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Agricultural Development and Sustainability: A Review of Recent and Earlier Perspectives

by

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Clem Tisdell[†]

January, 2015

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The *Economics, Environment and Ecology* set of working papers addresses issues involving environmental and ecological economics. It was preceded by a similar set of papers on *Biodiversity Conservation* and for a time, there was also a parallel series on *Animal Health Economics*, both of which were related to projects funded by ACIAR, the Australian Centre for International Agricultural Research. Working papers in *Economics, Environment and Ecology* are produced in the School of Economics at The University of Queensland and since 2011, have become associated with the Risk and Sustainable Management Group in this school.

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Agricultural Development and Sustainability: A Review of Recent and Earlier Perspectives

ABSTRACT

Concern about agricultural sustainability emerged as a major issue in the closing decades of the last century as part of the global debate about the sustainability of economic development. In the 1980s, the three pillar concept of sustainable development was proposed and specifically applied by Conway to the evaluation of alternative agroecosystems. Although Conway's contribution was important at the time, it was limited in its perspective. Recent approaches adopt a wider approach, and in this century, attention has been focusing on ways to sustainably increase agricultural supplies rather than to just maintain these. This recognizes the fact that a substantial increase in demand for agricultural produce is expected in this century. Consequently, the scope and rationale for sustainably intensifying agriculture is examined (in some detail), and the extent to which greater use of organic agriculture is able to contribute to sustainable agricultural development is assessed. The comparative roles of agroecology and economics in guiding agricultural production are discussed, and the concept of multifunctional agriculture is re-examined in the light of proposals for the sustainable intensification of agriculture. Important shifts in the debate about agricultural sustainability have occurred in this century.

Keywords: Agroecology, agroecosystems, multifunctional agriculture, organic agriculture, sustainable agriculture, sustainable intensification of agriculture, sustainable development.

JEL Classifications: Q18, Q56, Q57.

Agricultural Development and Sustainability: A Review of Recent and Earlier Perspectives

1. Introduction

Concern for agricultural sustainability has become a prominent issue in recent decades as part of the debate about the sustainability of economic development generally. This concern was originally underlined by the report of the World Commission on Environment and Development (1987), *Our Common Future*, also known as the Brundtland Report, and by subsequent international conferences on this subject, the most significant of which was the Second United Nations Conference on the Environment and Development held in Rio de Janeiro in 1992.

The purpose of this paper is to provide an updated discussion of the subject of agricultural sustainability taking into account recent approaches to this subject and concepts associated with that discussion. This paper is set out as follows. First, early concepts of agricultural sustainability developed in the 1980s are outlined and discussed paying particular attention to the three pillar concepts and to the more specific analysis of Gordon Conway (1985; 1987). This is followed by consideration of the varied attributes of agriculture which it might be desired to sustain. This raises the problem that not all of these sustainability goals may be compatible and not all may be attainable. Therefore, difficult choices sometimes have to be made involving trade-offs between goals, that is, compromises in objectives. Subsequently recent concepts and approaches to agricultural sustainability are outlined and examined paying particular attention to the concept of sustainable intensification of agriculture and to the potential role of organic agriculture as a means of achieving sustainable agriculture.

The concept of sustainable intensification of agriculture has now assumed overriding importance in the assessment of policies for the development of agriculture given the very large increase in demand for agricultural produce predicted to occur in this century. This increase will arise as a result of:

- Global population increases,

- A growing global pool of population with higher per capita income,
- The expansion in the number of end-uses for agricultural produce (such as for biofuel), and
- The greater use of crops (particularly grain) for feeding livestock.

Issues involving agriculture sustainability are more important now than ever before.

2. Early Concepts of Agricultural Sustainability Developed in the 1980s

In the 1980s, the three pillar concept was formulated and suggested as a guide for the attainment of sustainable development, and Gordon Conway (1985; 1987) provided an application of this framework to the assessment of alternative agrosystems. Let us consider the three pillar concept and in turn, Conway's analysis of the 1980s.

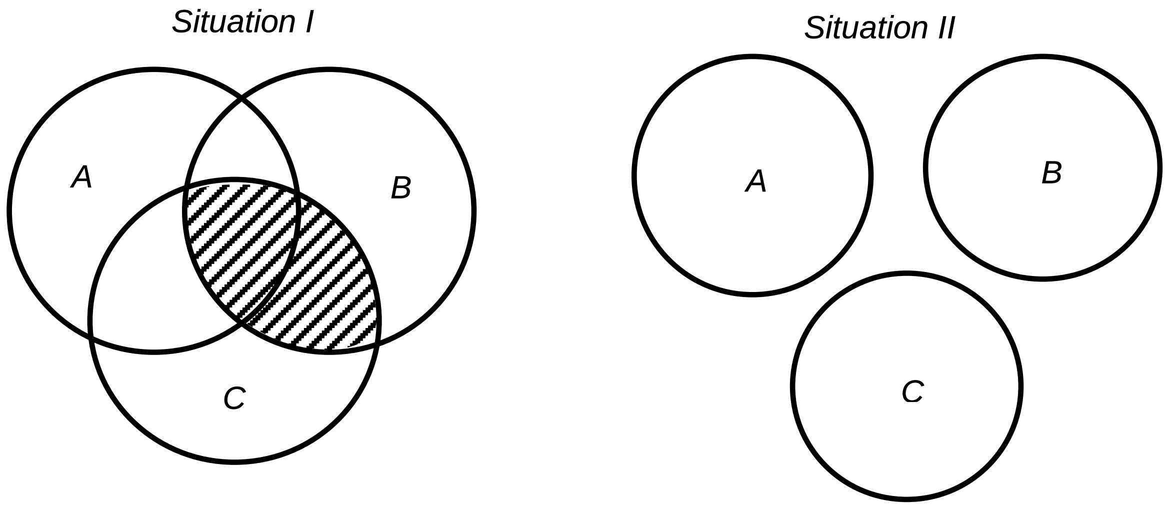
2.1 The three pillar concept of sustainable development

The view was widely expressed in the 1980s that three conditions need to be satisfied by development policies in order to achieve sustainable development (see, for example, Barbier, 1987). The requirements were that these policies should be:

- Ecologically sustainable,
- Socially acceptable, and
- Economically viable.

The satisfaction of these conditions was also believed to be necessary for the attainment of agricultural sustainability. In essence, it is envisaged that when all these conditions are satisfied, a harmonious equilibrium is attained by society. The objectives are appealing but from a pragmatic point of view, this approach to selecting desirable development policies has some limitations.

First, it is not clear what policies or development paths satisfy these objectives and indeed, whether any are able to satisfy all these objectives. Two possible situations are illustrated in Figure 1. Set *A* corresponds to the set of development possibilities that are ecologically sustainable, set *B* denotes those that are socially acceptable, and set *C* identifies those that are economically viable. In Situation I, the development possibilities corresponding to the intersection of these sets (the hatched set) are able to satisfy the three criteria. However, it is not possible to say which of the alternatives in this set is the most desirable one.



