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by

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Agricultural Sustainability and the Introduction of Genetically Modified Organisms (GMOs)

ABSTRACT

In order to cater for the predicted growth in global population and aspirations for increased living standards, the world needs to increase substantially its level of agricultural production and sustain agriculture's increased productivity. New technologies may enable this to occur but they also bring with them increased sustainability problems. There are many complex dimensions to achieving agricultural sustainability such as deciding on what agricultural attributes are worth sustaining and considering what trade-offs in objectives are required. These issues are discussed from a conceptual point of view. It is also shown using economic theory that market-based agriculture limits the opportunity for individual farmers to adopt sustainable agricultural techniques because of competitive economic pressures. It is argued that while modern agricultural methods and increased inter-regional trade have substantially increased agricultural supplies, they have also exacerbated the problem of sustaining agricultural production and yields and have had a disequilibrating effect on rural communities. Although genetic engineering is seen by some as a way forward for increasing agricultural production, it is shown that GMOs do not ensure sustainability of agricultural production and that they can be a source of rural disharmony and can threaten the sustainability of farming communities. Extension of intellectual property rights in new genetic material in recent times, particularly the granting of patents not only on techniques for producing GMOs but on the organisms themselves, have added to sustainability problems faced by modern agriculture.

Keywords: Agricultural development, agricultural sustainability, biodiversity, co-evolution, economic sustainability, genetically modified organisms, GMOs, monopolisation, patents, social sustainability.

JEL Classification: Q000; Q010; Q200; Q300; Q500; Q570

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Agricultural Sustainability and the Introduction of Genetically Modified Organisms (GMO's)

1. Introduction

Global population is expected to increase by about 30% between now and 2050, and most of this increase will occur in developing countries. This means that in order to just maintain food and fibre supplies obtained from agriculture at present per capita levels, agricultural production needs also to rise by 30% in this time period. However, the demands on agriculture to increase its level of production may be even greater than this. As global stocks of oil decline, agriculture might be called in to supply more fuel in the form of ethanol and biodiesel and to make a larger proportionate contribution to the supply of fibres because most artificial fibres (such as nylon and polyester) are derived from oil. Is it possible to expand agriculture production sufficiently to meet these challenges? If so, how can this higher level of agricultural production be sustained?

The application of modern technologies to agriculture and continuing agricultural innovations have resulted in huge increases in global agricultural output. The question, however, arises of whether this process can continue unabated. Furthermore, are the contemplated increased yields of agriculture able to be sustained?

Again, we may ask what type of sustainability issues does modern agriculture face? Therefore, this article considers first what sustainability attributes of agriculture appear to be valued by societies and then outlines a series of potential threats to the sustainability of those attributes. Then the particular case of the introduction of genetically modified organisms (GMOs) to agriculture is considered. Genetic engineering is a relatively novel technique, the results of which are increasingly applied to agricultural production. It is believed by most of its proponents to be the key to substantially increasing agricultural production (see for example, Shapiro, 1999). However, the introduction of GMOs raises several types of sustainability issues, many of which are outlined in this article. Some of these sustainability issues are of an ecological nature whereas others have an economic basis. Particularly worrying is the nature of property rights bestowed on owners of GMOs by patents.

This is because these patents can be used to limit the rights of farmers and can have negative effects on agricultural sustainability, for example on the sustainability of future agricultural yields and on the desired characteristics of agricultural communities.

2. Attributes of Agriculture that Societies may wish to Sustain.

In itself the word 'sustainability' only takes on meaning when it is related to an object(s) or to an attribute(s) of things. The social desirability of sustaining objects or attributes varies. Sustainability may be desirable or **undesirable** depending on the object to which it relates. For example, few would claim that it is desirable to sustain poverty although some dictators might want this if it helped to sustain their political power. On the other hand, most individuals would agree that is desirable to achieve and sustain a reasonable standard of living for all.

