How to use the global land bank to both produce food and conserve nature: examining extensive vs intensive agriculture

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Summary

The world is facing unprecedented long term pressures on agricultural landscapes. It will be necessary to increase food production to meet demand but this must be undertaken sustainably, with a minimum of environmental and social impacts. "Sustainable" farming is often equated with less intensive approaches such as organic farming practices that are generally more extensive than industrial farming. Such extensive farming methods are often beneficial to the local environment but typically also have lower yields and, therefore, make the challenge of increasing global production more acute. To explore the tension between our global need to produce food and conserve nature it is useful to think of agricultural landscapes as systems that produce two axiomatic products: food (and other economic goods) and ecosystem services (which may relate to biodiversity, water, carbon storage or environmental health). Given that most empirical evidence shows that extensive farming produces lower yields and less local environmental impact than intensive systems, there are two basic land management strategies: land can be farmed extensively over a large area thereby producing less food but more ecosystem services on the same land (a "land sharing" strategy), or farmed intensively over a smaller area and the remaining land can be "saved" to be managed exclusively for ecosystem services ("land sparing"). Recent research indicates that when the extra land needed to maintain yields under extensive systems is taken into account, land sparing strategies may often be optimal in terms of balancing food production while maintaining overall ecosystem services. Furthermore, if farm management increasingly reduces intensive agriculture’s impact on the environment (say through new technologies that reduce the green house gas emissions from conventional farms) the conflict between intensive and extensive systems will be additionally reduced.

Key words: Extensive and intensive agriculture, sustainable farming practices, organic farming, world food security, population growth, biodiversity and ecosystem functioning

Abbreviations: GHG: Greenhouse gasses

Glossary:

Extensive vs intensive: Intensive production systems are ones aiming to maximise the yield per unit area and typically require larger investments (in labour or capital) than extensive systems. Extensive farms yield less agricultural produce because production methodologies are less intense. We use the terms extensive vs intensive as simple labels, whilst recognising that they are relative.

Organic farming: There is no universally accepted definition of organic agriculture but the core of organic agriculture is refraining from the use of synthetic fertilizers and pesticides, genetically modified organisms. Pests and diseases are controlled with naturally occurring means and substances according to both traditional as well recently developed ideas. Note that organic farming may be extensive or intensive (e.g. with high application rates of green manure, large fields etc); organic and extensive are therefore not necessarily synonyms

Conventional farming: we use conventional farming as a label to describe common farming practice in the recent past (i.e. non-organic). This is typically also intensive. As we develop a low carbon economy, conventional farming will necessarily become greener so conventional intensive farming may have lower (local) environmental impacts.

Ecosystem services: Ecosystem services are those services that ecology provides that have value to humans. They break into four main categories: provisioning (e.g. food production), regulating (e.g. water quality, pollination, pest control), supporting (e.g. soil fertility) and cultural services (e.g. providing habitat for biodiversity of cultural value).

Introduction

The food security challenge

The world's population is predicted to increase by 35% by 2050 (UNDP 2008). At the same time, per capita food demand is rising because as individual wealth increases, consumption, and especially the consumption of resource-intensive products like meat and dairy, also increases. These factors mean that the global demand for food is likely to grow at a greater rate than the population and although there are uncertainties, the most widely cited prediction comes from the FAO who calculated that 70% more food will be required by 2050 (Bruinsma 2009).

Currently, pests, diseases and post-harvest losses account for a significant waste of the global harvest. Although Parfitt *et al*. (2010) conclude that there is little useful data on actual post-harvest losses it is possible that we lose 15% of China’s rice harvest due to poor storage, losses in transport and inefficient processing. As a result, many suggest there is a huge scope for improving efficiency (Smil 2001). Furthermore, any behavioural change (e.g. reduced consumption of meat and dairy: see Godfray *et al*. 2010) will also reduce demand. Nonetheless, many argue that to meet projected demand, global food production will need to continue increasing at rates similar to those of the last two decades (Foresight 2011).

