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Agriculture and the Environment

In these notes, a few of the issues that relate to agriculture and the environment are briefly reviewed. Some of the material here consists of items from the 2nd edition that were not retained in the 3rd or 4th editions. The document concludes with a structured bibliography, compiled from a variety of sources.

1. Agriculture and environmental externalities [1]

As Shortle and Abler (1999) demonstrate, agriculture is both a source and a receptor of environmental externalities. In this section, a brief review is given of environmental activities generated by agriculture – its role as a source. A later section considers its role as a receptor of externalities generated elsewhere.

Externalities generated by agricultural activity are both beneficial and adverse. Two frameworks described in Chapter 2 of the textbook are useful ways of marshalling ideas. The laws of thermodynamics - and in particular the materials balance principle - suggest that externality problems can be approached in terms of physical and biological flows of inputs into agriculture, the transformations of these inputs, and the destinations of flows of various outputs. Many of the adverse external effects are associated with the unintended (or uncompensated) outputs of agriculture. Our discussions in Chapter 2 about the variety of services provided by environmental resources provides a framework in terms of which the beneficial external effects of agriculture may be set. We begin by considering some of the more important harmful externalities.

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[1] Section 1 of this document draws quite heavily on material from the following review paper: Shortle, J.S. and Abler, D.G. (1999) *Agriculture and the Environment*, in van den Bergh (edited): Handbook of Environmental and Resource Economics (1999). Edward Elgar, Cheltenham, UK.

1.1 Negative externalities

Two categories of process dominate the literature about agricultural activities. The first comprises the consequences of the use of fertilisers, pesticides and herbicides in farming, particularly in its more 'developed' or intensive form. The second concerns opportunity costs associated with land use conversion into agriculture. We may classify impacts by the environmental medium affected.

(a) Water pollution

Run-off of agricultural chemicals and organic manures from agricultural lands appears to be a leading form of non-point source pollution, particularly in Western Europe and North America (OECD, 1991) and a major cause of surface water pollution (US EPA 1994). Particular concern has been expressed about accumulations of nitrates and pesticides in groundwater used for drinking water.

Much research has been devoted to investigation of the health impacts of pesticides. Knowledge of this is far from complete, but evidence is building up that even low exposure over a long term may have significant effects, with some studies implicating pesticides in rising incidence of cancer, genetic mutation, and reproductive disorders (Council on Scientific Affairs, 1988; WHO, 1990). If these concerns prove to be well-founded, this is particularly worrisome given continuing trends of structural change in agriculture and intensification of livestock production, which have led to widespread deteriorations in water quality (again especially in Western Europe and the USA).

These effects are by no means confined solely to the more affluent countries. Many developing economies are experiencing a rapidly growing use of pesticides, herbicides and inorganic fertilisers in agriculture. Pesticides, one foundation of the remarkable production hikes over the past few decades, continue to underpin many national development strategies in developing countries. Yet research suggests that the benefits of pesticides have been exaggerated and that they pose substantial dangers both to the environment and to human health. The situation in regard to pesticides is examined in *World Resources 1994-95* (WR 1994). Similar worries apply to the consequences of inorganic fertilisers, the use of which is growing at 3.4% per year (FAO, 1994) in spite of evidence suggesting that fertiliser applications are of declining effectiveness (Brown and

Kane, 1994). Finally, there are reasons to believe that agricultural intensification, in conjunction with long-term climate change, is contributing to the loss of soil fertility and increasing desertification, although these remain poorly understood phenomena. We examined soil fertility changes and desertification in Box 1 in the 2nd edition.

Other (non-health) costs include reduced sporting and recreational values, materials damages, and various ecosystem impacts. A number of environmental hazards are associated with irrigation activities. Good discussions of damage estimates may be found in Ribaudo (1986, 1989) and Crutchfield et al, 1995.

