NAE Chapter 3

Environmental, Economic and Social Impacts of NAE Agriculture and AKST

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Key Messages

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Environmental Impacts:

1. The relatively intensive and highly productive types of agriculture practiced extensively in NAE have had undesirable impacts on the environment in NAE. However, there is considerable potential for reduction, or in some cases reversal, of these impacts by application of knowledge to identify and select improved practices. Increased fertilizer use has resulted in raised levels in nitrogen and phosphorus in rivers and coastal waters causing changes in aquatic populations and contributing to eutrophication. Pesticide and sediment run off from erosion can also damage aquatic populations. Adoption of farming practices to prevent over fertilization, have helped to reduce environmental damage (e.g., controlled timing of treatments, more precise rates, creation of buffer zones). Reduction in pesticide uses through methods such as integrated pest management and switching to less persistent and harmful products has reduced impacts but problems from non-target effects of pesticides remain. Soil quality in parts of NAE has been degraded by a variety of intensive land use and irrigation practices.

2. The adoption of mechanization in NAE has contributed to substantially larger fields and farm units. In some regions, this has resulted in loss of traditional landscapes and hedgerows with a subsequent loss of wildlife habitat and biodiversity. Policies and programs, especially financial payments, are available in some areas of NAE, to restore farmland habitants and increase wildlife populations.

3. Greater intensity of animal production systems, combined with the increased spatial segregation of crop and animal production units, has led to concerns over water and air pollution, development of antibiotic resistance and animal welfare. These changes in production systems have created areas where the amount of wastes cannot easily be returned as soil amendments, leading to water pollution in many parts of the NAE. Concerns over impacts have led to stronger regulatory frameworks, especially in the EU.

4. Aquaculture production in NAE, especially salmon, has been growing rapidly over the last few decades. Feeding these farmed fish with fishmeal has put further pressure on fish stocks. Also waste from such operations may overload the capacity of local waters to absorb or process these nutrients, leading to environmental degradation. Further, caged aquatic livestock can incubate diseases that may infect wild populations and escaped fish bred for fast growth in aquaculture may out-compete native wild populations.

5. Agriculture is a sizable contributor to greenhouse gas emissions, especially of methane and nitrous oxide. Greenhouse gas emissions from agriculture are in the range of 7-20% of total country emission inventories (by radiative effect) for NAE. Approximately 30% of global methane is thought to originate from agriculture, of which digestive fermentation from ruminant livestock is by far the greatest contributor. Agriculture in NAE contributes at least one third of global emissions of nitrous oxide and it is the primary contributor to increases in reactive nitrogen.

6. The evidence for the presence of direct environmental impacts arising from the current genetically engineered (GE) crops grown on a large scale compared with conventional agriculture remains controversial. Conclusions that the production of GE crops in N. America have not led to adverse environmental effects are not accepted by some stakeholders. It must be pointed out that the agricultural system chosen as comparator is important in the evaluation of GE crops**.** Measurable reductions of insecticide use have been observed with insect resistant GE crops but not eliminated and vary with crop type. Herbicide tolerant GE crops have facilitated conservation tillage resulting in environmental benefits. Weed populations tolerant to herbicides used in conjunction with certain GE herbicide tolerant crops have become an issue in some parts of North America, but options exist for their management.

7. Bioenergy crops. The use of crops for the production of biomass and liquid biofuels is increasing rapidly. Their use is already having an impact on food crop surpluses, crop production patterns and prices. There is concern that high levels of production of biofuels from food crops could encourage crop production on lands presently reserved for conservation purposes with undesirable effects on the environment.

8. Reorganization of supermarket supply chains and consumer demand in NAE for varied fresh food products and counter-seasonal food products have caused an increase in the long-distance transport of food (food miles). Agricultural policies have encouraged the production of high-value horticultural crops in developing countries which must be shipped in high-energy cool chains. While this trend has had negative effects on the environment, primarily because of increased energy use, it has given some farmers in developing countries access to export markets. In contrast, another trend towards sourcing local food whenever possible may reduce food transport miles in the future.

Economic impacts:

9. The application of AKST in a dynamic economic and political environment has allowed consumers to purchase food at relatively low prices, but the technologies that have developed from AKST have encouraged concentration at all levels of the agriculture and food sectors. Decline in prices have forced farmers to adopt more productive practices or increase production and landholdings, reducing the number farmers and, in many cases, necessitating dependence on off-farm incomes to maintain living standards.

10. Across much of the NAE, large-scale food retailers and processors have a dominant role in determining what people can buy and farmer profits. This has given rise to concern about the impact on competition across the chain and the relatively weak position of farm and food businesses that supply those companies. The development of standardized products which can be processed intensively, as well as the imposition of quality/safety standards by retailers and processors, can increase monopoly power. However, there is an increasing desire among certain consumers to source foods they perceive to have improved quality/safety (e.g. organics, fair-trade), which is providing new opportunities for some farmers.

11. In the last 30 years, a number of food safety breakdowns and animal health issues (e.g. Salmonella, *E-coli 0157:H7* and BSE) have occurred and have had extensive impacts, given the increased scale of agricultural and food production. In response to these breakdowns, most of the NAE region has developed far-reaching regulatory mechanisms (e.g. tools for traceability and biosecurity) to detect and prevent the spread of pathogens, weeds and pests and for the detection of pesticide and chemical residues. Some vertically integrated food chains have developed new forms of governance by setting up articulated system of quality standards, including those aimed at increasing food safety and animal welfare. These forms of governance have been used by major food retailers in some parts of the NAE as a way to regain consumer confidence after food safety scandals. Some retailers have required farmers to comply with specific farm assurance schemes for quality standards in order to sell their products. This can potentially increase costs and raise barriers for farmers.

12. Many of the applications of AKST in agriculture and food systems have created significant waste streams across the food chain, from post-harvest wastage of raw product to end-consumer packaging. Disposable packaging and creation of uniform products have increased commercial appeal of food products and have contributed to food hygiene, but have also increased costs to local communities for disposal.

Social impacts:

13. Since 1945, food insecurity across the NAE region has largely been resolved, due to an increasingly wealthy population, decreases in the real prices for food and the substantial increases in food production and productivity. But some sectors of the population across the region remain food insecure (e.g. one in ten households in the U.S.).

The needs of labor intensive agricultural systems (such as fruits, vegetables and meat processing) are being met by migrant (largely immigrant) workers. While this has allowed the survival of these labor intensive agricultural systems within NAE and provided workers with a foothold into richer host countries, it has left these workers vulnerable to exploitation across the NAE. They typically have poor working and living conditions, low wages and lack rights to organize. In many cases, they have high levels of poverty and in some regions (especially North America), high levels of food insecurity.

14. Despite gains in agricultural productivity, food security and overall wealth, inequities remain in much of the food system. Within NAE populations there are large variances in the degree of rural poverty, access to affordable, nutritious diets and the sharing of benefits from the reorganization of the food system and global trade. There has been a growing interest in much of the NAE in 'alternative' food systems, in which participants seek to incorporate principles of social, environmental and economic sustainability. These systems are currently still small in scale but are increasing.

15. Obesity and associated diseases (diabetes, cardiovascular diseases and metabolic syndrome) have become an increasing concern across the NAE, partly as a result of inadequate nutrition. This is due to the interaction of various factors: general abundance of food and a high degree of food marketing, lifestyle and dietary choice. Some nutritional and educational policy changes have recently been instituted, particularly in schools, to ameliorate these trends, but their impact is yet to be evaluated. Despite a situation of overabundance of food, some sections of the population cannot access a sufficiently healthy diet, mostly due to poverty. Some countries are now facing the double burden of food insecurity and nutrition-related diseases.

Impacts outside NAE:

16. NAE has had a major impact on agriculture in the rest of the world, both directly by importing food and raw materials and indirectly, through the impact of NAE AKST. This impact of NAE import requirements has had environmental and economic consequences for the rest of the world. Research undertaken in NAE has also had a global impact. While other countries have derived some benefit, the focus of NAE research has not been on their problems. The development of international research capacity, via the CGIAR institutions, has sought to balance this by stimulating research relevant to the needs of developing countries. The intellectual paradigm that determines the conduct and direction of this research remains powerfully influenced by the model of research in NAE countries and this may sometimes have diminished the usefulness and applicability or research results.

3.1 Environmental Impacts of Agriculture and AKST within NAE

Farming practices have a considerable impact on the environment. Cultivation agriculture has replaced natural forest or grassland ecosystems with species and varieties of plants that have been adapted to cultivation and planted in near-monoculture, such that the original native ecosystem and its native biodiversity have been severely modified or lost altogether. Grazed lands may be similarly altered by the grazing of cultivated livestock and the deliberate planting of forage. Agroforestry has often replaced the native mix of trees with species selected for a desirable eventual harvest creating a different and likely less diverse forest.

In NAE, where most available arable land has been under cultivation for decades, if not centuries, the farmlands, grazed rangelands and forest plantations may be viewed as a normal or accepted state, even though these systems are far from natural ecosystems. Relative to urban and peri-urban environments, the agricultural landscapes provide valuable habitats for wildlife, non-cultivated plants and animals, open space, catchments for watersheds and recreation areas.

Given the general acceptance of agricultural lands in NAE, the changing environmental impacts of evolving agricultural practices over the last 50 years on the off farm environment and on the agricultural lands themselves, can best be viewed relative to farming in the early parts of the 20th Century, rather than to pre-existing non-farming environments in NAE. The trends in agriculture over the last 50 years, increased mechanization, larger average farms, increased use of fertilizers and pesticides, are documented elsewhere in this report (see Chapter 2). This section address the environmental impacts of agriculture as practiced in recent years, recognizing that agriculture practices are continuing to change, and is organized into sub-sections by different agricultural practices.

3.1.1 Environmental consequences of changes in crop production

While certain natural processes can damage soil quality, human activity in agriculture can initiate or accelerate soil degradation. The major threats to soil functions have been identified as erosion, a decline in organic matter and overall soil nutrition status, local and diffuse contamination, sealing and crusting, compaction, a decline in biodiversity and salinization (Van Lynden, 2000; CEC, 2002).

3.1.1.1. Environmental effects of soil management

In both Europe and North America agriculturally induced soil degradation has been a major concern over the last 50 years and, indeed, was of considerable importance in the earlier decades of the 20th Century (e.g. the Dust Bowl in the Great Plains of the USA in the 1930s). Soil erosion, by both wind and rain, is arguably the most serious issue (Kirkby et al., 2004). In general, soil erosion is more severe in North America than in much of Europe, due to in part to differences in climate, e.g. higher intensity rains and climatic extremes (hot summers, cold winters) increasing the soil's susceptibility to water erosion (Lal, 1990). Other reasons are related to intensive land use, monocropping without frequent use of soil-conserving cover crops, continuous cropping and the excessive and often unnecessary use of heavy machinery (Lal, 1990). According to expert estimates based on non-standardized data (GLASOD, 1992), 26 million ha in the EU suffer from water erosion and at least 1 million hectare from wind erosion. Erosion particularly affects the Mediterranean region but problems also arise in other parts of Europe (GLASOD, 1992; CEC, 2002). USDA data on soil erosion on U.S. cropland indicated soil losses of 1.75B tons, with sheet and rill erosion of 971 million tonnes per year and wind erosion of 776 million tonnes per year (Fig. 3-1) (USDA-NRCS, 2003a). However, these figures also demonstrated a dramatic decline of 43% since 1982.

Figure 3-1. Erosion on cropland by year in the U.S.

