North America and Europe

Chapter 6 Options for action

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Key Messages

1. **Successfully meeting development and sustainability goals and responding to new priorities and changing circumstances will require widespread recognition of a paradigm shift that is already in process. This new paradigm accords increased importance to the multiple functions of agriculture and its adaptability to local environment and social contexts.** This multifunctionality* of agriculture can only be understood and managed by developing new conceptual tools to take into account the complexity of agricultural systems and by placing agriculture in its social and ecological context. New institutional and organizational arrangements are essential to support a more integrated approach to the development, dissemination and uptake of AKST, with increased emphasis on interactive knowledge networks between research, education and extension, multi-disciplinary research programs, the involvement of stakeholders in defining research agendas and the provision of education, training and advisory programs that enable a wider group of stakeholders to address these new complexities. Working successfully on this new agenda for agriculture suggests a need for ongoing attention to achieving the proper balance between public and private involvement in AKST with respect to funding, property regimes, delivery and overall governance. Successfully meeting development and sustainability goals requires a range of interactions among the various regions of the world.

AKST Options for Addressing Global Issues

2. **Develop strategies to counteract detrimental effects of the agrifood system on climate change and reduce vulnerability to such change.** Reducing agricultural emissions of greenhouse gases within NAE will require changes to farming systems, land use and practices throughout the agrifood system, such as increasing energy efficiency and carbon sequestration. In addition, AKST can be developed and used to reduce the adverse effects of climate change on agriculture in NAE and other regions, for example through drought, pest, temperature and salinity tolerant plants.

3. **Develop interventions that aid in prevention and better management of new and emerging human, plant and livestock diseases as well as weed and insect problems.** The epidemiological dynamics of the overall system from both spatial and temporal scales require better understanding and the development of suitable surveillance and response networks. Early detection and new diagnostic and curative tools are important.

* The term “multifunctionality” has sometimes been interpreted as having implications for trade and protectionism. It is used here solely to express the inescapable interconnectedness of agriculture’s different roles and functions.

4. **Develop and evaluate biofuels.** Innovations in AKST can contribute to the development of economically feasible biofuels and biomaterials that have a positive energy and environmental balance and that may be ethically justified by not compromising the world food supply. Research could focus on improving the energy content of biofuel crops and other raw materials and the overall energy efficiency of these systems, as well as new systems that do not compete with food production for land and water such as marine algae and cyanobacteria.

5. **Understand the processes and consequences of international trade and market liberalization and identify actions to promote fair trade and market reform to achieve development and sustainability goals.** NAE has an obligation to facilitate AKST, which can enhance capacity together with other regions regarding:

- viable production systems to achieve food security and sustainable rural livelihoods,
- improved access to and further development of global and local markets,
- policies to promote fair trade and address market failure, including review of practices such as the use of subsidies, dumping and regulatory regimes and
- mechanisms for interactive knowledge and technology exchange among NAE and other regions, including the participation of international governmental and government organizations and trade and farmer associations.

AKST Options for Improving Food and Farming Systems and their Sustainability

6. **Intensify the focus on nutrition, health, food quality, diversity and safety** 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 can usefully continue in several directions: to obtain a deeper understanding of the relationships between food, diet and health; to improve quality of raw materials; to enhance the ability to trace along the food chain to support quality and safety assurance; to devise better systems to control food safety vis-à-vis microbial contamination, mycotoxins and xenobiotics.

7. **Enhance research in ecological and evolutionary sciences as applied to agricultural ecosystems to devise, improve and create management options that contribute to multifunctionality.** Such options call for an ecological approach to agroecosystems for better water, soil and biodiversity management at landscape scales and improved preservation of genetic resources in special collections and in natural conditions.

8. **Improve standards of soil and water management among farmers, including irrigation, as a critical component of sustainable farming systems**. There is continuing need

to improve the scientific understanding of soil and water processes, simultaneously drawing on local knowledge, in order to support the wise use of these fundamental agricultural resources through the development and widespread adoption of appropriate farming technologies.

9. **Strengthen breeding activities, generate basic and applied knowledge and further develop relevant technologies, including biotechnologies.** It is essential that classical breeding be maintained and expanded to a wider diversity of species. The use and development of both functional genomics and systems biology and the establishment of new breeding methods integrating genomics information will be essential. There are varying opinions in NAE on the potential benefits and risks of transgenic organisms as well as the required regulatory framework. Assessment of new breeding products requires evaluation of the social, economic, environmental and health implications of their dissemination and must have a long term and wide scale perspective.

