International Assessment of Agricultural Science and Technology for Development

Summary for Decision Makers for North America and Europe

Draft: April, 2007

Key Findings

- An increased number of technologies and tools have become available to agriculture in NAE through advances in AKST supported by dedicated food supply oriented policies. These have significantly increased agricultural productivity over the last 50 years, largely resolved the problems of hunger, decreased real food prices and generated surpluses in many parts of NAE;

- Intensive cropping and livestock systems have caused significant adverse environmental impacts, e.g., soil degradation and salinization, water scarcity and pollution, loss of biodiversity and emissions of greenhouse gases that contribute to human-induced climate change, and is leading in a rise in environmental regulations;

- A general abundance of food calories and fats has caused nutrition related chronic diseases including obesity;

- Successfully meeting the IAASTD development and sustainability goals requires continuing recognition of the importance of balancing and supporting the multiple functions of agriculture, i.e., producing food and fiber, providing environmental services, conserving resources and biodiversity, providing livelihoods and supporting the quality of rural life;

- This “multi-functionality of agriculture” can only be understood and achieved by further developing and using new conceptual tools, policies and markets that aid in taking the complexity of agricultural systems into account and by setting agriculture in the entire context of society and ecosystems. Institutional and organizational arrangements are required that support a more integrated approach to the development, dissemination and uptake of AKST.

- Innovative modes of production (crops, forestry, livestock and fisheries) need to be developed that meet the dual goals of maintaining productivity while reducing environmental impacts through diversification and selection of inputs and management practices that foster ecological relationships and biological processes within the entire agroecosystem.

- AKST needs to be strengthened to: (i) support breeding activities, basic and applied knowledge generation, as well as the development of relevant technologies including biotechnologies; (ii) counteract the detrimental effects of agricultural activities on climate change and to reduce agriculture’s vulnerability to this phenomenon; (iii) ensure food quality and diversity, food safety, nutrition and health; and (iv) understand the root causes of new and emerging human, plant and livestock diseases.

- Increased emphasis on inter- and multi-disciplinary research programs, the involvement of more diverse stakeholders in defining research agendas, and the provision of education, training and advisory programs that enable a much wider group of stakeholders, policymakers and the public would help to address these new complexities.

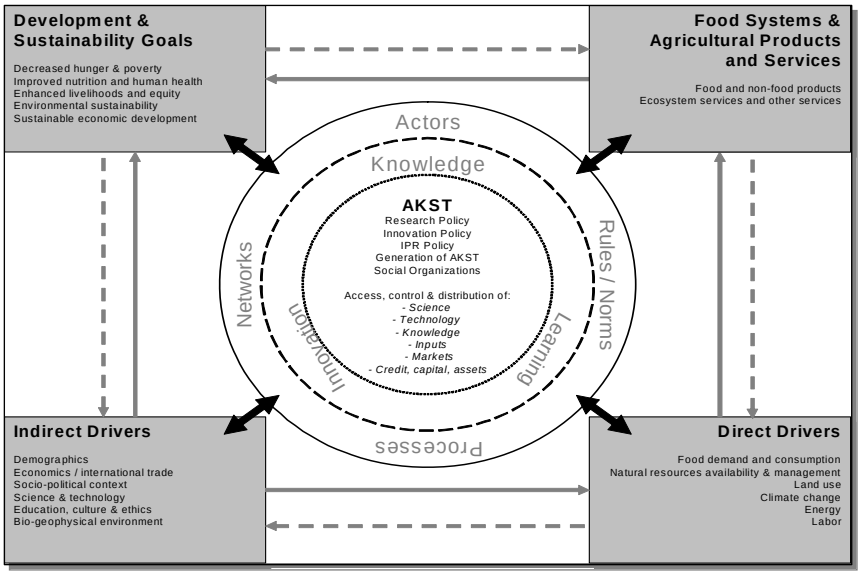
- Increased and more diverse funding (public and private sector) and delivery mechanisms in agricultural R&D and human capital development are needed, with public investments focusing on aspects of the public good and human development.

Introduction

Different political and socioeconomic histories during the 20th Century have driven very different paths of agriculture and agricultural knowledge, science and technology (AKST) across North America and Europe (NAE) that are now converging around a common agenda where the importance of the multiple functions of agriculture (producing food and fiber, providing environmental services, conserving resources and biodiversity, providing livelihoods and supporting the quality of rural life), and its adaptability to local environment and social contexts is increasingly recognized. Agricultural systems in NAE are mainly temperate; and agricultural resources (environmental, social, infrastructural, financial, etc.) are relatively abundant per capita. Until the 1980s agriculture and food systems across NAE primarily sought to produce abundant, cheap food, resulting in large areas being dominated by intensive food production, generating food surpluses. Increasing productivity of agriculture in Western Europe and North America came with environmental and social costs. From the 1980s onwards in Western Europe new social demands called for a more multifunctional agriculture. These demands are being heard in North America as well, although political responses have been weaker. In Western Europe, the subsidy of food production is giving way to payments for social and environmental benefits, at the same time as consumer demand is increasing for food produced and supplied that contributes to animal welfare and social justice, and for local provenance. Environmental protection in agriculture has improved through increasing regulation. In North America, subsidies are still largely coupled to agricultural production and contribute to production of surpluses and serve to maintain the current power structure in the food system. Consumer demand for local and social value-added goods is rising in this part of the region as well. Thus, in North America and Western Europe, policies and regulations are moving from ensuring food security to a more multifunctional view of agriculture.