What type of sustainability attributes associated with agriculture are likely to be valued? One wish might be that agricultural output could be sustained without a large increase in effort, or that it could be increased and sustained so that there is not a fall in the per capita availability of agricultural produce. For these involved in the supply of agricultural produce to markets, this would require that their economic returns be maintained. **Economic** sustainability is required. However, sustainability of agricultural production will, amongst other things, depend on the continuing availability of important materials used in modern agriculture, such as chemical fertilizers many of which are derived from depletable non-renewable natural resources. Furthermore, sustainability of agricultural production will depend on the long-term ecological viability of agricultural systems and the ability of agriculture to adapt to environmental changes, such as climate change.

Another attribute of agriculture judged by some societies as important is sustaining an agricultural way of life and rural communities. For example, the European Union partly provides economic support to agriculture as a means of maintaining this way of life. To some extent, this attribute is treated as if it is a merit good. Even in the United States, some see virtue in an agrarian way of life involving independent family farms and closely knit local communities. They regret the disappearance of these features in

American agriculture which is becoming more commercialized, industrialized and increasingly dominated by companies.

Often trade-offs are required between the sustainability of attributes. For example, society might want to sustain a high level of agricultural yields or economic returns as well as maintain a close-knit agricultural community or some other desirable attributes of this community. However, a compromise between these sustainability objectives is required if a curve like the ABCD in Figure 1 relates sustainable levels of agricultural yield or returns to a measure of desirable community attributes. For the set of possibilities in the segment CD of this curve, there is no conflict between raising yields or returns and securing a more desirable rural community but in the segment ABC, there is conflict. Higher agricultural yields or returns require a reduction in the perceived quality of the rural community. While the socially most desirable possibility occurs in the segment ABC, finding the socially optimal combination of possibilities is not easy in practice. Perhaps a social welfare function could be considered as way out of this problem. However, such an approach is problematic unless there is widespread agreement about the type of social welfare function that is appropriate. If the social indifference curves indicated by W_1W_1 and W_2W_2 apply, then the combination at B is the socially optimal choice. This means that in order to obtain higher agricultural returns, some reduction in the desired quality of the local community is required. However, individual self-interest may propel the agricultural system to point A because communal relationships are a product of externalities as far as individual farmers are concerned. This means that the social optimum corresponding to point B does not prevail but an inferior result. Individual self-interest is unlikely to promote the collective good in this case due to the presence of social externalities.

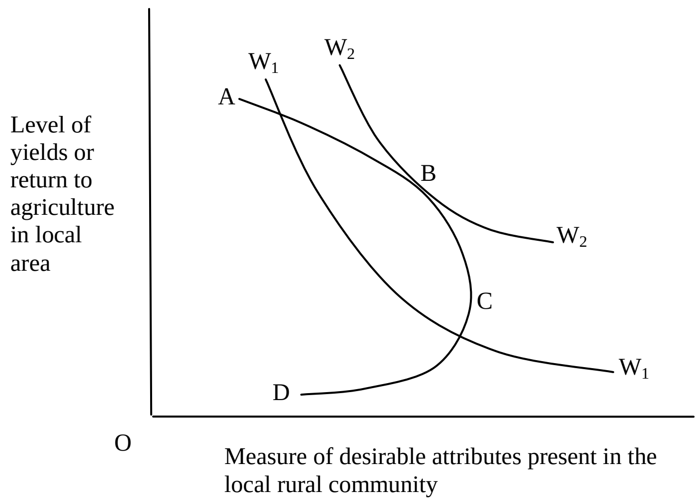

Figure 1: Achieving desired economic objectives and desired attributes for the nature of rural communities often requires trade-offs. As illustrated in this figure, it may be necessary to forgo desirable attributes of a rural community in order to achieve higher yields or returns from agriculture. Achieving and sustaining a socially desirable balance between these objectives is not easy because the nature of societies is an external consequence of individual decisions.

3. Farmers who want to Adopt Agricultural Practices to Sustain Agricultural Production and Yields may be Powerless to do this.

Farmers who want to adopt agricultural techniques to sustain agricultural production and yields may be powerless (because of economic competition) to do so. If enough other farmers are more myopic or discount the future more heavily (have a high time-preference) than those farmers who wish to be ‘virtuous’ by adopting sustainable techniques, the latter may be forced by economic competition not to adopt sustainable techniques. However, if all farmers adopt sustainable techniques, the choice of sustainable techniques may be profitable and the extent of current economic sacrifice by those wanting to switch to sustainable techeques may become manageable (compare for example, Tisdell, 1999; Wilson and Tisdell, 2001).