Legend *A*: ecologically sustainable set
B: socially acceptable (sustainable) set
C: economically viable set

Figure 1: Two alternative situations which can arise in trying to satisfy the three pillar concept of sustainable development

Situation II illustrates the worst case scenario in which no development strategy satisfies any of the pillars for sustainable development. Apart from these two situations, there are three other possibilities corresponding to circumstances in which two of the pillars can be satisfied but not the third.

The three criteria are like thresholds. They leave no scope for trade-offs. However, trade-offs are needed if a situation other than that illustrated by Situation I in Figure 1 occurs.

A second problem is that the criteria are not very precise. For example, how is social acceptability to be gauged? What if the only economically viable development strategies make some people worse off and others better off? Are these strategies acceptable to those who are made worse off? How is social acceptability to be determined? Douglass (1984) suggests that in the case of agriculture, this requires rural communities to be sustained, but not all city-dwellers may agree with his view.

The third problem is that knowledge changes with the passage of time and so do social values. Furthermore, the economics of alternative uses of resources alters. What is economically viable now may be no longer so in the future, and it is even possible for ecological conditions to alter, for example due to climate change. This requires that in order to sustain a desired course of action, decisions need to be made about resource use for conservation which permit some flexibility or adaptability in future decision-making. This is particularly important in agriculture. It may, for example, be rational (given the relevance of the precautionary principle) to conserve at a cost, a greater variety of crop germplasm than would otherwise be conserved by farmers and seed producers. It is also rational to exercise some precaution before releasing new genetically modified organisms. Many other examples exist. However, there are no hard-and-fast general rules about how much precaution should be exercised and how this ought to be done.

While it is important to consider the three pillars mentioned above in devising strategies for agricultural sustainability, they are too general to provide specific guidance. Furthermore, these criteria give no consideration to changing circumstances and the best way of coping with these, for example, by adopting precautionary measures which enable greater flexibility or adaptability in future decision-making. Despite this they are of some value in devising agricultural policies as is illustrated by the management of the farming of saltwater crocodiles (see Tisdell, 2014, Ch. 9)

2.2 Gordon Conway's analysis of agricultural sustainability

Gordon Conway (1985; 1987) made an important early contribution to the discussion of the sustainability and assessment of alternative agroecosystems. This is so despite his analysis being incomplete and too categorical in its comparison of the attributes of modern and traditional agroecosystems. He identifies four attributes that should be taken into account and assessing alternative agroecosystems. These are:

- The level of returns, yields or productivity attained by their use.
- Their variability of returns or yields.
- Their sustainability of returns or yields.
- Their effect on the distribution of income.

Agroecosystems which have a high level of returns or yields which vary little, which are very sustainable, and which provide a comparatively equal distribution of income are (according to Conway) more desirable than those lacking comparatively in these qualities. According to Conway's assessment, an agroecosystem with the properties illustrated by the diagrams on the left hand side of Figure 2 would be preferred to one with the properties displayed on the right hand side of this figure.

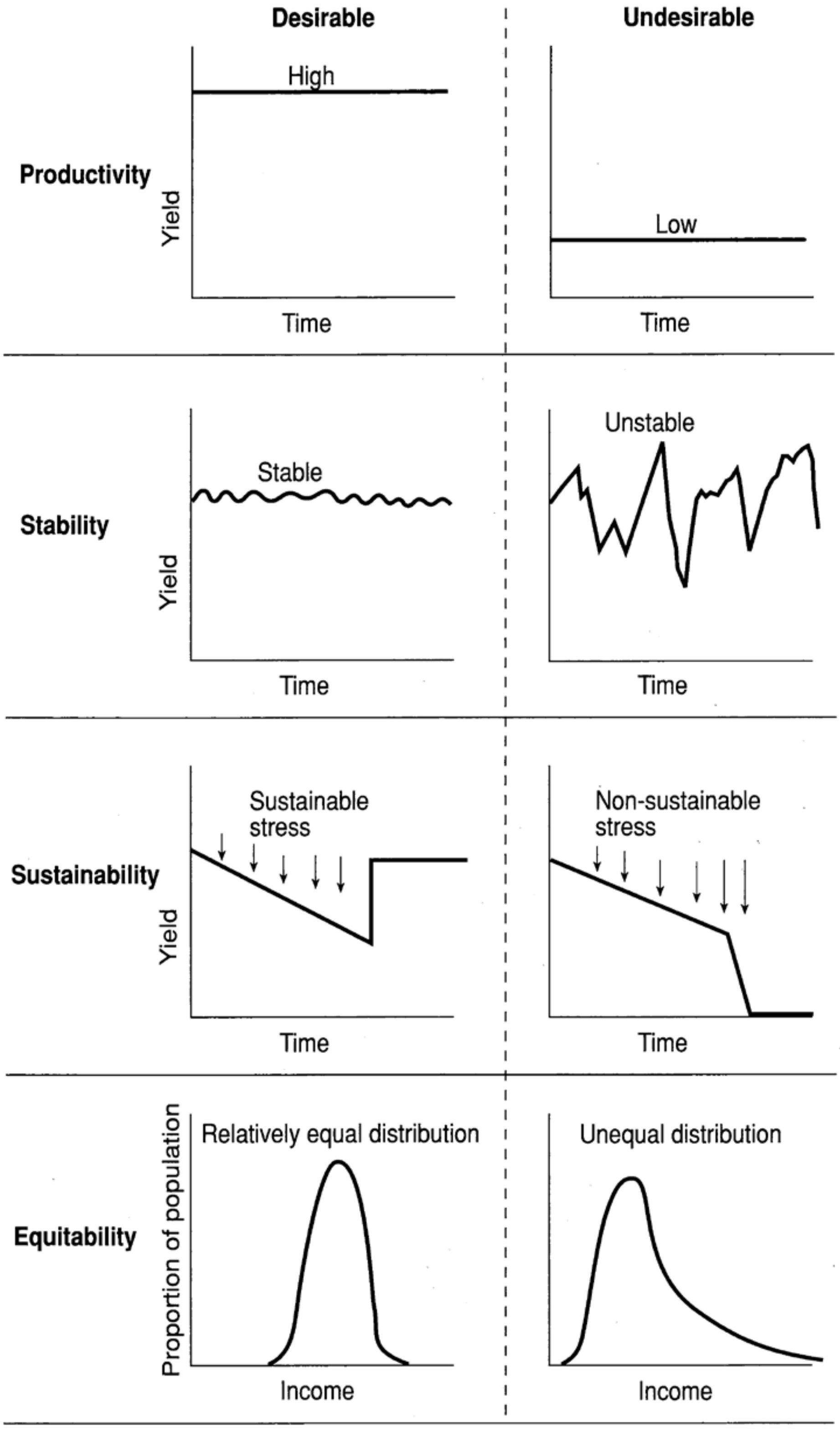


Figure 2 Characteristics of a desirable and an undesirable agricultural system according to Conway's criteria (Source: Tisdell, 1993, Fig. 10.1, p. 149)

Conway (1985; 1987) expresses the view that yields from modern (industrial-type) agroecosystems compared to traditional ecosystems are

- Higher,
- More variable, and
- Less sustainable.