The relationships among agriculture, AKST, and the IAASTD development and sustainability goals are complex and illustrated by the following conceptual framework (Figure 1), which shows the inter-relationships among and between the indirect and direct drivers of change, food systems and agricultural products and services, the development and sustainability goals, and how each of these influence and are influenced by AKST.

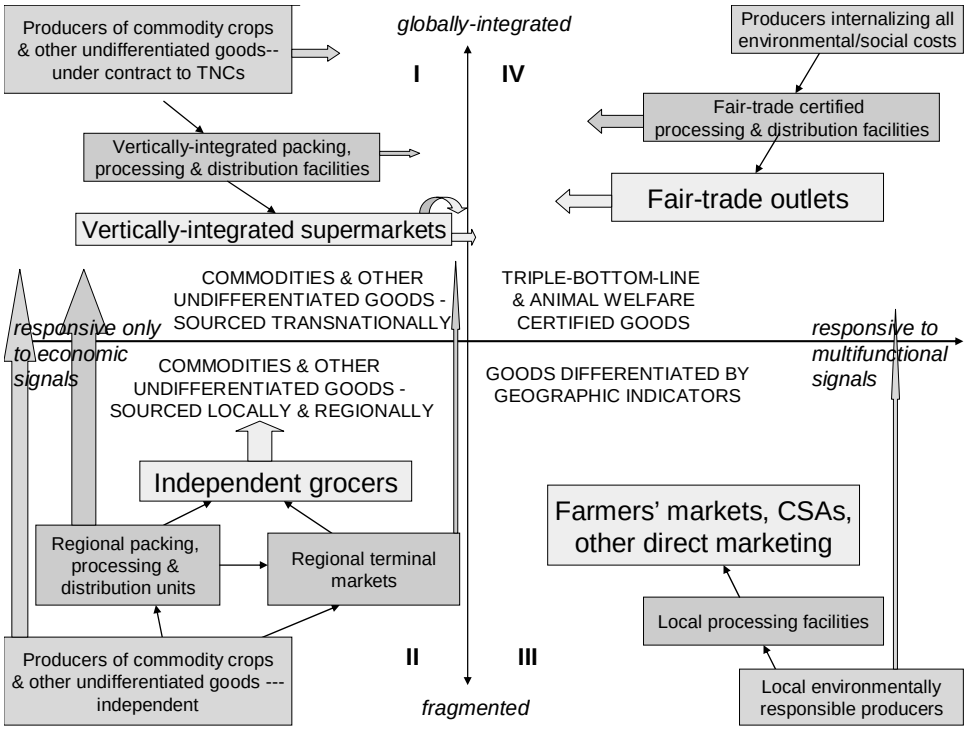
Figure 1. IAASTD Conceptual Framework



The main drivers of changes in AKST in NAE over the past 50 years have been shifts in policies, regulations, and markets. Knowledge and technological progress outside agricultural systems have been as or more influential than factors internal to agriculture. In particular, technological advances in transportation and communication that allowed the globalization of food supply have been critical. Changes in international property regimes, especially the development of Intellectual Property Rights, have influenced how benefits of AKST are distributed.

Agricultural value chains, currently dominated by multinational corporations responding to economic signals, are becoming more socially and environmentally responsive, becoming a significant driver of AKST. These new "value chains" driven by consumer demand for products that embed social and environmental values are shown in Quadrants III and IV of the Figure 2, which shows typical products for each quadrant. Value chains are operating in all four of these quadrants at present, but products in Quadrant I and businesses operating in that mode dominate global agricultural markets. Businesses in Quadrant II are losing market power because they are unable to compete with the economies of scale that globally-integrated businesses (in Quadrant I) achieve, and the added value of "place-based" or geographically-indicated goods (in Quadrant III) and products that respond to new consumer demands (in Quadrant IV).

Figure 2. Typical products from alternative agricultural value chains.



