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Is it time for a socio-ecological revolution in agriculture?

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1. Abstract

Sustainable intensification is touted as the future for agricultural land management in a world demanding greater food production. Agricultural practices remain primarily driven by the 'intensification' and not the 'sustainable' agenda. To turn this around requires clear evidence from ecologists about the nature of farming systems, the fundamental underpinning role of natural resources and ecological processes within them and the provision of feasible alternatives. Alternative ecologically based farming systems must reflect current wider food systems and the actors engaged in them with ecologists playing a key role in advocating change; from international global agreements which force political change, through changes in focus for agri-businesses, to decision-making by individual land owners.

Key words: agriculture, agri-business, ecology, ecosystem services, natural resources, society

2. Introduction

Over the past decade or more ecologists have engaged with both the ecosystem service (ES) agenda (MA, 2003; Zhang *et al*., 2007) and the need for developing sustainable agricultural systems (Firbank *et al*., 2013; Robertson & Swinton, 2005). The increasing numbers of publications concerned with 'food security' and 'sustainable intensification' in recent ecological journals reflect continuing concerns about the pressures of increasing food production on agro-ecosystems (Garnett *et al*., 2013; Letourneau & Bothwell, 2008; Swinton *et al*., 2007).

In the Green Revolution of the 1960's, ecological knowledge was used to revolutionise agricultural systems resulting in the dangerous contraction of the crop varieties used in agricultural production; the widespread use of fertilisers in response to their nutrient requirements and the use of pesticides, to reduce competition with other plants and limit the effects of herbivorous insects on those crops. Impacts on farming ecosystems were far reaching in both time and space, and highly damaging (Robertson & Swinton, 2005) as both the products themselves and the means of dispensing them began to dictate the farming landscape. What was missing from the processes which led to the drastic changes in farming was an evaluation of how these products would be used, their potential impacts beyond field scales and their wider impacts on society and ecosystems; the understanding that food production is part of a socio-ecological system. If we are to move towards more sustainable ecological practices in the future, we need to ensure that ecological knowledge is used within the wider context of the social-ecosystems in which 'agri' 'culture' is practised, so that we have a better understanding of, and more influence over how ecological innovation will change our world.

Whilst current food insecurity is a social issue, it will have devastating impacts on ecosystems if the ecological integrity of agricultural systems is not maintained. This paper presents the view that the time is right for ecological innovation in agricultural systems which promote sustainability of production, but advocates that we must innovate in close collaboration with all the other actors in current food systems in order to avoid perverse outcomes (Waterton et al. 2006) in other words, the food production and distribution network needs to be considered in its entirety.

3.1 Sustainable intensification

The term 'sustainable intensification' has been coined to encapsulate the need for increasing the intensification of management on agricultural land without further damaging ecosystems (Foresight, 2011; Tilman *et al*., 2011). For those in the business of agriculture the term provides validity for continuing current 'intensive' production practices (Petersen and Snapp (2015), but encourages thinking around how these can be better maintained in the longer term (e.g. by improving land quality). For ecologists the emphasis is on 'sustainable' and the preference is for a term like 'ecological intensification' (Bommarco *et al*., 2013; Tittonell 2014) which provides a clearer understanding of the need for any intensification to be focused on enhancing the regulating and supporting services underlying agricultural systems. Such contrasting interpretations, and a lack of clarity and definition of the term across agronomic and ecological perspectives, as well as from a social perspective (Loos *et al.* 2014), are likely to have significant impacts on society's ability to achieve productive and sustainable farming systems into the future.

Another key issue is the starting point from which we propose to sustainably intensify production. In countries or areas where significant intensification has been taking place over decades the potential to provide more product out of ecologically impoverished land is far more challenging than in countries where land has never been intensively managed. From an ecological perspective the back drop of negligible improvements in yields in intensive systems in countries over recent years (Ray *et al.,* 2013) infers a need for identifying new efficiencies which will better optimise ecosystem processes as part of the agricultural system (Smith *et al*., 2008). The will include factors such as the long term provision of nutrients as external input availability declines (Pretty, 2013) and optimising cropping options, both crop type and variety, to reflect ecological conditions both currently and under future climate change (Mathur 2013). Getting land into good condition for appropriate crops for sustainable long term production should be the ecological focus. This may, however, result in a loss of production in the shorter term thereby requiring agricultural producers to focus on longer term production patterns.