In addition, he believes that modern agroecosystems result in greater inequality of income than traditional ones. This implies that only one attribute (high yields) of modern agroecosystems is more desirable than those of traditional agroecosystems and the rest are less desirable. One conclusion which could be drawn from Conway's analysis is the need to give particular attention to the increasing sustainability of the yields and returns from modern agroecosystems and at the same time, adopt measures to reduce the variability of these. In addition, he expresses concern about the consequences of modern agroecosystems for the distribution of income. Nevertheless, it is doubtful if he was advocating the replacement of modern agroecosystems by traditional ones.

Economic, ecological and social elements of sustainability are combined in Conway's analysis. The level and the variability of returns partially relates to the economic dimension, the sustainability of yields involves ecological factors, and the distribution of income involves the social acceptability dimension.

2.3 Some limitations of Conway's analysis

While Conway's analysis of agroecosystems helped to advance discussions of the sustainability of agriculture, it had important limitations. These include the following:

1. It did not take account of the different types of modern and traditional agricultural systems.
2. It did not take account of the environmental externalities associated with the development of agriculture.
3. It did not take account of the connections of agriculture with the rest of the economy as a result of backward and forward economic linkages, for instance, the sustainability of the supply of external inputs (such as artificial fertilizers and irrigation water) to agriculture.

4. It takes no account of importance of common pool resources for the sustainability of agriculture. Such resources can include the stock of genetic resources, and shared water resources.
5. It failed to consider the fact that social acceptability of agricultural methods does not only depend on their effect on the distribution of income. Other social concerns affecting the sustainability of agriculture include views about animal welfare and the consequences of agricultural development for the conservation of natural environments, as well as food safety issues.
6. Conway's comparison between modern and traditional agroecosystems involves stereotypes. It seems likely that many traditional agroecosystems did not result in sustainable yields and that these yields were quite variable. Consider, for example, early forms of shifting or slash-and-burn agriculture. In fact, it can be argued that both these factors motivated human beings to develop techniques which would enable them to exert greater control over these effects.

There is no doubt that the development of agriculture has resulted in major environmental changes both in areas where it has taken place and outside those areas. Figure 3 highlights important relationships involved in agricultural production. The inputs to an agroecosystem consist of (1) human controlled inputs and (2) environmental inputs not completely controlled by human beings. These generate the output of agricultural products as well as the external environmental effects from land used for agriculture. The linkages involved can be extended further. However, none of the components in Figure 3 should be ignored in assessing the nature and sustainability of agricultural development.

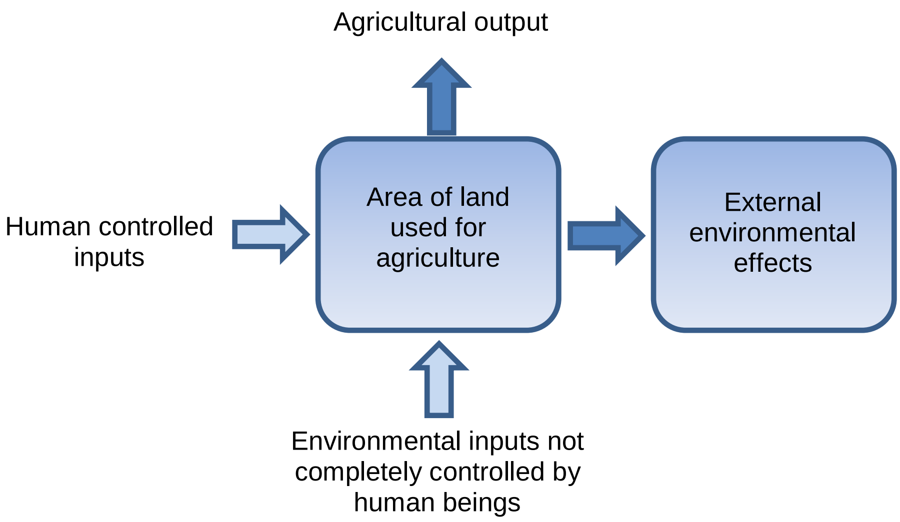


Figure 3: The general nature of an agroecosystem

With the passage of time, human beings have developed techniques to exert greater control over the functioning of agroecosystems, and today the level of external inputs used to manage agricultural systems is much greater than in ancient times. Most modern agroecosystems involve a high-level of external inputs and result in a comparatively high-level of output or yields. There are several concerns about how long these systems can be sustained, and about their environmental consequences. The latter concerns arise from the nature and long-term availability of the external inputs (many of which are non-renewable) as well as from the large and increasing use of the earth's land area for agriculture and from the growing intensification of agriculture.

2.4 Agricultural resilience

In the 1980s, many authors (including Barbier and Conway, ibid.) identified the presence of the resilience of ecosystems as a quality necessary for their sustainability. This was considered to be a requirement both for the sustainability of natural ecosystems and human-dominated ones, such as agroecosystems. An ecosystem is said to be resilient if after an ecological disturbance it returns to its original equilibrium. Therefore, the concept implies stability of this equilibrium. Unfortunately, this concept of sustainability has several limitations (see for example, Tisdell, forthcoming, Ch. 8) one of which is that the original equilibrium may not have been socially desirable. In some cases (possibly many) agricultural systems which replace sustainable natural systems may be socially more desirable than the latter. For example, the clearing of land and the draining of wetlands in some parts of Europe in order to develop agriculture, eradicated malaria-carrying mosquitoes and some societies preferred this result to the pre-existing situation. Conserving a natural ecosystem which is resilient is not necessarily socially ideal. Nevertheless, in assessing the desirability of alternative agroecosystems, it is necessary to consider their stability properties, including their resilience together with other factors.

2.5 Historical context

It should be observed that when the above mentioned concerns about the sustainability of modern agriculture were raised, the 'Green Revolution' was well under way (Alauddin and Tisdell, 1991). It involved the planting of high yielding new varieties of crops. These varieties required increased levels of external agricultural inputs (such as chemical fertilizers, pesticides) to significantly raise yields. This revolution resulted in the substantial intensification of agriculture in many developing countries and in considerable increase in annual multiple cropping (Alauddin and Tisdell, 1991).

The possibility existed that the 'Green Revolution' would be unable to sustain increased agricultural yields. Despite this, due to this revolution and other factors, average annual yields of wheat, paddy rice and maize have increased since 1961 for the world as a whole and for all its major regions according to FAO statistics (Commission and Genetic Resources for Food and Agriculture, 2010, Fig. 8.2, p. 188). Nevertheless, it is still possible that yields will not be sustainable in the long-run or that they will grow insufficiently to meet predicted increases in demand for agricultural produce. Past statistical trends cannot always be safely projected to predict the future.