Part I: Present and Past Consequences of AKST on the Development and Sustainability Goals

In NAE, an increased number of technologies and tools have become available to agriculture. These have been primarily developed from biology, medicine, and chemistry through advances in AKST supported by dedicated food supply oriented policies. The application of these tools and technologies has allowed farmers, foresters, and fishermen to greatly increase the productivity and quality of cropping and livestock systems, aquaculture, and forestry in NAE. Dissemination of these new knowledge systems benefited from new tools and technologies (e.g., advances in information and communication technologies) for efficient knowledge transfer systems in the governmental and private sectors:

- ***Production of arable crops has at least doubled over the last 50 years in NAE particularly in output per unit area.*** These increases are due to increased mechanization, new breeding techniques, and changed management systems (e.g. the use of fertilizers, herbicides, pesticides, decision support). Development of more and better irrigation and

drainage, coupled with the conversion of pasture to permanent cultivation also contributed to these increases;

- ***Livestock productivity and output in NAE has increased enormously since 1945 driven by policy (including subsidies) and increased demand resulting from a growing and wealthier population.*** Meat production has more than doubled in the United States since the 1950s with similar changes in Europe. This production has been driven by improved animal breeding, improved pest and disease control (including the use of antibiotics), increases in pasture output per unit area, and the development of intensive rearing systems;
- ***NAE is the only world region where there has been an increase in forest area since the 1960s, partly as a result of increased tree farming and partly resulting from reversion of marginal agricultural land.*** Demand for forest products has increased dramatically because of a larger and wealthier population. In the past twenty years, especially in Europe and Canada there has been a trend away from productivity-driven forest management systems towards systems aimed at multiple uses of forests, especially for the provision of biodiversity and leisure activities. This trend is opening up new economic opportunities for the application of AKST. New technologies have also been introduced into forestry to meet increased demands for timber, resulting in more efficient harvesting and processing and better access to remote areas. These tools and technologies have developed in parallel with policies that have aimed to increase productivity as well as advances in research; and
- ***Aquaculture output has and continues to increase, mainly due to saltwater finfish production.*** Breakthroughs have been made in both saltwater and freshwater fish farming leading to significant increases in productivity at a time when fish catches from the open oceans are decreasing because of over-fishing in many parts of the world.

The increase in agricultural productivity in NAE has led to a significant decrease in real prices for agriculture products over the last 40 years. The decrease in real prices and increased availability of food has led to more affordable food for the majority of the population in NAE. The combination of the decrease in food prices and an increase of personal income in NAE countries has resulted in a decreasing share of household expenditures for food, which in part has led to the development of food processing, food service and catering businesses, concurrently with an increasing demand for food variety, including a higher demand for ready-made foods, quality foods, organic foods, fair trade and animal friendly produced foods and ethnic regional and traditional foods.

During the last 60 years, AKST has made a major contribution to achieving food security in North America and Northern and Western Europe, largely, but not completely, resolving the problems of food shortages experienced after World War II. It has also led to a

situation of surpluses in much of the NAE, where supply exceeds demand of crops, livestock and forestry products:

- Higher levels of food production per capita were achieved in western regions of NAE compared to the eastern regions partly due to a more decentralized approach to decision-making in AKST and more integration among research, education and extension. North America and Western European countries have become major exporters of agricultural products (with Government subsidies for some commodities), resulting in market distortions throughout the rest of the world. NAE agricultural policies have supported food security by erecting substantial trade barriers and providing direct and indirect subsidies in key agricultural sectors that reduce the ability of other countries including developing countries to compete.
- In Eastern Europe and Russia from 1945 until the 1960s, agriculture was more directly managed by the state than in the West through central planning, collectivization and state farms. As a result, the degree of food self-sufficiency increased, but from the 1960s until 1989, the former USSR begun to import food from Western Europe, USA and Canada. While hunger and food insecurity are far less common in NAE than in most other parts of the world, they still exist.

The food supply oriented policies were very successful at increasing the total production and increasing the productivity of labour and land. By the mid-1960s, the productivity improvements started to generate surpluses. Competition for labour from other sectors of the economy has forced the farming sector into larger entities and to improve efficiency by specialization and mechanization, which has led to: (i) a need for fewer of farmers and farm workers resulting in a rural exodus in many sub-regions; (ii) a changed pattern of work for the hired labor force; and (iii) an increase in contract work and part time farming.

