NAE Chapter 1
Setting the Stage

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Key Messages

1. The application of agricultural knowledge, science and technology (AKST) within NAE since 1945 has increased productivity and production substantially, such that NAE produces more than enough food overall to meet basic needs of the region. Yet its application has also undermined the achievement of development and sustainability goals within the region and in other sub-global regions by contributing to environmental degradation (e.g., habitat transformation, freshwater contamination and over-exploitation of fisheries), increasing inequity in wealth and assets in the food system, increasing the vulnerability of livelihoods dependent on agriculture and contributing to diet-related diseases, obesity and overweight.

2. NAE's agricultural activities have significant influence on the capacity of countries in other regions to meet development and sustainability goals. This is largely due to NAE's volume and variety of exports and imports and the many actors and networks based in NAE that dominate agrifood chains and AKST. For example, businesses within NAE have a powerful impact on consumer demand in the rest of the world; they obtain and profit from commodities, landraces and other valuable genetic resources and immigrant labor from other regions. NAE countries house the greatest world plant diversity in their *ex situ* genetic resources collections, and they have a legacy of substantial investment in AKST dating back centuries. NAE generated and initially used many advances in AKST, so this region shows the impacts of specific forms of AKST over the longest time period and can provide illustrative lessons on its application and resulting positive and negative (intended and unintended) consequences.

3. Choices about investment in, generation and control of, and access to AKST have great potential to help solve critical current and future challenges to human well-being within NAE and globally, including

- mitigating and adapting to global climate change,
- managing resources for human use while maintaining their ability to provide a full array of ecosystem services,
- creating markets with fair access and compensation to participants,
- developing renewable energy sources and other alternatives to products made from fossil fuels,
- improving human health and reducing exposure to foodborne contaminants and disease,
- increasing the availability of and equitable access to food and other agricultural products,
- improving equity across gender and social divides, and
- creating and sustaining urban and rural livelihoods.

4. AKST interacts with and is driven by knowledge and technology in non-agricultural domains such as demography, economics, international trade and cultural developments. It encompasses formal and informal education, training, research, research and innovation policy, national and international regulations and agreements. Regulations and agreements address issues such as control, exchange and access to agrobiodiversity and natural resources; information and technology; land tenure arrangements; and Intellectual Property Rights.

5. AKST within NAE has been characterized by a paradigm emphasizing increases in production and productivity. The generation and dissemination of knowledge and development of technology has typically been fragmented and heirarchical, with some stakeholders excluded from setting and implementing AKST agendas. This paradigm is changing; continued development of a new paradigm for generation, access and use of AKST is important to meeting development and sustainability goals.

6. Different political and socioeconomic histories during the 20th century and variable access to all forms of capital (human, social, financial, physical and natural) have driven very different paths of agricultural development and agricultural AKST within NAE's sub-regions (North America, western Europe, eastern Europe and Israel). These are associated with widely varying attitudes about the importance of national agrifood self-sufficiency, trade and subsidies for agriculture. At the same time, geographic and political similarities across the region have important consequences for AKST and agrifood systems: most of the region is in a temperate zone; the region overall has enjoyed relative peace and stability over the last half-century compared with other sub-global regions; and many of its countries and businesses have made substantial investments in AKST.

7. **Very small numbers of people (less than 2% of the population) are engaged in primary agrifood *production* in some NAE countries, although the proportions of small-scale subsistence or semi-subsistence growers remain quite high in other countries.** Agrifood *systems* (including processing, distribution and sales) employ a substantial proportion of the population in *all* countries. In addition to providing raw materials for traditional products—food, feed, seed, fiber, fuel, paper, etc.—agricultural management in NAE is expected to deliver environmental, social and cultural goods and services. These include clean, abundant water; biodiversity and landscape quality; rural employment; recreation; and mitigation of climate change.

8. Agrifood systems have become dominated by fewer, larger actors. All sectors of agrifood systems have shown vertical and horizontal integration, although in many eastern

European countries, smallholders and local outlets still raise and market most of the agrifood products (especially livestock, potatoes and other vegetables). Agrifood systems are starting to respond to consumer markets for food and other goods produced to high environmental and social standards (known as the ‘quality turn’). Small- and mid-scale producers and distributors through most of NAE increasingly market higher-value, differentiated goods. Vertically integrated supermarkets are attempting to expand market share and satisfy regulatory requirements for higher quality, codified in environmental and social standards and implemented in labeling and certification schemes. Concentrated enterprises and changing expectations and standards require different forms of AKST than sufficed for previous agrifood systems. Choices about future investment in AKST and associated policies will affect who benefits from and who controls agrifood systems and their products, thus affecting who is able to meet development and sustainability goals.

1.1 Scope and structure

1.1.1 Geographic scope of NAE

For the purposes of the IAASTD, the North America and Europe (NAE) region is considered to consist of three sub-regions. North America comprises the US and Canada; western Europe comprises the 27 countries of the European Union[1] with Iceland, Norway, San Marino and Switzerland; while Eastern Europe is the remaining countries in the Balkans[2], Russia, and its neighboring states Belarus, Georgia, Kazakhstan, Moldova, Uzbekistan and Ukraine. Israel is also included in the region.

1.1.2 Structure of the report

This chapter introduces the NAE assessment and leads to an analysis (Chapter 2) of the changes in agrifood systems that have occurred over the past 50 years resulting from the generation, introduction and application of AKST (Figure 1-1). Chapter 3 examines environmental, economic and social impacts of these changes over the same time period; and Chapter 4 examines changes in the organization and institutions of AKST and their consequences for development and sustainability goals. Chapter 5 introduces forecasting as a method for analyzing the consequences of different options in AKST, congruent with different alternative future developments in the region, and describes major trends affecting agriculture and AKST in NAE. Chapter 6 draws from the lessons summarized in Chapters 2, 3 and 4 about the past generation and application of AKST, and significant trends noted in Chapter 5, to explore options for future investment, policies, education, training and funding.

[Figure 1-1. Roadmap for NAE sub-Global Assessment]

1.1.2.1 Interface with global assessment and other sub-global assessments

The sub-global assessments (including NAE) were developed simultaneously with the Global Assessment by different working teams, which gave limited opportunities to coordinate the findings. However, representatives of the different assessments met together twice and shared their plans. Each sub-Global assessment has a slightly different structure to accommodate the particular issues that contributors thought needed the most attention. The Global Assessment is longer and more comprehensive than any of the sub-Global assessments, but does not go into detail on individual regions other than to illustrate points via case studies or vignettes. The separate Synthesis Report combines the major points of all of the reports (Global and sub-Global) and highlights findings from the crosscutting thematic issues.

[1] Countries of EU27 are: Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, United Kingdom.

[2] Other Balkan countries are Albania, Bosnia and Herzegovina, Croatia, Macedonia, Serbia and Montenegro

1.1.2.2 Thematic issues.

Each sub-Global assessment deals with the past 50 years of AKST in relation to the development and sustainability goals specified in the original mandate to conduct the IAASTD. However, certain themes emerged that deserved special attention because of their importance to meeting the development and sustainability goals, their contentiousness, or the lack of adequate attention to them in previous assessments. These themes are:

- Bioenergy
- Biotechnology
- Climate change
- Human health
- Natural resource management
- Traditional knowledge and community based innovation
- Trade and markets
- Women in agriculture

The Global and sub-Global assessments contributed experts on these issues to develop key messages and integrate their treatment across the reports.

1.1.3 Conceptual framework

1.1.3.1 Conceptual diagram

AKST is the intersection of knowledge, science and technology (including that developed in other realms) with agricultural systems. It is influenced by and draws from other kinds of knowledge and technology in important ways not confined to food production. For example, advances in transportation and communications technology have been key to the globalization and integration of global value chains.

While the term “AKST” is often used in the IAASTD as if it were a consistent, coherent bloc, there are many different forms and permutations of AKST that have different development histories and impacts. For example, the AKST underlying traditional practices of hunting or grazing on communal lands is vastly different from the AKST leading to the patenting of goats that have been genetically engineered to express human lysozyme in their milk. Therefore, in referring to drivers of AKST or impacts in specific circumstances, it is important to clarify which forms of AKST are under consideration.

The conceptual diagram (Figure 1-2) depicts in a very general way how indirect and direct drivers of change affect development and sustainability goals through AKST. Note that AKST is a subset

of science and technology, which is only one of several indirect drivers of the development and sustainability goals.