3. The Need to Decide on the Attributes and Dimensions of Agriculture which should be Sustained

It is frequently argued that agricultural sustainability is desirable. The difficulty, however, is that the term 'agricultural sustainability' is too general to be operational.

There are many different attributes and dimensions of agriculture the sustainability of which could be sought. However, sustaining all of these may not be possible nor desirable. It is therefore, necessary to determine what attributes of agriculture it is important to sustain. Possibilities include yields, economic returns, the total level of agricultural production and the total level of food production, just to mention a few.

Sometimes, concerns about the sustainability of agriculture are about sustaining the **growth** of selected variables. For example, currently there is concern about sustainable growth of aggregate food production to meet rising demand generated by the increasing global population and rising incomes. In addition, there are also concerns about the composition of agricultural production. For example, is the composition of agricultural production such that it supports a nutritious and affordable diet?

To further complicate matters, the geographical dimensions of the concern for agricultural sustainability needs to be specified. For example, does the concern relate to a region, a country or to the globe? In addition, it needs to be decided whether the concern about agricultural sustainability, relates only to a particular agricultural industry (for example, rice) or to a large set of such industries. Moreover, the time-period for which it is aimed to achieve agricultural sustainability needs to be specified.

The implications of agricultural development for environmental sustainability have received much attention in recent decades. Environmental spillovers from agricultural production (see Figure 3) can affect the level and quality of agricultural production and alter the operation of other ecosystems. At the same time, external environmental effects from other industries and activities can alter the sustainability of agriculture for production. These relationships are discussed in Tisdell (1999). Changing social demands or values have increasingly required these external effects to be taken into account in assessing alternative patterns and policies for sustainable development. This is reflected to some extent in the policies developed in the EU to take account of the multifunctional nature of agriculture (see, for example, Tisdell and Hartley, 2008, pp. 76-80). These policies recognize that the value of agriculture does not solely depend on the volume of its production and indicate that account ought to be taken of its total economic value.

4. Recent Concepts and Approaches to Agricultural Sustainability

Since the 1980s interest in the subject of sustainable agriculture has continued to grow and new aspects of this subject continue to be explored. In this section the following subjects (which have attracted particular attention in this decade) will be considered in turn:

- The FAO guidelines for the sustainability of food and agriculture systems;
- The sustainable intensification of agriculture, particularly IFRI's perspective on this;
- The potential role of organic agriculture in contributing to the sustainability of agriculture, and
- The role of multifunctional agriculture in contributing to the sustainability of agriculture especially in view of growing support for sustainably intensifying agriculture.

Particular attention will be paid to the debate about sustainable agricultural intensification given the predicted increase in demand for agricultural production in coming decades.

4.1 FAO guidelines for the assessment of the sustainability of food and agricultural systems

The FAO has in recent years, been actively proposing guidelines for achieving agricultural sustainability. As part of these endeavours, it prepared the *SAFA* (*Sustainability Assessment of Food and Agricultural Systems*) *Guidelines* (FAO, 2012). The document identifies four dimensions as important for the sustainability of food and agricultural systems, namely:

- Good governance;
- Environmental integrity
- Economic resilience; and
- Social well-being (FAO, 2012, p. iii).

More specifically, it states 'the challenge of delivering sustainability lies in the effective integration of the environmental, economic and social dimensions of development. This can only be achieved by good governance' (FAO, 2012, p. 6).

Consequently, the three pillars mentioned in the previous section are retained in this formulation but there is an addition, namely that effective integration of these three domains requires good governance. Close analysis of this statement indicates that it is rather vague and of limited practical value for guiding policy. Various queries are raised by it. What is effective integration and how is it to be achieved? What constitutes good governance? The latter is a normative matter and opinions about this subject can vary widely.

Nevertheless, according to the proponents of the SAFA Guidelines, adopting the above approach is seen as an important step in establishing a 'Green Economy', that is 'an economy that results in improved human well-being and social equity, while significantly reducing environmental risks and ecological scarcities' (UNEP, 2011). This appears to be an admirable goal but is not clear how human well-being and social equity is to be measured nor just what 'significantly' implies in this context. According to the SAFA Guidelines, the concept of Greening the Economy with Agriculture (GEA) requires policies to be adopted which:

- Satisfy the right (of humans) to adequate food;
- Ensure food and nutrition security in terms of food availability, access, stability and utilization;
- Contribute to the quality of rural livelihoods;
- Manage natural resources efficiently; and
- Improve resilience and equity throughout the food supply chain (FAO, 2012, p. 6).

Once again, it can be observed that while these goals may be desirable, they are not very concrete.

Nevertheless, the authors of the SAFA guidelines do endeavour to make their four sustainability dimensions more concrete by specifying 20 themes and 60 sub-themes which should in their view be taken into account by decision-makers, in seeking the sustainability of food and agricultural systems. These can be regarded as the independent variables in this model on which this sustainability depends. The result is that many variables are identified which are of social concern but in the end, the amount of guidance given to decision-makers as a result of this exercise is limited.

In relation to governance, the authors of the SAFA guidelines limit their recommendations to the governance of corporations or businesses, and these organizations are left to decide whether they will voluntarily follow the SAFA guidelines. The role of governments in fostering the sustainability of food and agriculture systems is not considered.

In elaborating on the variables which should be taken into account in ensuring sustainability of food and agriculture systems, decision-makers are frequently advised in this FAO document to apply indicators of their own choice. This makes the exercise rather open-ended.

One of the several sustainability themes considered in this report is biodiversity conservation. This has become a matter of social concern and was not mentioned in Conway's analysis of the 1980s. The SAFA guidelines indicate that attention should be given to the conservation of agricultural and wild biodiversity and natural and near-natural ecosystems. However, it is difficult to interpret some of the recommended guidelines. For example, in relation to agricultural biodiversity, it recommends that it be managed so that 'The diversity of used species and their genome (crop varieties, livestock breeds, fish species) is at the optimum level achievable under given conditions' (FAO, 2012, p. 54). This begs the question of how the optimum level is to be determined.

It is also proposed that account be taken of the 'share of utilized area where crop rotation is in place, and/or several species are used at the same time (diverse pastures, agro-forestry, intercropping, rice-fish systems, integrated crop-livestock production)' (FAO, 2012, p. 54). Presumably, it is implied that the larger are these shares the more sustainable is the relevant system. However, in some cases, these systems could prove to be uneconomic and could threaten economic viability. Ecologically sustainable combinations are not necessarily ones that are economically viable. Ecological considerations, although important, should not be the sole arbiter of decisions about agricultural sustainability. They need to be considered concurrently with economic and social factors, and this will normally entail trade-off between objectives.

4.2 The sustainable intensification of agriculture

There is no doubt that demand for agricultural products will increase substantially in this century. This has raised the question of whether and how this increased demand can be met sustainably and how this can be achieved? Can the demanded increase in agricultural production be achieved without greater environmental loss? If greater environmental loss is inevitable, how can it be minimized?

