iela 1, Riga.

☎ +371 26196240

✉ biomodeling@lu.lv

https://biosystems.lv

FUNDING

This research was funded by the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement no. 798365.