As demand is increasing, three factors limit productivity: land use change, climate change, and the need to reduce fossil fuel based inputs in farming. Land use change arises from a number of causes (Holmgren *et al*., 2006). For example, urbanisation is changing the relationship between society and the land, not least as rural populations decline and this reduces farmers' access to labour, capital, and transport thus changing agricultural practice. In particular, many in rural Africa are asking "where is the life in farming?" and are shifting away from food production. Land is also increasingly used for non-food crops such as cotton, oil palm and biofuels. Environmental degradation such as soil erosion and salinisation has led to abandonment of agricultural land (Smith, Gregory et al. 2010). Climate change will have major impacts on agricultural productivity and practices (Lobell, *et al.* 2008; Battisti and Naylor 2009; Challinor *et al*. 2010). In particular, by 2050 agricultural yields in sub-Saharan Africa are projected to decrease by between 7 and 27%, with higher productivity areas being most affected (Schlenker and Lobell 2010). Finally, movement towards a low carbon economy, coupled with tighter environmental regulations, mean that agriculture will have to reduce its use of agrochemicals, mitigate green house gas emissions, and sequester carbon in soils and biomass. This suggests that the historical growth of productivity, which is largely based on energy intensive agricultural inputs, will become more difficult to maintain. Indeed, if low- or no-input agriculture is required, yields in many productive farming systems may drop. Thus, on the one hand demand is increasing, and on the other hand, production growth may be difficult to maintain.

Although the area of cultivated land on the planet could double (Fischer *et al*. 2002), meeting demand and boosting harvests cannot be met by simply taking more land into agriculture for three key reasons. First, some of the land that could be cultivated is currently tropical forest, and deforestation is a major driver of current climate change (Smith *et al*. 2010). Bringing such land into agriculture is counter-productive as it would increase the rate of climate change and, therefore, will require more costly mitigation, whilst simultaneously impacting on the world's most biodiverse habitat. Second, the most productive land is already cultivated so diminishing returns are likely if cultivation expands into marginal areas, as well as it causing increased land degradation. Third, non-cropped land has other uses such as for tourism, conservation of natural resources, human habitation, cultural significance, carbon storage and water quality regulation (TEEB, 2010). Although these goods and services have not been fully valued economically, their importance is increasingly recognised and incorporated into environmental policies.

We are, therefore, facing a global "perfect storm" of problems in that we need to increase productivity whilst not increasing the environmental impact of farming on the land.

The sustainability challenge

There is increasing recognition that agriculture needs to become more environmentally sustainable, in that any environmental degradation caused by agriculture should not impact on future generations' ability to utilise natural resources for their own livelihoods (WCED, 1987). There are many arguments in favour of "sustainability" but an important utilitarian one is the recognition that ecosystems provide a range of goods and services, and unsustainable production implies that these would be impeded. The value of the ecological services provided in agricultural landscapes is only just beginning to be recognised (Costanza *et al*. 1997; TEEB, 2010); some services assist a farmer's yield, others provide more disbursed services of value to society in general. For example, 15-20% of total crop production arises from plant species that are wholly or partially animal pollinated (Klein *et al*. 2007), amounting to a direct contribution of about 10% of all food production at a value of $153bn (Gallai *et al*. 2009). Similarly, "natural enemy" services provided by a range insects, such as small wasps, beetles and spiders, suppress pest outbreaks and a recent study suggests control of the soy bean aphid, *Aphis glycines*, by such natural enemies in just four US states is worth $239 million per year (Landis, Gardiner *et al*. 2008). Elbert *et al*., (2009) estimate that the autotrophic micro-organisms in dryland soils absorb a petagram of carbon (1 billion metric tonnes) each year. Not only does this improve soil fertility, this amount of carbon removed from the atmosphere is valued at *ca* $20 billion. Thus, there are clear indications that ecology has a direct value in production systems, and may become more important in future agriculture, especially when chemical inputs and mechanisation may be restricted by carbon costs.