This can be illustrated by Figure 2 assuming that buyers are unwilling to pay a premium for sustainably grown agricultural produce. For simplicity, suppose that farmers can be divided into two groups. Group I is relatively myopic and favours the use of techniques that yield high profits and high yields in the short-term but reduced levels of these in the longer term whereas Group II consists of farmers who favour techniques that result in lower profits in the short-term but higher yields and profits in the long-term. The supply curve of product X of Group I farmers in the initial period might be as represented by the line marked S_1S_1. If they happen to be the only suppliers, the equilibrium market price would be P_1 and they would supply X_2 of the product. The supply curve for Group II farmers in the initial period might be as shown by line S_2S_2 if they were to adopt sustainable techniques. However, by adopting these techniques, they are unable to make a profit. Hence, farmers in Group II are forced by liquidity and profit considerations to join farmers in Group I and adopt unsustainable techniques even though they could record a profit in the long-run by adopting sustainable techniques. In the short-run, the market supply curve will therefore, correspond to line S_0S_0 with market equilibrium established at E_0.

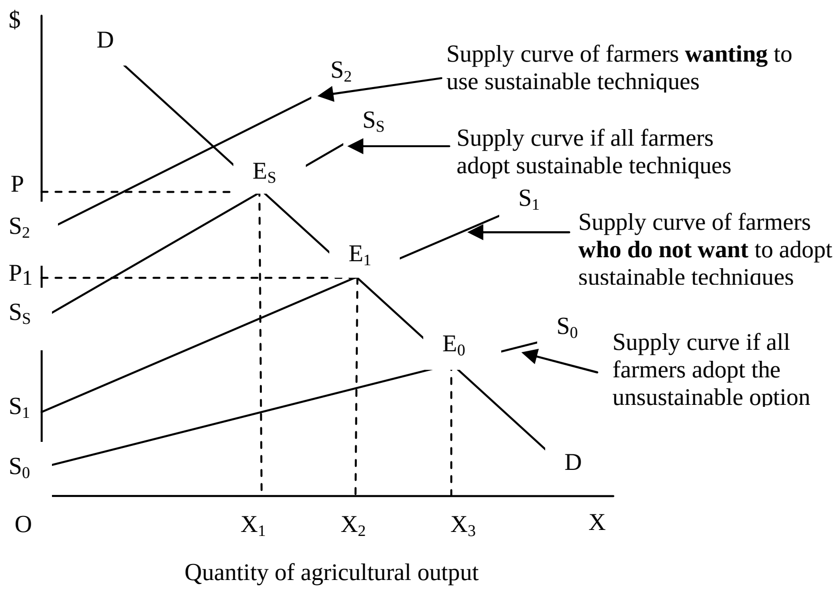

Figure 2: Market competition can prevent those who wish to use sustainable agricultural techniques for doing so because of the economic pressures generated in the short-term. This can (as is explained in the text) be illustrated using this diagram.

On the other hand, if all farmers adopt the sustainable technique, the market supply curve in the short-run might correspond to S_sS_s with market equilibrium corresponding to E_S. Use of the sustainable technique is now profitable even though supply of X in the short-term is lower and its price is higher than if the less sustainable technique is adopted. In the long-term, the opposite relationship should hold. Some economies from expansion of the market based on sustainable techniques may also be obtained of a Marshallian type. For example, economies of specialization in supplying inputs for farmers using the sustainable technique may occur. Consequently, the collective per unit cost of switching to the sustainable technique may be lower than appears initially to be the case for switching by an individual farmer.

4. To what extent have Increased Agricultural Yields and Production been Obtained at the Expense of their Sustainability?

Research and scientific advances have resulted in large increases in yields per hectare of agricultural land and have facilitated the extension of agriculture. Furthermore, growing international and interregional trade has contributed to increased agricultural output by encouraging greater specialisation in agricultural production by regions (as is predicted by the theory of comparative advantage) and many inputs or resources used in modern agriculture are now traded over greater geographical distances than in the past. The latter development makes agricultural production less dependent on local resources.

