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Integrating top–down and bottom–up approaches to design a new framework to asses crop diversification sustainability

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1 – Introduction

Crop diversification which is the object of the H2020 project DiverIMPACTS (https://www.diverimpacts.net/) has been identified asone of the key lever to promote redesign and sustainable development of agro-food systems (IPES-Food, 2016). Temporal and spatial diversification of crops in field and along the rotation, the adoption of multiple and intercropping schemes, are able to simultaneously fulfil the need to produce different outputs (food, feed, fibers, other industrial products, etc.), to enhance ecosystem services and, in the longer term, to reverse the trend towards specialization and intensification imposed by modern agriculture (Kremen and Miles, 2012). Nevertheless, there is still a lack of knowledge on the potential synergic and trade-off effects resulting from the implementation of different crop diversification strategies. Considering the sustainability of the agricultural systems, those effects have to be carefully considered and evaluated, in order to avoid that “a solution generates new problems”.
Accordingly, a new adapted framework of performance indicators, sensitive to crop diversification, was defined in DiverIMPACTS. The new set was specifically developed to assess the overall sustainability of diversified agro-food systems considering economic, environmental and social dimensions and the benefits and drawbacks of diversification at different spatial scale (field, groups of fiels, farm, territory).

2 – Materials and methods

The new framework was designed by integrating top-down and bottom-up approaches (Figure 1). The top-down approach was addressed by DiverIMPACTS researchers referring to the hierarchical structure of FAO-SAFA framework (FAO, 2013) that was used to identify a priori a list of criteria and potential indicators considered relevant and sensitive to crop diversification. For each selected SAFA criterion, the researchers

identified the potential indicators and the relative data needed to evaluate the sustainability of the diversified agricultural systems at different scales, taking into account the potential synergies and trade-offs.
In order to integrate the point of view of stakeholders and local communities and achieve a set of agreed indicators, researchers strongly interacted with actors of the 25 Case Studies involved in the DiverIMPACTS project (grouped into five clusters – CL, according to their crop diversification strategies) thanks to the implementation of several Co-Innovation Workshops (CIWs).

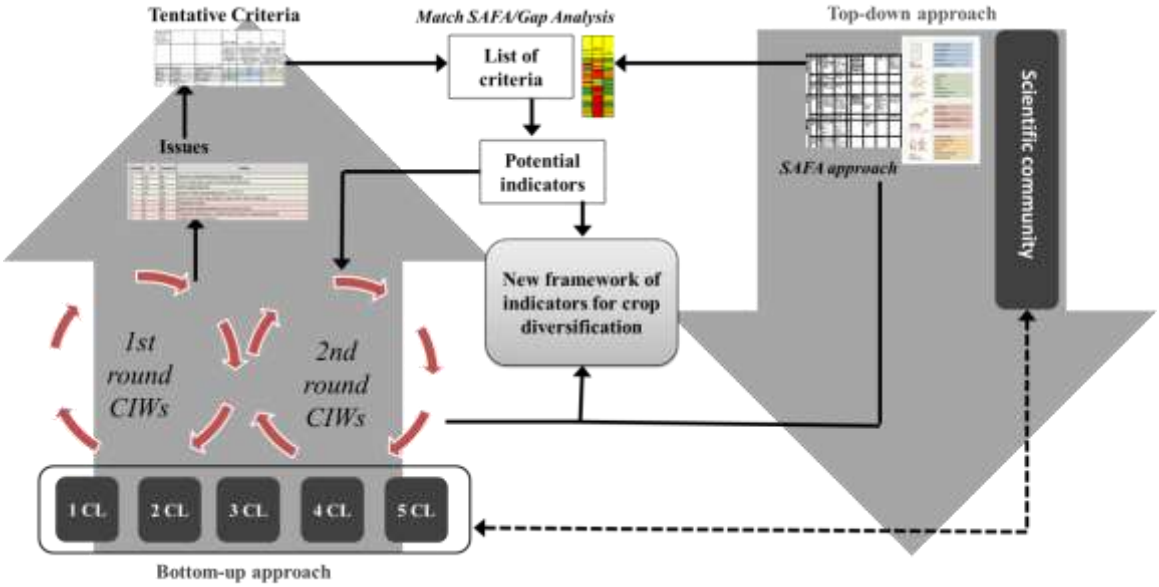

Figure 1. Methodology implemented to combine top-down (scientific community) and bottom-up (actors involved in the five clusters – CL - of the Case studies) approaches to support the design of a new adapted framework of indicators for the sustainability assessment of crop diversification within the DiverIMPACTS project.

During the first round of CIWs, actors were involved to reflect on aspects considered relevant for the sustainability assessment of diversified agro-food systems. These issues were subsequently clustered according to their homogeneity and similarity, thus generating a list of "Tentative criteria" that was crossed with SAFA-FAO reference scheme and with the list of criteria obtained by the top-down approach to identify missing or underrepresented areas and sub-areas (gap analysis) and obtain the final list of the criteria. Once the sustainability criteria framework was defined, researchers identified the indicators to be used for the quantification of each criterion considering the following aspects: relevance for crop diversification; non-redundancy; scientific soundness; feasibility; effective to assess trade-offs; indicator type (causal or effect indicators (Bockstaller et al., 2015); spatial and temporal scale.
Further interactions took place with the CSs within the second round of CIWs and through a specific survey in which actors were interviewed principally on indicator relevance and computational problems (e.g. lack or hardness to find and/or retrive input data, etc.). Subsequently, in order to achieve the final set of indicators were amended according to

the received feedbacks to further increase feasibility of the indicators and mitigate the risk of potential constraints.

3 – **Results – Discussion**

The final DiverIMPACTS framework was characterized by 19 criteria and 29 performance indicators. In particular, the identified criteria were selected to cover the following sustainability dimensions: 6 criteria for the economic pillar (Productivity; Stability of production; Profitability; Dependency on external inputs; Product quality; Local valorisation), 11 criteria for the environmental sustainability (Ecosystem/landscape Diversity; Crop diversification; Genetic diversification; Soil degradation; Soil quality; Water withdrawal; Water quality-nutrient; Water quality-pesticide; Air quality; GHG balance; Non-renewable resources; and, 2 criteria for social dimension (Famer and public health; Farmers' quality of life).
The 29 indicators to quantify the criteria were identified to capture the carry-over effects of the diversification over time and space. In fact, benefits of new crops or diversification strategies are often viewed ~~in isolation~~for their direct effect (e.g. profitability of the new legume crop) while carry-over effects (e.g. reduction of nitrogen fertilisation of the crop after ~~a~~ the introduction of a grain legume) may exist at the rotation level and they may balance possible shortcoming results (Meynard et al., 2013). For this reason, the DiverIMPACTs performance indicators were adapted to encompass the whole rotation using the length of the rotation as temporal scale and, when possible, averaging the results on the number of the years of the rotation. Simoultaneosly, to fully capture the different impacts of diversification over space, indicators covering different scales (from field to farm to territory) were included.

4 – **Conclusions**

The ensemble of the indicators is beeing used for monitoring CSs during the implementation of their crop diversification strategies. As the transition toward more sustainable agriculture is a complex process that has only been activated and fortified by the DiverIMPACT project, the reserchers are currently working for making available to the involved actors the operational tools for calculating the performance of their systems even after the end of the project.

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