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Making transition towards ecological intensification of agriculture a reality: the gaps in and the role of scientific knowledge

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Transition towards ecological intensification in agriculture is a knowledge intensive process that should not be perceived as the promotion of old traditional practices. The science supporting such an option is relatively young and its analytical framework has not been tested over many years. It is therefore important to identify and address what we poorly know, that is understanding bio-ecological mechanisms at work in agro-systems, using agro-biodiversity as leverage for intensification, exploring the multiple and complex links between the technical dimension of practices and socio-economic and political changes. This means revisiting the notion of performance in agriculture. This also leads to orchestrating research partnerships, at local and global levels, and implement multi-stakeholders' original learning approaches that embed scientific knowledge into local innovation systems. After describing the specificity of knowledge gaps, this contribution identifies the main knowledge gaps and explores new research approaches, arrangements and roles.

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Introduction

Ecological intensification (EI) consists of intensifying ecological processes in the cultivated space to enhance performance; EI represents one of the main avenues to improve the sustainability of agriculture, that is, its capacity to answer the needs of current and future generations [1,2••]. Agriculture of the world, in its great diversity and as a whole, is concerned with EI. The challenge of a transition towards EI does not only relate to high input agriculture in the OECD countries but also to low input systems in developing countries, through specific pathways. In any case, knowledge will be a key element of the process as rightly emphasized by FAO in its definition of EI as a knowledge intensive process [3].

The science supporting such an option is relatively young and its concepts, methodologies, techniques, and analytical framework have not been tested over many years. It is therefore important to identify what we do not know, where we are unsure about and where we think there is a need to revisit current approaches, concepts, paradigms, methodologies and instruments. After examining the importance of EI of agriculture for addressing sustainable development in the first section, this article provides an analysis of the gaps in scientific knowledge in the second section. The third and last section moves into the need for new research approaches and roles for addressing these challenges.

Given the significant developments around the term agroecology and its possible congruence with EI, we cannot ignore the links between these two terms and will also refer to agroecology when considering specific questions. Since its first definition by Bensin in 1930 (quoted by Wesel *et al.* [4••]) as 'an applied ecology to plant production and agricultural land management', many authors have proposed definitions of agroecology. They all agree around the basic idea that agroecology is the application of ecological principles and methods in agricultural science. Stated this way, this is very congruent with EI, which stresses the dynamic of intensification of biomass production through biological and ecological processes. This is confirmed by the recent bibliographic FAO report [3] on ecological intensification which builds upon literature on agroecology. Other authors such as Wezel *et al.* [4••] emphasize that agroecology may have a wider meaning and refer to a scientific discipline, to an agricultural practice and/or to a political and social movement.

Why considering ecological intensification of agriculture towards sustainable development and what is at stake?

Through examining the current challenges faced by agriculture, we show in this section how these call for the necessary exploration of new paradigms. As suggested by IAASTD [5], 'business as usual is no longer an option'.

Such an analysis leads us to arguing for the need to renew the conception of the notion of performance in agriculture. Indeed, addressing the multifunctionality of agriculture makes performance a cornerstone. Finally, we stress the importance of considering diverse sources of knowledge and learning processes to make the transition towards EI a reality. This brings along the need for a renewed role for farmers and local communities in the knowledge generation process. These three combined analyses, that is into the challenges, for renewing the notion of performance and for reconsidering knowledge generation processes, serve to identify the gaps in the second section of this paper.

Changes and challenges for agriculture: exploring new paradigms

While facing tremendous economic, environmental, demographical and political challenges, agriculture and rural areas go through in-depth transformations [6]. The way for future agriculture transformation is structured by the opposition between two different visions. According to some stakeholders and decision makers, the top priority is to feed the world and this would rely preferably on fewer entrepreneurial farmers mobilizing high levels of technical skills and financial fluxes. Such an option relies on land acquisition and high input agriculture, and is being justified by its proponents by the threat of food insecurity, the perspective of climate change, the weakness of some land tenure regimes and opportunities offered by biomass based energy. Others remember the role of agriculture in terms of employment and income, and highlight the importance of peasants to address both production objectives and development goals, in particular the fight against poverty. As highlighted by the recent report from the High Level Panel of Experts on Food Security and Nutrition [7•], agriculture is not only about producing food. A new deal is called upon for supporting smallholders' capacity to contribute to household, national and global food security. The opposition between these two visions shows how much agricultural transformation is connected to a whole set of development patterns and might depend upon and impact on many different sectors. Of crucial importance to understand such a controversy is whether performance is assessed against commodity output at any cost or against the whole set of outputs and impacts agriculture contributes to. Whatever the way towards development, the model of artificialized agriculture, that is, substituting each time more ecological processes by chemical inputs, irrigation and fossil fuel, is increasingly questioned for its dramatic consequences and its economic, social and environment global cost. These relate to the environment on the one hand [8] and to the exclusion of poor farmers, social justice and political stability on the other. There is a growing consensus that a new paradigm is required to make farmers more resilient and the agricultural sector sustainable. Not only because we would have to anticipate the growing demand to feed more than 9 billion people in 2050 [9•], but also to address the environmental footprint already left by the incredible leap from a 1 to 7 billion populated planet in the last two centuries [10,11]. In addition, if the demographic scarecrow of the Malthus-like injunction of the second half of the 20th century should still be considered, equations to be solved and challenges to be addressed are unique and unknown [12].

In such a context of rapid transformation, the richness of agricultural contributions to human welfare and environmental health through its ability to meet a great variety of demands is a critical dimension. That is how the notion of 'multifunctionality of agriculture' emerged during the 1990s as '*a consequence of the undesired and largely unforeseen environmental and societal consequences and the limited cost-effectiveness of the European Common Agricultural Policy (CAP), which mainly sought to boost agrarian outputs and the productivity of agriculture*' [13,14]. Some European researchers started to reinvestigate the role of agriculture for society at large, with their work often informing policy reviews and evaluations [14–17]. In North America, an interdisciplinary approach has progressively developed into the field of political ecology [18], which not only links agriculture and land use patterns with technology and ecology, but also with socioeconomic and political factors. While demographic dynamics underpinned the focus of agricultural development on increasing production during the 20th century, the rediscovery of the multiple functions of farming currently taking place is changing the way to look at the relationship between agriculture and society, leading to a more integrative view [19]. There is no doubt that, after having been a contested concept for being suspected to be a pretext for legitimizing market distortions in the context of GATT and WTO agricultural and trade policy negotiations, officially for being fuzzy, loose and fashionable [20•], the idea of multifunctionality is nowadays widely acknowledged.

In parallel, in the environmental field, and in relation with the Millenium Ecosystem Assessment dynamics in the 2000s, the notion of ecosystem service initially popularized in the scientific community in the 1990s [21] progressively became institutionalized and its scope enlarged. This has served to account for the recognition that, besides the production of biomass, agriculture provides multiple services to our societies that are in general not compensated for through the mediation of markets and therefore to recommend redirecting agricultural subsidies in the United States, EU and Japan towards the reward of sustainable practices [8]. Overall, environmental services are increasingly perceived and valued by society. This is confirmed by an increasing number of theoretical and empirical studies [22]. Yet, as stated as the first key message of IAASTD's third chapter [5], the