In addition, new agricultural methods have made agricultural yields less dependent on local natural environmental conditions than in the past. These methods have enabled humans to regulate (to a considerable extent) the actual environmental conditions experienced by crops and domesticated animals. **Both** new methods of agriculture production **and** increased ability to import agricultural inputs to regions that are deficient in these inputs have made agricultural production less dependent on local natural resources and environments than previously. For example, irrigation methods make agriculture less dependent on local rainfall, and chemical fertilizers can be imported to compensate for local soil deficiencies. As a result, there is greater control of agricultural micro-environments and increased agricultural yields. However, such developments are not without their risks because the high levels of agricultural production associated with these developments may not be sustainable. There are several reasons for concern.

First, many of the inputs used in modern agriculture are derived from depletable, non-renewable material resources, for example, oil. As these become scarcer, it will be more difficult to maintain agricultural production. At the very least, new agricultural technologies will be required to sustain agricultural production.

Secondly, the developments mentioned above reduce the genetic resources available to agriculture (Tisdell, 2003). This is because agricultural varieties that give high yields or returns under controlled environmental conditions replace those that give lower yields or returns under natural environmental conditions. However, these high yields depend on the ability of farmers to maintain desirable environmental conditions. In the long term, this may prove to be impossible because resources used for environmental control may be exhausted or disappear due to natural causes. Two cases can be used to illustrate this matter.

Suppose that in a region two varieties of a crop are available. Variety I is a local variety and is well adapted to local environmental conditions. The magnitude of a relevant environmental condition is indicated by a variable, x. This might be water availability or soil fertility, for example. The production from variety I (yield per ha.) is assumed to be as indicated by curves ABCD. If the natural environmental condition is x_1, yield will correspond to B in the absence of any effort by farmers to alter this environmental condition. Suppose also that an improved variety, variety II, is available and that this has the yield relationship indicated by curves EFGH. This technique can give higher yields but only if natural environmental conditions are sufficiently controlled. Suppose that it is profitable to regulate the environmental conditions if variety II is adopted so that the artificial environmental conditions experienced by the crop are x_3. Yields then correspond to point F and variety I can be expected to disappear because it is less profitable than variety II.

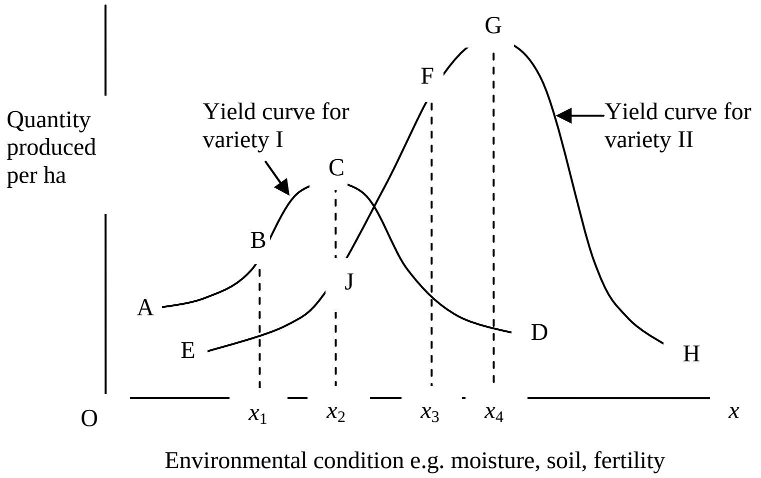

Figure 3 Under natural conditions, variety I of a crop gives the highest yields but if environmental conditions can be regulated economically, variety II gives the highest yields and the highest economic returns. There is however, a problem if environmental conditions cannot be regulated in the future or if this cannot be done economically.

However this situation can give rise to sustainability problems because the resources that allow the local agricultural environment to be regulated may not always be available, or may become very costly due to their increasing scarcity. For example, climate change may result in irrigation water no longer being available or supplies of artificial fertilizer may start to run out. Consequently, farmers may have to rely on natural environmental conditions again or may have to do so to a considerable extent. Therefore, yields using the improved variety fall drastically. For example, it may only be economic to regulate the environmental condition to x_2 and yield then falls to a level corresponding to J.

