



FARMING SYSTEM DESIGN FOR SUSTAINABLE AGRIFOOD SYSTEMS: THEORIES AND PRACTICES

**Proceedings of the 8th International
Farming System Design Conference**

*Marion CASAGRANDE, Marie-Hélène JEUFFROY,
Gentiane MAILLET*

25 - 29 August 2025
Palaiseau (France)
Campus Agro Paris-Saclay



A new indicator framework for multicriteria assessment of co-designed agroecological crop rotations

SKORUPINSKI Solème¹, VUZ Nadiia², DE WIT Allard³, FOU DI Sébastien⁴, MONTOYA Daniel⁴, RAYNAL Hélène⁵, REDHEAD John⁶, TERMANSEN Mette⁷, WILLAUME Magali⁵, BOHAN David², BOCKSTALLER Christian¹

¹Université de Lorraine, INRAE, LAE, 68000 Colmar, France, ²Agroécologie, INRAE, Institut Agro, Univ. Bourgogne, Univ. Bourgogne Franche-Comté, Dijon F-21000, France, ³Wageningen Environmental Research, Wageningen University & Research, The Netherlands, ⁴Basque Centre for Climate Change, BC3, 48940 Leioa, Spain, ⁵Université de Toulouse, INRAE-ENSAT, UMR AGIR, F-31320 Castanet-Tolosan, France, ⁶UK Centre for Ecology & Hydrology Wallingford, Crowmarsh Gifford, Wallingford, Oxfordshire OX10 8BB, UK, ⁷Department of Food and Resource Economics, Københavns Universitet, Frederiksberg C, Denmark

Keywords: multicriteria assessment, cause-effect chain, INDIC database framework, cross-analysis indicator framework

Introduction

To meet the major challenges facing agriculture which involve an increase in agricultural production while preserving natural resources and adapting to new climatic conditions, in-depth rethinking of agricultural systems is urgently required (Wezel et al., 2014). This rethinking hinges in particular on the redesign of crop rotations (i.e., the sequence of crops grown in a more or less regular or long cycle) which need to be more diversified and composed of crops adapted locally in view of climate change. The TRANSFORM project aims at accelerating the innovation of co-designed arable and mixed farming crop rotations, as nature-based solutions to deliver multiple economic, societal and ecosystem service benefits. To support this co-design process, an assessment framework is needed and must include indicators of ecosystem services and environmental impacts induced by a change in crop rotation. The framework must be adaptable for use in different regions to meet local constraints and objectives, and by different stakeholders (e.g., farmers, researchers, public authorities). To our knowledge, there is no already-existing method that meet all these criteria (Lairez et al., 2015). The aim of this work was to propose a list of indicators that is structured to facilitate a judicious selection of indicators to be used for the multicriteria assessment of innovative crop-rotations, integrating ecosystem services and tailored to case-specific constraints and objectives.

Methods

To support the selection of indicators when performing multicriteria assessment of agricultural systems, (Bockstaller et al., 2023b) built the *INDIC database framework*. This database offers an initial structuring according to themes and sub-themes for each dimension of sustainability. We paired this database with a new *cause-effect conceptual framework* (Bockstaller et al., 2023a) which is resumed in six entities relating either to causes, system status and functioning and effects. This framework is based on an integration of previous conceptual works (e.g., Payraudeau and Van Der Werf, 2005) and has the benefit of being more precise and less linear. Our research group was tasked with proposing a first list of indicators to assess crop rotation sustainability. The relevance of the proposed indicators was considered according to its position in the so-created *cross-analysis indicator framework* (Figure 1) with respect to the main purpose of our study (i.e., to focus on environmental impacts and services induced by a change in crop rotation). A revised list of indicators was established and was supplemented, when necessary, with additional indicators to better describe a theme or sub-theme deemed under-represented. The resulted indicator list was divided in two categories: 1) *key-performance indicators*, related to system functioning, properties and impacts that are best able to describe the services and impacts of crop rotations ; and 2) *complementary indicators*,

related to causes that are less precise but easier to calculate and more suitable for communication.