Intensive agriculture can also have great effects on soil fertility. This can manifest itself in loss of nutrients and organic matter and in soil acidification. Many practices can cause these effects including: intensive cropping with inadequate or no return of crop residues, heavy tillage systems which accelerate organic matter decomposition and increase nutrient release, excessive or inappropriate application of fertilizers and lime and irrigation. According to the European Soil Bureau nearly 75% of the total area analyzed in Southern Europe has a low (3.4%) or very low (1.7%) soil organic matter content. Land use changes from forest or grassland to arable agriculture have been and still are a significant source for the release of former plant and soil carbon into the atmosphere (Sauerbeck, 2001, with references), thus increasing atmospheric levels of CO_2. With increased AKST, considerable advances have been made over the last 30 years in resolving these issues, but problems remain both in North America and in Europe. For example, conservation tillage has been a major part of the U.S. conservation program since the 1970's and is being used to sustain or increase soil organic matter (SOM) (Bruce et al., 1990; Havlin et al., 1990; Wood et al., 1991; Franzluebbers et al., 1994; Reeves and Wood, 1994; Aase and Pikul, 1995). Similarly, the introduction of no-till and reduced till techniques is reported to have increased the carbon content of arable soils in Europe (Arrouays et al., 2002). This increase results in a net transfer of CO_2 from the atmosphere to the soil. While it is clear that conservation tillage increases SOM in surface soils (up to 0.2- 0.3 m), consideration of SOM in deeper soils (which is much less often measured) indicates that reduced tillage may not promote carbon sequestration as much as earlier studies based on samples from surface layers of the soil indicated (Baker et al., 2007). So, although reduced cultivation may have other benefits (e.g. reduced energy use, less impact on soil invertebrates), its effects on total profile soil carbon levels are not clear.

Human activities have also greatly increased the amount of soil compaction, largely related to mechanical stress caused by off-road wheel traffic and machinery traffic (Hakansson and Voorhees, 1998). Heavy metals and other industrial pollutants, together with synthetic organic and inorganic chemical used in agriculture have all had a negative impact on soil fertility and can end up in surface and groundwaters (Thurman et al., 1992). These issues are discussed in more detail below, in relation to pesticide use.

The highly productive agriculture in much of NAE has been supported by increased inputs of fertilizers, especially synthetically produced inorganic fertilizers (see Chapter 2). Not all the nitrogen and phosphorus applied to agricultural fields ends up in the target crops. For example, it is estimated that for the US only 65% of the nitrogen applied to fields is harvested (NRC, 2000) and 20% leached to water. A small, portion of the nitrogen is volatilized to the atmosphere (2%) and the remainder is either building up in soils or is denitrified. Nutrients that are lost from fields often become large sources of nitrogen and phosphorus that can severely pollute aquatic and marine ecosystems. Manure used as organic fertilizer also contains nutrients, which can run off fields after application. Where livestock is finished in intensive feeding operations which produce large amounts of manure, a local oversupply of fertilizer may be created which if not properly managed can also cause pollution (see 3.1.2).

Phosphorus from agriculture can contribute to eutrophication of fresh waters and agricultural nitrogen to eutrophication of coastal marine waters (Lavelle et al., 2005). In recent decades concern over eutrophication has been focused on effects in coastal waters, as there are numerous hypoxic zones in the coastal waters of North America and Europe (UNEP, 2004). The contribution of agricultural nitrogen to coastal eutrophication in different watersheds is quite variable (NRC, 2000) and depends upon the relative amount of atmospheric deposition of nitrogen from combustion sources and point sources in the watershed. Nevertheless, it is clear that agricultural nitrogen is often a significant, if not the major source.

Ammonia emissions to the atmosphere from manure and ammonia-based fertilizers can contribute to local odor problems. The ammonia can be converted to nitrate in the atmosphere, contributing to acid rain and the nitrogen will be redeposited, contributing to eutrophication. Another volatilization path results in production of nitrous oxide (N_2O), a greenhouse gas of importance secondary only to carbon dioxide and methane. The increased soil nitrogen availability from agricultural fertilization has led to greater N_2O production.

Use of appropriate on-field farming practices can make major reductions in fertilizer runoff and emissions without significant reductions in agricultural productivity (Table 3.1). Significant runoff reductions can be achieved through use of uncropped 'set-aside' areas as buffer zones and wetlands, or pastures can be used to process runoff from croplands adjacent to surface waters (Table 3.2).

[[Insert Table 3.1]

[[Insert Table 3.2]

While it is known that adopting different farm practices can make substantial reductions in nutrient runoff, the challenge is in having sufficient numbers of farmers adopt the practices to make widespread improvements in the environment.

3.1.1.2 Environmental consequences of pesticides and other agricultural chemical use

Pesticides are chemicals that target pests, weeds, or disease organisms and include veterinary products (see 3.1.2). Their potential toxic or other adverse effects on farm workers, persons handling pesticide containers, members of the public exposed to spray drift near farms and the issues of residues in food and drinking water are important topics, but are not addressed here.

While pesticides are intended to control organisms that adversely affect crop and animal production, they can also affect non-target organisms, including beneficial ones (e.g., Somerville and Walker, 1990). For example, certain insecticides are toxic to honeybees and other pollinators of cultivated and wild plants and so their usage can result in both environmental and economic losses. Insecticide and herbicide run-off from farmers' fields may have direct toxic effects on aquatic organisms.

Low-level exposure to pesticides through the food chain may affect certain organisms (Hinga et al., 2006). The case of the chlorinated, persistent pesticide DDT being concentrated in predatory birds and leading to reproductive failure is well known. Research is revealing other unpredicted effects from low-dose exposure. For example, the herbicide atrazine has been shown to feminize amphibians, with implications for reproduction in other species (Hayes et al., 2002, 2006). Endocrine disrupting and chronic effects of pesticides have been traced in mammals (Choi et al., 2004). The potential for effects that are not easy to predict or to identify is a continuing concern.

Pesticides may change the availability of food sources for higher level organisms. For example, the control of insect pests can reduce insect prey populations, which in turn limits the size of a bird population feeding on the insect. Similarly, herbicides may change habitats or limit plants that are the foundation for specific food chains. Specific research projects have demonstrated that herbicide, insecticide and fungicide use has decreased the breeding success of several farmland bird species, including grey partridge and yellowhammer (Rands, 1986; Boatman et al., 2004; Hart et al. 2006).

The unwanted effects of pesticides can be mitigated in a number of ways, including decreasing the intrinsic toxicity of the pesticides themselves. Modern pesticides are generally more environmentally benign than the older products that they have replaced. Good farming practices can also reduce unwanted exposures to pesticides These practices include adoption of Integrated Pest Management (Kogan, 1998); treating pests when needed rather than as a preventive measure; timing spraying to avoid winds and rain; using appropriate and well-maintained machinery; training operators to reduce poor spray practices and disposing safely of waste. Use of biological controls agents, biopesticides and integrated pest management techniques, such as traps with chemical lures, may reduce pest damage sufficiently to avoid general treatment of the whole field, greatly reducing the amount of pesticide used.

3.1.1.3. Environmental consequences of increased field drainage

The land in many parts of NAE, especially the U.S. and western Europe, has been drained with sub-surface tile drains or ditches, to allow lands that were wetlands (with standing water), or were frequently wet enough to preclude tillage, to provide suitable conditions for successful crop growth. However, artificial drainage also facilitates the transport of sediments (especially in the ditches), nutrients and pesticides from agricultural fields. Drainage also affects the hydrology of watersheds as the creation of drains and ditches results in less local water retention and increasing peak flows leading to increased risk of downstream flooding. In removing wetlands, where water may be retained, there is a loss of function of the wetland to act as a site of nutrient removal (see 3.1.1.1) and the degradation of agricultural chemicals. In the UK, over 300,000 ha of wet grassland were lost between 1970 and 1985 (Bradbury and Kirby, 2006). In the U.S., the conversion of wetlands, primarily for agricultural use, has resulted in the loss of approximately half of the original inventory. In recent decades U.S. conservation policies have acted to reduce agricultural wetland loss and the total amount of wetlands on agricultural lands in the U.S. has increased since the early 1990’s (Wiebe and Gollehon, 2006).

There are a number of practices which help mitigate the undesirable loss of, sediment, nutrients and pesticides. Control structures may be installed on tile drains to manage the flow of water to both reduce runoff and help provide water for growth when needed by plants. Drainage ditches may be vegetated to help prevent erosion, catch eroded sediments and take up nutrients. Both drainage ditches and tile drains may be directed into constructed or re-established wetlands to process nutrients and agrochemicals. However such practices require a significant investment and to establish wetlands some land has to be taken out of production, presenting barriers to adoption of these mitigation measures.

3.1.1.4 Environmental consequences of irrigation.

Although irrigation has had tremendously beneficial effects on crop yields, irrigation systems can have detrimental environmental, economic and social effects upstream of the system, at the site of the irrigation system and downstream (Hillel and Vlek, 2005). Poorly managed irrigation can cause problems of salinization (build-up of salts), water-logging, erosion and soil crusting.

Irrigation water applies water-borne salts to the soil surface and if there is not sufficient drainage, salts accumulate and they can markedly reduce the fertility of the soil. Irrigation in naturally saline soils, without careful management of drainage, may mobilize salts to the root zone, impairing plant growth. The water drained from agricultural fields where salinization is an issue, whether from the build up of salts delivered by irrigation or through the mobilization of native salts, may have a high salt content which can cause environmental problems in the receiving waters and associated wildlife, e.g. bird deformities resulting from selenium in the drainage water (Letey et al., 1986). Soil salinization affects an estimated 1 million hectares in the EU, mainly in irrigated fields of Mediterranean countries and is a major cause of desertification. Similarly, there are approximately 10 million ha in the western U.S. affected by salinity-related yield reductions (Barrow, 1994; Kapur and Akca, 2002).

In the last half of the last century, extensive work has been carried out in the U.S. and globally, to research, diagnose, improve and manage salt-affected soils on irrigated agricultural lands (Miles, 1977; Moore and Hefner, 1977; Ayers and Westcot, 1985; Hoffman et al., 1990; Rhoades, 1990ab; Tanji, 1990; Rhoades et al., 1992; Umali, 1993; Sinclair, 1994; Rangasamy, 1997; Rhoades, 1998, 1999; Gratan and Grieve, 1999). Modern management techniques are being deployed to improve water use efficiency to overcome these problems, by targeting the water more accurately and by using the most appropriate application technologies. Productivity can often be maintained in salt affected areas through careful application of appropriate practices (Miles, 1977; Hoffman et al., 1990).

Soil crusting can be caused by the use of certain irrigation systems. For example, center-pivot sprinkling irrigation in the Coastal Plain area of the U.S has caused soil crusting arising from the sprinkler drop impact energy (Miller and Radcliffe, 1992). The water application rates of this high energy impact irrigation system are often limited by low infiltration rates due to crust formation. Changes in application practices can reduce this problem (Singer and Warrington, 1992;

Rhoades, 2002). Erosion can also be caused by inappropriate irrigation practices (eg. Carter et al. 1985; Carter, 1986).

Irrigation can create problems resulting from the removal of water from other locations. Abstraction of water from rivers can cause major reductions in water flow with consequent negative impacts on river and associated wetland habitats. The drying and salination of the Aral Sea as a result of abstraction of water for irrigation from the main rivers feeding the sea is a particularly stark example of off-site impacts (Micklin, 1994, 2006). Similarly, abstraction of water for irrigation from boreholes can cause a lowering of the water table with adverse effects on neighboring natural wetland areas. Society needs to assess the overall impact of irrigations schemes, not just the agricultural cost and benefits (Lemly et al., 2000). Various strategies are needed to ensure long-term sustainability of irrigation including restricting irrigation to high value crops and using the best equipment and soundest management practices (Hillel and Vlek, 2005.

3.1.1.5 Environmental consequences of the adoption genetically engineered crops

Transgenic crops are those created through the techniques of biotechnology to select a gene from one species and incorporate it to the same or different species (also called genetically modified, GM, genetically modified organisms, GMOs, or genetically engineered, GE). These new cultivars will have new properties. Accordingly, the environmental effects of each new transgenic variety may differ and regulatory systems have to evaluate each new variety individually. Current GE crops have to undergo an extensive environmental risk assessment throughout NAE (see e.g. Directive 2001/18/EC for EU requirements (www. europa.eu.int/eur-lex/pri/en/oj/dat/2001/l_106/l_10620010417en00010038.pdf) and http://usbiotechreg.nbii.gov/lawsregsguidance.asp for EU and US requirements).