In addition, it is likely that variety I will have disappeared during the time interval in which variety II was the superior economic choice. Thus, it is impossible to revert to the use of Variety I even though it would be the superior possibility in the conditions that have eventuated. In this case, genetic loss adds to the agricultural sustainability problem.

A closely related aspect is that some local varieties of crops (or breeds of livestock) may be **more tolerant** to variations in environmental conditions than improved varieties. Consequently improved varieties only turn out to be commercially superior if variations in environmental conditions can be sufficiently regulated. If the resources for such regulation should become unavailable or scarce, more tolerant local varieties are likely to give higher returns on average (Tisdell, 1983). Once again, if local varieties have disappeared during the time in which greater environmental control was possible, this adds to agricultural sustainability problems. This issue is likely to become more important with global warming because global warming is predicted lead to greater **variability** of weather patterns.

A third problem is the erosion of the genetic stock due to social causes. The increased ability of farmers to control local agricultural environments and their greater specialisation due to the expansion of markets and trade have increased dependence of agricultural production on narrow ranges of agricultural varieties, (Tisdell, 2003) the populations of which have increased in abundance because they are favoured by humans for agriculture. Their increased abundance raises the exposure of these varieties to diseases and pests and makes them more susceptible to these and in the longer term, can be expected to reduce their ecological fitness. The presence of a greater diversity of crops and breeds of livestock reduces this sustainability problem.

Fourth, the yields from some crops and livestock depend on the use of pesticides. The effectiveness of these pesticides tends to decline over time as targeted pests develop biological resistance as a result of evolutionary processes. The maintenance of yields in such cases depends on effective new pesticides being developed to replace those that have lost their effectiveness. How long this process can be maintained is unknown.

While many modern agricultural innovations have added to concerns about agricultural sustainability (Tisdell, 2007) it would be wrong to believe that all agricultural innovations have reduced agricultural sustainability. Sustainable crop rotations, green manuring and some types of intercropping and polyculture can add to agricultural sustainability. However, the availability of artificial fertilizers often curtails these practices. In many cases, excessive use of artificial fertilizer is encouraged by government subsidies on their supply. Because the use of such fertilizer usually results in negative environmental spillovers, it would be more appropriate for governments to restrict their use rather than encourage it.

5. Genetically Modified Organisms (GMOs), Agricultural Production, and Ecological Sustainability.

In the last 25 years or so, spectacular advances have been made in the genetic engineering of organisms. These have made possible significant advances in medicine and more debatable progress in agriculture. It is sobering to realize that the first GM crops were only released in 1996 and that their rate and extent of adoption has been so rapid (Kinderlerer 2008, p.14).

Advocates of genetic engineering believe that it holds out the promise of greater agricultural yields, high economic returns, and greater environmental sustainability. Skeptics and critics of the genetic engineering revolution argue that the advantages of genetic engineering are overstated, that the environmental risks associated with GMOs are considerable and that yields from GMOs are likely to be unsustainable in the long run, (Wolfenberger, Engels and Phifer, 2000; Batie and Ervin, 2001: Andow and Zweblen, 2006). In addition it should be kept in mind that the potential for the creation of GMOs with particular attributes is limited by biological and physical constraints – the possibilities for genetic engineering are **not** unlimited. Even though Engels (1959) once triumphantly declared in criticizing Thomas Malthus that nothing is impossible to science, we know that this is not so.

To date there have been two principle types of genetic engineering introduced into agriculture and both are associated with the control of pests of crops. The first technique is the genetic engineering of crops to make them more tolerant of the application of particular herbicides, for example glyphosate sold under the trade mark of ‘Roundup’. This involves the insertion of genetic material into crops from plants that have shown themselves to be resistant in the field to the herbicide. The second innovation in the genetic engineering of crops is to incorporate within them toxins fatal to insect pests, mostly the larvae of moths and butterflies and some beetle species. For this purpose, genetic material from a bacterium (*Bacillus thuringiensis*, shortened usually to Bt) has been widely used. This bacterium is naturally fatal to several types of insects and occurs in some soils.

Crops that have been modified for herbicide resistance include soya beans and canola (rape). Crops that have been Bt modified include maize and cotton. Progress has been made in genetically modifying rice so that it is herbicide resistant as well as toxic to a range of insect pests but this rice has not been released for general cultivation.