The utilization of AKST, which operates within a dynamic economic and political framework has brought about significant changes in farm and food systems, contributed to lower prices, benefiting consumers, but has led to pressure on farming communities and structural change in the food industry. In North America and Western Europe (EU15), this has substantially increased the relative power of retail and processing food business in relation to processors and farmers. Agriculture has become more capital intensive and less labour intensive, resulting in changed lifestyles within rural communities, particularly increasing the amount of off-farm work and leading to substantial migration within and between countries. Application of AKST has contributed to the horizontal and vertical integration of the whole food industry, where there is a growing influence from large-scale retailers and catering/food service businesses as well as dependency on inputs (for machinery, chemicals, and pharmaceuticals

from other sectors. The large-scale production systems of these integrated food chains have resulted in:

- Potential larger scale consequences of breaches in food safety leading to increased regulatory requirements and costs;
- Lower prices, which have benefited consumers, although there is increasing demand for foods which that are perceived to have improved quality/safety (e.g., organics, fair-trade);
- Farmers facing reduced income, with many families now depending on off-farm incomes to maintain living standards;
- Market power shifting towards large retail and food service organisations that now wield enormous influence in decisions regarding products that are promoted for sale and where these products are sourced from.;
- Increased levels of waste generation (food and packaging); and
- Increased transportation of foods and agricultural products.

Health conditions relating to diet-related diseases and obesity are rising, and are more severe and prevalent in NAE than elsewhere. A general abundance of food calories and fats in most parts of NAE has caused nutrition-related chronic diseases including obesity in much of NAE over the last 15 years has a heavy economic, public and social cost. In some countries, more than 30% of adults are obese (with a body mass index higher than 30 kg/m^2) and obesity is estimated to account for 2 to 7% of total health care costs. NAE is now facing a new challenge: favouring healthy diets and educating the consumers to choose appropriate diets and increase physical activity in order to maintain their health and reduce their risk of nutrition related chronic diseases.

Significant adverse environmental impacts caused by intensive cropping and livestock systems, as practiced in NAE and elsewhere, have included:

- *Soil degradation:* Salinization and erosion of soils in vulnerable areas due to unsustainable irrigation practices; soil erosion and soil compaction caused by intensive cultivation practices, and aided by increased mechanisation; and overgrazing and land degradation from livestock;
- *Water scarcity and pollution:* Intensive irrigation demand and overuse of water resources (mining) that leads eventually to scarcity in dry regions; eutrophication of rivers, lakes and coastal waters as well as contamination of groundwater due to elevated levels of nitrogen and phosphorus from excessive fertilizer use, manure application and intensive animal production wastes; and contamination of freshwater by pesticides.
- *Greenhouse gas emissions:* Emissions of greenhouse gases that contribute to human-induced climate change;

- *Loss of biodiversity:* Loss of biodiversity and agrobiodiversity in crops and livestock breeds; and reductions in biodiversity associated with intensive pesticide use.

Awareness of the adverse environmental impacts of agricultural practices has resulted in the rise of environmental regulations (which mainly resulted from concern over the widespread use of agrochemicals), new tools and technologies, as well as safeguards on how these may be used. It has also resulted in the further development of alternative production systems, including Integrated Crop Management (ICM) and organic agriculture. This awareness is also leading (especially in Western Europe) to recent changes in agricultural policies away from production-led subsidies towards more market-led, sustainable, and environmentally friendly systems.

Greenhouse gas emissions from agriculture in NAE, which contribute to climate change, are in the range of 7-20% of total anthropogenic emissions (by radiative effect):

- Approximately 30% of anthropogenic global methane emissions are thought to originate from agriculture, of which enteric fermentation from ruminant livestock is by far the greatest contributor. AKST is contributing to the development of feedstuffs to minimize this, and has already developed anaerobic digestion technology, which could treat animal manures and capture useful by-products (i.e. biogas production);
- Agriculture contributes at least one third of global anthropogenic emissions of nitrous oxide due to the development and rise in the use of inorganic nitrogen fertilisers. AKST has made a significant contribution to reductions in these through better fertilizer application; and
- Carbon dioxide emissions from agriculture are small, globally estimated to be 5% of the total (not counting contributions from deforestation). Direct energy use only accounts for between 1 and - 2% of emissions. The conversion of fields from conventional to conservation tillage increases the organic carbon content of soils (carbon sequestration in soils) causing net removal of the greenhouse gas carbon dioxide from the atmosphere.

The adoption of genetically engineered (GE) crops has so far not led to the creation of invasive species or had major impacts on non-target organism populations in the limited areas of NAE where they have been used. Uptake of genetically engineered crops has differed markedly in the region and has been applied in just a few cropping systems (soybeans, corn, canola, and cotton) in North America. Use of insect resistant GE crops has resulted in lower pesticide use by adopters in some commodities, and use of herbicide tolerant crops is associated with wider adoption of conservation tillage. However, there are some governments and members of society in both NAE and in other regions that continue to have science-based concerns about the potential negative impacts in the long term. Consequently, understanding the potential positive and negative impacts of GE crops needs to be further strengthened and the actual

effects documented. The cultivation of GE crops with their benefits and potential hazards to the environment should continue to be considered within broader ecosystems on a case by case basis to factoring in the GE trait, and region where it is to be used, and how it is to be used.