[Figure 1-2 Conceptual diagram of IAASTD]

1.1.3.2 Drivers of change

The direct drivers of AKST highlighted in the conceptual diagram are food demand and consumption, the availability and management of natural resources, land use, climate change, energy and labor. These drivers of change are influenced in turn by a set of indirect drivers, including demographics; economics and international trade; the socio-political context; the broader context of science and technology; education, culture and ethics; and the biogeophysical environment. Chapter 4 examines the complexities of how AKST has interacted with these factors over the past 50 years. AKST is a driver of agrifood system changes, but it is also influenced by these changes.

1.1.3.3 AKST dynamics

[Figure 1-3. AKST dynamics]

Actors and networks are the agents or groups of agents that generate, disseminate, use or control AKST, e.g., public and private agricultural research organizations, universities, public extension services, independent agricultural consultants and other businesses, the International Consultative Group on International Agricultural Research (CGIAR), supply chains and civil society organizations.

Processes are the avenues by which AKST are developed, transmitted and used, and avenues that determine their development and availability, access and use. They include knowledge and technology generation, dissemination and extension, adoption, and evaluation for all sectors in supply chains; trade; public-private investment; advertising; and provision of credit and other financial resources.

Rules and norms are the sociocultural and legal conventions that manage and control AKST processes. They include international agreements and treaties, such as the International Treaty on Plant Genetic Resources for Food and Agriculture and the Convention on Biological Diversity; agreements related to trade, such as trade-related Intellectual Property Rights and World Trade Organization (WTO) settlements; international quality standards such as ISO14000 and the Codex Alimentarius; subsidies; national regulations; tax structures; and local customs.

Many of the actors, rules and norms relevant to the development, distribution and use of AKST were established by World War II Allies in the post-war years. The United Nations (UN) and the World Bank were founded in 1945 to promote economic development and the avoidance of conflict; and the UN agencies Food and Agriculture Organization (FAO), United Nations Children's Fund (UNICEF) and the World Health Organization (WHO) were created shortly afterwards. International agricultural research stations were established during the 1960s, with support from the Rockefeller Foundation, and became the first centers of the new CGIAR in 1971. Discussions among wartime allies of the United States in the late 1940s to create a multilateral agreement for the reciprocal reduction of tariffs on trade in goods led to the General Agreement on Tariffs and Trade negotiation rounds and ultimately the WTO in 1995.

1.2 Agriculture, development and sustainability goals

1.2.1 Eradicating hunger and food insecurity; providing adequate amounts of healthy, safe food; and improving human health

The development and implementation of agricultural knowledge, science and technology have delivered real benefits in food availability worldwide. Few countries in NAE have large numbers of hungry and impoverished people, yet food insecurity is still present in all of them. For example, the United States (US) has the highest Gross Domestic Product of NAE countries; but 10.9% of the US population was food-insecure in 2006, meaning that they lacked access at all times to enough food for an active, healthy life for all household members; and 4% suffered from "very low food security," indicating that the food intake of one or more adults was reduced and their eating patterns were disrupted at times during the year because the household lacked money and other resources for food (Nord et al., 2007). Food insecurity in NAE is more frequently a consequence of poverty and specific government policies that fail to ensure access to available food than due to general lack of AKST, yet such policies are elements of agrifood systems, and can draw upon AKST.

Advances in agricultural productivity have been uneven through NAE, and subsistence farming still predominates in parts of Eastern Europe, with high levels of food insecurity in some countries that have been torn by war or political instability or have been under Soviet influence. The FAO estimates that rates of food insecurity are no more than 6% in countries that have recently acceded to the European Union; but levels are higher in the Balkans and some of the countries in the Commonwealth of Independent States (Skoet and Stamoulis, 2006; Figure 1-4). Food security in Uzbekistan has deteriorated since 1993-1995; it was over 25% in 2001-2003. Food insecurity in Georgia was also high, but improved significantly during the same time period as it emerged from armed conflict (Skoet and Stamoulis, 2006). Comparing food security across NAE is difficult, as different countries use different metrics.

[Figure 1.4. Prevalence of undernourishment in countries in transition, 2001-2003].

In NAE, policies and investment in AKST have led to frequent surplus production of many crops over the past 50 years, the overconsumption of foods that lead to poor health and rising incidences of obesity and overweight. Of course, many factors contribute to obesity and dietary choices in addition to AKST. However, the development and application of food-processing technology to meet interests other than health; the use of advertising to promote foods of low nutrient value; and policies that determine the availability, price, access and consumption of healthy foods are partly responsible for the rapid rise of obesity and diet-related diseases in the region. Average life expectancy in the US is expected to fall over the next few decades as a result of obesity and associated health problems (Olshansky et al., 2005), reversing for the first time a steady upward trend that has persisted for centuries. The three leading causes of death in the US—heart disease, cancer and stroke—are diet-related; adult-onset diabetes, which is closely correlated with obesity, ranks sixth (NCHS, 2006a). The percentage of adults between 20 and 74 years that is overweight was 66% in 2001-2004, with 32.1% obese. During the same time period, 17.5% of children between the ages of 2 and 17 were overweight (NCHS, 2006b). For adults and children, the proportion of the population that is overweight and obese is significantly correlated with sex, race and ethnicity (NCHS, 2006b).

Obesity and diet-related diseases are rising throughout the NAE region, although not as rapidly or to the levels currently in the US. For example, the Canadian Community Healthy Survey estimated an obesity rate of 23.1% among Canadians 18 and older in 2004 (Tjepkema, 2006); and 26% of Canadian children between the ages of 2 and 17 were overweight or obese (Shields, 2006). The Regional Office for Europe of the World Health Organization reports that the prevalence of obesity has tripled in many countries in the region since the 1980s and continues to rise, with obesity already responsible for 2-8% of health costs and 10-13% of deaths in different parts of the region.

Outbreaks of salmonella, foot and mouth disease (FMD) and bovine spongiform encephalitis (BSE) and its human form variant Creutzfeldt-Jakob Disease (vCJD) have raised concerns over disease transmission via food. FMD does not transfer to humans; and up to December 2006 there were 158 deaths attributable to vCJD in the UK, or about 15% of all CJD cases (Andrews, 2007). Other diseases associated with agriculture and the food chain continue to emerge. Avian flu is an example, with a total of 335 cases and 206 deaths from avian influenza A/H5N1 reported by November 2007 (WHO, 2007).

Pesticide poisoning occurs in NAE through ingesting contaminated food, through manufacture and through end use. For example, over 1,000 cases of illness were associated with aldicarb use in watermelons in California in 1985 (Goldman et al., 1990). Although reported agricultural pesticide poisonings decreased from a yearly average of 665 cases (1991–1996) to 475 (1997–2000) in California, the numbers are considered to be conservative because farmworkers face numerous barriers to reporting poisonings (Reeves and Schafer, 2003). Many people in the US carry high body burdens of pesticides, with children bearing the highest levels of some toxic pesticides such as the organophosphate chlorpyrifos (CDC, 2005). There are additional potential health risks to humans through reductions in water quality caused by run-off from fertilizers, slurries and manures that contain fecal coliforms (Mølbak, 2004); and from the conversion of nitrates in water to nitrite in the guts of small children, reacting with their hemoglobin and resulting in the “Blue Baby syndrome.”

1.2.2 Reducing extreme poverty, improving livelihoods and creating rural employment

While the application of AKST has contributed to NAE’s development and relatively high levels of wealth, it also has contributed to the persistence of poverty and poor prospects for livelihoods based on agriculture. Inequity is rising in some countries of NAE, such as the US; and many people are trapped in pockets of underdevelopment characterized by poverty and non-viable rural livelihoods. Poverty is most intense in eastern Europe: for example, 14% of the population of Uzbekistan lives in extreme poverty, defined as subsisting on less than US$1 per day (Skoet and Stamoulis, 2006).