Extensive vs intensive: which is more sustainable?

Our aim in this paper is to examine the relative costs and benefits of extensive vs intensive farming in meeting both the food security and sustainability challenges. We highlight the issue that if farming is more extensive it requires more land to produce the same food, which itself carries an environmental cost that needs to be considered; and that in some circumstances "intensive farming" may be more sustainable when judged from a broad perspective. The discussion takes a holistic view of how the goods and services required by society can be optimized in agricultural landscapes, rather than contrasting farm management strategies from a farmer's perspective. Furthermore, we briefly discuss the relative carbon costs per unit output of organic vs intensive agriculture and that organic farming may be similar in efficiency to conventional agriculture. We conclude that further greening of "conventional" agriculture, coupled with appropriate management of spared lands, may allow high production areas to maintain high production in a sustainable way, whilst other areas may be naturally suited to extensive farming. We hope, therefore, that this paper contributes to a mounting body of evidence that there is less need for a polarisation of views towards extensive (= sustainable) and intensive (=unsustainable).

The landscape view of agriculture: Sparing vs sharing

There is a considerable debate in the literature as to the extent to which different farming systems have the potential to produce adequate nutrition for the global population (for example see: Connor, 2008; Badgley and Perfecto 2007). There are many studies that cite specific cases of highly productive organic farms and argue that organic methods have the potential to “feed the world” (Coleman 1995; Badgley *et al*. 2007). Similarly, there are others who identify conventional farms that are high in biodiversity, and low in other environmental impacts, to demonstrate that conventional farms need not be bad for the environment (e.g. Linking Environment and Farming 2011). Nevertheless, most of the scientific literature points out that minimising the local environmental impacts of farming is favoured by extensive farming, of which organic farming is typically seen as an exemplar. Extensive farms are usually less productive in terms of yield but have more biodiversity than conventional farms. So, when we stand aside from specific examples, there is a general consensus in the literature that if farmers traded off yield to minimise local environmental impacts (such as by adopting the organic methods that certain groups of consumers demand), then, at a global scale, agriculture would expand its land base to maintain production. This exposes a very serious tension since it seems that, given the most commonly used conventional and organic practices, our need for more food competes directly with our need to conserve land for biodiversity and ecosystem services[2]. One way of resolving this tension lies in not thinking of a farmer's field in isolation, but thinking of a field within a landscape.

Ecosystems, and the service they provide in an agricultural region, reflect not only the organisms present in the cultivated fields but also those in the landscape around the agricultural land (Weibull *et al.* 2003; Gabriel *et al.* 2006; Carre *et al*. 2009; Batary *et al*. 2010; Chamberlain *et al*. 2010; Diekotter *et al*. 2010). Therefore, management of ecosystem services (which may be achieved through national level policy that establishes incentives that reward farmers who use farm management that sequesters carbon, provide habitat, etc.) requires consideration of the field, farm and landscape together. This view implies that while a field may be specialized for production, a landscape can be multifunctional as it produces both agricultural produce and biodiversity. Society demands both products and so the conceptual question becomes "what is the optimal way to deliver both products from the same landscape?"

Situating farm ecology within the larger landscape is highlighted in a landmark paper (Green *et al*. 2005) where the authors contrasted alternative hypothetical strategies when a set level of food was required from a single landscape. The first hypothetical landuse strategy was where the whole area was farmed extensively, in a way that yielded less food but consequently gained more biodiversity (so called "land sharing"). The contrasting option was where some of the land was farmed intensively to produce the required yield, thus allowing "spare land" to be managed for

[2] The following argument broadly applies for a range of ecological currencies, so we'll use "biodiversity" as a generic term for ecosystem service or ecology

biodiversity ("land sparing"). Green *et al*.'s paper analyzed "optimal land management" as a function of the costs and benefits to both yield and biodiversity.