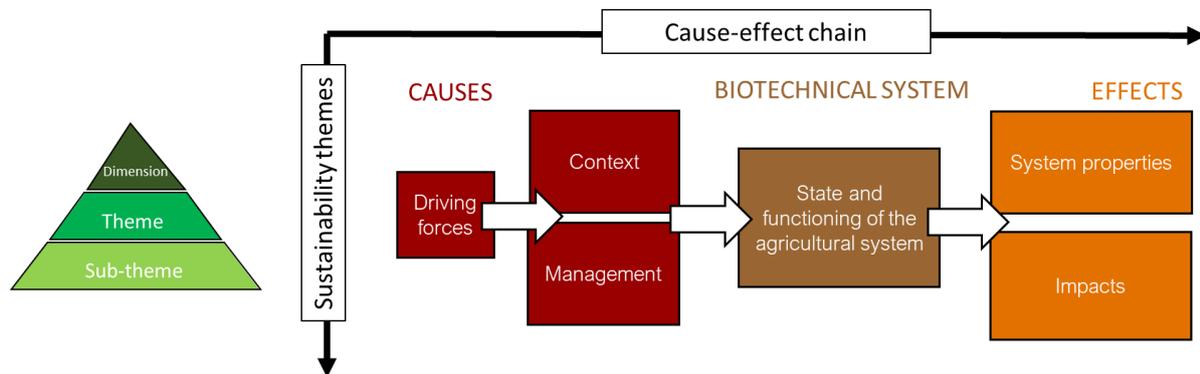


Figure 1. Cross-analysis indicator framework combining INDIC database framework and the cause-effect chain.

Results

The final list consisted of 74 indicators, of which 53 (respectively, 13 and 8) were related to the environmental (resp., economic and social) dimension. We identified 51 indicators as key-performance indicators. Table 1 provides an extract from the final list for the environmental dimension.

Discussion

Multi-criteria sustainability assessments are indispensable tools for redesigning farming systems according to the agroecological transition. These redesigns require restructuring on several scales and the involvement of a variety of stakeholders. To accelerate this transition, tools that can be adapted to different contexts and users are needed. Here we proposed an innovative method based on a cross-indicator analysis framework to help select the most relevant (in view of the study objective) sustainability criteria and related indicators to be included in multicriteria assessments. This framework has the major benefit to include indicators assessing ecosystem services and environmental impacts, which is rarely considered in today's assessment methods. As a proof of concept, we have applied our method to a specific object of study: assessing the sustainability of crop rotations co-designed for the future, as part of a European project involving several case studies. In the final list of indicators, a large part is related to the environmental dimension of sustainability and concerns the cropping-system functioning and impacts. This is in line with the core aim of the project (focusing on crop-rotation benefits) to reduce environmental impacts and increase resilience through increasing ecosystem services) but the economic and social criteria of sustainability might be under-represented. This will be further reviewed and it could also be adjusted at the evaluation step, when weights are assigned to the final criteria.

Perspective

This bi-dimensional framework will be enriched with an *indicator readability tool* to add a third categorization layer according to the optimal use and possibilities for interpretation of each indicator. From the resulted structured indicator list, we will select relevant sets of indicators based on the stakeholders' feedback on their specific needs and requirements. We will propose a set of assessment methods, from indicator dashboard to aggregative methods, designed to be operational for the stakeholders to be implemented.