Currently, most transgenic crops are either insect resistant (IR, or are tolerant to a herbicide (HT). Cultivars with other characteristics have been approved for use in parts of NAE, or are in development, including disease resistance, pharmaceutical chemical production, abiotic stress tolerance (drought or salinity), nutritional characteristics (e.g. fatty acid composition) and storage characteristics (e.g. increased shelf life after harvest). (AGBIOS data base lists crops and traits that have been approved by nation: http://www.agbios.com/main.php).

A general review of the 10-year history of cultivation and testing of the currently planted genetically engineered crops concludes that there is no scientific evidence that the commercial cultivation of GE crops has caused environmental harm (Sanvido et al., 2006) though they note that there are no requirements to monitor for potential effects where GE crop varieties have been approved for unregulated use. This conclusion is not accepted by some stakeholders. Because of the nature of the technology it has raised greater public and governmental concerns than ‘conventional’ plant breeding, resulting in closer scrutiny of potential environmental effects. Recommendations exist for further study of the environmental effects of transgenic crops (FAO, 2003).

Insect resistant crops are based upon the inclusion of a gene derived form bacteria resulting in production of a protein (Bt) that is toxic to certain groups of insects (moths and butterflies). As the toxicity is limited to particular groups of insects, farmers will often also treat with pesticides to control other insect pests. The primary concern is that insect resistant crops may have toxic effects on non-target or beneficial organisms (Sears et al., 2001, Dively et al., 2004). Another concern is the persistence of insecticidal proteins in the soil ecosystems, particularly over cold winter periods, although no negative impacts on non-target soil organisms have been found so far (Stotzky, 2004). As IR crops have been in use since 1996, there has been significant experience with their use. A significant reduction in total pesticide use has been found for IR crops relative to comparable non-IR varieties, especially in cotton (Brookes and Barfoot, 2005; Fernandez-Cornejo et *al*., 2006). Different pesticides have very different toxicities and persistence, so the total amount of pesticide used is a rather poor measure of environmental impact. A more direct measure of effect is on non-target populations. Non-target insects are generally more abundant in Bt fields than in non-transgenic maize and cotton fields managed with insecticides, although not as abundant as in pesticide free fields (Marvier et al., 2007). Concern remains about non-target effects, e.g., indications that pollen from Bt corn can affect aquatic Lepidoptera (Rosi-Marshall et al., 2007).

The planting of herbicide tolerant (HT) crops allows the farmer to control weeds by treating with a broad-spectrum herbicide because the crop will not be affected. As HT crops are intended to be used with herbicides, there is little or no reduction chemical use. However, the herbicides used in HT crops tend to be less persistent and toxic than the herbicides they have replaced (e.g. Fernandez-Cornejo and McBride, 2002; Brimner *et al.,* 2005). One of the environmental benefits of using HT crops is that they facilitate the use of conservation tillage which provides a number of environmental benefits (see Reeder and Westerman, 2006). A major environmental concern with HT crops is the potential development of herbicide tolerant persistent weed species through cross-pollination of transgenic crops to wild relatives or to other (non GE) varieties of the crop. The risk of gene-flow to wild relatives needs to be assessed for each new GE event and the particular geographical region, before release. Where the risk of cross-pollination to wild relatives is considered too high, restrictions have been applied. Also, it has been predicted that continued herbicide use, associated with HT crops, could lead to a reduction in the broad-leaf weed flora

(Heard et al. 2003) and could potentially have toxic effects on ecosystems, including soil microflora (Lerat et al., 2005).

There is considerably less experience of potential environmental effects with the other traits that may come into use. One exception is virus resistant papaya, which was approved for use in 1996 in the U.S. and now represents over 50% of the Hawaii papaya plantings. There is probably little environmental cause for concern in a reduction of transmission of a disease virus specific to papaya. This may also be true for bacterial and fungal diseases, provided the method of protection does not introduce properties detrimental to non-target organisms. Alteration of agronomic traits, to increase salinity and drought tolerance, which determine the conditions under which a plant can survive and grow, have greater potential for creation of varieties that could become feral and a problem either directly, or through cross breeding.

It is anticipated that, as is the case with conventional insecticides and herbicides, that insects will develop resistance to the transgenic toxin proteins and that weeds will develop resistance to the herbicides used in combination with transgenic HT crops. Weed resistance to Roundup (glyphosate) is now a serious concern in the US and other places where Roundup Ready crops are grown on a large scale (Baucom and Mauricio, 2004; Roy, 2004; Vitta et al., 2004). The development of weeds resistant to the herbicides used for transgenic crops will require farmers to switch (return) to other herbicides, potentially with consequent environmental changes.

If insects were to develop resistance to the toxic proteins used in IR crops this would cause the loss of effectiveness of the IR crops but also pose a threat to cultivation of organic crops on which the same insects are controlled by topical applications of Bt protein. The Bt protein itself and certain formulations of it, being natural products, are permitted as treatments on organic crops. As Bt is one of a very few such treatments available to organic growers, the loss of effectiveness of Bt would be a serious loss in such instances. Accordingly, growers of IR crops are required to create no- IR refuges in order to decrease the chances of development of resistant insects.

The evidence for the presence of direct environmental impacts arising from the current genetically engineered (GE) crops grown on a large scale, compared with conventional agriculture, remains controversial. Conclusions that the production of GE crops in N. America have not led to adverse environmental effects are not accepted by some stakeholders.

3.1.1.6 Environmental consequences of increased mechanization

The introduction of powerful engine driven plows opened up areas for crop production that were previously difficult to work due to less tractable soil conditions. One consequence has been large-scale removal of hedges to create larger fields to assist maneuverability of the large machinery (Wilson and King, 2003). Deep plowing can increase soil erosion, but mechanization has also increased the potential for less environmentally damaging minimum tillage soil cultivation practices. The ability to spread more fertilizers or pesticides because of increased mechanization may pose dangers of run off into streams and rivers resulting in water and air pollution beyond the farm gate. However, the greater precision of modern machines has tended to reduce some environmental hazards (e.g. reduced spray drift, more precise fertilizer application). Frequent passes of heavy machinery in fields causes damaging soil compaction which is exacerbated when the crop is harvested in the winter months on wet ground, as can be the case in Northern Europe (Culshaw and Stokes, 1995). Thus, increased mechanization can have both positive and negative effects on the environment.

Agriculture, is a contributor to global CO_2 emissions from the burning of fossil fuels used in farm machinery, energy use for irrigation pumps, temperature control in indoor and glasshouse units, the burning of agricultural waste and drying of agricultural crops for storage. Since the mid 1960's the primary direct energy use on US farms has shifted from gasoline (petrol) to diesel powered engines. Farm energy use in the USA has been estimated to be 9.2 and 3.5Tg $C0_2$-C equivalent for diesel and gasoline respectively (Lal et al., 1998). However, relative to other sources of CO_2, these sources are small. Estimated CO_2 emission directly from agricultural energy use in the USA in 2001 is only 2% of total CO_2 emissions (USDA, 2004). Similarly, UK statistics suggest that emissions due to use of agricultural fossil fuel and lime accounted for less than 1% of total CO_2 emissions in the UK (MAFF, 2000).

3.1.1.7 Environmental consequences of changes in farm size and structure

One of the changes in farm structure over the last 50 years has been the increase in sizes of fields and farms and the simplification (in the number of products per farm) of cropping systems. In Europe changes in farm sizes are often associated with other changes in agricultural practice, which it turn can have environmental impacts. The fine grained nature of traditional European landscapes, with small fields separated by hedges, trees, walls and ditches and with small semi natural areas between fields, has become coarser with the loss of many of the traditional boundary features that are often the key to the success of indigenous plants, invertebrates, mammals and birds. (Roschewitz et al, 2005; Herzog et al., 2006)

Intensification of production in eastern Europe during the socialist era has resulted in greater negative environmental effects, than has occurred in western Europe. Although crop yields were increased, politically driven, central management has resulted in greater erosion, salination and chemical pollution (Bouma et al., 1998). Changes since 1990 are now endeavoring to limit adverse side effects from agriculture.

3.1.1.8 Environmental consequences of growing more bioenergy crops

One incentive for the use of biofuels and biomass crops is their replacement for fossil fuels. While any burning of fossil fuels (without sequestration) contributes to increases in carbon dioxide in the atmosphere, power produced from bioenergy appears neutral at the point of use as the carbon in the bioenergy crops came from the atmosphere. However, much of NAE agriculture is energy intensive and the emissions saved by use of biofuels and biomass crops is significantly reduced by the fossil fuels used directly (e.g. running farm machinery) or indirectly (energy used in the production of fertilizer and agrochemicals) during the production of the crop. There are some estimates that the current production of biofuels (maize-based ethanol) is actually carbon negative in that it takes more fossil fuel to produce biofuel than the petroleum it is intended to replace (e.g. Pimentel and Patzek, 2005) though the consensus seems to be that there is a positive net carbon balance in the production and use of biofuels (e.g. Farrell et al., 2006; Worldwatch, 2006).

Two concerns associated with the expansion of biofuel and biomass production are that there is likely to be competition for land between requirements to grow crops for food or for bioenergy, with associated impacts of food prices and that there could be pressure to put uncropped land into energy crop productions, especially highly erodible lands, wetlands, buffer areas and mature forests. Many of these areas are currently providing environmental benefit and their loss would increase environmental impacts. Production of energy crops with irrigation would put increasing demands on water use. Putting or returning uncropped lands into agricultural production may (depending upon the clearing and agricultural systems used) also release the carbon in biomass and soil organic carbon into the atmosphere.

The prospects for greater production of biofuels without greater effects on the environment rely on a second generation of biofuel sources. It is expected that in the relatively near future that it will be possible to produce ethanol from the non-starch and non-sugar components of plants, expanding the amount of carbon that can be converted from food crops and making non-food plants suitable for biofuel production (Gray et al., 2006; Tilman et al., 2006). However, agricultural practices will have to assure that sufficient plant materials remain in the soil to maintain soil health and soil organic carbon and maintain other benefits (e.g. Lal and Pimentel, 2007). Losses of soil organic carbon would tend to negate benefits from use of fossil fuels.

Future developments may also entail breeding of food crop varieties and non-food plants specifically to increase their utility for energy production. Non-food crops may include hardwood species such as poplar and willow, switchgrass and even algae. It should be noted that ethanol and biodiesel are not the only prospects for second generation fuels. Butanol can also be produced by (bacterial) fermentation of sugars and may have significant advantages over ethanol as a gasoline replacement (Ramsey and Yang, 2004). Biogas may also be produced from plant materials.

3.1.2 Environmental consequences of changes in animal production

3.1.2.1 Environmental impacts of differing animal husbandry systems

There are three distinct animal production systems in the NAE (Seré et al., 1996): grazing, mixed farming and industrial systems. Each has potential environmental impacts, especially the latter. The increased specialization that has occurred in the last 50 years has resulted in many areas in separation of production into ‘crop production areas’ and ‘animal production areas’. As a result the number of mixed farms has declined.

Grazing systems feed animals mostly on native grassland, with little or no amounts of other plant material and rarely including imported inputs, resulting in low calorific output per unit land area (Jahnke, 1982). However, if too many livestock are kept on the grazed area, the desirable forage plants may be reduced too severely, creating opportunity for invasive species.

Mixed farming systems integrate livestock and crop activities and have traditionally been the dominant approach to agriculture. By-products (crop-residues, manure) from one enterprise can serve as inputs for the other, resulting in environmentally friendly systems. Thus, the detrimental environmental effects from fertilizers can be minimized by efficient use and recycling of nitrogen and phosphorus. However, even in mixed farming systems, animal by-products can cause environmental damage, if they are not recycled efficiently. The shift from haymaking to silaging for feeding grassland-based cattle in mixed (and intensive) farming systems, assisted by increasing mechanization, has led to reductions in non-grass biodiversity in pastures and meadows (Johnson and Hope, 2005).