Many people in production agriculture in North America face poor prospects of sustainable livelihoods when incomes are tied solely to the market; for several decades the majority of producers’ income has been derived from off-farm sources and government subsidies rather than crop or product prices. For example, the average proportion of household income from farming activities across all farm types was only 18% in 2005 in the US; the remainder came from off-farm sources. The average government payment was more than half of the average income from farming activities (USDA, 2005). In Canada, farmers’ Market Net Income, which subtracts out government payments, fell to negative $10,000 per farm after bottoming at negative $16,000 in 2003. Market Net Incomes dropped close to zero in the 1980s after 40 years of relative stability (NFU-Canada, 2005). While crop prices have gone up recently because of increasing demand for meat and biofuels and poor harvests, the strength and longevity of this trend is uncertain. Production subsidies have allowed farmers to stay in business through periods when product prices were below costs of production, but they are now contested by many actors because of their impacts on total commodity production and on incomes of producers in developing countries. Subsidies in the US tend to support the largest farmers disproportionately because

they are based on historical production of commodity crops (MacDonald et al., 2006). Medium-scale and large-scale farms in the US received 78% of the commodity program benefits paid to farmers in 2004 (Hoppe et al., 2007). Production subsidy payments contribute to concentration of farmland among fewer farm operators and raise land prices, thus creating a barrier to beginning farmers. Furthermore, patterns of discrimination in their allocation have prevented minorities from receiving subsidies at the same rate that white male farmers receive them (Oxfam America, 2007).

Wageworkers in agrifood systems (e.g., farmworkers, meat-packers, poultry processing workers, waitresses, cashiers in supermarkets) often have incomes below the official poverty threshold, and may face hazardous or substandard working conditions. Farmworkers in the US are excluded from legislation that guarantees rights such as forming trade unions and bargaining collectively. They suffer from low and stagnant wages, job instability, dangerous and unhealthy working conditions and substandard accommodations (Oxfam America, 2004). Undocumented farmworkers are the most vulnerable of all people in the food system, yet they have little recourse in the current political and legal environment. An estimated 10.3 M undocumented workers are in the US, with about 57% from Mexico (Passel, 2005). Migrants to NAE countries frequently work in low-wage agrifood system jobs, but their livelihoods are precarious because of their legal status.

In contrast, people involved in management tiers of agribusiness have seen dramatic rises in wealth and power because of policies that created environments conducive to the success of larger businesses reliant on AKST. Agricultural resources and most stages of input production and commodity processing, distribution and retail have become concentrated into fewer, much larger enterprises at an accelerating pace over the past century. Five of the inheritors of the Wal-Mart fortune were among the top thirty wealthiest people in the world in 2006 (Kroll and Fass, 2007). Wal-Mart's Supercenters sell more groceries than any other retailer in the United States, and Wal-Mart has moved rapidly into other countries in NAE and other regions.

1.2.3 Promoting equity across gender and social gaps.

The proportion of women and minorities that are farmers and work in other sectors of agrifood systems varies considerably across NAE. Women and minorities constitute small proportions of the farm population in most North American and western European countries, but the numbers of women operators have been increasing. For example, in Canada, 27.8% of farm operators were women in 2006 (Statistics Canada, 2006). In the USA, women are 9% of farm operators but 16% of operators of limited resource farms. Minorities account for 5% of all principal operators and a similar percentage for each farm type except for limited-resource farms, of which about 12% have a minority operator (Hoppe et al., 2007).

In contrast, women are a large proportion of the population engaged in agricultural production in some of the countries newly acceded to the EU, eastern Europe, and transition countries in the Balkans and the Commonwealth of Independent States. Women tend to be employed at the same or even slightly higher rates than men in agriculture in these countries: 42% of employed women in Moldava were in this sector in 2003 (compared with 44% for men) and 37% in Romania (compared with 35% for men). Women also are more likely to be engaged in subsistence agriculture and agricultural jobs in the informal sector, as their employment rates in the formal sector dropped markedly after the early 1990s (Jacobs, 2006). Women constitute a small minority of migrant farmworkers, but they are particularly vulnerable to exploitation in that occupation.

AKST needs of women and minorities are often different from others working in agrifood systems. Women and minorities tend to have smaller farms in the US and Canada, although farms operated by Hispanics in the US are larger on average because more are extensive livestock operations (Effland et al., 1998). Women and minorities also tend to raise a different selection of crops and livestock than white male operators. They may face special barriers in attempting to access information and technology because of language, culture or discrimination; and they may be at greater risk of losing their farms (Effland et al., 1998; FAO, 1996; Oxfam America, 2007).

1.2.4 Enhancing environmental quality

The application of AKST in NAE has led to habitat transformation, loss of biodiversity, declining quantities of fresh water and increasing competition for what remains, degradation of the quality of groundwater and surface water, and impacts on soil quality. Transportation of agricultural products contributes to greenhouse gas emission and poor air quality due to particulates. AKST can also improve environmental quality, through practices such as no-till planting, crop rotation and sustainable management of cultural landscapes.

The consequences to agricultural production of over-exploiting natural resources are seen most vividly in the abrupt decline of marine fishery stocks (Pauly and Alder, 2005). Perhaps the most dramatic illustration of contamination is the hypoxic zone extending into oceans from the mouth of all major rivers in industrialized countries, caused by run-off of unused nitrogen applied as fertilizer to agricultural systems (Schlesinger et al., 2006). The full environmental costs associated with substantial gains in human well-being and economic development are only now becoming apparent (Tegtmeier and Duffy, 2004; MA, 2005ab; Sumelius et al., 2005; Foster et al., 2006).

The development and sustainability goals are interlinked, and ways that they intersect with agriculture and AKST are complex (Chapters 3 and 4). Awareness of environmental costs and

their implications for future generations has given strength to demands for a more multifunctional agriculture, promoted through policy incentives and supporting the production of ecosystem goods and services beyond provisioning food and feed, water, fuel, fiber and forest products. Policy supporting multifunctional agricultural systems would compensate producers for maintaining supporting ecosystem services such as nutrient cycling and soil formation; cultural services such as aesthetic, spiritual and educational value; and regulating services such as climate and flood regulation and water purification (Aldington, 1998; OECD, 2001; Boody et al., 2005). The recent rise in food prices in NAE, triggered in part by the diversion of land from food and feed grains into ethanol production, adds urgency to finding the right approach to agriculture that is both sustainable and meets human needs (e.g., Cloud, 2007; Howden, 2007). There is an emerging agenda for AKST that fosters economically, environmentally and socially sustainable farming and food systems; public benefits via the food value chain; and equity between producers within the region and with those elsewhere in the world. Yet many tensions remain to be resolved in implementing this "new agenda" and ensuring that people most in need – within NAE and globally – are among the beneficiaries.

Across the region, agriculture is in flux as regulators seek to limit or reverse environmental damage caused by agriculture, migration and other demographic shifts change the complexion of rural areas, and consumers and citizens become more concerned about diet-related health issues and social externalities of agriculture. Increasingly differentiated markets are responding to new consumer desires in what has been denoted as a "quality turn" (reviewed in Wilkinson, 2006). Markets are opening up in NAE for products that promote social and environmental quality, with labels such as "Fair Trade Certified", "organic" and "dolphin-safe." The consequences of greenhouse gas emissions on global climate change have led to new attention on "food miles", or the distance that food travels from point of production to point of consumption, and interest in consuming foods producing locally. Enthusiasm for local foods is also fed by the desire to preserve unique foodways, cultures and landscapes associated with agricultural production; this has resulted in the defense of geographic indicators to demarcate foods' point of origin.

1.3 Significance of NAE in the Generation, Use and Control of AKST

1.3.1 Importance within the region

1.3.1.1 Impacts on development and sustainability goals

In most NAE countries, AKST is less relevant than public policy in other realms to meeting development and sustainability goals of reducing hunger and poverty, improving nutrition and human health, enhancing livelihoods and equity, fostering environmental sustainability and sustaining economic development. That is, AKST is not the main limiting factor in achieving these

goals, although it is increasingly important to deal with emerging issues, such as building resilience and adaptive capacity to deal with consequences of global climate change: learning how to restore degraded ecosystem services and to deal with new foodborne, crop and livestock diseases. In addition, uneven access to AKST in countries in transition within the NAE region constrains productivity and has serious effects on abilities to meet development and sustainability goals.

1.3.1.2 Economic

Many NAE countries and businesses have made substantial investments in AKST, which have resulted in economic gains for actors in those countries in addition to benefits in other regions. The past few decades of application of AKST resulted in the consolidation of global value chains that control the supply of most agricultural products, and have had tremendous effects on the distribution of wealth in society and prospects for making a living through agricultural production. In general, only producers with very large-scale operations are able to support a household by full-time commodity farming; other commodity producers are reliant on off-farm income because of low and unstable commodity prices. This problem is aggravated in the US by lack of universal access to health care, so that an off-farm job with associated affordable health benefits is often necessary to provide social security for a farm household. On the other hand, immense wealth is sequestered among the small number of shareholders with expansive holdings, owners, and executives of transnational corporations involved in food supply (TNCs). The application of AKST has enabled the growth of these companies, sometimes through research partially subsidized in public universities and laboratories and other forms of public support, such as the development of irrigation and water delivery systems, roads and railroads.