Several suggested solutions to these problems have been proposed. These include:

- The adoption and development of 'smarter' agricultural technologies which enable agricultural production to be increased economically and which at the same time, reduce or limit the adverse environmental consequences of agricultural production;
- Reductions in food waste and other forms of post-harvest loss;
- Limiting the use of agricultural production for purposes other than the supply of food (for example, its use for biofuels); and
- Discouraging relatively inefficient forms of supplying food for humans, for example, by the use of grains to feed livestock and of fish meal to feed some species of cultured fish as well as shrimp.

In its *2013 Global Food Policy Report*, the International Food Policy Research Institute (IFPRI) pays particular attention to the first mentioned of these policy possibilities. In this report, an article by Ringler et al. (2014) favourably considers the prospects of innovative farming practices resulting in sustainable agricultural intensification. Ringler et al. (2014, p. 43) state:

> By sustainably increasing agricultural production, we can enhance food availability, which is a necessary condition to combat hunger. Experts agree that greater production must be achieved by increasing yields while using fewer resources and minimizing or reversing negative environmental impacts. This sustainable agricultural intensification approach is fundamentally about making the current agricultural system more efficient

through the use of new technologies or by improving current production systems.

Note first of all that increasing agricultural production is not the only way in which food availability can be increased, as will be apparent from the options listed above. For example, using reduced amounts of agricultural produce to supply biofuel is one possible contributor.

Ringler et al. (2014) claim, by relying on simulation modelling, that substantial increase in yields of maize, wheat, and rice can be obtained by adopting alternative technologies. These technologies are listed in Table 1 in decreasing order of their predicted role in increasing yields.

Table 1: Alternative technologies predicted by Ringler et al. (2014) to result in substantial increases in yields of maize, rice and wheat by 2050 if adopted. They are arranged in order of their decreasing impact on increasing yields.

1. Increased nitrogen-efficiency	7. Improved crop protection against insects
2. No till [(a)]	8. Drought tolerance
3. Heat tolerant crop varieties	9. Drip irrigation
4. Precision Agriculture	10. Water harvesting
5. Integrated soil fertility management	11. Sprinkler irrigation (rather than flood irrigation)
6. Improved protection against weeds	

Note: (a) Does not apply to rice

The adoption of no-till technology is predicted to increase maize and wheat production by 16% and more efficient nitrogen-use is estimated to boost rice yields by about 20%. These alternative technologies are also considered to be more environmentally friendly than current technologies which it is hoped they will replace. However, the possibility that the adoption will have some negative environmental consequences cannot be dismissed. For example, the development of drought-tolerant crops could result in the extension of agriculture to drought-prone areas and to an increase in multiple cropping as a result of cropping into dry seasons of the year. This can have a negative effect on wild biodiversity. Furthermore, the recommendation that there by greater water harvesting on farms can have negative external effects. For example, the building of more earthen dams on farms may reduce water availability downstream to users downstream and can adversely affect wildlife which depends on water flows.

Some proponents of the sustainable agriculture intensification proposition believe that it can result both in an increase in agriculture production and an improvement in environmental quality, including greater conservation of wild biodiversity. They envisage an outward shift (shift to the right) of the trade-off function between the level of agricultural production and environmental quality occurring as a result of the adoption of alternative techniques to those currently used. This is illustrated in Figure 4 by an outward movement of the production-environmental quality relationship from the curve identified by ABC to that designated by DEFGC. If B represents the current situations, a movement to a point such as D following the adoption of alternative techniques would be possible. Both the level of agricultural production and environmental quality would increase in this case. However, there is no guarantee that this type of movement will occur.

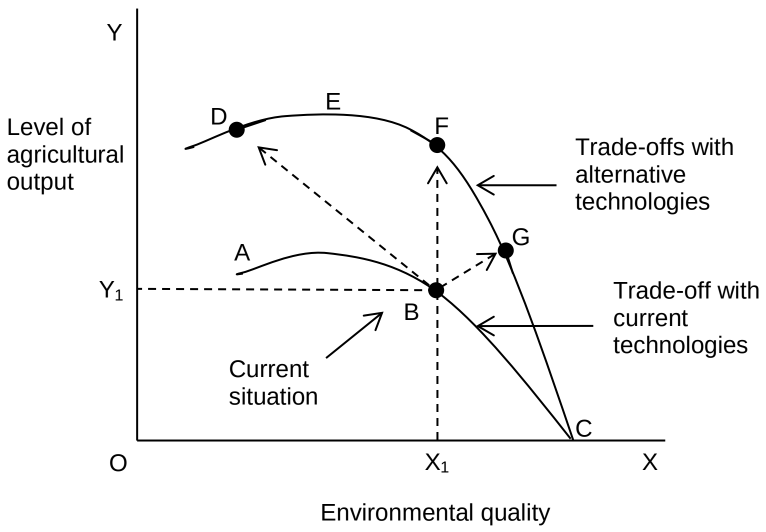


Figure 4: It may be possible to adopt agricultural technologies which enable both agricultural production to be increased and environmental quality to be improved. However, even when that is possible, a win-win outcome may not eventuate.

In the absence of government intervention (improved governance), a situation such as that shown as F could emerge. It may emerge as a result of both market and political failures. In fact, one cannot entirely rule out the possibility that a movement to a point such as D occurs. In this case, attempts to increase agricultural production using the new techniques has a negative influence as both the level of agricultural production and environmental quality, that is the amounts of agricultural output and environmental quality are both lower than they need be.

To some extent, specification of the environmental quality variable involves a value judgment about what constitutes an improvement in environmental quality. This is evident in the debate about changes in wild biodiversity as a result of different ways of increasing agricultural production. Some ecologists favour agricultural intensification rather than the extension of agriculture on the basis that will result in less biodiversity loss and less disruption to natural or near-natural ecosystems. It is however, probable that both strategies will result in some biodiversity loss and affect natural ecosystems. It is also possible by the adoption of particular strategies to minimize this loss whether or not intensification, extension of agriculture or a combination of both occurs. In the end, however, some valuation of the alternatives is needed.

That this is necessary is evident from the illustration in Figure 5. If agricultural production is increased solely by intensification the set of wild species in the disc marked *A* is assumed to be lost. If the same increase in production is obtained by agricultural extension the set of wild species in the disc marked *B* are lost. Although set *B* may be larger than set *A* it is possible that the species lost by intensification are economically considered to be more valuable, for example, in Asia some of the crane species. In any case, one would probably need to consider the value of particular species and tailor changes in ecosystems to allow for the different values. The alternative proposals are too coarse or simplistic.