Intensive, industrial production systems have evolved from the less intensive mixed farming systems in response to increased demand for meat, resulting in animal concentrations that are greater than the waste absorptive and feed supply capacity of nearby available land and which can cause major pollution problems and human health risks. Indoor production systems are now predominant for pigs, poultry and veal cattle. These agricultural systems have become increasingly controversial because of: the amount of waste produced, odor problems, the potential for surface and groundwater contamination and animal welfare concerns. In intensive livestock farming areas excessive loss of nutrients and farm effluents in surface run-off and /or leaching, are the principal causes of degradation of water quality (Hooda *et al.,* 2000; Tamminga, 2003).

3.1.2.2 Environmental effects of manures produced by animal production

Awareness of the environmental impacts of some animal production systems, especially in relation to phosphorus and nitrogen pollution of water and the presence of antibiotics, pesticides and micro-organisms in manures, has resulted in the development of more sustainable management practices. Increased mechanization has enhanced efficiency of management of animal waste, resulting in reduced potential for negative affects on the environment, but the use of mechanization to increase intensity of production can counteract these benefits, by producing much greater quantities. In some European countries changes in management have been supported by legislation restricting the way manures are processed. An evaluation in 2003 of the Danish National Action Plan for the Aquatic Environment showed that nitrogen leaching (primarily from intensive pig farms) had declined by 50% since 1989 (Grant *et al.,* 2006). A range of measures have also been introduced in The Netherlands, including a manure phosphorus quota which has been allocated to every farm, limiting the amount of P that can be applied to the land (Kuipers and Mandersloot, 1999). In the UK a range of management options have been introduced to encourage reductions in water pollution from livestock farms (Hooda *et al.,* 2000). Further legislation on the impact of nutrients on water is included in the EU's Water Framework Directive (http//ec.europa.eu), currently being promulgated across Europe. All countries in the NAE are endeavoring to reduce the effects of animal manures on the wider environment. A range of new technologies are also being developed and adopted, especially in the USA, to minimize the environmental impact of animal production such as, optimized feeding strategies and the identification of feed additives that could improve the efficiency of utilization forages and crop residues, while reducing methane emission (Makker and Viljoen, 2006). However, manure from industrial livestock systems and its impact on water systems remains a significant concern in some areas of NAE.

3.1.2.3 Animal husbandry and methane

Husbandry of ruminant animals is the major source of increased agricultural emissions of CH_4 (including lagooning and management of waste) (Prather et al., 2001). It is estimated that ruminant livestock production (including cattle and sheep) accounts for 90% of agricultural methane because of their unique digestive system allowing them to digest coarse plant material. The most recent UK estimates are that 80% of emissions are from enteric fermentation and 20% from animal waste (Anon, 2006). Beef and dairy cattle combined account for over 90% of the CH_4

enteric emissions in the USA. In the UK cattle alone account for 75% of these enteric emissions. Manipulation of the diet in these concentrated animal feeding operations (CAFO's) is one of the major methods available to manage these emissions (MAFF, 2000).

Where methane can be collected from manure, the methane can be used as an energy source to generate heat and electricity (e.g. Williams and Gould-Wells, 2004). Extraction energy from the conversion of methane to CO_2 reduces the greenhouse effect, as CO_2 is not as strong a greenhouse gas as is methane. Such manure management also reduces potential for runoff pollution from manure wastes and may also reduce odor problems.

3.1.2.4 Environmental consequences of the use of veterinary medicines

Animal husbandry in industrialized systems often requires the use drugs to keep animals healthy or stimulate growth. Residues of such pharmaceuticals are excreted and may escape through runoff to be dispersed in the environment. Of particular concern is the routine use of antibiotics for growth promotion or prophylaxis rather than disease control. It is a near certainty that microbes will develop a tolerance if given steady exposure to low levels of antibiotics, eventually rendering the antibiotics ineffective for treatment of disease (Cohen and Tauxe, 1986). Administered hormones may be excreted by livestock, especially those held in dense populations and can affect other organisms at very low concentrations. Estrogenic compounds may affect growth, behavior and sexual development and hence breeding ability. Practices that control agricultural runoff, such as buffer zones and wetlands, are effective in retaining and degrading agricultural pharmaceuticals to prevent release into the wider environment (Lorenzen et al., 2005; Shappell et al., 2007).

Current FAO studies of the influence of livestock development practices on the natural resource base will provide information to predict and prevent possible negative affects of intensified production and enhance positive ones,. These livestock studies involve feed quality, use of biomass for animal fodder, avoidance of overgrazing, manure management, animal waste disposal, domestic animal genetic diversity, plant and animal wildlife diversity and integration of cropping and livestock systems (FAO/IAEA, 2006).

3.1.3 Environmental impacts of a larger aquaculture sector

The different types of aquaculture have very different potentials for impacts on the environment and it is useful to divide aquaculture into three major categories in order to address their risks.

Substantial increases in the production of caged aquaculture in open ecosystems (e.g. salmon culture in coastal ecosystems or tilapia in caged cultures in parts of fresh water lakes) have affected wild fish populations. Aquaculture's substantial demand for fish meal is driving a large wild capture of small fishes (that are the base of food chains) (Naylor et al., 2000). In part, the over-fishing of some fish populations is to support the aquaculture industry. Recognition of this has lead to research and efforts to replace fish protein and lipids in fish meal with vegetable sources and byproducts from livestock processing (e.g. Glencross et al., 2003, Montero et al., 2003; Higgs et al, 2006).

A second issue with caged cultures in natural waters is habitat degradation in the areas of the cages due to the large inputs of organic matter and nutrients (nitrogen and phosphorus) in the feed for the aquatic livestock. These inputs can lead to reduced water quality, undesirable algal blooms and alteration in benthic communities in the near vicinity of the aquaculture operations (e.g. Gyllenhammar and Hakanson, 2005).

Caged aquaculture inevitably loses some of the cultured fish, through small accidental escapes and through occasional large losses in storms, to the wild. The escapees may interfere with native populations (Canonico et al., 2005). Where the number of escaped fish are small relative to native populations, the impacts of the escapees are probably minor. However, in the case of Atlantic salmon (*Salmo salar*) escaped populations may be relatively large compared to native populations. Although aquaculture salmon may be more aggressive and may out compete native populations they are less reproductively viable and may cross-breed, with native populations leading to reduced viability of offspring, which threatens the survival of the native gene pool (Naylor et al., 2005).

A final concern of caged populations is that dense aquaculture populations are incubators for diseases and parasites (e.g. Heuch et al., 2005), which can then spread to wild populations. Because fish diseases have led to major economic losses in aquaculture, there is increased use of veterinary drugs and vaccines in intensive production systems. The use of antibiotics in aquaculture can rapidly lead to the adaptation of disease microbes and loss of effectiveness of the antibiotic (Garcia and Massam, 2005). However, antibiotics are not used either as prophylactic (before disease occurs) agents or as growth promoters in temperate water aquaculture production in Europe and North America (Alderman and Hastings, 1998). In recent years the use of antibiotics has fallen dramatically in the farmed salmon industry in Norway from about 50 to less than one tonne annually (Figure 3.2). This is largely as a result of the successful development and use of vaccines against the principle fish pathogens (Alderman and Hastings, 1998).

[Insert figure 3.2]

Closed-system aquaculture, such as in farm-based catfish ponds, trout farms and some seawater closed systems, avoid many of the problems of caged aquaculture as the possibility of escape of the livestock or transmission of diseases to native populations is greatly reduced. However, the effluent from such systems may be rich in organic matter and plant nutrients. Unrestricted discharge of these waters could impair receiving water quality. Use of systems that used the discharge from farm ponds to directly irrigate and fertilize farm fields, or use additional ponds to grow algae, which in turn is used as a fertilizer or livestock feed supplement, can eliminate or reduce the impacts on receiving waters.

Filter feeding molluscs (clams, mussels, oysters, scallops) in aquaculture rely on natural suspended particulates (i.e. phytoplankton and detritus) rather than external food sources. Such systems do not add new materials to the ecosystem and are unlikely to create the eutrophication problems of finfish caged aquaculture. However, these systems may redistribute organic matter and concentrate organic materials in sediments below the structures holding the cultured organisms.

Similarly, seaweed culture does not rely on external inputs and therefore does not have the eutrophication impacts that can occur in caged, externally fed organisms. Indeed, it has been suggested that carefully placed mollusc or seaweed culture, used in an integrated system with caged culture, could help clean-up the organic residue and algal growth promoted by externally fed aquaculture (Lindahl et al., 2005, Troell et al., 2005).

3.1.4 Environmental consequences of changes in forest management

Forests cover an appreciable proportion of the land surface of the NAE, especially in parts of N. America and in Russia, so changes in forest management have the potential to have appreciable environmental impacts. Forests provide environmental benefits of wildlife habitat, plant and animal biodiversity, timber, provision of clean water and carbon storage. High-quality riparian areas trap sediments, slow runoff, provide habitat for wildlife, fish and plants (USDA-USFS, 1999).

The quality of forests may be affected by clearing, but also can be damaged by air pollution, e.g., acid rain and ground-level ozone (USDA-USFS, 1999). Forests may also be damaged by fire, invasive species and unmanaged recreation (Bosworth, 2004). In addition, nitrogen deposition from the atmosphere may potentially cause a shift in composition of some forests. The USDA Forest Service has also identified how ozone damages trees and has screened tree varieties for those less susceptible to this gas. Studies are on-going to identify ozone-sensitive trees in areas of ozone exposure, increasing our understanding of how to manage forest resources (USDA-USFS, 1999).

In Europe, the replacement in the last century of mixed aged stands of often deciduous woodlands with uniform age conifer plantations has had negative effects on biodiversity, especially ground flora and mammalian fauna and sometimes on soils and surface waters (Hartley, 2002; Humphrey *et al*., 2002*;* Spiecker, 2003; MA, 2005). Bird populations may also be adversely affected but in some cases, conversion and intensive management has boosted populations of birds and some mammals that were previously rare in primary forest (such as crossbills (*Loxia curvirostra*) red squirrels and pine martens) in Scotland, where 90% of woods are plantations (Marquiss and Rae, 1994). About 40% of the hundred European 'priority' forest bird species are in unfavorable conservation status, mainly due to declines in old-growth forest (BirdLife International, 2007). Coniferous plantations also appear to increase the acidity of precipitation falling on them, leading to reductions in pH of streams, rivers and lakes within forested areas (Spiecker, 2003). Although the area of forested land in Europe is increasing, most of the increase is made up of plantations and secondary woodland and this does not necessarily offset the reductions in flora and fauna caused by conversion of natural forests to intensively managed plantations. Awareness of the negative impacts of uniform age conifer plantations has resulted in much debate in Europe as to the economic viability of replacing them with mixed species stands, with both conifer and deciduous species (Spiecker, 2003). Despite declines in natural forest quantity and quality in W. and some E. Europe countries, European forests remain one of the most important refuges for wildlife on the continent. Additionally, the increase in forested timber volume within the NAE increases carbon sequestration and is of value in reducing atmospheric levels of CO_2.

Environmental concerns about forestry have resulted in changes in approaches to tree production and to management in the USA since 1970. In the 1970s public concern in the USA about the effect of current clear-felling and re-forestation practices led to the 1976 National Forest Management Act (NFMA). One of the important developments following the passage of this Act was the establishment of the Long-Term Soil Productivity (LTSP) research program (Williams, 2000) to explore and reduce the environmental effects of forestry practices (e.g. see Powers et al., 2005). Changes in practices arising from AKST have had some success in the last 30 years in ameliorating some of the negative environmental effects of forestry in the USA. However it must also be noted that new technologies developed since the second world war allow faster and more efficient harvests and access to timber in areas previously considered too fragile for harvest, thus expanding the potential managed forest areas.