10. **Reduce environmental impacts through diversification and selection of inputs and management practices that foster ecological relationships within agroecosystems.** These conservation agriculture practices include ecologically based pest management, minimum tillage, protected cropping and precision farming, among others. AKST is required to analyze the environmental footprint of agriculture and determine the environmental limits within which it must operate. New research in AKST can help design management practices and policy measures that improve environmental performance as a critical component of sustainability.

11. **Assess impacts of management systems on animal welfare and develop and promote humane practices.** Ethical standards of animal handling and slaughter and attention to the environment in which domestic livestock are raised can significantly reduce stress and suffering of domestic livestock and should be included in future management.

12. **Explore, promote and manage the multiple roles of forests to conserve soil, maintain water quality and quantity, protect biodiversity and sequester carbon.** Assigning value to ecosystem services and forest resources and improving long-term sustainability and resilience to environmental change will enhance forest stewardship and the livelihoods of people dependent on forest resources.

13. **Improve the sustainability of coastal capture fisheries and aquaculture.** Fisheries and aquaculture management will benefit from ecosystem management and monitoring that reduce the ecological effects of fishing technology, facilitate selective fishing and create markets

for by-catch. Aquaculture can be improved by better understanding the relationship between fish immunity and disease and reducing effects of escapes on native fish. Reducing impacts of waste and developing more sustainable alternative sources of fish feed are critical needs.

14. **Comprehensively assess new technologies for their impact on the environment, economic returns, health and livelihoods.** All new technologies (transgenics, nanotechnology, biofuel production, etc.) will benefit from thorough analysis with tools such as life-cycle impact analysis and social, economic and vulnerability impact assessment. In the past, the rapid application of technology before full assessment has led to unforeseen problems. Analytical tools that allow the examination of effects on different stakeholders, different agrifood sectors and different dimensions (e.g., environmental and social) are essential.

15. **Improve the social and economic performance of agricultural systems as a basis for sustainable rural and community livelihoods:**

- Improve the understanding of factors affecting social welfare and the vulnerability of farming communities at the local scale including institutions that govern access to and use of natural resources, systems of incentives and rewards and sources of conflict in rural communities.
- Evaluate the range of goods and services deriving from agriculture and design economic instruments that promote an appropriate balance of private and public goods.
- Assess the performance of farming systems at the farm, regional and national scales that accommodate the multifunctional role of agriculture.

16. **Determine research and policy changes that lead to improvement in the welfare of migrant and/or temporary farm labor.** Appropriate measures could help ensure the availability of qualified labor for agriculture while reducing inequalities. Much agricultural labor is done by immigrants with precarious legal status in NAE. Changes to immigration law may be required to improve the situation of farm labor.

17. **Respond to gender related issues in agricultural research and the agricultural economy.** These include equity considerations in research and educational institutions; farm ownership and gendered work roles among farm families and hired labor; problems posed by family fragmentation among migrant workers.

AKST Options for Strengthening Human Capital and Organizational Arrangements

18. **Strengthen human capital and reconfigure organizational arrangements to facilitate the development, dissemination and wider use of AKST.**

- Strengthen interactive knowledge networks involving multiple and more diverse stakeholders among the research, education and extension components of the AKST systems. These cooperative efforts could be encouraged by governments.
- Improve AKST processes for involving, informing and empowering stakeholders, in particular women and others whose interests have previously been inadequately addressed. New stakeholder involvement mechanisms are advisable for developing and using methods to establish standards of legitimacy for inclusion in these processes.
- Develop and utilize 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 multifunctional vision of agriculture.
- Enhance meaningful interdisciplinary research, educational programs and extension/development work without compromising disciplinary excellence while identifying and surmounting systemic barriers to interdisciplinarity.
- Strengthen links between research and higher education to promote lifelong learning and the creation of a learning society.
- Strengthen information and knowledge-based systems to enable a rapid, bi-directional flow and utilization of information and knowledge between the wider agricultural sector and the AKST system.
- Promote appropriate organizational arrangements that facilitate the development of human capital within the AKST system.

19. **Devise, evaluate and institute new patterns of ownership and employment.** This would promote effective participation, equity, development of human capital, cultural change and ongoing education and training.

20. **Recognize more fully the important role that traditional and indigenous knowledge plays in agriculture and in the culture and welfare of particular people.** Respectful interaction with indigenous peoples and traditional practitioners and serious consideration of the value of their knowledge, experience and techniques can contribute broadly to sustainable and equitable agriculture and the development of new AKST.