3.2 The Ecosystem Approach

The ecosystem approach is one piloted by the Convention on Biological Diversity and forms the primary framework for action under the Convention. It is a strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way (CBD, 2013). Recognising agriculture as a socio-ecological system i.e. a social system embedded in the natural environment, provides a good starting point for beginning to understand and influence the complexity of food systems (Figure 1). Ecologically based research investigating potential long-term sustainable agricultural ecosystems (Bommarco *et al*., 2013; Firbank *et al*., 2013; Scherr & McNeely, 2008) recommends the integration of biodiversity based agricultural practices alongside more intensive management approaches, including: traditional farming, small holder enterprises, organic farming and agro-forestry (Cunningham *et al*., 2013; Firbank *et al*., 2013; Scherr & McNeely, 2008). Restoration of semi-natural habitats as part of a farming matrix, or a 'land-sparing' approach (Green *et al*., 2005; Phalan *et al*., 2011) may help to balance trade-offs between production, biodiversity and other ES, but such decisions need to be made at all scales from local to global (Cunningham *et al*., 2013; Swinton *et al*., 2007). Perverse outcomes may occur at national as well as at local scales, for example, from a global perspective, importing foods from other countries while reducing local (national) impacts on ecosystem services or biodiversity is only transferring the problem of agriculture's impact on wider ecosystems from one place to another. Similarly, intensification to ensure adequate food production may allow some land to be spared (Phalan *et al*., 2011) particularly in high output regions of the world, but will inevitably lead to high levels of inputs elsewhere (Pradhan *et al.,* 2015) and their associated environmental problems, taking us back into the cycle of unsustainability that we currently occupy.

Farming sits at the hub of our food systems (Figure 1). If scientists are to be involved in improving agro-ecosystems, it is essential for them to work alongside those managing the land (Cunningham *et al*., 2013; Dube *et al*., 2012; Robertson & Swinton, 2005; Scherr & McNeely, 2008; Zhang *et al*., 2007) and the food systems which rely on production (Loos *et al*. 2014). Integral to this is the need to incorporate social science which can help to improve our understandings of food producers and consumers and the political and economic systems of which we are a part, i.e. the 'cultural' parts of agriculture. Examples include understanding /land owner/land manager/farmer motivations and their cultural acceptance of agricultural practices and of the need to manage land for the production of ecosystem services (Burton & Paragahawewa, 2011; Greiner 2015). Research investigating farmers responses to the 'food security' issue in the UK have shown that most of the (predominantly livestock) farmers interviewed believed that they needed to be part of an effort to increase food production and asserted the importance of reconciling this with wider sustainability (Fish *et al*., 2013). If new or, in some cases, revived practices are to be adopted there is likely to be a need to create social and cultural capital around the adoption of these practices, for example, certification based on product quality, breeding, good husbandry and land stewardship skills (Burton & Paragahawewa, 2011). An important and significant challenge in the developed world will be changing what have become the accepted 'norms' of modern agricultural practice (Fleury *et al.,* 2015). Farmers have become accustomed to all-but eliminating non-crop species in pursuit of 'tidy' farms (Burton, 2012) and to farming monocultures of a restricted range of food crops. Encouraging farmers to adopt practices and cropping patterns which will see their farms transformed will take time, not least because of the need for acceptance within their peer group (See Koesling *et al*., 2012). Potentially the push will come from broadened dietary preferences or social desire for more diverse and complex landscapes.

3.3 Revolutionary ecological agricultural systems

What will the agricultural landscape look like if driven by ecological objectives of sustainable management? Research points to the prevalence of biodiversity based systems described above, alongside the use of traditional breeding, the re-development of locally suited varieties, intercropping, mixed farming systems, ensuring maximising nutrient and water use efficiency and the potential use of new technologies. For developing countries, the options may be wider. Highly productive (and often highly diverse) long-term sustainable natural systems provide valuable reference points for agriculture in the tropics (Bommarco *et al*., 2013; Foresight, 2011) as may successful tropical agricultural systems already in place (Altieri et al. 2012). In developed countries, the lack of such a reference point in terms of fully natural systems may mean that we need to look again at farming systems in temperate environments that have undergone little change during the period of the Green revolution (Mikulcak *et al*., 2013) as well as at innovative systems which focus on sustainability. We have to be prepared for the possibility that the systems which can support high levels of production and be sustainable in the long term either do not yet exist or require massive social change to accommodate from both farming and consumption perspectives.