Analyzing the economic impacts of AKST and impacts on distribution of wealth in NAE are important in order to understand ways to meet the development and sustainability goals of more sustainable livelihoods and greater economic security for producers and wage-workers in agrifood systems, and to increase rural employment. While enhancing productivity, the application of AKST in globalized agrifood systems has increased the vulnerability of many livelihoods dependent on agriculture because production sites have become more specialized and more sensitive to sudden changes in the market. Farms usually are linked with processing, distribution and marketing enterprises in value chains that can have global reach. Therefore, producers have less control over prices and the timing and circumstances of sales; they are more likely to be price-takers than price-setters; and they are in competition with other producers globally rather than in a local or regional market.

1.3.1.3 Sociocultural

The application of AKST within NAE is associated with changing diets and health, and the disconnection of most people from food production. While AKST has improved the availability and access of many foods in NAE and eased hunger, diet-related health problems caused by excessive consumption of processed foods low in nutrient value and lack of physical activity are on the rise.

The loss of traditional knowledge is apparent in many parts of NAE. At present, indigenous populations are small and often concentrated in lands that are marginal for agriculture. In North America, 90-95% of the indigenous population died in wars or through exposure to diseases introduced by European settlers; so indigenous models of agriculture and resource use are scarce and can only be understood through laborious archaeological investigation. Traditional knowledge such as the *acequia* systems of irrigation in the southwestern US were part of agricultural systems sometimes maintained for centuries and could be valuable in the future. Assessing the value of traditional knowledge and technology can help in efforts to conserve it.

1.3.1.4 Environmental

The impacts on AKST on ecosystem goods and services and social factors in NAE may preview some of the unintended consequences of the application of contemporary AKST elsewhere in the world, and also how they can be managed. Examples of unintended environmental consequences include the vulnerability to disease that often accompanies widespread monocultures; soil erosion and fertility declines from deforestation and inappropriate methods of soil disturbance; changes in biodiversity and flood risk from draining wetlands; aquifer depletion and land subsidence from overpumping aquifers; and effects of synthetic agricultural chemicals on water quality, biodiversity, and related ecosystem services. It is possible to draw tentative conclusions about the attributes of AKST that are most likely to enhance the resilience and sustainability of global agroecosystems and ecosystem services, based on experiences in NAE.

1.3.2 Importance to the rest of the world

1.3.2.1 Impacts on development and sustainability goals

Countries and companies based in NAE control resources that are crucial for achieving development and sustainability goals, such as uncultivated arable land, the world's most extensive *ex situ* gene banks, money, scientific infrastructure and human capital. Therefore, development and sustainability goals in other countries can be met more easily with investment and material assistance from NAE. Enterprises based in NAE and governmental agencies in its countries control technology now that could make a real difference in poor regions, were it affordable to the people who most need it. However, the assistance needed most desperately may be in building capacity to educate poor regions' farmers, food system employees, teachers

and researchers so that they can generate their own site-specific agricultural knowledge and technology. Resources for building such capacity are most likely to come in part from NAE, as the source of greatest wealth and AKST assets at present, although some developing countries are catching up very quickly.

Global climate change is predicted to cause less severe environmental disruption in NAE than in developing regions, even though NAE countries bear the most responsibility for the accumulation of greenhouse gases. NAE may be an essential source of emergency food assistance and resources for restoration of productive capacity in other regions following severe storms, heat waves, floods and droughts that will result from global climate change.

Some of NAE's current policies and patterns of trading with developing countries diminish their ability to feed their own people by dumping food at below the cost of production, thereby undercutting prices of farmers in developing countries, and delivering food aid that cuts out local and regional farmers. These policies have led to demands by producers and consumers within NAE and other regions for food sovereignty, the right of peoples and sovereign states to control their own agricultural and food policies.

1.3.2.2 Export of AKST, other forms of KST and concepts of development

NAE countries produce much of the knowledge and technology used outside the region, as well as within. International development agencies, financial institutions and TNCs have exported many elements of the agricultural systems developed in NAE into developing countries through extension services, other types of training, demands to adopt certain kinds of agriculture as part of structural adjustments on which loans are conditioned, market incentives and deals set up between corporations and the governments of developing countries. This is a push/pull flow of knowledge and technology because developing countries often are eager for access to the factors that have helped NAE become a dominant force in global production and marketing of agricultural goods and services.

Although NAE no longer controls most of the developing world as colonies, it still holds sufficient political and economic power to influence the internal affairs of developing countries, including choices of development paths. Along with tangible exports and discrete clusters of AKST, NAE has the influence to ensure that concepts and ideas about economic development held by powerful entities in the region are adopted in other regions. These concepts have been especially influential when they infuse mandatory structural adjustment plans or poverty reduction plans, or when granting a loan or other aid is contingent on adopting them.

1.3.2.3 NAE's footprint

The application of AKST in NAE has expanded its ecological footprint and social impacts in other regions. This is largely due to NAE's volume and variety of exports and imports, and the many actors and networks within NAE that dominate agrifood chains. The globalized agricultural system, in which importers source raw products from the cheapest source and seek to sell processed products where they garner the highest price possible, touches every country in the world. Developing countries frequently supply the genetic resources; unprocessed food, feed and fiber; and labor to process commodities into goods that can be sold at higher prices, yet they do not garner the profits gained from adding value. Demand for cash crops, including biofuel, has trumped land use for subsistence farming from Brazil to Indonesia; demand for cheap labor for farm work or food processing results in workers finding it increasingly difficult to earn livelihoods from agriculture.

Nations do not simply use the natural resources within their own borders. For example, a country may appear to be self sufficient in water if water is not imported directly, but large quantities of "virtual water" may be imported via water used to grow, manufacture and transport agricultural and industrial produce. The US has the largest water footprint in the world, with 2480 $m^3\ yr^{-1}$ per capita, followed by the people in southern European countries such as Greece, Italy and Spain (2300–2400 $m^3\ yr^{-1}$ per capita) (Hoekstra and Chapagain, 2007). Equally, by importing food, countries import primary production also, denying it from local ecosystems. Most countries in NAE have footprints beyond the capacity of their own territories to support, except for the arctic countries of Canada, Russia and Sweden, and Romania and Belarus (Global Footprint Network, 2006).

NAE has a "consumption footprint" as well as a footprint connected with production. "Western" diets high in fats, salt, sugar and processed foods have spread rapidly into developing countries around the world. Their brand-names can be seen in the smallest and remotest villages. Advertising has helped to create demand for dietary changes, such as more processed food and bottled water, which has large impacts on material use and waste disposal. Dietary changes in the proportions of beef and other large animals consumed have dramatic effects on land use worldwide and the amount of land required to feed a population.

1.3.2.4 Wealth and political power

Countries in NAE have unique characteristics stemming from their histories and assets that make them critical to meeting development and sustainability goals. NAE countries and corporations have disproportionate power in AKST (and in science and technology more generally) compared with other world regions. The NAE region contains the wealthiest nations in the world and many

of the countries with the steadiest and most sustained growth in per capita income since 1945. Much of this wealth has accrued through extracting resources and the profits of labor from other regions.

Agricultural knowledge and technology are controlled in unusual ways in NAE, compared to other regions of the world: the private sector plays a dominant role, especially in North America. The ratio of public to private investment in agricultural research has dropped steadily since 1980. As late as 1940, agricultural research represented 40% of all federal research funding, but national security concerns became pre-eminent with World War II (Fuglie et al., 1996). Investment in private agricultural research has grown more rapidly than public investment in research and has exceeded funds for public research since 1980 (Meeks, 2006). NAE countries are the point of origin of most TNCs that now dominate globalized food systems. Six of the top ten pesticide companies by total sales, eight of the top ten seed companies, all of the top ten global food retailers and all of the top ten beverage and food processing corporations are based in the United States or Western Europe (ETC Group 2005). NAE countries are also the source of development of most genetically modified organisms, and companies based in NAE hold more than half of the Intellectual Property Rights (IPR) relevant to agriculture.