NAE regional activities significantly impact the ability to globally meet the development and sustainability goals because of: (i) agricultural surpluses distort markets (a product of good agricultural land, and the mix of technologies, practices and policies in place); (ii) the large volume and variety of imports; and (iii) the many actors and networks that dominate food chains, fuel chains and AKST (including Intellectual Property Rights and patents). Businesses within NAE have a powerful impact on consumer demand in the rest of the world and extract commodities, genetic resources and labor from other regions.

NAE AKST has played a mixed role in the development of the world's agricultural systems:

- The international contribution of NAE AKST was established in some regions with great success for increasing food security, but has had severe consequences for sustainability in some other regions, and most technologies developed in NAE are not appropriate for poor farming communities. Factors that increasingly limit technology transfer from NAE to developing countries include access to credit, infrastructure, human and organizational capacity and regulatory policies, e.g., Intellectual Property Rights, biosafety protocols, and trading regimes;
- The indirect effects of NAE agriculture, diet, policies and food systems have distorted markets and reduced the potential for food and water security in many areas of the world; and
- Many advances in AKST were generated and initially used in NAE, so this region can show the impacts of specific AKST over the longest time period, thus providing illustrative lessons on its application and resulting positive and negative (intended and unintended) consequences.

There has been a trend away from public sponsorship of AKST towards private ownership of AKST, particularly where it yields products that have intellectual property protection. Investments of the private sector in agricultural R&D have increased since the early 1980s and were estimated to be 55% of all agricultural R&D in developed countries in year 2000. The focus of NAE AKST has shifted more towards meeting market-driven goals and away from provision of public goods. There has been increasing privatisation of knowledge systems, particularly in genetic biotechnology. Where new technologies have emerged that can produce products protected intellectual property rights (IPR), often industry consolidation has occurred.

Consolidation has created efficiencies but has also limited the technological options as smaller firms, which can often bring dynamism to a sector, find it hard to compete.

Competition and short-term contracts have increasingly been built into the public sector funding for AKST in NAE. The stated aim of these changes has been to ensure quality, transparency, and efficiency. However, there is evidence that short-term contracts reduce rather than increase quality and efficiency. In addition, short-term approaches are not necessarily appropriate for all areas of AKST relevant to the development goals (e.g. integrated approaches, research aimed at improved sustainability and ecosystem management).

Part II: Future Challenges

Successfully meeting the IAASTD development and sustainability goals and responding to new priorities and changing circumstances will require widespread recognition and a continuing evolution of the paradigm shift that accords increased importance to the multiple functions of agriculture (producing food, feed, fiber and fuel; providing environmental services, conserving resources and biodiversity, providing livelihoods and supporting the quality of rural life), and its adaptability to local environmental and social contexts. This "multi-functionality of agriculture" can only be understood and achieved by further developing and using new conceptual tools, which can take the complexity of agricultural systems into account and view agriculture in the entire context of society and its economic and ecosystems. Institutional and organizational arrangements are required that support a more integrated approach to the development, dissemination and uptake of AKST. Emphasis must be on inter- and multi-disciplinary research programs, the involvement of more diverse stakeholders in defining research agendas, and the provision of education, training and advisory programs that enable for a much wider group of stakeholders, policymakers and the public to understand and address these new complexities.

Encouraging the multiple functions of agriculture through policies and the creation of new markets is an increasing priority across the region (especially in Western Europe) with the growing importance of non-food and ecosystem goods and services, including recreation, ecotourism, water management, conservation and protection of biodiversity and landscapes, and energy from renewable sources. In adopting a broad perspective, there is a necessary recognition of resource and environmental limits. Many of the emerging markets and labelling schemes (such as fair trade, organic and animal welfare) reflect changing consumer values and internalize environmental and social costs of agricultural-food systems. Rising

concerns over security of the supply of food, water and energy and the threat of significant changes in climate have already led to changes in land and other resource uses in some parts of NAE.

Identifying a plausible range of possible futures is helpful in assessing options for future decision- making. When considering plausible futures it is important to take into account the interaction between the agricultural system and the AKST system, and how AKST is influenced by different direct and indirect drivers, such as the socio-political situation and economic, environmental, and S&T policies (see Figure 1). This assessment explored four different types of plausible future AKST systems, which are contrasting, but not mutually exclusive. As they are intertwined in many areas, decision makers will want to assess and combine elements of each of the systems depending on values, priorities and resources. These four explored systems are:

- Market-led AKST to satisfy consumer demands of NAE and also contribute to the provision of sufficient affordable and safe food in and outside NAE;
- Food-supply oriented AKST to satisfy immediate needs potentially at the expense of long-term sustainability;
- Ecosystem-oriented AKST to encourage all countries to effectively mitigate and adapt to the effects of global climate change and other environmental changes; and
- Local learning AKST as a means of integrating across related policy issues.