While dividing land management strategies into these two broad categories is useful from a heuristic perspective, it is important to acknowledge that in the real world, most landscapes should be seen as falling along a continuum that ranges from those that intensively produce food (thus representing the land-sparing approach) to more those more extensively managed that would represent the land-sharing strategy. It is also important to note that most farmers do not explicitly adopt land sparing or sharing as management strategies, but rather chose those management methods they believe will provide an economic livelihood. It is typically only at an aggregate level that we can then categorize the resulting landuse patterns as representing land sparing or sharing strategies. With these two caveats aside, the arguments about the merits of land sparing and sharing have been empirically explored in a recent study that compared organic and non-organic farms in the UK (Gabriel *et al*. 2009; Gabriel *et al*. 2010; Hodgson *et al*. 2010). On a very well controlled, like-for-like comparison, organic farms were better for biodiversity (though the effect varied across different plant and animal groups) with biodiversity increasing by about 12% on average (Gabriel *et al*. 2010). But also in a like-for-like comparison of the field yields, yields of organic winter cereals in each field were only about 45% of the conventional paired field. For butterflies, for which biodiversity was ~40% higher on organic farms, this study also assessed biodiversity on spared land in local nature reserves.

The butterfly biodiversity data were then used to model the optimal landscape configuration to maintain food production while maximising biodiversity. This approach indicated that if organic yields were greater than 87% of the conventional yields, organic farming produced more biodiversity whilst retaining food yields across the landscape (Hodgson *et al*. 2010). Alternatively, when organic yields were below this threshold, biodiversity and food production was maximised by farming intensively to maximise production in some places while allowing land elsewhere to be spared for biodiversity. As the observed yields in the collected data were below this critical threshold, the conclusion of this study is that in the lowlands of the UK, a land sparing strategy is optimal for both food production and biodiversity conservation.

But this result is highly context dependent. The conclusion that land sparing is optimal in a productive landscape does not mean that everywhere else should embrace intensive farming practices as the best way of producing both food and biodiversity. For instance, studies on the production of the biofuel crop *Jatropha curcas* in Africa and India highlight that small-scale and community-led developments are able to produce reasonable yields, make a meaningful contribution to local livelihoods and can help to protect ecosystem services, including biodiversity. In particular, where such small scale projects have been introduced, scholars have observed that in addition to boosting farm income, such projects may help farmers retain landscape heterogeneity better than large scale bio-energy operations (see Achten *et al*., 2010). This result is confirmed by studies from rural Malawi that demonstrate that a range of ecological problems (from pests and diseases: ecosystem disservices) make large scale plantations less attractive than small scale projects (Dyer *et al*., submitted). Together these studies suggest that in schemes for *J. curcas* production in Africa a local-scale land sharing strategy is the best option.

Our conclusion is that whether land sparing or land sharing is optimal depends crucially on the place. For instance, regions with small fields, steep valleys, or large amounts of non-cropped habitat impose constraints on intensive production. In such regions, yields will be lower but biodiversity may be higher owing to the greater habitat heterogeneity (Benton *et al*. 2003). In such regions, land sharing strategies will likely be optimal. Conversely, a flat landscape with fertile soil may naturally be low in biodiversity and so the optimal management would be to farm more intensively to spare land elsewhere for biodiversity conservation.

Inputs and outputs: the carbon costs of farming

When there is a need to produce a given amount of food, the argument above suggests that in many productive landscapes, conventional farming (because it minimises the land area required) may be more sustainable than extensive or organic farming at producing both food and ecosystem services. However, a further argument for extensive systems being locally more sustainable is that they are "environmentally friendly" due to their lower inputs[3]. This need not always be the case. A recent study developed a full carbon-account for 17 years of a corn-soybean rotation system in Michigan (Gelfand *et al*. 2010). This showed that the efficiency (the outputs per unit input) were almost identical for organic and conventional approaches. Although organic methods "saved" energy costs by not using synthetic chemicals, they "spent more" on the greater mechanised costs of farming (for example requiring more passes with machinery during weed control and a winter cover crop of clover). So, although, extensive farming in the guise of organic production may have environmental benefits in locally raising biodiversity, it does not necessarily reduce the carbon cost of farming (per unit of production) and it also requires more land to produce the same outputs.