(b) Air Pollution

Agricultural activity is also a large contributor to air pollution. Principal pathways include the loss of nitrogen to the atmosphere via denitrification and volatilisation. These are important contributors to acidification (Hidy, 1995; OECD, 1995) and have been estimated, for example, to be the major source (>60%) of acidification substances in the Netherlands (OECD, 1995). Agriculture is also a large source of greenhouse gas emissions. With the inclusion of land use changes – particularly conversion of forests to agriculture – and methane emissions from livestock and wet rice cultivation (which may be quantitatively more important than forest conversion), Watson et al (1996) estimate that around 20% of annual GHG emissions are attributable to agriculture.

(c) Loss of biological diversity

Land conversion, expansion of the agricultural frontier, and agricultural specialisation play contributory roles in biodiversity loss. We discuss this no further here, but see the document *What is causing the loss of biodiversity?* in the *Additional Materials* for Chapter 17.

1.2 Positive externalities

The externalities generated by agricultural activity are not all adverse. Suggested beneficial externalities include some consequences of drainage (such as malaria elimination in Europe and North America) and the conservation of land as a habitat for wild species (although whether this is in fact the case is no doubt very situation-specific. The role of agriculture in the provision of landscape amenity values is often remarked upon.

1.3 Policy

Agricultural policy has traditionally been targeted at maintaining and stabilising farm incomes (or agricultural prices) and promoting (or regulating) agricultural trade. In recent decades, controlling adverse environmental impacts has become an increasingly important target of policy. This has taken place rather later than was often the case for industrial (point) pollution; indeed until recently pollution policy has concentrating on point source pollution, and largely ignored non-point sources. By ignoring relative abatement costs and benefits, this practice has been cost inefficient (Freeman, 1990).

The design, implementation and monitoring of non-point source pollution control instruments with attractive cost-effective policy is, however, difficult (Shortle and Abler, 1997). Monitoring individual emissions sources is largely impractical (due to large numbers), and attributing pollution impacts to individual sources – even if individual emissions were known – is virtually impossible (complex pathways and diffusion processes). So, as with much mobile-source pollution, 'first-best' emissions-based controls are currently impractical.

1.4 Instruments available

Technical controls, combined with assistance to adopt environmentally benign technology (and public persuasion), are examined in OECD, 1989, 1993. These and other studies suggest that, without financial assistance, they have limited impacts. (Dubgaard, 1994; Feather and Amacher, 1993; Feather and Cooper, 1995; Norton et al, 1994).

A second instrument class consists of agricultural input controls – restrictions concerning which inputs may be used and their conditions of use. Pesticide controls are examined in OECD 1986, Thrupp, 1988, and Cropper et al, 1992. The use of tradable farm manure quotas in the Netherlands, with taxes on use above quotas levels is examined in OECD, 1995). The Netherlands has also developed crop-based quotas on phosphate and nitrogen applications. Input controls are not 'first-best' instruments, of course. By only indirectly targeting polluting emissions, they will diverge from least cost controls to the extent that conditions are heterogeneous within agriculture (Lictenberg, 1992, Zilberman et al, 1991)

Shortle and Abler (1999) suggest that heterogeneity over sources points strongly to watershed-based approaches to agricultural pollution policy (see also Babcock et al, 1997; Bouzacher et al, 1990; Braden et al, 1989; Duda and Johnson, 1985; Lee et al, 1985; Park and Shabman, 1982; Ribaudo, 1986; Lichtenberg and Zilberman, 1988; Hochman and Zilberman, 1978). For a discussion of environmentally-friendly technologies – such as Integrated Pest Management schemes – and the potential role that may be played by biotechnology, see Chrispeels and Sadava, 1994, and Fransmann et al, 1995.

1.5 Agricultural Policy Reform

We conclude this section by listing some of the main current areas of agricultural reform, giving for each some indicative reading references:

- Agricultural policy coordination and integration (OECD, 1989, 1993)
- Removal of policy distortions (Abrahams and Shortle, 1997; Tsai and Shortle, 1997)
- Decoupling of farm prices and incomes from agricultural output levels (OECD, 1989)
- Controls over land use, land conversion and land degradation, including formation of land use agreements in Europe (Environmentally Sensitive Areas) and in the USA (Conservation Reserve Program)

Good general overviews are found in OECD 1994b; National Research Council, 1989, 1993.