Consider now some of the sustainability issues that can arise from the introduction of GMOs. If they actually give higher returns than traditional varieties (or farmers believe they do), they are likely to replace traditional varieties thereby reducing the biodiversity of organisms used in agriculture. Therefore, the types of problems mentioned in the previous section are likely to be exacerbated. Furthermore, for ecological reasons, the yields from GMOs are unlikely to be sustained.

In the case of herbicide-resistant crops, they are likely to cross-pollinate with their weedy relatives over a period of time. If this occurs, some of the targeted weeds in crops become resistant to the herbicide and the effectiveness of the genetic engineering is reduced.

Reduced sustainability of pest control is likely to occur more quickly for genetic engineering of crops that introduce toxins into plants to kill insect pests. This is mainly due to the rapidity with which new generations of insects occur. This accelerates evolutionary processes and the selection of populations of insect pests that are resistant to the toxins. This problem is now widely recognized by ecologists and policy-makers. In some countries, such as the USA and Australia, growers of Bt cotton are, for example, required to grow areas of non-Bt cotton to help sustain populations of insects that are not Bt resistant. The purpose of this is to slow the rate at which the total population of the pest becomes resistant to Bt. This, however, merely slows the process of the erosion of the effectiveness of the genetic engineering in raising agricultural yields. In the end, its effectiveness is likely to be completely undermined and the genetically modified crop varieties may give lower returns than traditional varieties.

We can conclude that ecological forces make it unlikely that increased agricultural yields obtained in the short to medium term as a result of advances in genetic engineering can be sustained in the long run (Botie and Ervins, 2001). The ecological forces involved seem to differ little from those that come into play when chemical pesticides are used to control pests. In such circumstances, the maintenance of increased agricultural yields is dependent on a continuing stream of innovations that enables new biological advances to replace earlier techniques that have lost their effectiveness. Whether or not such continuing scientific and technological momentum can be maintained is uncertain. A treadmill-type of phenomena is involved with the sustainability of agricultural production highly dependent on the ability of science to provide a stream of new advances. Once this flow stops or declines, lack of agricultural sustainability is liable to become a major problem. However, social sustainability problems are also raised by the use of GMOs in agriculture.

6. Concerns about Social Sustainability and the Introduction of GMOs to Agriculture

Norgaard (1994) has argued that agricultural technologies and social relationships should evolve in relative harmony by a process of steady non-rapid co-evolution and Tisdell (2000) has elaborated on this theme. The type of co-evolution that Norgaard had in mind was achieved in the past when agricultural (or more generally rural) innovations originated in local communities. For example, in the past, genetic improvements in crops and domesticated livestock were achieved by human selection of lines that showed superior traits in daily use.

Today, this pattern of agricultural innovation has largely been replaced by the development of agricultural techniques by large firms and companies (many of which are multinationals) having no (or only limited) contact with local rural communities. Consequently, major changes in agricultural technologies can occur rapidly and cause social distress and disequilibrium in rural communities as these communities try to adjust to the new situation. This may be one reason why human illnesses such as hypertension (high blood pressure) associated with psychological stress are becoming more common amongst farmers. Adjustment to rapid technological and economic change can be stressful and the problem is exacerbated if social structures and relationships fail to adjust at a sufficiently fast rate to cope with these changes, as seems increasingly to be the case.

The separation of agricultural innovation from local rural communities was partly a result of the Industrial Revolution but has been reinforced by the extension of intellectual property rights for inventions. Governments have extended the types of inventions for which patents can be granted or similar types of entitlement given. The most recent extensions include the granting of Plant Variety Rights for new varieties of plants obtained by selective breeding, and of greater social consequence, the granting of patents covering not only techniques to produce GMOs but also in several countries, the organisms produced by applying these methods. Both types of monopoly rights of patents apply in most developed countries e.g. the United States and Canada, but in some developing countries, such as China, only the techniques for producing GMOs can be patented. The United States in particular has been very active in its political lobbying for the recognition and enforcement of intellectual property rights internationally (Phillips, 2007). This is because the United States has been the source of many innovations in current use and stands to gain economically from the international recognition and enforcement of such rights.