The Gelfand study also explored the relative efficiencies of two further management systems: "no till" (i.e. without deep ploughing but maintaining chemical inputs) and "low input" (i.e. where there is low chemical input coupled with mechanised weed control). These “alternative management” strategies demonstrated greater production efficiencies than either conventional or organic, and the no-till system also had a greater average yield than the conventional system. No-till systems maintain soil carbon stocks (West and Post 2002) and require less energy owing to reduction in the fuel costs of mechanisation. Whilst these alternative systems may not be universally appropriate, they illustrate that more sustainable conventional farming practices are possible. Thus, rather than creating a misleading contrast by dividing farming systems into either organic/extensive and conventional/intensive there needs to be greater recognition that future farming has the potential to maintain yield whilst becoming "greener" by further optimising inputs and practices to reduce environmental impacts. We return to this issue below.

The spatial scale of sparing vs sharing

The key point of the land sparing vs land sharing argument is that the costs and benefits of different land management strategies must be *assessed across all affected*

[3] Extensive farming, with lower or zero inputs of synthetic products, does not necessarily equate to a lower environmental impact. Green fertiliser, if over-applied, can lead to eutrophication of water courses; and permitted organic chemical uses include some high-impact toxic chemicals such as copper and natural pyrethroids for pest control. Furthermore, organic methods of weed control may require greater fuel use, contributing to GHG emission.

land. If a fixed level of production is required in a particular area (farm, landscape or region) converting to extensive farming implies that farming elsewhere will need to intensify (e.g. by converting extensive into intensive, or converting semi-natural land to farmland) and so the net landscape-scale effect needs consideration. The best solution is place-dependent (as discussed above) and scale independent. For example, if within a country costs and benefits vary regionally, higher productivity in one region will go make a larger contribution towards meeting production needs, thus allowing other regions to be relatively spared. Hence, one can imagine hierarchical applications of this argument: comparing landscapes within a region, land sparing in some, land sharing in others; comparing regions, with greater proportions of intensive production plus spared land in the higher production regions, and more sharing in the lower production regions and so on.[4] Of course, it is important to acknowledge that farmers do not manage at the landscape scale but an awareness of these tradeoffs at larger spatial scales is important for the policy makers who establish the rules and incentives that farmers are bound by.

To extend this argument, consider the case for organic farming within the EU. Organic farms tend to support local ecology as their farming practices promote landscape heterogeneity (through a diversity of crops and rotations), in addition to the reduction in synthetic applications of fertilisers and pesticides. This extensification usually leads to lower yields. All things being equal, if consumers demanded more local organic products, and farmers in Europe responded by expanding the number of hectares farmed using organic methods, we might expect a reduction in gross European food production, and this could result in more food imports from regions such as Asia and sub-Saharan Africa. Under such a scenario, we might expect an increase in intensification or more land being brought into production in these regions to meet both their growing home markets (where demand is growing faster than in EU) and to supply extra EU demand. This carries both environmental and economic implications. Adding further complexity the EU has much tighter environmental regulations relative to other regions, so greater intensification elsewhere may result in greater environmental damage than in Europe. Finally, since biodiversity is typically

[4] There are clearly a number of policy levers that can be used to encourage the "optimally designed" landscape; for example, agri-environmental subsidies, planning regulations or even local taxation; the key concept is for any such schemes to be responsive to different places.