Institutional and organizational shifts in NAE agriculture may presage similar shifts in developing countries. As the influence of traditional agricultural interest groups and state governments wanes, the power of organizations dominated by the private sector and civil society is waxing. These power shifts are related to the application of AKST: greater wealth and power allow greater access to AKST and sometimes greater capacity to create AKST to serve one's own needs. For example, knowledge of global market trends and prices is critical to the success of major agribusinesses involved in trade, and they can access this information more readily than a small-scale producer. While part of their advantage is due to economies of scale, policies that favor large businesses are influential as well. Power shifts in agriculture in North America are mirrored by rising inequity of wealth and assets.

1.4 Description of the Region

1.4.1 Social, political and economic development

1.4.1.1 Prior to 1945

It is thought that people first entered the NAE region via southwest Asia, spreading northwest into Europe and east into Asia some 40,000 years ago, and into North America across the Bering Strait land bridge between 15,000 and 9,000 years ago (Dixon, 2001). While waves of nomadic migration, conquest and trade resulted in intermittent interactions among the Eurasian cultures, sea level rise cut all but the most tenuous links with North America until European exploration and

colonialism began in the 15th century. The subsequent migrations into North America were essentially economic, involving well over 12 M people from Europe (Gibson and Lennon, 1999) and an estimated 500,000 slaves imported from Africa (US Census Bureau, 2002). As the United States grew in area and economic power, the indigenous peoples were greatly reduced in numbers and largely displaced by the end of the 19th century. Indigenous food systems based largely, but not entirely, on hunter-gathering were replaced by arable agriculture and extensive grazing. Simultaneously, Russia expanded its political control from eastern Europe to the whole of mainland north Asia and Alaska (sold to the US in 1867). At the turn of the century, the global economy of the region was politically and economically dominated by NAE major powers linked by trade and diplomacy. However, the Russian Revolution, the economic and agricultural depressions of the 1920s and 1930s and World War II polarized the region into the largely communist eastern Europe and USSR and the largely democratic and capitalist western Europe and North America. This polarization, along with variable access to all forms of capital (human, social, financial, physical and natural) drove widely varying attitudes about the importance of agricultural development, agrifood self-sufficiency, trade, subsidies for multifunctional agriculture and AKST in the different sub-regions of NAE in the following decades.

1.4.1.2 After 1945

Post-war economic recovery in western Europe was rapid, despite the loss of cheap raw materials and captive markets as Britain, the Netherlands, France, Belgium and Portugal decolonized from around the world. Comprehensive welfare systems were developed, drawing on lessons from the depression in the interwar years. Belgium, France, Italy, Luxembourg, the Netherlands and West Germany established the European Economic Community in 1958. Denmark, Ireland and the UK joined in 1973 (a referendum in Norway rejected membership), with Greenland withdrawing in 1985. Greece, Spain and Portugal joined in the 1980s, by which time they were governed by democracies. Further expansion took place in 1994, leaving only the neutral Switzerland, Norway and Iceland as major western European countries outside what had become the European Union (EU). The early focus of the European Economic Community was on the Common Agricultural Policy (CAP) and common policies for coal and steel. Over time, a much wider range of common policies were developed, addressing domains including culture, consumer affairs, competition, the environment, energy, transport and trade.

After liberation from Nazi occupation, countries in central and eastern Europe found themselves strongly influenced politically and economically by the Soviet Union. In response to the establishment of NATO in 1949, the Soviet Union and its allies set up the Warsaw Pact in 1955. Creation of the Berlin Wall marked the final division of the communist East (including Czechoslovakia, Hungary, Bulgaria and Romania) and capitalist West by the “iron curtain”.

Despite also being communist, Yugoslavia was never part of the Eastern Bloc, and Albania broke away in the 1960s, aligning instead with China. In eastern Europe, private enterprises were mostly taken over by the state, as was agricultural and forest land, except in Poland and Yugoslavia. The Communist Party controlled production through rigid Five-Year Plans for required outputs by sector and by commodity. These were not uniform, nor did they provide consistent benefits. Hungary introduced limited market mechanisms, and relaxed controls on compulsory deliveries and land ownership. By the mid-1960s Hungary was relatively prosperous, as was Yugoslavia, where private ownership of land and enterprises was maintained along with freedom of international trade and travel. Elsewhere, Five-Year Plans gave the illusion of continuing quantitative success even when growth rates slowed and targets failed to be met.

By the 1980s it was obvious that the Soviet Union was lagging economically behind the West. Uncontrolled military spending (consuming over 30% of the Soviet GDP) and diminishing domestic economic returns could not be maintained politically or economically (Davies, 1996). Communist regimes started to lose power; in 1989 the Berlin Wall came down and in 1990 East Germany committed to unity with the West, while the communist federal government of Yugoslavia gave way to largely nationalist democracies in the constituent republics. A wave of establishment of independent states followed: Czech Republic, Slovakia, Serbia, Slovenia, Croatia, Bosnia-Herzegovina, Macedonia. The Soviet Union was dissolved in 1991. While most of these transformations were peaceful, many thousands of Bosnians, Croats, Serbs and Albanians were killed during the wars of 1991-2001, and disputes continue in the Caucasus. Overall, NAE has enjoyed relative peace and stability over the last half-century, compared with other sub-global regions.

The basic choice facing post-Communist governments was either to attempt a quick transformation from subsidized socialist economies into market-driven capitalism or to proceed cautiously, disposing of problematic sectors of the economy while preserving for as long as possible cheap rents, guaranteed jobs and free social services. Poland, Hungary and the Czech Republic already enjoyed relatively high standards of living (with average monthly wages approaching $400 in the late 1990s) and familiarity with western lifestyles. These countries adopted the first approach and were among the ten countries joining the EU in 2004; Bulgaria and Romania followed in 2007. By contrast, Ukraine (with monthly wages around $80 in the late 1980s) was reluctant to liberalize domestic markets or reduce the state’s share in the economy and delayed change (Judt, 2005). Further east, attempts to reform the inefficient and militarized economies of the former USSR caused sharp rises in unemployment and destitution.

Foreign investment into Canada doubled during 1945-55, and discoveries of oil, gas, iron ore and other raw materials helped to expand industrial production (Sautter, 2000). The US economy was much larger, producing half of the world's goods by the 1950s. Standards of living soared; and new, consumer-based lifestyles evolved, increasingly reliant on cars. By contrast, 39.5 million people in the US lived below the poverty line, with African Americans, American Indians and farming households particularly affected. Racial segregation led to the civil rights movement in the 1950s and 60s, to be followed by campaigns promoting peace, women's rights and the environment. Their development was closely associated with pop and rock music that proclaimed a radical, English-language culture across the radio waves of much of NAE (Jones, 2005).

During the period 1913-1998 but primarily prior to 1950, populations in western Europe increased 1.5-fold and those in eastern Europe and USSR increased 1.7-fold, while the US population increased 2.8 fold, much nearer the global average of around 3.3-fold (Maddison, 2001). NAE populations have become older: the median age in the US is now 36 years, although it was 28 as recently as 1970. In Europe, 1.6% of the population was aged 80 or over in 1970, and today the figure is 3.5% (UN Population Division, 2005b). Life expectancy is 80 years for Canada, 77 for the US and 79 in western Europe, but only 65 in Russia and 66 in the Ukraine (UN Population Division, 2005b). In the latter countries, there are now twice as many deaths as births; health problems include alcohol, smoking, tuberculosis and AIDS/HIV (Meier, 2006). Populations in Russia and eastern Europe are forecast to decline by over 20% by 2050; those in western Europe and North America are more likely to increase slightly (UN Population Division, 2005a). This disparity is reflected in the great variation in wealth across the region: the gross national incomes (GNI) per capita of Luxembourg, Norway and Switzerland exceed $50,000, while several countries in eastern Europe have GNI values of less than $5,000 (World Bank, 2006).

Israel was created in 1948 as a Jewish homeland in part of what had been known as Palestine, bringing people together from across many areas of the rest of NAE. Relations with the rest of Palestine and Arab states in the region have dominated Israel's politics to this date. Life expectancy at birth is nearly 80 years, with GNI per capita of $18,000 (World Bank, 2006).