The material in Section 2 was originally printed in the second edition.

2 Population, agriculture and the availability of food

Common sense suggests that continuing population increases will place increasing pressure on world agriculture and threaten the availability of adequate supplies of food. But the evidence does not give any strong support for this view. Johnson (1984), in summarising the principal features of the world food system, noted that a family's access to food had become primarily dependent upon the family's income, and not on the availability of food *per se*. A food system had become established that was capable of making food available to almost every person in the world, a situation that had been impossible just a few years prior to 1980. This change had taken place in spite of the fact that global population had doubled in the previous 30 years. Johnson argued that hunger and malnutrition should be tackled by policy directed at reducing inequalities of income within and between countries, rather than by supply-side targeted measures.

Johnson's analysis suggested that real food price data show very little evidence of rising food scarcity. The real price of grains (the major source of calories for poor people) and the prices of many other food products, including rice, sugar cane, corn, poultry and eggs, had declined in the decades leading up to 1980. Livestock prices (beef cattle, hogs), however, exhibited slowly rising trends. Where food shortages had occurred, these were primarily attributable to government intervention in the markets for food or to other political factors (including wars and civil strife). In particular, trade restrictions and government interventions in some regional markets reduced food prices in 'uncontrolled' areas, reducing incentives to supply commercial food crops and to modernise and improve agricultural inputs.

Johnson's analysis was not, however, uniformly optimistic. He also noted that:

1. Increasing affluence tends to change demand in the direction of meat and away from direct consumption of vegetables and grain. This imparts considerable physical

inefficiency in food production, and causes prices to rise, reducing food access to lower-income families.

2. There was limited availability of land to bring under cultivation. The scope for expanding the extensive margin of agriculture had become quite restricted. However, the most cost-effective method of obtaining output increases has been through expanding the intensive margin of agriculture. Furthermore, large productivity increases remained to be exploited through land irrigation.
3. Increasing the intensive margin was likely to become more difficult as a consequence of higher energy prices, leading to higher relative prices for inorganic fertilisers.

To what extent do Johnson's conclusions remain valid today? Studies by the Food and Agriculture Organization of the United Nations (FAO, 1994) and the World Bank (World Bank, 1993) concluded that production increases can accommodate effective demand for food over the period to 2020. In *World Resources 1996-97*, the World Resources Institute concludes that agricultural production in much of the developing world has been very successful in recent decades. Production is growing and will continue to do so in the next couple of decades. This has been true in all regions of the world with the exception of the dramatic (but probably only temporary) collapse in the countries of the former Soviet Union. Those developing countries that are most dependent on agriculture (with over one third of the economically active engaged in agriculture, but with low levels of food *per capita* and low purchasing power on world markets) have seen agricultural output not merely growing but doing so increasingly quickly.

However, Africa (particularly sub-Saharan Africa) has not fully participated in these successes. African food production has more than doubled since 1961, but this output growth has been insufficient to keep pace with population. As a result *per capita* food production has fallen by 20% since 1970, and low real income prevents Africa from gaining access to food on world markets. To use Sen’s phrase (Sen, 1981), many Africans have insufficient food entitlements to stave off the chronic malnutrition that prevails.

Africa will regularly face serious food shortages during the next few decades unless income grows or food output rises at historically unprecedented rates.

There are other causes for concern about the current state of agriculture. First, the prices of agricultural commodities have been falling in real terms for the past 15 years, thereby squeezing monetary incomes and adding to problems of national debt even where output has been rising. This is a worrying trend on at least two counts:

(a) Large proportions of the population in many developing countries are seriously undernourished, because low incomes constrain their effective demand for food;

(b) Continuing indebtedness and low *per capita* incomes appear to be contributors to environmental degradation.