richer in warmer parts of the world, the environmental damage caused by an expansion of organic farming in Europe, may add additional stress to vulnerable and ecologically valuable parts of the world. It has recently been estimated that European imports of food already account for a virtual land grab of the equivalent area of Germany (34 M ha) (von Witzke, 2010; von Witzke & Noleppa, 2010). If Europe increased the proportion of its land devoted to organic farming to 20%, then it is likely that >10 M ha, an area equivalent to the size of Portugal, would need to be devoted to export crops from the developing world to Europe (von Witzke, 2010; von Witzke & Noleppa, 2010). Hence, organic farming in Europe may help conserve European environments, but only through the potential export (and magnification) of the environmental costs to elsewhere in the globe.

Finally, it is important to acknowledge the argument that exports from Latin America, Africa and SE Asia to the developed world provide much needed hard currency for poverty ridden economies and this is a helps maintain food security for millions of people in these regions. Nevertheless, one of the arguments from this paper is that rich nations may risk under-producing many crops and that importing produce from poor nations may undermine ecosystem services in these environmentally fragile and important regions. For example, the UK government's Foresight report addresses this and argues that long term food security global food can only be met if productive areas continue to be our main centres of production (Foresight, 2011). Does this mean the arguments presented here could be used to justify protecting our own farmers, thereby cutting the developing world off from access to western markets? To resolve this tension, policy makers in the EU need to consider a portfolio of policies that, on one hand, reward farmers who use green-yet-intensive farming practices in regions that are naturally productive. Simultaneously, other policies need to be enacted that reward farmers in other regions (and especially those in the Global South) for maintaining ecosystem services and farming using more land sharing methods to serve the needs of local markets.

The future

A world where extensive farming dominates is possible to imagine, in that extensive agricultural systems can potentially provide sufficient energy to maintain a healthy life for the growing population. However, this future would require such considerable change in individual and societal behaviour (e.g. the widespread adoption of vegetarian diets) that, in our opinion, this is unlikely to happen in the short term. Our pessimism is born out of our observation about how society has responded to climate change: despite the threat of, and evidence for, climate change, behavioural change to date has been relatively small. It is also not clear that an "organic world" is actually the most sustainable solution. Moving to organic production may intensify pressure on landscapes and this could lead to greater deforestation, greater release of carbon into the atmospheres and greater long term climatic effects.

Despite our pessimism about the likelihood of shifting behaviour, we take from our analysis that farming has unnecessarily been polarised into an intensive vs. extensive debate (in any of the many variants of this debate). High output systems are by definition intensive, but this need not equate to "industrial farming" or "high environmental cost" farming. Greening of "conventional" agriculture is already underway, partly driven by consumer demand, agri-environment schemes, tighter environmental regulation and recognition of the rising cost of oil driving up input costs. Furthermore, research demonstrates that practices such as no-till and low-input agriculture can maintain production, increase efficiency and have lower environmental impacts than "conventional" farming (and perhaps also lower environmental impacts than organic farming, if one accounts for the extra land need for organic production). Increasingly, both policy makers and producers are valuing the ecosystem services that contribute to yields and, therefore, ensuring operations have minimal impact on local biodiversity. Hence, we believe that the weight of the evidence suggests that ecological, or green, agriculture can exist without wholesale adoption of extensive or other organic practice. In the developed world, greener intensive agriculture may manifest itself in an increase in no-till, low-input and other agronomic systems. Plus the further development of precision agriculture using remote-sensed data producing high-resolution maps of fields to target inputs can also radically improve efficiency and reduce inputs (Bongiovanni and Lowenberg-Deboer 2004). Clearly, plant-breeding technologies (including molecular techniques such as gene tilling, for creating and identifying new variants, and also genetically modified crops) are potential partial solutions for maintaining or increasing yield in a "greener" way. These variants may also require fewer inputs (in terms of fertiliser; or water by changing root architecture or by modifying resistance or pests).