AKST is essential, but not sufficient to, fully address the challenges in reducing hunger and poverty, improving rural livelihoods, improving nutrition and health and facilitating sustainable development goals. Policy changes, enhanced capacity development and additional investments will be essential to take advantage of advances in AKST.

Part III: Options for Action

1. Developing innovative farming and food systems that meet people's needs and support rural livelihoods in ways consistent with the principles of sustainable development

a) Respond to climate change

AKST needs to be developed to counteract the detrimental effects of agricultural activities on climate change and to reduce agriculture's vulnerability to this phenomenon New farming systems, agricultural practices and land use changes leading to a reduction in GHG emission are necessary. In addition to effective mitigation, AKST must facilitate rapid adaptation of

the food production system and the agricultural sector at large to reduce its vulnerability to climate change. Some possible ways of reducing this vulnerability are improving the capacity to predict future effects of climate change on geographic distribution and productivity of agriculture, and reconfiguring NAE production areas to adapt and optimize available space and resources in "new climate environments". In addition, there is a pressing need to maintain genetic diversity (*ex-situ and in-situ*) that would facilitate the rapid adaptation of agriculture to climate change and other environmental changes.

b) Guarantee food quality and safety through a diversity of agricultural systems and accord more importance to health issues associated with production systems

Given societal concerns, AKST in NAE should focus on food quality and diversity, food safety, nutrition and health. This could be achieved through different agricultural systems ranging from intensive systems providing basic commodities to more extensive and local systems providing differentiated products. Research and technological developments in new food systems need to continue in several directions: deeper understanding of the relationships between food, diet and health; improved quality of raw materials; better systems to control food quality safety vis-à-vis microbial contamination, mycotoxins and xenobiotics and efficient traceability along the entire food chain to ensure quality. All of the above developments could be pursued in the different agricultural systems. Additional research efforts are required on local systems to understand these systems better and to respond to societal demand for these new systems and products.

The root causes of new and emerging human, plant and livestock diseases should be better understood and systemic interventions should be developed that aid in their prevention and better management. In addition, the epidemiological dynamics of the overall system, spatially and temporally, need to be better understood and suitable surveillance and response networks developed including early detection and new diagnostic and curative tools.

c). Position farming systems as part of the ecosystems

AKST should be developed in the ecological and evolutionary sciences as applied to agricultural ecosystems to improve and create management options to contribute to multifunctionality. Such options call for an ecological approach of agro-ecosystems for better water, soil and biodiversity management. Some of the areas for further research and technological developments to facilitate agro-ecosystem management for some natural resources are:

- Understand the factors affecting both quantity and quality of water resources at landscape level better and further develop technologies to harvest water and minimize crop failure in dry areas and to recycle wastewater for agriculture.
- Understand the impacts of land use on soil properties and processes in order to design technological advances to improve soil fertility and other soil functions and to decontaminate polluted soils.
- Elucidate the interrelations between agricultural systems and the spatial distribution and evolution of biodiversity at the landscape level. Advances are also needed in the application of remote sensing, precision mapping as well as other new technologies that allow for more precise monitoring of natural resource uses.
- Promote identification, preservation, characterization and evaluation of wild and cultivated genetic resources and improve the scope and reliability of conservation and utilization of genetic resources through gene banks and in situ and ex situ preservation.

d). Develop innovative food and farming systems

Innovative modes of production need to be developed that meet the dual goals of maintaining productivity while reducing environmental impacts through diversification and selection of inputs and management practices that foster ecological relationships and biological processes within the entire agro-ecosystem. Presently available methods and practices include ecologically based pest management, no-till conservation agriculture and precision farming among others.

Innovative and multifunctional forestry agro-ecosystems, - which in addition to the production function, are main reservoirs of carbon and biodiversity, improve water quality and availability, and control floods and the Earth's climate -, need to be developed through AKST. The increased complexity of the multifunctional roles of forests (economic, social, and environmental dimensions) should be further explored. This includes in particular, methods and tools necessary to monitor and improve productivity, environmental sustainability and ecological integrity of forests through enhanced forestry technologies and improved risk management skills. In addition, methods should be developed to estimate the value of forest ecosystem services, to improve their resilience to climate change and other environmental change, and techniques to regularly assess quantity and quality of forest resources.

The importance of aquatic products in food diets and declining fish stocks call for improvement in the sustainability of the systems for coastal capture fisheries and aquaculture. Regarding coastal capture fisheries, AKST should focus on a comprehensive

understanding of the marine ecosystem with systemic collection of data over a long period (biological and ecological as well as social and economic) and the development of tools and indicators that will help in the management of the ecosystem as a whole. In addition, technologies that facilitate selective fishing are necessary. Urgent priorities in AKST for aquaculture include the need to address provision of alternative sources of fish feed, currently provided from unsustainable capture fisheries, and to continue research into reducing pollution from aquaculture units in both fresh and saltwater environments.