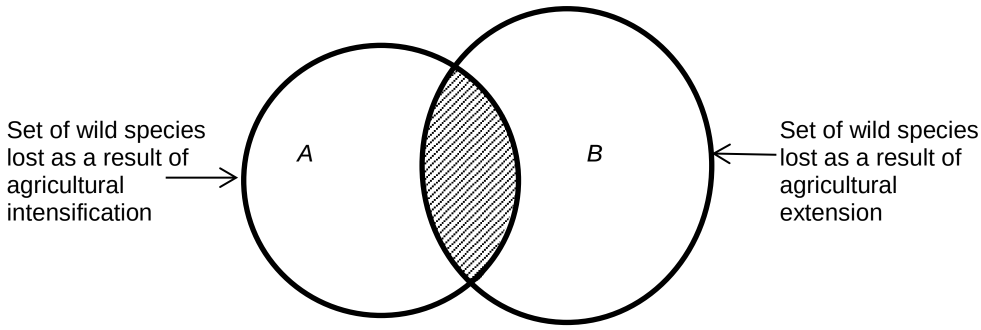


Figure 5 If agricultural production is increased only by intensification or only by extension different sets of wild species are likely to be lost but there may be some overlap in the species lost (the hatched area in this figure indicates overlap). Increasing agriculture production by a combination of intensification and extension can be expected to result in the loss of a different set of species, consisting most likely of subsets of *A* and *B*.

Note that Table 1 relates only to some bulk agriculture commodities. Achieving a nutritious diet would also require attention to the supply of other commodities such as vegetables. Furthermore, the IFPRI report as far as intensification of agriculture is concerned appears to mainly focus on the type of agriculture practiced in high income countries. More attention needs to be paid to the way in which differences in the costs of different factors of agricultural production affect the choice of techniques or methods which can contribute to the sustainable intensification of agriculture.

In countries which have an agricultural labour surplus, labour-intensive methods will be more economic than in countries in which labour is a relatively scarce resource and capital comparatively abundant. This may for instance, make ‘companion-planting’ of crops (a form of mixed cropping) more economic in less developed countries than in higher income countries. Different methods of sustainable intensification of agriculture are likely to be economic in different parts of the world depending on differences in relative factor prices and local environmental conditions. For example, appropriate means for the sustainable intensification of agriculture can be expected to be different in parts of Africa, in Korea and in the United States.

There is no doubt that new agricultural techniques can be developed and existing knowledge could be more widely applied to increase agricultural production at a reduced environmental cost. Whether this approach will on its own result in a sufficient increase in agricultural production to meet the predicted increase in demand for agricultural produce in this century is not yet clear.

It is also not clear that all governments have the will to sustainably restrict the extension of agriculture, and alter the governance of agriculture.

Observe that in Table 1, the potential yield-enhancing role of genetic improvements in cultivated and domesticated species is not mentioned. This is somewhat surprising because the Green Revolution depended heavily on the introduction of new varieties of crops. Since then, several new technologies have become available, such as genetic engineering, for developing new plant varieties. However, their potential for increasing and sustaining yields is still unclear and there is a risk that they will continue the process of eroding agricultural biodiversity, thereby potentially undermining long-term agricultural sustainability.

4.3 Organic agriculture and sustainability

A large group of individuals are concerned about the possible health and environmental of the use of chemical pesticides and fertilizers in agriculture as well as genetically modified organisms. They, therefore, favour organic produce. Sometimes, it is also suggested that yields from organic agriculture are more sustainable than those from conventional agriculture and may even, in the long-run, be higher.

However, scientific evidence indicates that yields from organic agriculture are on the whole lower than from conventional agriculture. For example, Kirchmann et al. (2008, p. 39) report that 'in a global perspective, the scientific literature shows that organic yields are between 25 and 50% lower than conventional yields, depending on whether the organic system has access to animal manure'. Furthermore, Kirchmann et al. (2008) state that crop yields on less fertile land are less responsive to organic than conventional agricultural practices. Also, increasing yields by means of organic agriculture often relies on the import of organic material to the farmed area – it is not a 'bootstrap' operation.

It is possible that if there was a global switch to organic agriculture that agricultural extension would be magnified but more likely agricultural production could become uneconomic in marginal areas for agriculture. A substantial fall in the aggregate level of agricultural production is likely. Given estimates of Kirchmann et al. (2008), total agricultural production could fall by more than 50% if all agriculture was forced to depend only on organic methods. Furthermore, lack of sustainability of yields might occur in areas subject to rapid leaching of nutrients and organic matter (due to soil disturbance caused by cultivation). This is likely to be a serious problem in tropical and sub-tropical areas.

As a result of the total conversion of agriculture to organic methods, the spectre would be raised of agriculture not being able to support the current level of the human population, let alone the increased level of population expected in this century. Furthermore, widespread adoption of organic agriculture does not seem to be a practical means of achieving sustainable intensification of agriculture.

This being said, the principle of consumers' sovereignty implies that consumers who wish to buy organic produce should have the right to do it. Incidentally, the fact that the price of such produce is higher than that obtained from conventional agriculture is a strong indicator that it is less economic to produce than non-organic produce.

Since the demand for organic produce appears to be a continuing one, it is also important in the context of increasing demand for agricultural produce, to develop sustainable intensification methods for the support of organic agriculture.

4.4 Agroecology and sustainable agriculture

Agroecology involves the application of ecological principles to agriculture. By applying these principles judiciously, it is frequently possible to increase agricultural yields and enhance their sustainability. Nevertheless, their application requires economic principles and relations to be taken into account. For example, ecological studies may indicate a particular relationship between the yield of a crop and the organic content of the soil where the crop is grown. By increasing the existing organic content of this soil, it may be possible to increase the yield of this crop. Consequently, in a particular locality, the production function relationship

$$y = f(x) \tag{1}$$

may exist where y represents the yield of the crop and x designates the amount of organic matter added to the soil. Although the yield of the crop may be maximized by adding x_4 unit of organic matter to the land where the crop is grown, this is unlikely to be economic if costs are incurred in making these additions.

Figure 6 provides a single illustration of this aspect. There the curve marked ACFG is the production function, and the line, KCL, is the highest attainable iso-profit line. It is more steeply sloped the higher is the cost of adding organic matter to the soil compared to the price of the agricultural product. In the case illustrated, the most profitable amount of organic matter to add to the soil is x_2. The amount, x_4, which maximizes the yield of the crop, is not the most economic production possibility. Furthermore, the addition of amounts of x_1 or x_3 of organic matter would not be the most profitable choices.