Theme	Sub-theme	Cause-effect chain	Indicator
Crop management	Plant diversity	Causes	Functional attribute diversity =f(crop functional traits, number of crops)
	Soil cover		% soil cover =f(crop choice, amount of cover-crops)
State and quality of crops	Crop nutrient status		Nitrogen nutrition index =f(yield, N content)
State of soils	Soil state parameters		Soil depth =f(soil and climate local context)
		Clay content =f(soil and climate local context)	
Ecosystem services	Soil	State and functioning	Carbon sequestration (I-DRO carbon indicator) =f(crop biomass and distribution in plant, crop pairing)
	Pest regulation		Pest regulation (I-DRO pest indicator) =f(crop associated pests, crop pairing)
	Biodiversity and landscape		Habitat for wildlife (I-DRO habitat indicator) =f(crop associated biodiversity, crop pairing)
Efficiency	Nitrogen efficiency		N efficiency =f(yield, N content in crops, fertilizer applied)
	Water efficiency		Water use efficiency =f(soil water profile, water use for crop, runoff)
Soil	Erosion / runoff		Impacts
	Physical quality (compaction)	Soil compaction indicator =f(soil degradation/restoration)	
	Soil chemical fertility (organic matter)	C balance =f(C input by fertilizer and crop, C losses)	
	Soil chemical fertility (P)	P balance =f(yield, P content in crops, fertilizers applied)	
Quality of groundwater and surface water	NO ₃ transfers	Cumulative amount of NO ₃ -N leached at the base of the soil profile =f(soil sensitivity to leaching, fertilizers, crops sequence)	
	Pesticide transfers and risks	Pesticide risk (I-Phy 3 ground water) =f(pesticide properties, soil sensitivity to leaching)	
		Pesticide risk (I-Phy 3 surface water) =f(availability of pesticide, field sensitivity to runoff)	

Table 1. An extract from the key-performance-indicators list. For each indicator, a few examples of the factors involved are given.

Acknowledgements: The authors would like to extend their thanks to the European project TRANSFORM funded by the European Commission under Grant Agreement no. 101155748

References:

- Bockstaller, C., Alaphilippe, A., Angevin, F., 2023a. Quels indicateurs pour l'évaluation des systèmes agricoles en transition agroécologique ? Agron. Environ. Société. <https://doi.org/10.54800/cba951>
- Bockstaller, C., Tromp, E., Hufschmitt, E., Angevin, F., 2023b. INDIC, une base de données pour aider à s'orienter dans la jungle des méthodes d'évaluation et indicateurs de la durabilité. Agron. Environ. Sociétés. <https://doi.org/10.54800/cbe987>
- Lairez, J., Feschet, P., Aubin, J., Bockstaller, C., Bouvarel, I., 2015. Agriculture et développement durable - Guide pour l'évaluation multicritère, 1ère édition. ed, Sciences en partage. Editions Quae ; Educagri.
- Payraudeau, S., Van Der Werf, H.M.G., 2005. Environmental impact assessment for a farming region: a review of methods. Agric. Ecosyst. Environ. 107, 1--19. <https://doi.org/10.1016/j.agee.2004.12.012>
- Wezel, A., Casagrande, M., Celette, F., Vian, J.-F., Ferrer, A., Peigné, J., 2014. Agroecological practices for sustainable agriculture. A review. Agron. Sustain. Dev. 34, 1--20. <https://doi.org/10.1007/s13593-013-0180-7>



HAL
open science

Farming System Design for Sustainable Agrifood Systems: theories and practices

Marion Casagrande, Marie-Hélène Jeuffroy, Gentiane Maillet

► To cite this version:

Marion Casagrande, Marie-Hélène Jeuffroy, Gentiane Maillet. Farming System Design for Sustainable Agrifood Systems: theories and practices. 8th International Farming System Design Conference, Aug 2025, Palaiseau, France. 2025, 10.17180/j9xc-fs91 . hal-05219264

HAL Id: hal-05219264

<https://hal.inrae.fr/hal-05219264v1>

Submitted on 22 Aug 2025

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



Distributed under a Creative Commons Attribution - NonCommercial - NoDerivatives 4.0 International License

The correct citation of this book of abstracts is:

Farming System design for sustainable agrifood systems: theories and practices, proceedings of the 8th International Farming System Design Conference, Marion Casagrande, Marie-Hélène Jeuffroy, Gentiane Maillet, 2025. DOI: [10.17180/j9xc-fs91](https://doi.org/10.17180/j9xc-fs91)

The correct citation of articles in this book of abstracts is:

Authors, year, title. on: Farming System design for sustainable agrifood systems: theories and practices, proceedings of the 8th International Farming System Design Conference, Marion Casagrande, Marie-Hélène Jeuffroy, Gentiane Maillet, 2025. DOI: [10.17180/j9xc-fs91](https://doi.org/10.17180/j9xc-fs91)