3.1.5 Overall environmental consequences of changes in the agricultural industry

The previous sections of this chapter have highlighted the major issues associated with specific changes in crop and animal production and forestry. However there are also issues that transcend these individual components, as there are environmental consequences arising from overall changes in agriculture and which cannot easily be attributed to individual components. Two issues are highlighted here, the impacts of changes in the intensity of agricultural production on the natural ecosystem and the issue of 'food miles'.

3.1.5.1 Overall environmental consequences of increased intensity of agriculture

As the dominant land use throughout much of Europe, agriculture (including forestry), has a huge footprint on the overall ecosystem, especially in intensively farmed countries such as France, The Netherlands and UK. There have been widespread declines in the populations of many groups of organisms associated with farmland (e.g. arable plants, invertebrates, farmland birds) since the 1940s in Britain and North-West Europe. A review of 18 studies investigating changes in wildlife in arable farmland in Great Britain confirmed the decline of many taxa. In only two studies (on butterflies) was there evidence of an increase over the survey periods (Robinson and Sutherland 2002). Similar results have been found in Portugal (Stoate *et* al., 2001).

At a wider European level decline in farmland bird populations have been related to agricultural 'intensity' (Donald *et al*., 2002). At its simplest there is a link between average cereal yields (FAOSTAT) and the rate of bird decline (Fig. 3-3). A similar study on invertebrates has reported on changes in bees and hoverfly populations in Britain and the Netherlands pre and post 1980, concluding that there has been a decline in bee diversity in most of the assessed areas in both countries since 1980 (Biesmeijer *et al.* 2006). This decline seemed to be linked to declines in pollinator plants, which may well have become less common as a result of agricultural intensification (Preston *et al.,* 2002). The overall conclusion for Europe, east and west, is that increased farming intensity over the last 50 years, although leading to appreciable increases in production per unit area, has had a negative impact on the environment and ecosystem services (Tilman, 1999). A further complicating issue relates to the impact of land abandonment in some areas of East and Southern Europe on biodiversity. Economic pressures have resulted in fields not being farmed and as a consequence scrub has started to invade, degrading the habitats' suitability for many farmland species, though it does increase its suitability for others.

[Insert Figure 3.3]

Concerns about the impact of food production on ecosystem services loom less large in N. America, although American-based ecologists are as concerned as European scientists about the impact of agriculture on the ecosystem (Tilman, 1999). Agriculture has a much smaller 'footprint' in N. America, as in the USA it uses less that 50% of the land surface and in Canada less than 10% (FAOSTAT, 2006). In general, management strategies of U.S. natural resources have moved toward land or ecological-based systems which recognize the important role of the soil (Robertson et al., 1999). There has also been a changing philosophy to rangeland management in the U.S. over the last 50 years (Orr, 2006) with management evolving from purely grazing objectives, to a more scientific approach, recognizing the need for "resource rehabilitation, protection and management for multiple objectives including biological diversity, preservation and sustainable development for people" (Stoddart et al., 1975; Heady and Child, 1994). Despite this changed philosophy more than one-half of all U.S. rangeland ecosystems have lost 98% of pre-settlement flora, to agricultural use. The amount of U.S. grazing land and rangeland is expected to continue to decline slowly over the next 50 years, as the land use shifts away from grazing use but there is no indication that endangered rangeland ecosystem types are being lost except for desert grasslands.

The decline of biodiversity can be at least partly attributable to the changes in farming systems which advances in agricultural technology have made possible. These include:

- the widespread use of pesticides has affected non-target species
- the development of machinery capable of establishing crops on soils not previously amenable to crop production has caused a decline in natural and semi-natural habitats
- the increased size of machinery, aimed at increasing efficiency, has resulted in field amalgamations and losses of hedges and other semi-natural wildlife habitats
- Simplification of rotations so that only a limited number of crops are grown, has decreased the planting of those with different biology and planting times, that formerly provided a greater range of habitats for wildlife
- The replacement of hay crops by the earlier harvested silage, for intensive animal production has reduced the environmental value of grasslands

Such technologies have typically been adopted by farmers after weighing the complex tradeoffs, economic and environmental, inherent in each. However, AKST is also continuing to provide newer and better tools and expertise to assess impacts of agricultural changes on wider biodiversity and thus provide guidance on how to reduce biodiversity effects. Reduction in the overall intensity of agriculture has been proposed as a technique to help restore agricultural ecosystems and retain ecosystem services. For example, less intensive organic production systems have been identified by some as more environmentally benign. The 'ecological' emphasis implicit in ecosystem service approaches has been questioned by those who favor increasing intensity of production in some areas and thus conserving other areas for off-farm biodiversity (land sparing) (Green et al., 2005; Vandermeer and Perfecto, 2005). This debate may miss important opportunities for achieving win-win solutions incorporating productivity and ecosystem services (Pretty et al., 2006). The debate continues.

3.1.5.2 Environmental consequences of the increase in food miles

Increased geographical distance between producer and consumer, together with the regional specialization of agriculture has resulted in the availability of a wider selection of apparently cheap food for consumers, but at the cost of longer transport with the attendant consequences of greater energy use and deleterious effect on global climate. Distancing and regional specialization has encouraged less diverse production systems, complicating recycling of nutrients and carbon from animal husbandry back to crop production and from demand chains back to agriculture. Further, distancing consumption from production hinders feedback from the ecosystem to the human community, affecting the land-use, thus impeding adaptive management (Vergunst, 2003; Deutsch, 2004; Sundkvist et al., 2005).

The increase in food transportation has a significant impact on energy use, climate change, pollution, traffic congestion and accidents. Road transport generates six times more CO_2 emissions compared with shipping and airfreight 50 times more (Jones, 2001). The dramatic increase in transportation has resulted in a rise in the amount of CO_2 emitted by food transport (Smith et al., 2005). The cost of food miles is £9bn a year to the UK. This is greater than the total contribution of the agricultural sector to GDP (£6.4bn). Several studies show that shorter supply chains would be less detrimental to the environment. Transportation, especially for fresh products, is responsible for a considerable proportion of the total energy consumption, exceeding the energy consumed for cultivation of apples, for example (Jones, 2002). The use of fossil energy and climatic effects of transportation of more local food were smaller, even when taking into account the smaller amounts transported at a time (Carlsson-Kanyama, 2004; Poikolainen, 2004; Granstedt et al., 2005). The external cost of transportation in local food systems (food basket sourced from within 20 km of retail outlet) would be less than one tenth of the current one in the UK, depending on transport vehicles (Pretty et al., 2005). In the USA, that depending on the system and truck type, the conventional food system used 4 to 17 times more fuel and released 5 to 17 times more CO_2 than the Iowa-based regional and local systems (Pirog et al., 2001).

The environmental consequences of distancing are complex. If food supply chains are identical except for transportation distance, reducing transportation increases sustainability (Smith et al., 2005). However, differences in food supply systems often imply tradeoffs between various ecological, economic or social sustainability. Transport mode, transport efficiency (vehicle size and loading), differences in food production systems and food storage, all affect the final outcome. The total effect depends, for example, on the energy input to production and post-harvest processes. If production is clearly less energy-intensive when performed outside the region (Cowell and Parkinson, 2003), as it can be for greenhouse vegetables (Poikolainen, 2004) and for cereals with higher yields and lower energy need for drying in warmer regions (Sinkkonen, 2002), the benefits of reduced transportation may be more than offset by the increased energy costs for production. Therefore, a simple calculation of food miles is not a valid indicator for sustainability (Seppälä et al., 2002).

3.2 Economic Impacts of Agriculture and AKST within NAE

All changes in agricultural production in the NAE over the last 50 years have economic drivers and consequences, from the field to the 'plate'. This sub-chapter looks at the changes that have occurred in production systems, partly as a result of advances in AKST but also due to other technological and societal changes that have occurred during this period.

3.2.1 Economic context linking advances in AKST to production

In the past 50 years agricultural output in NAE has grown more rapidly than demand. (See Chapter 1 and Chapter 2) One result has been a trend for real prices for farm products to fall. (See EU, 2003; FAO, 2005; UK, 2005a) The driving force has been improvements in technology. Farmers who did not initially use the new methods have had to adopt them, find a new niche market for their products or face falling real income. Income earned outside farming may cushion this or even make it of no great importance but where these strategies cannot be used, many working farmers and their children have had to leave farming. Although rural populations have started to stabilize and more recently to grow in some areas, the decline in the farm labor force in the second part of the 20th Century has been dramatic (Fig. 3-4).

[[Insert Fig 3.4]

The pressure upon the centrally planned economies of the eastern European states after the Second World War to adopt technical innovations was enormous. Failure to supply sufficient and reliable food was a major problem for the Soviet Government. Some countries in eastern Europe, such as Poland, retained many very small farm holdings. Here it was more difficult to apply the larger scale investments associated with new farm technology. In contrast, as in Hungary where private holdings were merged into collective farms, large scale farming businesses looked for innovation and invested in production related research. A failure to keep pace with AKST technology across the food industry as a whole weakened the relative position of the centrally planned economies to those of the West. Consumers had fewer choices, products were often of lower quality and the centrally planned economies became less able to compete in global markets except by cutting prices. Although substantial investments in new technology were made these did not overcome the relative lack of competitiveness. Compared with market driven economies the intensity of production and the levels of productivity usually remained lower although output continued to grow.

The effect of new technology is seen in the sustained and substantial improvements in productivity that were achieved (see Chapter 2.). Measurements of this are complex. Yields per hectare of major crop products are a first and very rough proxy for productivity (Chapter 2).

Aggregated data of this nature conceals a good deal of variation but the overall message is clear. Yields have increased in every area and while the rate of improvement slowed in the 1980's it has recovered. The substantial gap between the former USSR and other areas has not been removed. This reflects underlying natural conditions. However, even here cereal yields have doubled over the 40 year period (see Chapter 2).

In contrast to many assumptions, GDP per person engaged in agriculture tends to be higher than in the economy as a whole in most NAE countries. Improved technology made possible rises in GDP per worker. In Europe and North America GDP (Gross Domestic Product) per person seems to have risen faster in agriculture than in the economy as a whole although the share of agriculture in the overall economy has declined (Fig. 3-5).

[Insert Figure 3.5]

3.2.2 Impact of AKST on supply and demand

The tendency for real prices to fall has led to demands for protection. Agricultural policies have mitigated but not prevented falling prices in markets such as the EU and USA. External markets, have had to absorb varying levels of surplus from these protected markets, have been volatile and experienced the full impact of the tendency for real prices to fall.

The EU is the largest agricultural trader (Fig. 3.6). Even when intra EU trade is excluded, it remains a major player in the market for many important commodities (Table 3.3). Price support combined with rising productivity led to a situation in which substantial export subsidies were needed to enable domestic production to compete in world markets. Since 2003 many subsidies have been decoupled from production allowing the prices farmers receive to reflect market realities. Income support has been provided by direct payments fixed on the basis of production in 2002 – 2003.

[Insert Figure 3.6]
[Insert Table 3.3]

Export subsidies mean that relatively modest shifts in consumption or production spill over into the world market where they may influence world prices. The effect of growing productivity within NAE countries, driven by AKST and price support, has thus been to depress world prices. The impact of improving productivity, combined with subsidies on exports is illustrated in the falling trend of commodity real prices shown below (Fig. 3.7).

[Insert Figure 3.7]

Falling prices can benefit consumers, especially poorer consumers who spend a relatively large share of their income on food. They also benefit net importing countries but may give rise to increased dependence on foreign supplies and reduced investment in local agriculture and its support services. This has had the effect of making import prices low and volatile for importing countries. For developing countries low import prices benefit consumers but reduce returns to domestic producers. Because imported food prices are also volatile, they can give rise to unpredictable and unaffordable trade deficits.