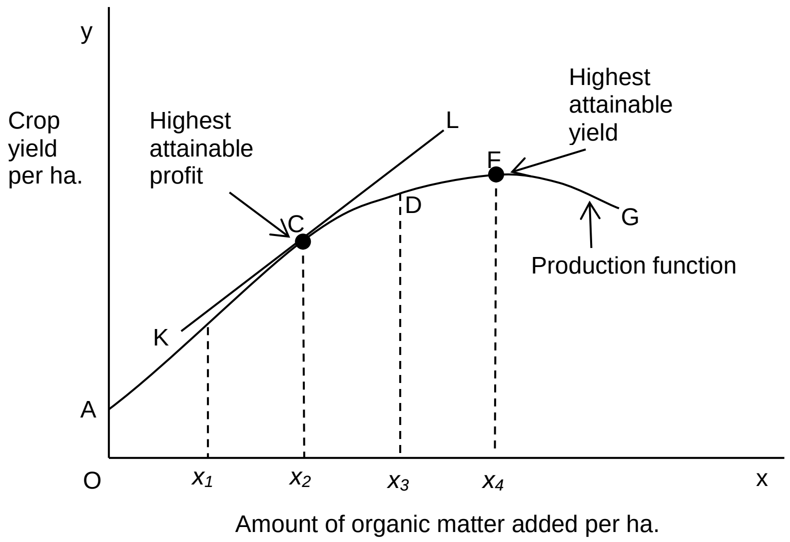


Figure 6: An illustration showing that maximizing crop yield is not economically ideal

In countries where the cost of adding organic matter to the soil is low relative to the price of the agricultural produce, it will be more economic to add larger amounts of organic matter, for example, by means of composting. In countries where the opposite is true, it is more economic to add less organic matter or in some cases, none at all.

In a similar vein, economic factors can make it uneconomic to engage in mixed cropping or in integrated farming even though ecological principles may indicate that these practices are desirable for increasing yields or sustaining these. While it might be maintained that the divergence between ecological and economic benefits only arises because environmental externalities and similar factors are not taken into account in the market system, this view is incorrect. For example, in the case illustrated in Figure 5, if the social value of adding organic matter is higher than its private cost, this could increase the social value of adding organic matter to the soil. Hence, a greater addition than x_2 would be socially ideal. But unless the social value of adding organic matter to the soil is infinite, the socially ideal application will still be less than x_4.

It is important to take ecological principles into account in managing agriculture but they cannot be the sole factor in determining agricultural decisions. Economics restricts their application. Nevertheless, when the external environmental effects of agricultural production are taken into account, it is likely to be desirable from a social economics perspective to pay more attention to these principles than currently is the case, as the above discussion indicates.

4.5 Multifunctional agriculture and sustainability

The concept of multifunctional agriculture recognizes that agriculture not only produces private goods such as food and fibre but has other functions or consequences such as environmental functions. Therefore, it is concluded that the contribution of agriculture needs to be assessed on a multi-dimensional basis. When the EU Common Agricultural Policy (CAP) was reformed from a system which basically only provided incentives for increased agricultural production, it was guided by a multifunctional approach to the valuation of agriculture. This meant that in supporting agriculture, greater attention was paid to its environmental effects and some of its social consequences than previously. Using this approach, it was possible to support the incomes of EU farmers while at the same time reducing economic incentives for increasing agricultural output and ensuring greater environmental sustainability.

Despite this more holistic approach than previously to agricultural policies, differences of opinion have arisen about whether the current CAP system is ideal from an environmental point of view. Some scholars seem to believe that the EU will need to increase its agricultural production to help meet the predicted global increase in demand for agricultural produce in this century and recommend that agricultural production be intensified on existing farmland and not extended to satisfy this increasing demand. Whether or not there is much scope economically for extending the area of farmland in Europe is, however, unclear, and a similar situation may exist in many other regions where agriculture has been long established. Nevertheless, intensification of agricultural production in such areas would reduce economic incentives for agricultural extension elsewhere, for example, in South America. It needs to be borne in mind that the economic scope for extending the area of agriculture is not unlimited, and much of the land to which agriculture could be extended is quite marginal economically given current technologies.

Figure 7 helps to throw some light on the multifunctional approach to agricultural policy, an approach which is not solely limited to the EU but which has also been embraced by countries such as Japan. In Figure 7, only two dimensions of agriculture are considered: the quantity of agricultural output, x, from existing land and the supply of environmental services, y, provided by that land. The trade-off function ABCD represents the relationship between the quantity of agricultural output and the supply of environmental services given initial agricultural methods and techniques. Prior to farmers being rewarded for taking into account environmental services in their decision-making, the combination of agricultural output and environmental services corresponding to point C may have prevailed. After the provision of economic incentives to take account of the supply of environmental services, a combination like that corresponding to point B is assumed to prevail. In order to increase agricultural production, more productive agriculture techniques could subsequently be introduced and a larger area of existing farmland could be allowed to be sown with crops. This might have the effect of shifting the trade-off function to the right, for example, from ABCD to AEFG. This could result in movement from point B to a point such as E or F. In both these cases, the supply of environmental services is less than at point B, and in the case of point F, less than at C. Of course, more favourable outcomes (such as a movement to point J) are possible but are by no means guaranteed.

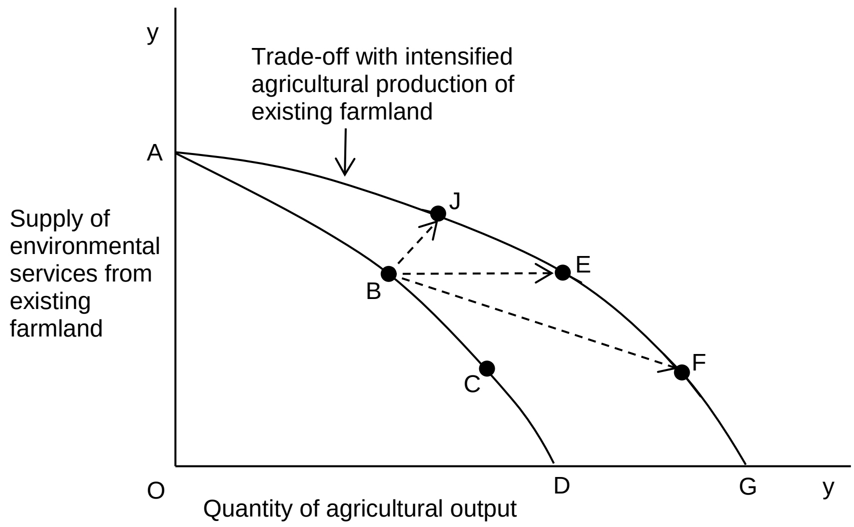


Figure 7 An illustration of possible reductions in the supply of environmental services as a result of the intensified use of existing farmland for agricultural production making some use of 'smarter' technologies.

Given that the environmental consequences of agricultural production on existing farmland, this can be expected to continue to be of social concern. Therefore, it would be unwise to permit increased intensity of use of all existing agricultural land for agricultural production. For example, the clearing of natural vegetation in hilly areas to increase cropping could have serious negative environmental consequences as might the removal of natural vegetation near watercourses. No doubt also the consequence of nutrient run-off will continue to be a concern. This is just to mention a few of the environmental issues that will need continuing attention.

4.6 The dichotomous approach to assessing increased agricultural production (extension versus intensification) could be flawed.

Given that agricultural production will need to be increased to meet rising demand, many scholars (including ecologists) have considered only two options, namely satisfy the increased demand by only intensifying agricultural production or only by extending it. The most frequent conclusion at the moment is least environmental or ecological damage is likely to be done if the increased production is met by intensification rather than extension. This, however, only takes account of two extreme possibilities and does not take account of the possibility of achieving this result by a combination of intensification and extension. It is possible that by a judicious combination of intensification and extension, the required increase in agricultural production could be met at minimum environmental cost. At the present time, the relationships involved remain speculative, no solid empirical analysis has been done to specify these.