The potential vulnerability of NAE agricultural systems to the declining stocks of fossil fuels can be reduced by developing and using alternative sources of energy and new forms of energy efficient, low-carbon, farming systems. On energy source, which is being promoted by many stakeholders, i.e., biofuels, requires the economic, environmental and social viability of their production to be carefully evaluated. AKST can contribute to the development of potentially economically feasible biofuels and biomaterials that have a positive energy balance, are environmentally sustainable, and that may be ethically justified by not diminishing the world food supply. Research priorities include improving the energy content and quality of biofuel crops and other biomass inputs increasing the overall energy efficiency of production, and improving the efficiency of processing methods (extraction and fractionation techniques).

e) Strengthen efforts for the generation of knowledge, both basic and applied, and biotechnologies for breeding purposes

AKST needs to be maintained to support breeding activities, strengthening efforts for both basic and applied knowledge generation as well as the development of relevant technologies including biotechnologies. Classical breeding is essential and needs to be maintained on a wide diversity of species. Both functional genomics and systems biology focusing on generic as well as more specific metabolic pathways and the establishment of new breeding methods integrating genomics information need to be further developed. There are varying opinions in NAE on the potential benefits and risks of transgenic organisms as well as the required regulatory framework. Assessment of all new breeding developments need to integrate social, economic, environmental and health context and implications for dissemination of new types of organisms, and it must have a long term and wide scale perspective.

f) Develop socially and economically sustainable food systems

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The social and economic viability of agricultural systems needs to be used more as a basis for creating sustainable rural livelihoods and communities. There is a need to

understand how AKST can reduce the vulnerability of farming communities to risk and uncertainty, such as from changing natural or policy environments. This requires understanding the processes by which AKST is developed, promoted and taken up by farmers and workers in response to changing needs, the motivations and responses of farming communities as they cope with uncertainty. New methods, using the concept of sustainable rural livelihoods, are needed to assess productivity and economic performance of farming systems at the farm, regional and national scales which accommodate the multi-functionality of agriculture and its interactions with ecosystems services. In addition, AKST is needed to improve understanding of factors affecting social welfare at the local scale, especially regarding essential 'freedoms' as they define the quality of life and the alleviation of rural depravation. A better understanding is required of institutions which govern access to and use of natural resources, the systems of incentives and rewards for those who earn their living in agriculture, as well as the sources of conflict in rural communities. AKST is also required to help identify and value the economic costs and benefits of the range of goods and services produced by agriculture, provide estimates of the contribution of agriculture and rural services to economic welfare and to design economic instruments that promote an appropriate balance of private and public goods.

2. Providing enabling conditions necessary for innovative AKST systems to function

a) Strengthen human capital and reconfigure organizational arrangements

Human capital needs to be strengthened and organisational arrangements reconfigured to facilitate the development, dissemination and wide use of AKST by:

- strengthening interactive knowledge networks involving multiple and more diverse stakeholders among the research, education, and extension components of the AKST system. (Governments should encourage these cooperative efforts through necessary organizational and structural arrangements.);
- improving AKST processes for involving, informing and empowering stakeholders;
- developing new skills and learning opportunities for existing and future AKST personnel and their various clients so that they can understand and function more comfortably in the context of the wider vision of agriculture;
- enhancing meaningful interdisciplinarity in research, educational programs, and extension/development work without compromising disciplinary excellence. Systemic barriers to interdisciplinarity need to be identified and surmounted;
- strengthening links between research and higher education to promote lifelong learning and the creation of a learning society; and

- strengthening information and knowledge-based systems to enable a rapid, bi-directional flow of information and knowledge between the agricultural sector and the AKST system.

Partnerships between NAE and other regions will need to be reinforced with a view to empowering people in other regions. The establishment of interactive knowledge networks and integrated trans-disciplinary research and educational programs could facilitate the development of working relationships between AKST institutions in NAE and in other regions. Regional and global forums and organizations, particularly the CGIAR, can help to set up such networks.

b) Reshape the policy, governance and market framework

The broad agenda of agricultural and rural development policies calls for a wider and much more coherent policy framework. The new framework should strike a balance between feeding an expanding population, using natural resources efficiently and sustainably, maintaining biodiversity, promoting economic development and the evolving cultural values at the local, regional and global levels. A trans-Ministerial approach is necessary to ensure a better coherence and harmonization of the complex overall framework.

New proprietary regimes that delimit clearly the rights of use and rights of property should be developed. The development of "common property regimes" (including the atmosphere) that go beyond either purely public or private ownership should be considered to optimally use hybrid public/private goods and resources. Identifying factors conducive to the organization of these new regimes would facilitate this. Significant public policy discussions of the nature and implications of these new proprietary regimes for the future are needed.