The second cause for concern is a slowing of the growth of agricultural production in many regions of the world. This seems to be partly associated with slowed yield growth rates. While crop yields have typically continued to increase, they have generally increased at much slower rates in the 1980s and 1990s than previously, particularly in developing countries. Other contributory factors are increasing scarcities of water, limits to the biological productivities of fisheries and rangelands, soil erosion, fragility of ecosystems in tropical and sub-tropical countries, and the fact that the ‘green revolution’ has involved a series of technological leaps which cannot be repeated indefinitely. (See, for example, Brown and Kane, 1994; Carruthers, 1994; Pimental *et al*, 1995). The prospect for increasing agricultural output is far higher in the temperate regions of Europe, the United States and Australasia than in much of the developing world, but that is of little help to food security for families in developing countries unless they are able to expand their export earning potential to purchase food requirements externally.

However, future prospects also offer some grounds for optimism. One of these is the likely future stabilisation and then decline of global population levels that we noted above. Another derives from the application of new technology in agriculture. Concerning biotechnology in particular, the World Resources Institute has written:

> Agricultural biotechnology, is an important source of hope for the future. Biotechnology offers numerous possibilities for agriculture. But these potential advances are decades away from realisation, carry some risk, and will not displace current agricultural practice altogether. Moreover, while the developing world is most in need of biotechnology's innovations, current research is concentrated on high-value crops grown in the industrialised world. WR (1996)

Box 1 Declining soil fertility and desertification

A June 1994 conference of the United Nations Environment Programme (UNEP) examined the issues of declining soil fertility and desertification. Delegates to the conference were told that 900 million people were at risk from dependence on agriculture in dryland in the Americas, Africa and Asia, in which soil fertility was being lost at an alarming rate. The United Nations believes that loss of soil fertility is a greater threat to poor people than global warming or upper atmosphere ozone depletion. UNEP estimates that just under one-tenth of the earth's land surface is significantly degraded, and that an area equal to the size of Italy has been more or less permanently lost to agricultural use.

More recent work by the International Soil Reference and Information Centre suggests that the losses are somewhat lower, estimating that 9 million hectares are extremely degraded (more or less complete breakdown of all biotic functions) and that 1.2 billion hectares - about 10% of the earth’s vegetative cover - are moderately degraded. There are several causes of soil fertility losses. In some cases, it is a consequence of the lack of organic inputs, combined with intensification of agriculture on already fragile lands. This process steadily depletes nutrients. Very often, these deficiencies cannot be compensated by use of inorganic fertilisers. A second cause is faulty agricultural practice - such as over grazing, poor draining of irrigated land and too short fallow periods - which is thought to account for about 28% of degraded soils (including two-thirds of degraded land in North America).

Extreme soil fertility losses can be a precursor to desertification. It is now widely accepted that the predictions, made in the 1970s and 1980s, about the rapidly growing spread of desert areas, were severely overestimated. Satellite surveys show that deserts expand and contract in natural cycles, and that most of the changes noted in those earlier decades can be attributed to such cyclical behaviour.

However, large areas of land are subject to potential desertification as a result of economic activity. Desertification can be induced by chronic losses of soil fertility in association with some forms of agricultural practices introduced in attempts to mitigate those losses. In Africa, for example, peasant farms in arid areas lack resources to maintain output as fertility falls, and tend to shift production to more marginal land. Soil fertility soon diminishes in these areas, and so agriculture follows a path of continuously shifting cultivation. However, environmental conditions are not conducive to restoring fertility in the vacated land areas. Wood clearing and burning for fuel, and overgrazing of savannah land by cattle, thins roots and leaves soils immune to wind and water erosion. Irrigation has also had unintended effects; while often being seen as a way of raising yields, it has often been counter productive, damaging soil through raising salt to upper soil surfaces.

Institutional factors play an important part in soil fertility losses. Land tenure is often very insecure, and environmental resources in arid regions are often effectively open access resources, destroying any incentives that farmers may have to conserve woodlands and soils. Finally, mention must be made of the effect that crippling poverty has on land degradation. Poverty denies peasant farmers access to credit and the resources necessary for sustainable and conservationist agricultural practices.