21. **Reinforce partnerships between NAE and other regions that empower poor and disadvantaged people and organizations.** Strengthening interactive knowledge networks and integrated trans-disciplinary research and educational programs facilitates the development of working relationships among AKST organizations worldwide.

22. **Increase NAE receptivity to innovative proposals from other regions for mutual**

capacity building. Harness human and organizational capacities, especially focusing on the capacity to build capacity. Regional and global forums can facilitate this networking and promote enhanced contributions to the global knowledge economy by AKST organizations.

AKST Options for Improving Policy and Governance

23. **Support coherent policy frameworks for agricultural and rural development and ensure that relevant government departments collaborate with private sector and NGO actors in their development.** Coordination between government functions can facilitate a balance among the goals of feeding an expanding population, using natural resources efficiently and sustainably and promoting economic development and cultural uses at the local, regional and global levels.

24. **Strengthen connections among all actors within the food chain and better balance power among all actors in food chain governance.** This requires policies to strengthen business and marketing skills among producers, build mutually beneficial relationships among all members of the food supply chain and educate consumers about farming and food products and systems.

25. **Develop policy instruments to internalize current environmental and social externalities of agricultural production and reward the provision of agroenvironmental services**. Examples include financial instruments to discourage use of environmentally harmful inputs and promotion of agricultural practices with low carbon emissions, watershed and landscape eco-management and carbon sequestration through agroforestry.

26. **Develop policy instruments to remove incentives for farm concentration and agribusiness concentration.** These include anti-trust measures, improved competition policies, more stringent corporate social reporting and greater transparency in corporate transactions.

27. **Implement more fully and further develop those treaties and conventions that promote Development and sustainability goals.** These include such areas as climate change, biodiversity conservation, genetic resource conservation, toxics control, desertification, sanitary/phytosanitary, intellectual property and biopiracy.

28. **Further consider and develop regimes that define rights of use and of property**. The development of “common property regimes” for scarce natural resources such as water that go beyond either public or private ownership could be further considered. Significant public policy discussions of the implications and nature of these proprietary regimes for the future are needed

to explore the full implications.

29. **Reshape Intellectual Property Rights and associated regulatory frameworks where necessary to facilitate the generation, dissemination, access and use of AKST and recognize the need to improve equitability among regions in use of intellectual property rights.** To achieve a better balance between public and private interests and between rewards for innovation and accessibility, consideration could be given to: patents that would be narrower, cross-licensing that would result in pooling of patents between universities and the private sector, compulsory or obligatory licensing when deemed necessary, broadening of exemptions of patents to facilitate research and open source technology that leads to collaborative invention.

30. **Devise modes of governance at the local level that integrate a wider range of stakeholders' perspectives.** Examples such as food policy councils in the US and water management groups that implement the European Water Framework Directive (France, UK, Ireland) already exist to a limited extent in NAE and should be promoted.

AKST Options for Funding

31. **Multifunctionality calls for new, increased and more diverse funding and delivery mechanisms for agricultural research and development (R&D) and human capital development**. Depending on circumstances, these could include:

- public investment to serve the public good, addressing strategic, 'nonmarket' issues that do not attract private funding, such as food security and safety, climate change and sustainability;
- public investment to strengthen human capital development and education programs, including multi-disciplinary research;
- private investments made by farming businesses and farmer associations as an important and growing source of new AKST;
- adequate incentives and rewards to encourage private investors to invest in new R&D, including supporting commercial services such as market information and credit;
- public–private partnerships to provide technical assistance and joint funding of R&D investments, especially where risks are high and where research developments in the private sector can significantly enhance the public good; and
- nongovernmental organizations to act as an alternate channel for public and private funding of technical assistance, knowledge transfer and applied research at the local scale. Further support will be needed to facilitate this.

32. **Establish effective procedures for funding rural and agricultural development by**

national and international agencies. This recognizes the strategic role of the agricultural and rural sectors in meeting Development and sustainability goals within the NAE regions and globally, allocating funds and managing investment programs for these purposes.