The extent of urbanization varies greatly across the region. It is highest in the densely populated countries of northwest Europe, reaching over 90% in Belgium. In the US, 60% of the population now live in metropolitan areas of at least one million people, and citizens move on average ten times during their lives. Demographic change and suburbanization have been similar in Canada, where there has also been a migration westward, especially to the oil-rich state of Alberta. Urbanization is least in eastern Europe (e.g., less than 50% of the populations of Albania and Moldova), where the differences in wellbeing between urban and rural people may be the

greatest. Thus in Moldava, a country where 48% still work in agriculture, half of the population earned just $19 per month in 2000 (Judt, 2005). Not surprisingly, many people in rural areas are seeking employment elsewhere, especially in western Europe, resulting in depopulation and land abandonment. It is estimated that two million Polish citizens (out of a total population of 39M) have left the country since accession to the EU, while an estimated seven million people have left the Ukraine to find work since the fall of the Soviet Union (Meier, 2006). Many of these people are employed in the food and agricultural sectors; this is also true of the 14M economic migrants to the US since 1990, mostly from Mexico and Asia (US Census Bureau, 2007).

The political and economic situation of indigenous peoples in North America has changed greatly in recent decades. In Canada, the Canadian Constitution was amended to protect Aboriginal rights and the Northwest Territories was partitioned to form Nunavat, a self-governing homeland of two million square kilometers for the Inuit. Canadian aboriginal peoples account for around one million of the total population of 32 M, and they are a young and increasingly urbanized population (Statistics Canada, 2006). The proportion of reported American Indian and Alaskan Natives in the US is smaller, at around one percent of the population, and also with a lower than average median age (US Census Bureau, 2007). The purchase of the Hard Rock Café chain by the Seminole and establishment of casinos on native lands indicate the increasing wealth and power of at least some of the tribes, yet sharp disparities persist between US American Indian and white populations in most indicators of health and well-being. There are far fewer native peoples in Eurasia, with around 30,000 native speakers of the Samoyedic and other languages dispersed across northern Scandinavia and Siberia and into the Aleutian Islands.

Literacy rates are high across the region, and funding for education is at least 3% of GDP in every country. The number of women studying for a university degree has dramatically increased since 1945. In both eastern and western Europe, the proportion of women students ranges between 45 and 62%, with almost twice as many taking humanities and arts than science, mathematics or computing. Women now account for over 40% of non-agricultural jobs across most of the region, but in all EU countries women earn less on average than men. The gender pay gap ranges from less than 10% in Portugal, Belgium and Italy to 22-25% in the UK, US and Germany; in the US white women earn 76% of the wages of white men for comparable work. In most EU countries women spend about twice as much time on domestic work as men, although the ratio is considerably smaller in Sweden and Finland and much larger in Italy and Spain (EUROSTAT, 2007b).

1.4.2 Natural resources and their exploitation

Taken as a whole, the region is well endowed with land, with temperate climates and soil conditions suitable for farming and forestry. The NAE region is circumpolar, bounded in the south by mountains, deserts and the Gulf of Mexico, Mediterranean and Black Seas. The climates, and hence conditions for agriculture, are determined largely by latitude, altitudes and proximity to prevailing winds from the oceans. North-south gradients range from polar to desert: Russia is the coldest populated country in the world, with a mid-annual temperature of –5.5°C, and more than half of the country currently covered with permafrost. By contrast, California experiences the hottest temperatures recorded on the planet. Precipitation is governed more by east-west gradients. In Eurasia, the climate is milder in the northwest, which is warmed by the Gulf Stream that also carries rain from the Atlantic. Further east, the climate becomes drier and more continental, with greater variation between winter and summer. The equivalent gradients in North America are east to west, with precipitation decreasing until deserts are reached in the southwest. Wet, warm winters and hot, dry summers characterize the climates of the Mediterranean and California.

1.4.2.1 Fresh water

The freshwater resources of the region are distributed unevenly across the region, both in terms of geography and per capita. In 1995, the region consumed around 300 km^3 of water, out of a global total of 1,800 km^3; nearly two-thirds of this was used for irrigation (Rosegrant et al., 2002). The rivers running from the region's mountains determine the water supplies to the lowlands and the potential for hydropower; the reliability of these resources is at risk because of changing climates. Water supplies in western Europe are most under pressure in Germany, France and the Mediterranean (including Israel) because of the low rainfall, high irrigation demand and high populations. Many states in Eastern Europe also have water use rates of over 20%. The Russian utilization rate is low (2%), but hides great inequalities. This is why it has been proposed to divert the Volga, Ob and Irtysh rivers to provide more water to Central Asia, with very uncertain environmental consequences. Increasing competition for water exists in the arid western sections of the US, not only to meet agricultural and hydropower needs, but also for drinking water in growing urban areas, Native American water rights, industry, recreation and natural ecosystems. As a result, many aquifers are losing water at rates far higher than recharge rates. In Canada, water consumption per capita is high by international standards (1420 m^3 per capita in 1996); but total consumption is only 2% of the available renewable supplies. The electricity sector consumed 64%, the manufacturing sector 14% and the primary-resource sector 11% (mostly for agriculture) (Gunton et al., 2005).

1.4.2.2 Energy

For much of the region's history, the major energy sources were wood and charcoal until replaced by coal. As agriculture intensified, it became increasingly reliant on fossil fuels for the production of fertilizers, the transport of materials and the processing and transport of the final product. A recent study in Sweden showed that a meal of beef, rice, tomatoes and wine required inputs of 19.0 MJ, compared with the dietary energy of a mere 2.5 MJ (Carlsson-Kanyama et al., 2003). Agriculture and forestry are increasingly seen as sources for renewable energy, in the forms of biomass, biofuels and biogas. Very large increases in production are anticipated, driven by changing policies across the region. The EU is now committed to replacing 5.75% of all transport fuels with biofuels by 2011 (EU directive 2003/30/EC); and US biodiesel production capacity is expected to increase to 9.5×10^9 liters per year by the end of 2008, from 6.5 million liters in 2000 (National Biodiesel Board, 2007). The diversion of large areas from food to biofuel production will have uncertain but very large consequences for agrifood systems, especially as land and water availability are simultaneously reduced through climate change, sea level rise and increased urbanization. These consequences are already becoming apparent in some countries as the price of bread and other staples has risen more rapidly than the rate of inflation.

1.4.2.3 Fisheries

The NAE region borders the largest marine fishery, the northwest Pacific (21.6 tonnes in 2004), and the fourth largest, the northeast Atlantic (10.0 M tonnes). Most of the marine fisheries are fully or over-exploited. Catches have declined in the northern Pacific, but not as precipitously as in the northwest Atlantic, where catches are now around two million tonnes yr^{-1}, around half the levels in the early 1970s. Five species of fish caught here are now considered to be critically endangered (Devine et al., 2006). To prevent further erosion of the resource base and ensure sustainable development, Fisheries and Oceans Canada is working with a range of stakeholders to develop and implement integrated ocean management plans as part of the 1997 Oceans Act (Quigley and Harper, 2006; Rutherford et al., 2005). Reporting of inland catch fisheries is much less precise, but it seems that Europe and North America account for only around 6% of global catch, with dramatic declines in Europe. Aquaculture is increasing, but at very low levels compared with Asia (FAO, 2007).

1.4.2.4 Marginal lands

The areas north of the tree line constitute the arctic and tundra. Hunter-gatherers have long exploited this biome, and were at least partly responsible for the extinction of the megafauna of the region. Indigenous peoples still continue traditional practices; but population densities are very low, and impacts on natural populations tightly regulated. Thus while Nunavat relies heavily on hunting for its economy, it has a total population of less than 30,000 (Statistics Canada, 2006). The Sami people of northern Scandinavia herded reindeer, but this nomadic lifestyle has only

been practiced by small numbers in recent centuries and has virtually ceased. It is continued by some of the Nenets people further east. The natural resources of the area (fossil fuels, minerals and marine fisheries) are exploited more by external peoples. Climate change is already influencing this biome: polar icecaps are shrinking, glaciers retreating and permafrost beginning to thaw releasing methane to the atmosphere, changing hydrology and transforming the region from a sink of greenhouse gases to a source (ACIA, 2005).