3.4 Moving to Sustainable Production Systems

If we view our farming systems as social-ecosystems, as in Figure 1, it is clear that society/consumers influence all aspects of the food system. The strengths of the relationships among different components of the system (denoted by shading of the arrows – darker arrows show greater influence) will determine the future sustainability of our agricultural systems. Ecologists need to be engaged with ensuring that production systems of the future are firstly, ecologically sustainable and secondly, productive. To do this, it is imperative that we work with those who are experts in production and consumption to identify practices which are spatially and temporally relevant, both for the producers and the consumers. These experts include agricultural scientists, agri-businesses, agronomists and food scientists, as well as the farmers and growers who make the everyday decisions about farm management. Working alongside farmers and understanding their decision making and the 'cultural' aspects of their practices as has been done in the developing world (Tittonell 2014; Foresight, 2011) can lead to productive and sustainable farming systems.

A key issue is the need to move away from singular approaches towards developing a diversity of systems. Singular approaches such as the adoption of GM technologies in Australia may result in a "linear view of modernisation" (Thompson & Scoones, 2009) precluding widespread adoption of other approaches. Particular issues with biotechnologies used in Western Europe surround the commercial control of crop varieties (both GM and non-GM) and their widespread adoption, which limit future sustainability of crop production (Heinemann 2013). More generally, it will be essential to include agri-business in a vision for revolutionary ecological agricultural systems which move away from the generic intensive approaches which dictate modern agricultural landscapes (Dibden *et al*., 2013). The positive influence of agri-businesses in combination with strategically directed funding from governmental interventions (such as the agri-environment schemes) potentially driven by an international impetus (like the Intergovernmental Panel on Climate Change, potentially the Intergovernmental Panel on Biodiversity and Ecosystem Services) towards climate and land degradation resilient farming systems could lead to significant positive impacts on future farming systems.

Clearly, the ecological sustainability of future of agricultural systems is about more than ecosystems, farming or production. Political and social drivers of change (Fig 1, consumers, food and governance) including obesity and malnutrition, world food prices and cultures surrounding; food production, processing, purchasing, use, seasonality, consumption and waste will all play a role in the development of sustainable food systems (Dube *et al*., 2012). Within this 'food' system, the role of ecological science is to ensure the long-term protection of ecosystems for current and future sustainable production. In order to play an effective role in the future we need to engage with the whole food system and recognise how our science can contribute effectively. Future agricultural sustainability relies on an understanding of natural resources and the associated ecological processes on which the long term sustainability of agricultural land and the multiple goods which it provides depend. Subsequent to that there is a need to identify ways to maximise the goods provided by agricultural land without negative impacts on ecosystems either locally or further afield. As other authors have already concluded (Bommarco, 2013; Cunningham *et al*., 2013) there are likely to be many answers and clearly these will differ according to social and natural contexts.

4. Conclusions

Ecologists should be advocating revolutionary agricultural systems which focus on sustainability rather than production and using their expertise, alongside that of others towards this end. This should involve:

- Promoting a far greater diversity of agricultural approaches across whole farms than currently exists (particularly in the developed world).
- Working together with social, agricultural and economic scientists to understand the role of ecological science within the complexity of food production systems. This should include investigating innovations in agriculture which are already successfully producing food using sustainable practices.
- Using our understandings of food production systems to influence positive change in the approaches of key stakeholders driving change in agriculture including consumers, policy makers and agri-businesses. This should include; providing evidence for the importance of natural resources in underpinning production system at multiple scales, encouraging good governance of natural resources across those scales and promoting sustainable solutions.
- Advocating the clear need for international agreement to ensure widespread political change which recognises the fundamental role of ecology within our food systems.