What policy initiatives offer hope for controlling or reducing the extent of these environmental and economic problems? Clearly, any changes that can offer the prospect of increasing the levels of real income of farmers in arid regions would be of substantial benefit, making possible the investments that are required for conservationist agricultural policy. The key step in avoiding severe cases of soil fertility losses is implementation of good agricultural practice. However, that may require substantial institutional reform. This would take the form of building local capacity for developing good practices and reforming the patterns of incentives affecting those who make a living from the land. It would be desirable to move towards more clearly defined property rights to land and other environmental resources, and to ensure more security in the tenure of land. Property rights need not necessarily be invested in individuals; common-property ownership rights can be effective in regulating the demands made on land, provided institutional mechanisms are established that prevent common-property resources degenerating into conditions of open access. This implies establishing local incentives to manage resources, enabling communities to regulate access, and reducing restrictions on how resources can be used. For example, simple restrictions prohibiting tree felling are almost certainly counter productive; they will be largely unenforceable, and will act as severe disincentives for future replanting by local communities.

Source: The June 1994 UNEP Conference on Soil Erosion and Desertification.

Desertification: additional reading

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END OF BOX 1

Box 2 Scientific advance, new crop varieties, and biotechnology in agriculture

Agricultural research institutes have had astonishing success in cultivating new crop varieties with improved yield or lower susceptibility to disease characteristics. This has been particularly evident in the case of rice, where new hybrids have raised yields, lowered the cost of seed and increased the geographical scope where rice can be profitably grown (CGIAR, 1994; Alexandratos, 1995).

However the intensification in agricultural practice associated with the employment of new crop varieties has contributed to adverse environmental impacts (discussed elsewhere in this chapter). The tools of biotechnology offer the prospect of dramatic gains in future food production potential without the imposition of significant environmental stresses. The principal benefits which it is hoped will be derived from biotechnology applications are:

- insect and disease resistance
- greater stress tolerance
- improved fruit ripening characteristics
- improved nutritional content of plants
- development of crops with special 'target' qualities, such as plant-produced biodegradable plastic (as a substitute for plastics from petroleum).

The key technologies include:

Genetic engineering: useful DNA material is identified in one organism and transferred into another unrelated organism. This technique can increase yields, promote pest resistance (and so avoid reliance on pesticides), alter harvesting characteristics of crops, and improve resistance of crops to environmental stresses such as drought or climate warming. These techniques are at an advanced state in tomatoes, soybeans, cotton and rapeseed. Progress is also being made with cereal crops.

Cell and tissue culture, by which plant cells or tissue are used to promote plant development in vitro. Commercial applications include clonal propagation, the mass production of genetic duplicates. These duplicates are guaranteed to be disease free, and can be planted in place of conventionally produced seeds, seedlings, cuttings or tubers. Crops that are currently cloned include potatoes, bananas, and oil palms.

Production of monoclonal antibodies: allowing mass production of specific antibodies that can be used as diagnostic test materials for the presence of diseases, and in animal vaccines.

Limitations and costs of biotechnology

As in many areas of scientific advance, expectations tend to focus on the positive potentials of the technology and (at least initially) pay insufficient attention to limitations and potential costs. The limitations are twofold. First, while the technology itself has advanced rapidly, the pace of innovation - the commercial application of biotechnology - has been relatively slow. Few major applications are widely diffused so far, and large-scale effects will probably not be felt for two or three decades.

The second limitation is also an economic one. Biotechnology is research intensive, and its applications tend to be directed at where profit potential is greatest. Researchers and innovators tend to be very conscious of intellectual property rights, being unwilling to allow their findings to freely enter the public domain. Thus, applications have so far largely been applied to high value added crops in the industrialised world, and have not been devoted to crop development in poor countries where, despite the most pressing needs, the ability to pay is low.