In the region's mountain chains, fishing and hunter-gathering is often dominated by tourists. Herders have traditionally exploited the uplands during summers, bringing cattle, sheep and horses down to lower elevations during the winter. This practice of transhumance influenced culture and biodiversity, creating and then maintaining very ecologically diverse landscapes of meadows interspersing forests. Transhumance continues on public and private lands in the US West. The conservation of transhumance in Europe is now a matter of choice more than economic necessity. The EC seeks to retain such landscapes through regional development and agri-environmental policies; but in many areas, meadows are giving way to forest as rural areas become depopulated and land is abandoned.

1.4.2.5 Forests.

South of the tree line is a belt of coniferous forest, extending across Canada, Scandinavia and Siberia. These boreal and taiga forests are very extensive, accounting for much of the estimated 1.6×10^9 ha found in NAE, 40% of the world total (FAO, 2006). Russia has the largest area of forest of any country, at 809×10^6 ha, nearly twice as much as Brazil, with the vast proportion found in Siberia. Canada and the US hold the third and fourth largest areas of forest (310 and 303×10^6 ha respectively). The forests continue to support indigenous cultures, including 80% of indigenous Canadians and 26 distinct peoples in Siberia (Taiga Rescue Network, 2007), along with populations of large mammals including moose, caribou and the extremely rare Siberian tiger. Further south of the coniferous forests, the climate is milder, suitable for a natural vegetation of broadleaved woodland where rainfall is high enough; scrub, grassland and desert elsewhere. In the absence of people, much of Europe west of the Black Sea and much of the US east of the Great Plains would have been forested. There remains very little European forest in its primeval state, most having been cleared or transformed by management by the 1500s. Deforestation took place much later in America. Most of the US east of the Mississippi was covered by virgin forest in 1650, with large tracts remaining 200 years later; now only fragments survive. Across NAE, most remaining forests have been transformed by management aimed at increasing productivity of timber. Conflicts between commercial, environmental and indigenous interests have sharpened in recent decades and in some areas forests are now managed to provide multiple functions, including leisure, fuel and provision of forest foods (FAO, 2006). Rates

of wood removal have been more or less constant during 1990-2005 (FAO, 2006). The industry now provides livelihoods for three million people in Europe.

1.4.3 Agrifood systems

1.4.3.1 The development of agrifood systems to 1945

Eurasian agriculture began in southwest Asia around 9,000 BC with the deliberate cultivation of emmer and einkorn wheat. Crops were typically small-seeded (e.g. wheat, lentils), grown with the use of plows. Most farm animals were domesticated in central and southwest Asia, except for the horse in the Caucasus and the pig in China (Solbrig and Solbrig, 1994). As arable agriculture spread north and west across Europe, forests and scrub were cleared by felling or fire to make way for complex farming and forestry systems to provide food, fiber, fuel and other products. Crop rotation systems were developed to manage crop nutrition and diseases. Terracing, irrigation, drainage and flood plain management were used to manage water availability, while woodland edges were retained as hedgerows and lines of trees to provide barriers to livestock, animal shelter and additional food resources. The resulting mosaics of woodland, crops, grasslands and heaths created landscapes now highly valued for their biodiversity, cultural heritage and beauty. Further east, nomadic societies developed that herded domesticated animals for meat, milk, hides and transport.

Agriculture developed independently in the Americas, with cropping of maize, squash and beans, sown with the help of a hoe and digging stick; plows were unknown until the arrival of the Spaniards. Cropping supplemented hunting and gathering for a population of around ten million in what is now the US in the late 15th century. The colonization of North America from Europe involved the import of farming systems, their crops and animals, and the introduction of some American plant species into Europe. This “Columbian exchange” resulted in the introduction of whole ecosystems to America, including pests, weeds and diseases, transforming indigenous habitats (Crosby, 1986) and subjecting the indigenous populations of the Americas to new diseases (Diamond, 1997). The much-reduced indigenous peoples were pushed to the margins of productive land or forcibly assimilated.

By the early 19th century, small-scale, mixed farming had developed in ways that had much in common across the region, providing farming families and local communities with food, fiber, animal feed and fuel. The genetic diversity of cropped species was maintained by adaptation to local conditions and selection by farmers, giving rise to many landraces of plant and animal species. Gathered (non-cropped) plants and hunted animals remained important in the diet until populations became urbanized.

Trade and exchange of agricultural produce has taken place for millennia, in both commodities (e.g. the import of grain from North Africa by the Roman Empire) and luxury goods (e.g. the medieval spice trade). The scale increased dramatically in the 19th and 20th centuries, thanks to developments in transport and refrigeration. Goods, capital and labor flowed freely between western Europe, North America and many other parts of the world as benefits of competition were considered to outweigh those of protecting markets.

In western Europe, profitability was sought through increases in production and labor efficiency, and developed through the increasing application of science and technology to breeding, fertilization and mechanization. The steppe areas of eastern Europe and the Great Plains of the US were brought into agricultural production for ranching and cereal cropping supported by irrigation. The rate of change was far slower in eastern Europe, where much land remained in the hands of peasants and former serfs. In the early years of the Soviet Union, all aspects of agricultural production and science development were influenced by the centralized administrative-command system. Collectivization began in mid-1918, and by 1940 as much as 97% of peasant holdings had been merged into kolkhozes.

Western agriculture fell into depression during the 1930s; and in the US, cropped lands recently converted from prairies were struck with drought, degrading the land and creating the “dust bowl”. Resulting poverty displaced hundreds of thousands of rural families from Oklahoma.

1.4.3.2 Agrifood systems post 1945

Many traditional agrifood systems were localized; food, fuel and fiber were consumed close to the point of production. In the second half of the 20th century, these fragmented agrifood systems became increasingly integrated so that global value chains based on the international trade of commodities now dominate the region. The axes used to develop scenarios in the Millennium Ecosystem Assessment (MA, 2003) are reflected in the contrasts between agrifood systems that are globally integrated and fragmented, and between those that are responsive to multifunctional signals or primarily to economic signals.

Fragmented agrifood systems, responsive to economic signals. Dependence on hunter-gathering for food is now restricted to very small numbers of people, almost entirely in polar and forest regions, though hunting, fishing and gathering natural products from forests is of high economic value, especially because of tourism. Labor-intensive patterns of land management declined, as they were both economically inefficient and increasingly unattractive to young people who increasingly migrated to urban areas.

In many eastern European countries, smallholders and local outlets still raise and market most of the agrifood products (especially livestock, potatoes and other vegetables). For example, in the Caucasus and southern Balkans, small farmers produce cereal and oil crops for subsistence and fruit, vegetable and animal products to supplement often very low incomes, in agrifood systems that are largely independent of the rest of the economy (Dixon et al., 2001). Disproportionate numbers of limited-resource and minority producers in the US sell their products through fragmented agrifood systems.

Globalized agrifood systems, responsive to economic signals. Post-WWII Europe faced massive food shortages. While food rationing was an effective crisis-management tool, the longer-term policy in western Europe and the US was to stimulate production by economic instruments (tariffs, quotas and subsidies) and by providing AKST in the form of new varieties, synthetic fertilizers, synthetic pesticides, machinery and advice on their use. Production increased, and the successful farmers were often those who responded to market signals and produced commodity foods at competitive prices, increasing efficiency by increasing in scale and productivity. The numbers of people employed in agriculture (including forestry, fishing and hunting) fell to less than 5% in the EU in 2005 (EUROSTAT, 2007a) and 1.5% in the US (Hecker, 2004). This happened throughout the supply chain, resulting in fewer, larger corporations providing seed, fertilizers, agrochemicals and machinery to farmers, and consolidation of the supply chain from the farm. This has increased inequality of wealth and assets in the agrifood system.

In the EU, food insecurity gave way to surpluses during the 1980s. In the Soviet Union, food production increased more slowly than in the West. Food prices were kept artificially low, with rationing and inflation, periodic food shortages and long lines in shops (Patterson, 2000).

NAE now produces more than enough food to meet its basic needs, and abundant food supplies are now taken for granted across most of NAE. The share of total income devoted to food varies from 14% in the US to well over 50% in the Balkans and Ukraine (FAOSTAT, 2006). After long periods in which the food supply has been constrained by economics, technology or politics, it became increasingly driven by consumers (Ponte and Gibbon, 2005). The experience of buying food has been transformed: at the turn of the 20th century, the goods in shops were on shelves behind a counter, and were packaged and passed to the customer by a shop assistant. Supermarkets reduced costs by enabling the customers to select the produce themselves. They first appeared in the US in the 1930s, and after WWII became part of suburban culture, combining car parking, low prices and an increasingly wide choice. There is now an abundant variety of affordable native and exotic foods available in all but the poorest countries in the region. Consumption of prepared food from shops, fast food outlets and restaurants has grown rapidly.