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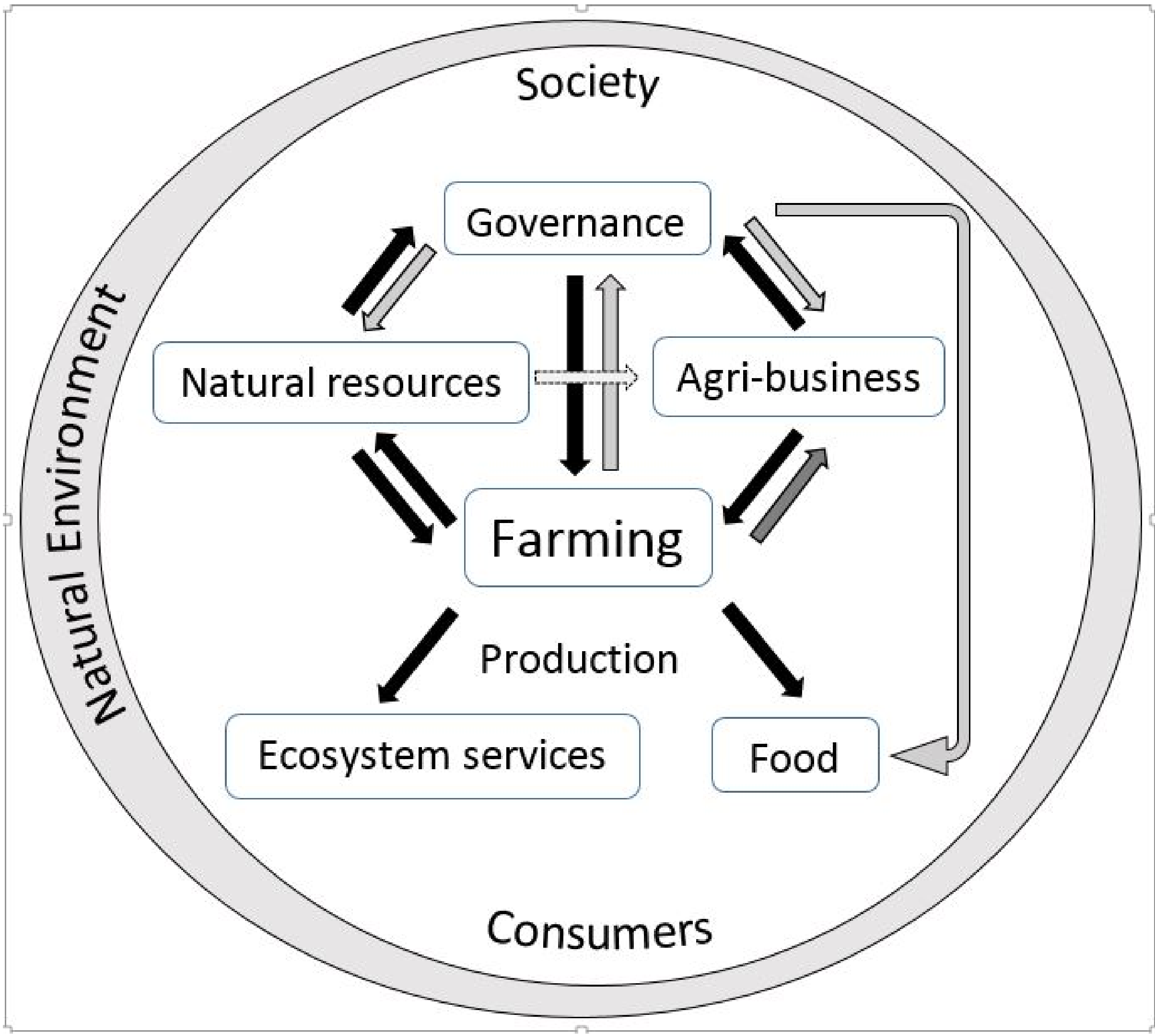
Figure legend

Figure 1. A socio-ecological framing of food systems for agro-ecological science. Society/consumers drive the whole system which is in turn entirely dependent on the natural environment. Arrows indicate strength and direction of influences of different components on one another. Darker arrows indicate stronger influence. Connections between components and the relative strengths of those are clearly subject to interpretation.

Ecological science has a key role to play within the system in ensuring that natural capital and ecosystem processes continue to support a productive and sustainable agricultural system. **Ecological scientists** need to play a role in influencing government, farming and agri-business as well as broader society of the fundamental importance of ecology for future food production.

Figure 1.


Society
Governance
Natural resources
Agri-business
Farming
Production
Ecosystem services
Food
Natural Environment
Consumers