Changed technology has also led to a transformation in the way in which food reaches the consumer (Regmi and Gehlhar, 2005; UK, 2005b; USDA, 2005) and has resulted in the production of anonymous, cheap and highly processed and packaged food. Some consumers have reacted to this by seeking alternatives that represent for them higher quality. The response is multidimensional. It includes a growing demand for organic products (Dimitri and Greene, 2002); growing requirements for farmers to increase the welfare of their farm animals in order to be able to sell their products to the European retailers (Defra, 2004a); a growing market for locally produced and fairly traded products (F3, 2007; Fairtrade, 2007).

3.2.3 Impacts of advances in AKST on the growth of output and on farm businesses

The application of AKST has enabled farmers to increase yields, but It has also resulted in a fundamental restructuring of the industry. Many farmers now sell directly to large scale retailers or processors using a variety of contractual relationships. Small and part time farms accounted for 86% of all farms in North America and almost half the farmers had full time jobs elsewhere (Thompson, 1986; Miljkovic, 2005). A growing number of farmers will have to get second jobs when subsidies from the CAP are slashed in 2013 (Barthelemy, 2007; Fischer-Boel, 2007).

Farmers have also sought to secure their position by diversifying their businesses to include activities that are not limited to agricultural production: these include direct selling (e.g. farmers' markets), agritourism or outdoor leisure activities For many of these pluriactive farms, a minority of income now comes from farming. For instance, UK data shows that more than 50% of farms have income from diversified activity and income from these sources accounts for more than 50% of total income for 43% of the farms concerned (Defra, 2007).

In the years between 1945 and 1989 many farms in eastern Europe were collectivized and in some countries state farms were established. Where this was not the case very small scale farming persisted, often using old technologies (European Commission, 2006) (Fig 3-8). On the large collective and state farms modern methods were used although the number of workers employed did not decline as rapidly as in the West. In the post 1989 period as central planning gave way at varying paces to competitive markets, adjustments are taking place in the structure of farming, the level of agricultural employment and the relationship between producers and consumers (Borzutzky and Kranidis, 2005).

[Insert Figure 3.8]

Farmers in countries that have recently become members of the EU now have to compete in a wider market. This will lead to application of more AKST both on the farm and in the processing sector in order to reach the levels of quality and productivity that market demands. EU data shows that there is still a relatively low level of participation in further education and training in agriculture in the new member countries (European Commission, 2006).

3.2.4 Impacts AKST driven growth in output on processors and distributors

AKST has been also critical in ensuring the safety and quality of food. Food borne diseases are a matter of alarm where mass distribution increases the number of people who may suffer if products are infected or contaminated. On the farm this means attention to issues such as biosecurity and the use of pesticides. In food processing, preparation and presentation, rules of hygiene and the provision of information about ingredients to which some customers may be allergic are essential. The most valuable asset for retail distributors is their reputation. Safeguards are needed this through ensuring that products are consistent and safe, can be branded and can be traced to ensure that any failure is rapidly identified (Hornibrook and Fearn, 2005). Changes in the role of processors and distributors have altered the supply chain.

Traditional arms-length markets have been or are being replaced by coordinated plans for production and delivery. These minimize some elements of market risk and are a channel through which new technologies may be encouraged and supported on farm (Duffy, 2005). This development has been closely linked to progress in transport and the use of information technology to monitor performance at all stages of the food supply chain.

3.2.5 Impacts on market power

The technologies that have developed from AKST tend to encourage concentration at all levels of the agriculture and food sectors (see chapter 2). Although farms in general remain small businesses, a high proportion of output comes from the largest units (McAuley, 2004). Beyond the farm gate the concentration of the industry has advanced much more considerably (Hendrickson and Heffernan, 2007; Wiel 2007). An important repercussion of this has been a sense among both farmers and consumers that they are helpless in the face of the businesses with which they deal. This has enhanced the importance of farmer co-operatives and of direct marketing to consumers. Direct marketing includes traditional open markets in local towns, still a major avenue of distribution in France and the South of Europe, or farmers markets that may take place on farms, or sometimes within open spaces in towns. Farm shops that may have started to sell the produce of the farm often develop to sell a diversity of products and services not produced on the farm itself but offering to the urban customer an attractive shopping experience.

The dominant position of multiple supermarkets in the UK led the Competition Commission to examine the food supply chain, pricing and the land banks owned by these companies (Wardell, 2007). They expressed concern about the extent to which owning but not developing sites impeded competition from other retailers. Overall, they concluded that consumers had benefited from the emergence of strong supermarket chains.

3.2.5.1 Cooperative responses to market power

Farmers have used cooperative buying and selling power to challenge the increasing power of transnational agricultural businesses. In the US and Europe, the agricultural cooperative movement flourished from the beginning to the mid-20th century. Farmers joined cooperatives to market agricultural products, as well as to obtain farming inputs and services. In Canada, the establishment of state marketing boards was a way to help farmers obtain fair prices for their products.

For example, after WW II, farmer cooperatives thrived. The total number of farm cooperatives in the U.S. declined from a peak of 12,000 1930 to 6,293 in 1980 to 3,140 in 2002. Today less than 3 million farmers belong to cooperatives in the U.S. In Europe, cooperatives are very important and powerful organizations in the marketing and processing of agricultural products and in the supply of credit to farmers (Table 3.4). Farmer cooperatives are more important in some countries than others (Fig. 3.9) and are also more important in some sectors than others. The dairy sector in the US, for instance, relies heavily on marketing cooperatives with 87% of US milk purchased at the first handler level through cooperatives (Kraenzle, 1998). In northern Europe and Ireland, agricultural cooperatives have captured almost majorities (or the entirety) of the dairy market and have significant shares of the markets for inputs in many western European countries. A majority of Canadian grain has been and continues to be marketed through marketing boards. However, cooperatives are less important in the livestock marketing sector in the US and Canada, while accounting for a larger portion of sales in northern Europe.

Traditional marketing and supply cooperatives have confronted the increased pressure from the consolidation of investor-owned firms and their increasing market share. Many cooperatives merged with other cooperatives, particularly in the dairy sector (Hendrickson et al., 2001) and those marketing grains and oilseeds (Crooks, 2000). Others developed joint ventures and alliances with investor-owned firms.

[Insert Table 3.4]
[Insert Figure 3.9]

The agricultural and food system, that AKST has made possible, requires substantial packaging, temperature control, processing and has appreciable delivery costs. Additional costs may also occur when food is discarded because temperature control has failed, or where the 'sell-by' date has been past. For packaged goods supermarkets sell products in predetermined pack sizes. These may not match the requirements of small households who find they do not fully use all the items in a package before its 'use-by' date has past. These costs have to be absorbed within the supply chain and born by the consumer. They may lead to environmental costs as a result of excessive packaging and problems of waste disposal. While such waste is of concern, it should be noted that substantial wastage occurred before modern AKST systems were used, as seasonal surpluses could not be safely preserved.

3.2.6 Structural change induced by AKST

The way in which resources are organized into businesses is determined by many factors including the competitiveness of different technologies. Among the other factors, affecting the food and agricultural sector, are rising labor costs, the development of communication systems, the operation of banking systems and the availability of transport systems. Even without changes in the state of AKST, changes in these areas would lead to changes in the sort of technology that was used in the sector.

At the farm level, the most obvious structural effects have included fewer workers, increased specialization and a tendency for full time farms to become bigger, while smaller farms become part time (see chapter 2). In some cases the statistics may not fully represent the degree to which decisions have been concentrated, as farmers share resources such as machinery or labor and in some cases run a single large enterprise on more than one 'farm'. The decline in the farm labor force has profound implications for rural communities. In areas where agriculture was the major source of employment the rural economy can be undermined. Community services such as schools, medical facilities and transport are no longer able to operate at an economic level. Business districts may disappear and the informal, voluntary activities that often form a crucial part of the social support system for community residents may decline. In regions close to urban centers this impact may be diminished. Instead of working on farms, former farm workers may commute to towns. Where the urban economy is buoyant, city dwellers may move into villages, raising the price of village houses and creating new and different communities. In this type of situation impacts measured in average data tend to show these communities as relatively affluent, although they contain many poorer people who once depended on farming for their incomes.

3.2.7 Impacts of changes in production driven by AKST on trade

Fluctuation in farm incomes at times presented a major problem for most NAE governments. Powerful farm lobby groups demanded support for farm incomes. In response, policies provided subsidies that prevented declines in farmer despite excess levels of production resulting from greater productivity. In effect, he EU and the USA subsidized farmers, limited imports and subsidized exports (Fig. 3.10).

[Insert Figure 3.10]

Dramatic changes in the level of support took place after the break up of the Soviet Union (Fig. 3.11). From the mid-1990s support had declined to levels below those of most other developed countries.

[Insert Figure 3.11]

Producers in other countries faced depressed prices and in some cases total loss of markets at least in part as a result of subsidies in NAE. This has become the major issue in international trade negotiations. Its impact extended far beyond agricultural trade itself because countries refused to make progress on trading issues without an agreement on agriculture. The debate included the level of domestic subsidies, the demand to remove export subsidies and to reduce all sorts of barriers to market access. In return for progress in these areas the NAE countries sought tariff reductions on manufactured goods; trade in services and agreements relating to intellectual property (WTO, 2005).

Agricultural issues remain critical in the current Doha round of trade negotiations. The Secretary General reported on 18 December 2005 that, after protracted negotiations, significant progress had been made on agriculture including an agreement to end export subsidies by 2013, However, he announced the suspension of those negotiations seven months later because of lack of progress. At the heart of the debate were failures to agree terms for access for developing country exports to developed country markets and to reach a settlement on domestic support (WTO, 2006). According to a review of more than 200 theoretical and empirical studies about *the effect of trade liberalization* on sustainability, the effects on economic welfare and overall sustainability depend on the nature and extent of the flanking and other supporting measures that are taken (Kirkpatrick et al., 2004). The potential, aggregate economic welfare gains to be made from free trade and increased foreign investment inflows, are not necessarily shared by all countries or by all socioeconomic groups within these countries. In many examples the social (and environmental) impacts are negative if protective measures are insufficiently effective.

The trends in global demand for food safety and processed products under the conditions of free trade raise concerns about the long-term viability of small farms in developing countries (Lipton, 2005). These have often already felt the disproportionately negative impacts of structural adjustment policies on smallholders during the 1980s and 1990s. The impact of trade liberalization on distribution of income within developing countries varies, however, according to country-specific policy conditions and socioeconomic structures. In Latin America, for example, the effects on equality in income have been positive in nine countries and negative in five countries (von Braun, 2003).

3.2.8 External economic impacts of the application of AKST

Negative impacts of AKST on the environment have been discussed in sub-chapter 3.1. These environmental and social costs generally do not figure in the accounts of the businesses concerned but do represent real economic benefits or costs to other individuals. These externalities may be positive or negative and their incidence is diverse. Some, such as the costs of restoring adequate water quality that has suffered as a result of farming practices, can be calculated with relative ease. Less easily assessed are environmental losses occurring where plant nutrients or pesticides contaminate water courses (see 3.1). The use of AKST in devising and using veterinary medicines, pesticides, herbicides and in the management of more intensive stocking of livestock can raise public health issues. Food-borne diseases represent costs to affected individuals and to medical services. For the industry, market collapses as a result of food scares can destroy the value of goods already produced. Governments seek to minimize risks to human health but the costs can be very large. For example the gross total cost to the UK and the EU budgets of measures to combat BSE between 1996 and 2006 ranged from a high in 1996/7 of 1496 million pounds to a low of 265.7 million pounds in 2005/6 (Defra, 2006a). Similarly, UK government costs to manage Avian flu between 1998 and 2002 ranged from 24.9 million to 73.9 million pounds.

The cost of introducing a new medicine or pesticide involves substantial expenditure by the company concerned on testing to the approved standards. Increased public concern has led to a progressive tightening up of standards in across the NAE, although particularly pronounced in western Europe and North America (Clark and Tait, 2001).