Two possibilities are illustrated in Figure 8 which show a couple of hypothetical relationships between the reduction in the value of environmental services and the percentage of given increase in agricultural production obtained by agricultural intensification, *x*. Note that 100 – *x* is the percentage attributable to the extension of agriculture. The hypothetical relationship ABC indicates that as reliance on intensification to raise agricultural production increases, the loss in the value of environmental services declines. Therefore, in this case, in order to increase agricultural production by a particular amount subject to minimizing environmental cost, it is optimal to rely only on intensification. However, this is not so if the relationship indicated by ADE applies. In that case, environmental costs are minimized when x_1% of increased agricultural supplies are met from intensification and (100 – x_1) % from extension. Furthermore, to evaluate only the end points (A and E) of this relationship would in this instance lead to the misleading conclusion that complete reliance on intensification is the ideal means of raising agricultural production.

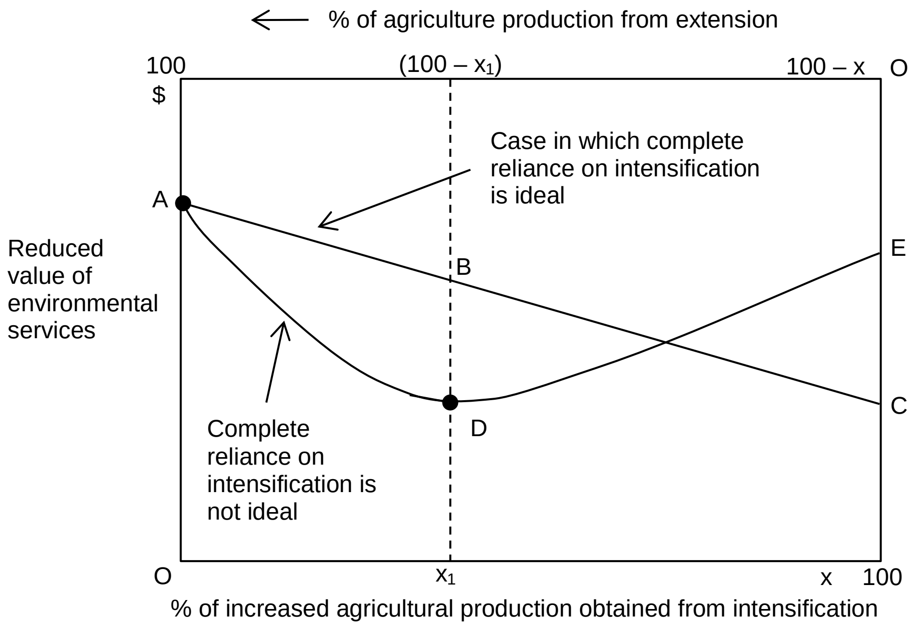


Figure 8 Two different hypothetical relationships between the reduction in value of environmental services and a specific increase in agricultural production relying on different contributions of intensification and extension.

It is even possible (even if not likely) that judicious extension of agriculture will cause less environmental damage than its intensification. To date, the relationships involved are mainly speculative and values have not been measured. Furthermore, different spatial patterns of intensification and extension are possible and these can have different environmental effects. This adds to the complexity of finding an optimal solution to the above problem. Nevertheless, spatial relationships should not be ignored in seeking solutions to this problem. It is necessary to distinguish patterns of agriculture extension and intensification which would result in a relatively large environmental loss from those in which the comparative environmental cost is low. This seems to be more relevant policy-wise than opting from either extension or intensification of agriculture. Probably a judicious combination of extension and intensification of agriculture will minimize environmental costs. However, at the same time, if it is wished to sustain environmental quality attention should also be given to policies which can mitigate the increasing demand for agricultural products.

5. Concluding Comments

Since the commencement of the Holocene era, humankind has become increasingly reliant on agriculture for its subsistence and economic welfare. The development of agriculture was essential for urbanization and industrialization. However, since the commencement of agriculture human beings have been involved in a constant struggle to sustain an increased level of agricultural production to support an ever growing level of human population demanding higher standards of living. This struggle continues today and the problem has magnified. It has become more critical given the enormous changes that *Homo sapiens* has made to natural environments. In some respects, scientific and technological advance has proven to be a two-edged sword for humankind. It has enabled living standards and the level of human population to be substantially increased but maintaining these relationships and catering sustainability for these increases has become more challenging, given global environmental trends such as climate change (global warming) and biodiversity loss.

The problem of achieving sustainable development was already raised by some scholars in the 1960s, for example, by Boulding (1966) but it was in the 1970s that it became widely accepted that continuing economic growth might not be sustained unless policy changes were implemented. This problem was raised at the 1st United Nations Conference on Environmental and Development held in Stockholm in 1972 and has been of global concern ever since. Various concepts were developed in the 1980s which improved our understanding of the issues involved. In this regard, Conway's analysis of the sustainability and other attributes of agroecosystems provided a step forward. However, in retrospect, it has proven to be too narrow in its conception and as well, the nature of the agricultural sustainability problem envisaged now differs from that imagined in the last couple of decades of the last century. At that time, the focus was mainly on the need to maintain the level of agricultural production.

The problem now is one in which it is actually necessary to sustain increased agricultural production to meet the predicted increased demand for agricultural supplies.

The challenge is to try to find how this can be done by adopting measures that are socially acceptable and environmentally sustainable, and/or to find ways to moderate the increased demand on agricultural production.

Some policy-makers believe that the secret to meeting this challenge is to engage in the sustainable intensification of agriculture. This quest is worthwhile, but it is by no means clear that it can achieve the results claimed for it. Furthermore, it has not been shown scientifically that a strategy involving the judicious intensification and extension of agriculture (in order to boost its production) would be inferior. Nonetheless, shortcomings in institutions and governance may result in less than ideal forms of agricultural intensification and extension.

Burney et al. (2010) have estimated that in order to meet the predicted increase in demand for agricultural supplies, overall agricultural production will need to be increased by 70 per cent by 2050, ‘taking into account demographic growth, as well as changes in the composition of diets and consumption levels associated with increased urbanization and higher household incomes’ (De Schutter, 2011, p. 6). It would be a great scientific feat to achieve this increase solely by intensifying agricultural sustainability. The only firm estimates Ringler et al. (2014) provide for an increase in agricultural production as a result of sustainable intensification is a rise of about 20 per cent or so in maize, rice and wheat production. Even if this figure is 30 per cent, this is well short of 70 per cent, and it is not clear that other crops will be able to achieve a level of increase of 30 per cent. The prospect of a very large increase in global agricultural production being obtained at little environmental cost solely by agricultural intensification is at best a hope. Engels (1959[1844], p. 204) once stated that nothing is impossible to science but we have since learnt that this is not true, even though science has achieved much, and will continue to do so.

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