Intellectual Property Rights (IPR) and its associated regulatory environment need to be reshaped wherever necessary to facilitate the generation, dissemination, access and use of AKST to meet the IAASTD goals. Patents issued need generally to be narrower, cross-licensing resulting in pooling of patents between the public and private sector needs to be encouraged, and compulsory or obligatory licensing needs to be promoted when deemed necessary. The terms under which research exemptions are granted for research and for the extension of existing patents needs to be broadened. Open source technology that leads to collaborative invention should be encouraged.

New modes of governance are required that call for the development of innovative networks at the local level. Tools to facilitate local governance (suitable participatory

approaches that involve the different stakeholders and result in the integration of their advice) need to be developed.

Value chain management needs to be structured to meet IAASTD goals both locally and globally by taking into account the diversity of agricultural systems and the diversity of players involved in these value chains (producers (both small-scale and big farming enterprises, processors, retailers, consumers etc.). Markets and public policies need to be coordinated to adjust supply and demand of agricultural products to contribute to a fair and equitable trade system and to guarantee the remuneration of public goods. Diversification of production systems and local markets are necessary to improve rural livelihoods and to meet consumer demand. New research should therefore investigate how these supply chain systems can meet both market and non-market related goals.

As NAE agriculture and food systems are highly dependant on inputs from other regions and linked with food and agriculture systems throughout the world, NAE governments and organizations should participate in the achievement of the IAASTD goals for everyone as well as in the development of a fair and equitable trade system. In those countries where it has major impacts, the NAE AKST should support the development of viable local production systems as well as safe and reliable food supply chains. A role for AKST will be to analyze the diversity of agricultures and the market mechanisms that are associated. The representation of complex agricultural systems in economic modeling should therefore be improved in order to measure the consequences of trade liberalization better and to promote appropriate agricultural policies. Given the concentration of AKST capabilities and investment in NAE regions, there is scope for knowledge and technology transfer to developing regions to help them meet their own needs. However, care is required to ensure that such transfers are appropriate and sustainable

3. Investments

The new paradigm of multifunctional sustainable agriculture calls for new, increased and more diverse funding and delivery mechanisms for agricultural R&D and human capital development. There is need for increased public funding to serve the public interest, as well as new investments by private organizations responding to market needs and opportunities. Funding arrangements should enhance cooperation among all stakeholders. Open dialogue, joint planning, and fair sharing of rewards are key success features in the promotion of these partnerships.

- Public investment in R&D should focus on aspects of the public good, addressing strategic issues such as food security and safety, mitigation and impacts of climate change, long-term environmental sustainability of the system, social viability, protection of biodiversity, achieving strategic balance between land use for food and bio-energy, as well as other "non market" issues that do not attract private funding.
- Public investment in human capital development will be necessary to achieve widespread understanding of the complexities of multifunctionality and to develop the knowledge and skill sets necessary for effective decision-making and participation by all stakeholders. These developments will encompass initial education, professional formation, and lifelong learning for AKST personnel as well as for a much wider range of clients, including civil society and public policy makers as well as farmers and others (especially women and minorities) involved in rural livelihoods.
- Public investment is needed in the development of multi- and inter-idisciplinary research and education programs that promote an articulation between research and educational goals consistent with the IAASTD goals. The research and educational outcomes should be judged against attainment of these goals.
- Private investments in R&D, made in response to market opportunities and potential private gain by those supplying and using new technologies, will continue to be an important and growing source of new AKST. It is critical that private suppliers of ASKT are given the necessary incentives and rewards to make new investments in R&D and have access to essential commercial services such as market information and credit.
- Public–private partnerships are needed to provide technical assistance and joint funding of R&D investments, especially where risks are high and where development of successful research capabilities and products/services in the private sector can significantly enhance the public good. Various forms of public-private partnerships will be relevant for advisory/information services of a near market nature. There are significant public good aspects to the development of human capital and skills relating to many pre-market, quasi-market or non-market multifunctional services, some of which may transfer to private funding later.
- Non-governmental organizations are likely to become more important channels for public and private funding of technical assistance, knowledge transfer and applied research, especially at the local scale. Further support will be needed to facilitate this.

3. Integrating the ethical dimension in the development and use of AKST

Some of the options suggested in this report raise important moral and ethical dilemma, including the distribution of benefits and costs among the current and future generations. AKST development will potentially modify stakeholders' influence and entitlement, favouring some more than others. It can shape the use of natural resources and redefine the relationship between people and the nature. There is a need to research the ethical dimensions of ASKT to help guide decisions on use and development of technology, for example in matters of worker safety, animal welfare, genetic engineering and cloning, bio-security, environmental and human health risk and the balance between demands for food and non-food crops.