3.3 Social Impacts of Agriculture and AKST within NAE

The increase in productivity achieved by NAE agriculture over the last 60 years with the help of AKST has contributed to providing people in NAE with more wealth, choice and mobility. In NAE there is today more food and a wider range of affordable food items available than ever before. People have also more choice in where they want to live and work than in the past. Rural regions have increasingly specialized in producing and exporting natural resource-based raw materials. This development has given rise to out-migration and to major changes in social structures in rural regions.

3.3.1 Impacts of changes in agriculture on community well-being

The social impacts of specialization in agriculture and increased scale of agricultural production are primarily related to well-being of communities and farm families. A great deal of evidence produced using at least five different methodologies, involving a number of different researchers and looking at different regions of the US showed detrimental impacts for community well-being from industrialized farming. These studies also showed that industrialized farming involved a tradeoff effect, did not consistently produce detrimental effects for all time periods or for all regions and involved beneficial impacts for some groups and detrimental ones for others (Goldschmidt, 1978; Lobao, 1990; Stofferahn, 2006).

3.3.2 Consumer concerns about the food system, with specific reference to GE crops

There are different attitudes in North America and Europe with regard to GE-derived foodstuffs. While foods from GE crops are available and do not require labeling in North America, in Europe foods derived from GE crops are generally not available and where sold are required to be labeled as containing GE ingredients. This situation is viewed in Europe as a clear reflection of consumer concerns. Some in U.S. industry and government, however, take the view that consumers have not yet been offered an adequate opportunity to accept or reject these products, because food manufacturers, out of a desire to preserve brand equity have reformulated products so they do not trigger mandatory European labeling requirements (Larson, 2002; USTR, 2003; Yoder, 2003; USDA, 2005a).

However, some experts have argued that the potential benefits of improved nutrition and increased yields from genetic engineering are so important, especially for developing companies, that GE crops should be readily and economically available (Nuffield Council on Bioethics, 1999). Early development of the technology has not been with poorer countries in mind (Kinderlerler and Adcock, 2003). Rather it has been aimed at securing profits for firms in industrialized country contexts selling products to relatively wealthy farmers. While public private partnerships and international agriculture research centers may be developing crops more appropriate to developing countries, general welfare, justice and access should also be considered (Kinderlerler and Adcock, 2003). A position that allows each country the right to accept or refuse GE crops, based solely on ethics, is not consistent with the science-based regulatory approach of the World Trade Organization, although as a matter of policy, countries are allowed to set their own level of SPS protection (Kinderlerler and Adcock, 2003).

Ethical issues are a major consideration in discussions about biotechnology and animals. A distinction is made between 'intrinsic concerns' (genetic engineering as wrong or morally dubious due to the mode of production or the source of the genetic material or 'it is unnatural to genetically engineer plants, animals and foods) and 'extrinsic concerns' based on animal welfare perspectives (Kaiser, 2005) and environmental impacts. Reviews such as those published by the Netherlands Advisory Committee on Ethics and Biotechnology in Animals and the UK Royal Society (2001) stress the need to consider a range of health and risk implications of genetically engineered animals to humans but also our responsibility to the animals themselves.

Intensive livestock production raises several other significant ethical issues. Treating animals as items on a production line offends many who feel this is an unacceptable relationship between humans and other species. In western Europe and North America the welfare of farm animals has become an area of increased significance for policy makers (USDA, 2003; Defra, 2004b; Webster, 2005). The mass production of animals to specification undermines traditional livestock businesses, reducing local employment and jeopardizes the economic survival of some communities. In an area in which emotions often play an important part in determining attitudes there are a wide range of pressure groups who criticize many aspects of intensive livestock production **(**Compassion in World Farming, 2007).

Livestock kept in intensive systems are prone to outbreaks of disease which have been controlled by slaughter policy in some cases (e.g. foot and mouth disease) or more often through the use of antibiotics. However some production systems routinely utilize antibiotics both for disease prevention and growth promotion. This has raised serious concerns within some parts of the NAE because of the rise of antibiotic resistant bacteria in humans which some argue is linked to livestock production (Mellon, 2000).

3.3.3 Social impact of increased mechanization

In all sections of agriculture increases in mechanization have resulted in redundancy in the farm labor force but the increased productivity/efficiency has also left more time for other work and enhanced worker environment by eliminating repetitive, dangerous and disliked tasks (Culshaw and Stokes, 1995; Wilson and King 2003;). Its ability to secure lower costs implies growing pressures on small farms that cannot, or fail to, apply similar methods. Where communities depend on traditional agriculture, as in many areas of Europe, it is likely to increase pressure on farmers and farm workers to seek employment off the farm and accelerate the continuing decline of the farm labor force. The social and political consequences of this are likely to remain at the centre of agricultural policy thinking into the 21st Century.

In forestry one of the greatest impacts of the increase in mechanization has been on a reduction in accidents (Figure 3.12). Forestry is an innately dangerous operation and in Sweden between 1970 and 1990 the number of accidents decreased from 8656 to 1469. The accident risk, expressed as accident frequency rate, was reduced from 90 to 35 accidents per one million man-hours worked (Axelsson, 1998).

[Insert Figure 3.12]

3.3.4 Migration from rural areas

In North America and western Europe today the population working in agriculture is only a small share of each country's overall population (Table 3.5). In contrast, in some countries in eastern Europe the proportion of the population in agriculture is still very significant (Table 3.5). The rural population is still declining in terms of percentage of the total population in most NAE countries (Table 3.6).

[Insert Table 3.5]
[Insert Table 3.6]

While overall trends are similar, different regions in NAE have different conditions impacting these changes. The farm population in the United States has decreased as a percentage of the U.S. total population, falling to 1% in 2002 from 17% in 1945 and the rural population to 21% in 2000 from 36% in 1950, respectively (Dimitri et al., 2005). The decade of the 1950s saw the largest exodus from farming (Lobao, 1990) while 600,000 farmers exited farming between 1979 and 1985 (Heffernan and Heffernan, 1986), the latter characterized as the “Farm Crisis” of the 1980s that particularly affected the economic base of rural communities in the Midwestern states. Still, while the portion of rural dwellers in the US dropped from 50% of the population in 1945 to about 21% in 2005, this does not signal an exodus from rural areas, as the actual rural population has held relatively constant over this time.

In western Europe, as technology advanced during the 50 years following the Second World War, the number of farms and the number of farmers and farm workers has also declined dramatically. In 1950 England had farm labor force of 687,000 people. By 2000, the labor force on farms had declined to 375,000 (Defra, 2006b). Similar trends are apparent in other western European countries.

The changes in eastern Europe are more complex as collectivization during the communist era greatly reduced the number of farming units in most countries. For example, in E. Germany in 1945, all large farms were reduced to 100ha and the rest of the land allocated to farm workers. Some of these private farms survived until 1955, but after the German Democratic Republic was established in 1949, pressure to collectivize them increased. The collectivization was completed in 1955 and after that no private ownership of land was permitted. Many of farmers left the land to work in the new factories. Then, following the demise of this system of land management in c. 1990 there has been a variable re-allocation of land to the former owners, resulting in fragmentation of the farming units. In turn there has now been re-amalgamation of the small units to create more financially viable enterprises (Bouma et al., 1998).

3.3.5 Equity (benefits, control and access to resources)

Food production per capita has been increasing in the NAE and globally, but major distributional inequalities exist. Current directions in the development of food systems have fundamentally changed the internal interaction and share of benefits in the food chains, disempowering local rural actors, such as farmers and small-scale processors. The share of retail for control and benefits in the food chains has increased.

3.3.5.1 Equity in terms of economic benefits and value-added

AKST has been a factor in enabling rural regions to specialize in producing and exporting natural resource-based raw materials for, e.g., food industry (Siegel et al., 1995) and enabling local demand to be met with imported food. The value added in production, food processing and food distribution has been transferred to urban areas and, increasingly, beyond national borders. Despite this, food production has played a central role in rural vitality and will do for a long time to come (OECD, 1996). The reduction in the number of farms and farm workers has led to out-migration and the break down of some social structures in the rural regions of all industrialized countries in Europe.

The transformation to a more advanced stage of industrialized farming over the past 60 years has led to significant increases in productivity with concomitant benefits to many consumers, but it has simultaneously, in many rural are*as*, had an adverse effect on economic and social vitality and arguably reduced the somewhat idealized independence of farmers (Goldschmidt, 1978; Ikerd, 2002; Stofferhan, 2006). The above description of events may be too sweeping because changes in social and economic structure of rural communities have differential effects, creating opportunities for some and disadvantaging others (Buttel, 1983). Such reasoning suggests that socioeconomic effects of industrialization and globalization are variable and fluctuate in response to local and non-local forces. Concern may also be indicative of a nostalgic worldview that idealizes how rural farming communities once were.

The rise of retail concentration (see Chapter 2) has led to the concern that retailers may abuse their market power vis-à-vis other actors with smaller market shares, in particular farmers and consumers (Hendrickson et al., 2001; Morgan et al., 2006). Farmers have for a long time noted how small a share of consumer prices for food and fiber products comes from what farmers receive for the raw commodities at the farm gate. The declining share of the consumer food Euro/dollar allocated to producers is reflected in rising retail-farm price margins. A factor contributing to this decline is the increase in consumer demand for off-farm or marketing services for food. Farmers' ever-increasing productivity has made agricultural products steadily cheaper in real terms; this alone would cut the farmer's share of retail prices if the margins for processing and retail distribution just kept up with inflation. But growing farm productivity is only half of the story. In some markets the farm-to-retail margins have risen significantly faster than overall food marketing costs. Growing retail margins may be variously explained in different markets (Reed et al., 2002). Reduced competition among retailers or (for some products) processors may produce monopoly profits, stifle cost saving innovation and dull the efficiency of management; alternatively, consumers may choose products to which more value has been added, fewer competitors may increase the importance of competition on things other than price. There may be more value-added at the retail level, including better service and a greater variety within the category. All farmers are facing a shrinking share of the retail dollar/Euro. With the ever-growing efficiency of production agriculture and the continuing tendency of the marketing system to add more value for wealthier consumers, this trend is expected to continue (Kinsey and Senauer, 1996).

3.3.5.2 Equity in access to resources

The development of agricultural technology in NAE, based on external, purchased inputs has affected global equity. Poor farmers especially in developing countries often do not have the option of introducing modern methods because of the lack of market integration and infrastructure, the heterogeneity of the environment, or because they cannot afford purchased inputs. The nutrient case illustrates the more general consequences. Large field areas of the NAE, especially in Europe, have been enriched with phosphorus and nitrogen but only a proportion of the industrially fixed nutrients is retained in food products. This leads to eutrophication and biodiversity decline in both aquatic and terrestrial systems (see Chapter 3.1). Conversely, the soils of several cultivated systems especially in sub-Saharan Africa are nutrient-depleted (Maene, 2003). This is especially problematic where fruits, vegetables and other crops are exported on a large scale from rural areas to urban centers, or from regions with nutrient-poor field soils to nutrient-enriched NAE. In fact, NAE increasingly relies on food, feed and resources originating beyond its boarders (Deutsch, 2004). For example, only a third of African phosphate fertilizer production was used in Africa in 2002 (FAOSTAT, 2006).

3.3.5.3 Equity in control and influence

Critics concerned with the global equity of agri-business assert that powerful food retailers situated in the North, whose success has been partly driven by NAE AKST, largely dictate the social relations of production in the South and provide little opportunity to encourage local value capture (Marsden, 1997). Such processes are seen to be powerful drivers for divergence and marginalization in traditional farming communities. Further, it is contended that the only way forward is for these localities to disengage and reintegrate into local and regional settings. Paradoxically, in some regions (e.g. Tuscany), these same phenomena described above have been the catalyst for stimulating vibrant new livelihood strategies (such as tourism) in traditional farming communities, as they have endeavored to innovate and adapt to rapidly changing circumstances (Miele and Pinducciu, 2001; Morgan et al., 2006).