Much of the genetic source material that is employed in biotechnology applications is obtained from biota taken from biologically diverse developing countries, where no mechanisms have yet been found to impose property rights on (and so gain income from) these materials. Once the technology has produced commercially profitable outputs, property rights over these products are fiercely defended. Yet the inability of the countries whose biodiversity is the source of the valuable genes to obtain financial rewards from it does not give them proper incentives to conserve that biodiversity. Here is an example of the failure (or in this case, absence) of market mechanisms to allocate and conserve resources in an efficient way.

The costs are harder to identify, but stem from the largely unknowable consequences of human-directed genetic manipulation and consequent disturbances to ecosystem balances. Genetic engineering may alter the relative competitive advantages of species in very dramatic ways, reducing biodiversity, and upsetting ecosystem dynamics. These fears, in conjunction with ethical concerns about genetic engineering, have promoted a rather conservative regulatory regime in some countries.

Sources: WR(1994), WR(1996), box 10.1.

Additional reading:

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End of Box 2

The material in Section 3 was originally printed in the second edition.

3. Andreasson (1990): The costs of different policies for reducing nitrate fertiliser use on the Swedish island of Gotland.

A study by Andreasson (1990) examines the costs of different policies for reducing nitrate fertiliser use on the Swedish island of Gotland. This study is discussed at length in Hanley and Spash (1993), in a chapter devoted to analysing the costs and benefits of nitrate pollution control. Andreasson investigates three policies for achieving the Swedish government's upper limit of 30 milligrams per litre nitrates in drinking water. Model calculations suggest the need for a 50% reduction in nitrogenous fertiliser application to meet that target (scenario B). However, uncertainty exists about the rate at which nitrate leaches from manure and fertiliser, and it is possible that a more modest reduction in fertiliser application (14%) would be sufficient to achieve the target (scenario A).

The three policy instruments investigated by Andreasson are (non-tradable) quotas on fertiliser use, a tax on nitrogenous fertiliser, and a tradable permit system. Table 1 presents the real economic (resource) costs of achieving the pollution target under the two scenarios for each of the three policy instruments. In addition, Andreasson estimates the effects on farm incomes of the alternative policies; these farm income effects are also shown in Table 1.

Table 1 Andreasson's real economic (resource) costs and effects on farm incomes

	Resource costs (million kronor)		Farm income (% of total income)	
	Scenario A	Scenario B	Scenario A	Scenario B
Quotas	24.1	34.2	-10.0	-15.4
Tax	18.7	21.2	-13.9	-12.4
Tradable permits	18.7	21.2	- 7.6	- 9.0

Source: Hanley and Spash (1993), page 202.

These results are consistent with the conclusions suggested by our analysis in this chapter. Look first at the real economic costs (called resource costs in Table 1). As both taxes and tradable permits are fully efficient, their theoretical costs are identical. Costs under non-tradable quota controls are higher - here by about a third in scenario A and a half in scenario B. These higher costs arise from the fact that non-tradability means that marginal pollution control costs are not being equalised between different users of fertilisers. Second, the effects on farm incomes differ widely between the three policies. Taxes cause the largest loss of farm income under the lower reduction scenario, whereas quotas hit farm incomes most harshly when a high reduction is sought. Tradable permits are the least costly from the viewpoint of farmers in each case. This arises from the fact that Andreasson's simulations assume that the permits are initially allocated free of charge; if they were auctioned on a free market initially, losses to farm incomes would, of course, be higher than those indicated in the table.

4. Data Sources

Useful official data on food and agriculture issues are found in United Nations (Food and Agriculture Organisation, Rome) The State of Food and Agriculture (1979, 1981, 1985, 1989, 1994 and subsequent issues). See also: WR 1994, *World resources 1994-95*; WR 1996, *World resources 1996-97, both* World Resources Institute, Washington DC and Oxford University Press, Oxford.

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6. Discussion questions

1 Examine the effects of alternative patterns of land tenure and property rights on the likelihood of soil fertility losses and desertification.