Post-production sectors of agrifood systems (processing, distribution and sales) now employ a substantial proportion of the workforce throughout NAE. Agrifood systems have become dominated by fewer, larger actors as companies have integrated both horizontally and vertically. Wal-Mart now dominates the American market, Carrefour in France and Tesco in the UK, integrating food production, distribution, preparation and supply into value chains and adding value at each step.

However, the increasing scale and productivity of agriculture became associated with increasing concerns over environment and human health. Environmental concerns included low levels of agricultural biodiversity: 80% of calories consumed worldwide (directly or through milk, eggs and meat) come from just four crops, wheat, rice, soybeans, and maize (Gressel, 2007). The loss of non-cropped biodiversity and landscape quality is regarded as an even more important issue, especially in Europe. Few un-modified habitats remain beyond the poles and high mountains, because so little potentially suitable land is not currently used for agriculture (Fischer et al., 2001). Farmland birds have declined from the 1970s across Europe, although losses of birds of prey due to bioaccumulative pesticides have now been reversed. Traditional agricultural landscapes are threatened by the twin pressures to either intensify or abandon production, resulting in landscape homogenization and further reduction in biodiversity (Petit et al., 2001). The increase in intensive agriculture has also been associated with the decline of other ecosystem functions, including resource protection, water supply and pollination (MA, 2005ab).

Fragmented value chains, responsive to multifunctional signals. Increasing numbers of consumers are concerned about the ethical, social and environmental concerns raised by intensive agriculture, new technologies and globalization (see e.g. Harvey, 1997; Pretty, 1998; Heller, 2003; Tudge, 2003). The vegetarian movement is largely a reaction to factory farming of animals and concerns over animal welfare. In Britain, for example, there were 100,000 vegetarians in 1945 and by the 1990s there were three million, the number having doubled during the 1980s. Purchasing goods certified as produced under standards of fair trade is a reaction to concerns that global trading systems and TNCs disadvantage those who are already poor. Health concerns focus on both the presence of undesirable “contaminants” in food and the overall diet. The increasing market for organic produce largely reflects the wish by some consumers to avoid pesticide residues, growth hormones, antibiotics and GMOs. Organic and locally-produced goods are also valued as ways of avoiding the perceived blandness and stereotypical nature of much modern food (Spencer, 2000). Local foods also benefit from increasing recognition that long-distance transport of food contributes to greenhouse gas emissions (Pretty et al., 2005). Each of these alternate systems has in turn promoted these concerns as a means of increasing their market share.

These trends have expanded markets for higher value, differentiated goods, not least to small farms that were not competitive in more integrated agrifood systems. Some are charging premium prices through farmers' markets, specialist retailers and on the Web. They have achieved this by adding value to the food more widely available in the supermarkets, such as by providing food that is organic, has local distinctiveness, has high standards of animal welfare or has been locally processed and packaged. Markets for food with local provenance, traditional varieties and breeds are increasing in both Europe and North America. Europe has seen a rapid growth in organic agriculture since the early 1990s. Latest figures suggest around 3.4% of EU agricultural land area is now organic, compared with around 0.3% in North America (Willer and Yussefi, 2006).

Globalized, integrated value chains, responsive to multifunctional signals. Most agricultural input industries and food processing, distribution and retail are becoming highly concentrated, with resultant shifts in power dynamics in food systems (ETC Group, 2005; MacMillan, 2005; Ollinger et al., 2005; Arda, 2006; Murphy, 2006). Interlinked networks of powerful TNCs have expanded their reach upwards and downwards in the chain of production through strategic mergers with input companies such as seed suppliers and biotechnology firms involved in seed production and through financial arrangements with global retailers. The outcome has been global value chains or networks that exert increasing control over what is to be produced, how and by whom (Gereffi et al., 2001).

Integrated agrifood chains are also adapting to changing regulations and customer demands. All levels of the industry are increasingly seeking to demonstrate their commitment to high quality, responsible production and retailing through accreditation, auditing, traceability and labeling. To help assure these new standards, companies such as Sainsbury's (UK) are establishing direct contracts with farmers around the world, bypassing systems of wholesalers. Such vertical integration of the agricultural system not only allows a more proactive approach to retailing, it allows control and auditing. The Environmental and Social Report of Unilever (Unilever, 2005), the environmental plans for Wal-Mart and the commitments to Fair Trade by Sainsbury's (Sainsbury's, 2006) are but a few of a rapidly increasing examples of industry efforts to implement and demonstrate to the public efforts to achieve greater sustainability and help meet development goals. Equally, some supermarkets are encouraging local production, exploiting the new markets in local food systems. In the UK, some ASDA stores (a Wal-Mart company) devote shelf space to local producers, while Waitrose and Booth's stores stress to customers their use of named local suppliers. In this way, agribusinesses are seeking to integrate local sensitivity within global strategies. There is competition from new companies, such as Whole Foods Markets, which

preferentially sells organic and “natural” produce through a rapidly expanding network of outlets in the US, Canada and the UK, each with considerable local autonomy.

1.4.3.3 The development of policy

Inevitably, public policy addresses all of the issues raised by changing agrifood systems. In response to the food surpluses of the 1980s, the CAP moved away from simply increasing production to transfer wealth from urban to rural areas, and transformed several million peasants into relatively prosperous farmers (Davies, 1996). Subsequently, the circle between the political requirements to stop subsidizing food production and to continue to support farming communities has been squared by changing the emphasis of the CAP to support rural development and environmental goals.

Sustainable development is a major policy goal across most of the region, encompassing agriculture, forestry and fisheries. It is monitored using a wide range of social, economic and environmental indicators. The policy trend in Europe is to promote more proactive agricultural systems, both global and fragmented, with a much greater emphasis on the provision of ecosystem services such as pollution management, carbon storage and diverse habitats, and the management of natural resources such as soil, water, air and landscape quality (Miliband, 2006). Regulations such as the EU Water Framework Directive and support mechanisms such as agri-environmental schemes are helping to raise the environmental standards of agriculture. The appropriate balance between open trade and the use of barriers, tariffs and subsidies remains highly contentious, as can be seen in the Doha Round of the world trade talks. The roles of international trading blocs, such as the EU and North America, consolidated commercially through the North American Free Trade Agreement (NAFTA), have increased.

Recently, issues of energy security (National Economic Council, 2006) and climate change (Stern, 2007) have increased greatly in priority. Policies and practices are being developed to use agricultural land to mitigate climate change by carbon sequestration (Lal, 2004) and to replace some fossil fuel use by the production of biorenewables (Brown, 2003). Increasing biofuel production is already leading to rising prices for cereals, and is likely to increase competition for land, with potentially dramatic changes to farming systems, landscapes and rural economies (e,g, Firbank, 2005). Potential markets in production and management of energy, pharmaceuticals and water add to the uncertainties about the future of agriculture.

1.5 Challenges for AKST

NAE agrifood systems are now facing new challenges that involve simultaneously enhancing social, environmental AND economic elements. The responses to these challenges within NAE will affect development and sustainability goals, both within the region and globally.

The importance of agrifood systems to human health and social change may become more pronounced. AKST is required to improve standards of nutrition; to reduce exposure to foodborne contaminants and diseases, including those transmitted from animals; and to increase the availability of and equitable access to food and other agricultural products. AKST also has a role in promoting markets with fair access and compensation to participants, improving equity across gender and social divides; and creating and sustaining urban and rural livelihoods. These goals must be met while maintaining the stability and resilience of agroecosystems, particularly as they are threatened by global environmental change.

AKST will be required if agrifood systems are to mitigate and successfully adapt to global climate change. Agriculture may need to cope with very different economic and environmental conditions, with new patterns of trade, climate, pests and diseases, while facing more stringent requirements to mitigate greenhouse gas emissions. Climate change may transform the conditions for management of land-based natural resources to ensure delivery of a full array of ecosystem services and food use. Demands are increasing for plant-based substitutes for fossil fuels for energy and industry, in competition with increasing global demands for plant and livestock products. These changes imply the generation and effective sharing, access and use of AKST to develop new genotypes, land management systems and value chains that can deliver multiple functions and are sustainable in rapidly changing social, governance, economic and environmental conditions.