Historically, some of the effects of the trends described above have been mitigated in Europe and the US by costly market intervention to support prices, often under the policy guise of rural poverty mitigation, rural development programs or more recently nature conservation (Petit, 1997; Dimitri et al., 2005). The impacts of these policies are in the decline in the US, but due to effective lobbying and public support the agricultural sector in the EU was largely exempted from trade liberalization agendas until the Uruguay Round in 1992.

Understanding the wants and demands of consumers within highly differentiated food markets has become a source of power within food systems. Related to this point, consumers are demanding more transparency and information (essentially control) about food production methods and labor relations on which to base purchasing decisions (Miele and Parisi, 2001; Blokhuis et al., 2003). Thus the role of knowledge and information is assuming more and more importance as a point of influence and control in food systems, especially in NAE. Supermarkets and fast food outlets with their proximity to customers have a unique capacity to influence the rest of the production and food distribution chain. These powerful retailers continue to strive to meet consumer welfare concerns (price, quality and variety), often to the detriment of producer welfare.

A recent spate of food controversies in North America and Europe has re-stimulated the continuing debate and concern about human and environmental health risks (the so-called food anxieties) associated with food production and consumption (Holloway and Kneafsey, 2004). The response is tougher more restrictive food quality criteria managed through resource intensive, producer responsible, certification processes to manage risk and quality. Clearly it is larger scale producers who are in a better position to meet such demands.

3.3.5.4 Rise of alternative food systems

Partly in response to the numerous concerns related to industrialized agribusiness there has been a growing interest in 'alternative' food systems. Some of these reject aspects of NAE AKST provided. Local food systems with their focus on their social and economic embeddedness can overcome high costs and reduce risk for farmers and consumers by adding value locally, thereby supporting rural development (Sage, 2003; Winter, 2003). Although there are many benefits attributed to locally-oriented food systems, these models have also been criticized as benefiting primarily those who can choose based on education or income (Allen, 1999; Hinrichs and Kremer, 2002; Hinrichs, 2003).

Conceptualizing the equity of food systems at different spatial scales generates different perspectives and responses. Projects based on regional identity (e.g. Tuscany) or branding (e.g. organics, Slow Food) have been promoted as rural development alternatives in NAE (Barham, 2003; Murdoch and Miele, 2004). However, they may also serve the privileged at the expense of the poor (Allen, 1999), through the decreasing affordability of products - perhaps even magnifying existing unequal relations of consumption locally (Bellows and Hamm, 2001; Allen and Sachs, 1991). Furthermore a focus on the local may well direct attention from global-scale inequities surrounding issues of food security and material welfare, although it may reduce local communities' (implicit) involvement as consumers in exploitative labor and environmental commodity chains. The local concentration of production and consumption may also restrict opportunities to import Fair Trade goods, thus limiting market access for developing country growers.

3.3.6 Distancing consumers from production

The increasing emergence of vertical food chains (see Chapter 2) has increased spatial and social distancing between sectors in the food chain (Sumelius and Vesala, 2005). Social distancing has helped to lessen consumers' understanding of the production system and the food chain thereby decreasing their ability to fully participate in a food system dominated by market logic. Issues of ethical, social and environmental concern are typically shielded from consumer view and may only be revealed if there are dramatic and direct societal consequences. The environmental effects of conventional agriculture and their social implications tend to be spatially bounded (rather than atmospheric or global) and often are remote from the end consumer (Marsden et al., 1999). In these circumstances price and convenience, which are still visible, have been the predominant determinant for consumers, while adverse social and environmental effects can be isolated from consumer view.

3.3.7 Nutritional consequences of NAE food systems

The most direct and tangible benefit of food is its role in enabling individuals to pursue active, healthy, productive lives as a consequence of adequate nutrition (MA, 2005). For these reasons access to adequate, safe food has been recognized as a basic human right. Decreased hunger and poverty and improved nutrition and human health are two of the Millennium Development Goals.

Although the food insecurity and prevalence of under nourishment and hunger has been reduced worldwide, there were still 9 million undernourished people in industrialized countries and 28 million in countries in transition in 2001-2003 (FAO, 2006). These data include 21 million people in the Commonwealth of Independent States (7% of the population), 3 million people in eastern Europe (former socialist states within and without the EU) (4% of the population) and 0.1 in Baltic States (1% of the population).

An increase in consumer purchasing power, progress in food production methods and changes in the marketing of food products have dramatically improved the food situation in many countries of the European Union and in the USA. Food has been generally available, although some sections of the population do not consume a sufficiently healthy diet. For example, the consumption of fruits and vegetables has declined in the U.S. in the last 100 years. People on a low income spend a greater proportion of their income on food, but eat a diet of lower nutritional quality than those on a high income (European Commission, 2002a).

The emerging challenges in relation to nutrition and health are thus different than those of some decades ago. North America and Europe are currently experiencing a high prevalence of non-communicable diseases, such as cancer, cardiovascular disease, diabetes, certain allergies and osteoporosis. These are the result of the interaction of various genetic, environmental and lifestyle factors (including smoking, diet and a lack of physical activity). Numerous studies suggest nutrition is important in maintaining health and preventing many of these major diseases (Ferro-Luzzi and James, 1997).

For the European Union, estimates have been made of the total burden of ill health, disability and premature death from all causes experienced by the population and the factors most responsible for this disease burden (European Commission, 2002b). Of a broad range of causes, diet-related factors are believed to be responsible for nearly 10% of the total disease burden —including overweight (3.7%), low fruit and vegetable consumption (3.5%) and high saturated fat consumption (1.1%). Together with lack of physical exercise (1.4%), these factors account for a greater proportion of ill health than tobacco smoking (9.0%).

[Insert Table 3.7]
[Insert Table 3.8]

In recent years, overweight and obesity have been growing at a very fast rate. Today obesity represents a real threat to the public health of certain groups in North America and Europe, as shown by data from IOTF and OECD (Tables 3.7 and 3.8). A particular concern is the rapid rise in childhood obesity (Fig. 3.13).

In the next 5 to 10 years obesity in the European Union will probably reach the high level of prevalence in the United States today, where one third of people are estimated to be obese and one third to be overweight. In many countries there is a 10-15 year lag behind the USA, but nevertheless European countries are narrowing this gap (Fig. 3.13).

[Insert Figure 3.13]

3.4 Impacts of NAE AKST through International Trade

NAE accounts for more than a quarter of global trade in agricultural products**.** The European Union and the United States are major players while trade flows with the Russian Federation are much smaller. Trade has also been growing (Table 3.9). Between 1986 and 2003, substantial changes in trade flows were associated with the breakup of the system of centralized command systems in the USSR and other parts of CEEC. Beyond 2004 the EU became 25 countries rather than 15.

[Insert Table 3.9]
[Insert Figure 3.14]

The U.S. has been a net exporter while the EU has been a net importer (Fig. 3.14). The EU has subsidized agricultural exports while the U.S. support system for farmers, combined with Food Aid programs, has made their farm exports competitive. Subsidized exports damage low cost producers in both developed and developing countries who face lower prices and may even lose markets to products that are effectively dumped into the world market. The damage done by export subsidies and policies that have similar effect has played a major role in trade negotiations. With the creation of WTO, agriculture was brought within the multilateral trade negotiating scene and pressure has grown for export subsidies to be reduced and eventually removed and for there to be greater access to developed country markets for produce from developing countries.

[Insert Figure 3.15]

The largest volume of agricultural trade in the EU is between its member countries. Much of the external trade takes place between the US and the EU (Figure 3.15). Many EU agricultural imports, particularly from the US and Brazil, are feedstuffs for the livestock industry rather than finished products.

For the U.S. the most important destinations for exports are its neighboring countries Mexico and Canada within the North American free trade area. Outside this free trade area Japan and the EU represent the major destinations for North American exports. China has markedly increased imports since 2002 and is expected to continue to do so in the future. A major development that may change the flow of exports from North America is the use of an increasing share of the U.S. maize crop will be used to produce bioethanol rather than enter the food chain.

There is a similar concentrated pattern for U.S. imports (see figures 3.16 and 3.17) but here the EU has recently overtaken Canada as the largest supplier. Imports from Mexico have risen relatively rapidly as a result of the North American Free Trade Agreement. Among the four largest suppliers only Australia secures its market without subsidies or preferential access to the market.

Agricultural trade flows can act as catalysts for the diffusion of AKST to exporting countries. Importers may invest in production and processing activities that employ technologies developed within their own countries to meet market needs. As markets are established imported technologies can be adapted to local circumstances developing skills within the local community.

Trade also plays an important role in putting into practice public and private initiatives to encourage the development of agricultural knowledge, science and technology in the developing world. Private initiatives through the Ford, Rockefeller and Gates Foundations, for example, have supported research directed specifically at the problems of production in low-income countries. Many aid agencies such as Christian Aid, Oxfam, Farm Africa and World Vision have supported the development of education and the application of new technologies in farming. While the focus of much of this activity has been to improve the productivity of traditional farming activities in developing countries as production moves from local self-sufficiency to meet market needs whether at home or abroad, there is a need to employ technologies that cope both with the needs of storage and transport.

[Insert Figure 3.16]
[Insert Figure 3.17]

Much of the final value of agricultural products is embodied in processing. Imports of processed products have been increasing and this provides new opportunities for developing exporting countries that are able to access and use appropriate technology to meet the safety requirements of importing countries and respond to the needs of their retailers and caterers. Production and transport is often organized by developed country suppliers who oversee production, handling and transport through to their final customers.

European livestock production and trade

For the past 30 years Europe has been producing far more meat and dairy products than it needs, becoming one of the world's leading exporters. Previously, the search for increased market share led to dumping of these products in less wealthy countries with consequent damage to the economic status of their agricultural producers. There are several well documented cases of disruption of and damage to, developing country agricultural markets as a result of this European strategy. As a result of rigorous CAP reforms in the 1990s, European production of beef and veal has fallen rapidly from around 50% over-production (EU-15) in the 1990s to around 96% self-sufficiency in 2004 (Table 3.10).

The large increases in European livestock production between 1960 and 1990 relied heavily on animal feed imported from Brazil, Argentina, North America and the Ukraine. In 2005 the EU 25 imported 30 million tonnes of animal feed, over half coming from Brazil and Argentina (data from Eurostat). Animal feed is the largest imported (aggregated) product for the EU-25 (European Commission, 2006). Total imports, expressed in values reached € 5 099 million during the 1st semester of 2005, i.e. a decrease of 27.2%, with Brazil having the largest share with € 1 834.1 million (-34 %). EU-25 exported a total of € 670.4 million during the 1st semester of 2004 and € 997.5 million during the 1st semester of 2005, with Algeria (€ 111.2 million and € 140.6 million) as the most important destination.

Pig meat is still being overproduced in EU-25 by about 8%, making Europe a net exporter of pig meat products, mainly to Russia and Japan. The EU is a net importer of sheep meat (EU-25 is only 78% self-sufficient in sheep and goat meat) and dairy products, mostly from New Zealand and also imports large quantities of poultry meat from Brazil and Thailand, where production costs are much lower than in Europe. Somewhat perversely the EU also exports large quantities of poultry meat and offal to Russia and the Ukraine and parts of the Middle East.

[Insert Table 3.10]

Next to India, the EU is the second largest producer of milk and milk products, exporting around 800,000 tonnes per year to a variety of global markets, including Africa (mainly Nigeria and Algeria), China, Russia and parts of the Middle East, especially Saudi Arabia. Exports of cheese and curd currently run at around 300,000 tonnes per year, going mainly to the U.S., Russia and Japan (Eurostat Agricultural Trade Statistics data).

The Common Agricultural Policy is moving away from production-led subsidies towards a more market-led and environmentally friendly system, but there is still a substantial subsidy paid to most participants in the livestock sector that reduces the competitiveness of developing countries.