In the developing world, a form of organic farming often represents good farming practice, in that considerable management is necessary to avoid loss of yield to pests and diseases. However, there is widespread acknowledgement that some synthetic inputs can radically improve yields (Vitousek *et al*. 2009), which can both reduce poverty and enhance food security. Relative to strictly followed organic practices, such low-input systems can create radical increases in yield and can be managed in a relatively sustainable way.

To balance competing needs for both food production and nature conservation, landscapes need to be actively managed for both outputs. In the land sharing scenarios, much of the biodiversity will exist in the background landscape. In land sparing scenarios, the spared land needs to be actively managed for biodiversity (and not simply left fallow). In the discussions above, we have not addressed how the spared land could be laid out. Given that agricultural land may increasingly require ecosystem services for which non-cropped areas may be prime sources (e.g. spared land may provide habitat for predator insect or bird species that reduce pest damage in cropped areas), then we must not think of spared land solely as being in blocks or "nature reserves". Rather, an optimal arrangement might be where spared land becomes a network of patches across the landscape linked by suitable corridors. So, even highly productive landscapes may have high biodiversity provided across the landscape. The management of this spared land may evolve from the considerable current research on the efficacy of agri-environment schemes linked with input by the land managers in specific localities. High production, land sparing landscapes, need not be the "green desert of industrialised farming" that people often imagine. Owing to the greening of conventional farming and proper management of spared land, these areas may be home to considerably more wildlife friendly land than has been true of conventional farming landscapes in the last few decades.

Conclusions

Extensification will not be the answer to global issues of food security owing to the two major barriers of having insufficient land to expand into, and the need for considerable change in dietary habits. A recent study (Smith *et al*. 2010 p2955) concludes: "Given the need to feed 9 billion people by the middle of this century, and increasing competition for land to deliver non-food ecosystem services, it is clear that agricultural productivity needs to be maintained where it is already close to optimal, or increased in the large proportion of the world where it is suboptimal".

Local extensification only becomes possible if somewhere else intensifies, and it becomes a matter of assessing the costs and benefits of regional, country and local strategies to minimise environmental impact, whilst maintaining the necessary food production. In naturally productive areas, it is likely that land sparing strategies give the optimal mix of ecology and food; whereas in naturally less productive areas, land sharing becomes optimal. This argument applies to a degree at a range of spatial scales.

Extensification is "not the answer", but suggestions for the answer can be found in the greening of existing methodologies to reduce climate impacts and synthetic inputs. This should be coupled with management specific to the local landscape and local users, consistent with appreciating that agricultural landscapes produce more than just agricultural produce. This landscape view contributes to a reconciliation of "conservation" and "production", because recognising that landscapes produce two (or more) outputs allows a conceptual optimisation of the landscape-design to produce the most of both.

Sometimes, the optimal landscape design will appear to be a traditional extensive landscape, other times it will look more like an intensively farmed landscape but with specific areas of land managed very actively to maximise ecosystem service production, biodiversity or conservation. This spared and managed land will most likely be required as a network crossing the agricultural landscape, allowing the provision of ecosystem services (the distance that many natural predators move into cropped land from non-cropped land is a few hundred metres). A greening of conventional agriculture that couples agronomy, information technology and remote sensing is required. This will allow low-input, low-environmental impact farming to push productivity in areas where conditions are suitable, linked with spared land managed to provide biodiversity. The goal (from a policy perspective) is to create incentives that result in a farming system that, at a landscape scale, is as good (or better) for biodiversity and ecosystem services than if the whole area was farmed organically. It is perfectly possible for there not to be a societal choice between producing sufficient food with high environmental impact OR producing insufficient food in a sustainable way, but BOTH to produce enough food and to do it sustainably. The landscape view of farming is a tool towards aligning the traditionally opposing camps, and moving towards more sustainable agriculture that helps provide food security for an expanding population, the livelihoods of hundreds of millions of people and a way out of poverty for many in the developing world.

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