As a rule, it seems that only large companies are in a position to develop new GMOs (because of the costs and risks involved), to effectively market these and to defend the intellectual property rights conferred on them by patents (Tisdell, 2008). The transaction costs involved in defending intellectual property rights can be very high. However, from a social point of view, transaction costs involve an economic waste because they are not productive – society would be economically better off if they could be avoided. Yet, given the type of social system adopted, they cannot be avoided. The potential reward for those who develop new GMOs, patent and market these are monopoly profits. If these are very high, they are likely to generate social criticism on the basis that there is inadequate sharing of the economic benefits of the innovation with farmers and consumers.

If a new GMO proves to be economically superior to traditional varieties, traditional varieties of crops are likely to disappear and farmers then become highly dependent on suppliers of GM seed for their future crops, especially if farmers are not permitted legally to save their GM seed or trade in it. The latter is the case in several countries (Phillips, 2007). Farmers may become hostile towards suppliers of GM seed if they become highly dependent and locked into this supply.

This economic dependence could be fostered by some suppliers of GM seed – they might engage in monopolisation. For example, a supplier of GM seed could initially keep its price low to encourage its adoption with the consequence that traditional varieties are no longer grown and are lost permanently. Once this has occurred, the supplier of GM seed would have a monopoly or near monopoly and be able to raise the price of GM seed to the detriment of farmers and consumers.

It has been said that some producers of GM seed are endeavouring to introduce a 'terminator' gene into their seed (Phillips, 2007). The seed obtained from crops grown from this seed might be infertile (or only have inferior quality) compared to the original GM seed. Therefore, farmers would have no incentive to save their seed or trade in it and the supplier of the GM seed would avoid many of the transaction costs involved in enforcing its intellectual property rights. This could have social economic advantages even though there is likely to be social opposition to the introduction of GM seed containing a terminator gene.

7. Concluding Comments

A major global challenge is how to increase the level of agricultural production and sustain it while taking into account the environmental impacts of agricultural production. Between now and the middle of this century, approximately a 30 per cent increase in agricultural production will be needed to maintain the current availability of agricultural products. Unless there is income redistribution in favour of the poor, an even greater increase will be needed to overcome food poverty. Agricultural production needs to be increased and the increased production needs to be sustained.

The concept of agricultural sustainability was shown to be complex. This is because it is desirable to sustain some attributes of agriculture but not others. Value judgments are needed to decide which attributes should be sustained these. Sustainability is by no means an absolute virtue and it is often necessary to trade-off desirable sustainability objectives (to some extent) to achieve other objectives, or to forgo one sustainability objective to achieve another. Sustainability objectives are subject to the economic principle of opportunity costs. This should always be kept in mind in order to avoid fantasy.

It was shown that when farmers are dependent on the market system for their survival or economic welfare, they are often unable to adopt techniques which would sustain agricultural production and yields even though they may wish to do this. If some farmers go against the tide by adopting sustainable techniques, they may fail to make a profit in the short- to medium-term and suffer liquidity problems. In many cases, a collective approach is needed to ensure the adoption of sustainable agricultural techniques.

While scientific advances in agriculture have increased agricultural production and yields and while increased interregional trade has helped raise agricultural supplies, both of these developments have increased the risks of agricultural production not being sustained. Several different reasons for this were outlined. For example, loss of agricultural biodiversity as a result of these developments was identified as a factor that is likely to have negative sustainability consequences for agricultural production.

An important development in recent years has been the development of GMOs and their use in agriculture. It was argued that these developments add to sustainability problems in agriculture. Ecological responses to the introduction of GMOs in agriculture may make it impossible to sustain the initial increase in agricultural production obtained by the adoption of GMOs. Secondly, the introduction of GMOs to agriculture can lead to social conflict and disharmony. Various mechanisms were identified that may interfere with the sustainability of rural communities as a result of the adoption of GMOs in agriculture. It seems likely that the use of GMOs in agriculture will reinforce the agricultural sustainability problem created by modern commercial and industrial agriculture and the sustainability of agricultural production will come to depend even more heavily on continuing scientific and technological advances than in the past. It is uncertain whether such progress can or will be sustained.

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