6.1 Paradigm Shift and Key Issues for AKST to Meet Development and Sustainability Goals

6.1.1 Why recognize a paradigm for research and action?

Advances in agricultural knowledge, science and technology (AKST) have been critical in making it possible to meet many of the needs for food and fiber in North America, Europe and other parts of the world. Agriculture is now being required to be responsive to new priorities, expectations and changing circumstances. Many of these are stated in development and sustainability goals, namely: reduce hunger and poverty, improve rural livelihoods and health, increase incomes and facilitate equitable, environmentally, socially and economically sustainable development. Meeting these multiple objectives is made more complicated by a variety of foreseeable and unforeseeable changes. These challenges necessitate emphasis on a new way of considering research, technology development, education and knowledge exchange. The new way of thinking requires that those working in the fields affecting AKST:

- recognize the importance of the multiple functions of agriculture not only in providing food and fiber but also in providing a range of environmental goods and services associated with land, water and living systems.
- engage the participation of all people concerned in the process of defining needs and solutions.
- be specific to local environmental, social and economic context.
- be adaptive to social and environmental change, including climate change.

Although the ‘farming systems approach’ and other research strategies in recent decades extended the boundaries of consideration for AKST, research and development has remained largely focused on the farm economy itself, with production at its center. The externalized costs of unintended and/or unanticipated negative social and environmental consequences of AKST have been dealt with largely through post hoc regulatory and policy approaches. Although such post hoc responses have in some cases encouraged or compelled positive technological innovation, they have often failed to resolve important problems that might have been better addressed at an earlier stage in the creation, design and implementation of AKST. There will be advantages for such broad anticipatory approaches to complement more narrowly focused R&D. Agriculture and AKST development could be re-conceptualized within the entire context of society and environment, introducing new levels of complexity in understanding and responding to future needs. This requires recognition of a paradigm shift in the way AKST is to be produced and delivered. Elements of this shift are already in process and have appeared throughout the NAE.

Shaping a newly recognized paradigm shift and learning to work successfully within it will require continuing work on the integration of knowledge across a wide range of disciplines. Researchers and policy makers will require new conceptual tools to better address complex questions and help in understanding the dynamic and interactive relationships among multiple relevant factors.

Working more effectively within the new paradigm will also likely require new institutional arrangements. These arrangements could be designed to support a more integrated approach to the development and dissemination of AKST. Methods for such integration will include the creation of multi-disciplinary research programs, the involvement of stakeholders in defining such agendas and the provision of education, training and advisory programs to support the exchange of knowledge competencies to deal with these new complexities. In addition, it will be necessary to carry on a continual re-evaluation of the proper balance between public and private interests and investments in the development of AKST.

6.1.2 New research approaches and supportive institutional change

Universities, other research organizations, training institutes and extension services may frequently find it advisable to renew and upgrade their capabilities to operate effectively within a new paradigm recognizing the complexity of agricultural AKST. The nature of the new challenges calls on universities and other organizations to greatly increase the emphasis on multi-disciplinary and interdisciplinary research. This can be done without sacrificing disciplinary excellence, which is the foundation for successful multi-disciplinary work. Much of this work could be focused directly on meeting development and sustainability goals.

Agricultural research and education, in all its forms, is faced with the challenge presented by what has been termed the “disaggregation” or “disintegration” of agricultural science. In recent decades there has been a strong tendency for many of the most important advances in AKST to come from the basic science and social science disciplines outside of the agricultural sciences. This trend creates an imperative for the agricultural sciences to interact more with the other disciplines both to fully capture the advantages that such contributions from outside the agricultural sciences offer and to help guide the research in directions most useful for agriculture. Organizations and institutions have sometimes recognized and should continue to consider that this cannot depend on individual researchers alone, but from changes in the ways that research and educational organizations are structured. Changes in the incentive systems for educators and researchers can facilitate the achievement of multi-disciplinary efforts that are properly recognized and rewarded rather than ignored or punished.

The development and pursuit of research agendas could involve interactive knowledge systems that call on the more active and effective participation of people outside academic disciplines. The multiple functions of agriculture and the imperative to rise to new challenges can only be met if there is active and effective participation by farmers, farm labor, consumers, environmentalists and other interested parties in the development of AKST. Links between research development on the one hand and education, training and extension on the other could be reinforced and where necessary redesigned. Multiple entry points for farmers and other agricultural practitioners into the AKST system can aid in both the identification of new research needs as well as in the implementation and application of new AKST. The role of farmer-to-farmer education and increased interaction of farmers and researchers with consumers, farm workers and environmentalists are some options that could be more seriously incorporated into the AKST system. Such increasingly interactive systems of research, education and extension will be essential in the innovation necessary to achieve development and sustainability goals.

6.1.3 Achieving the proper balance between the public and the private sectors

Working successfully on a new agenda for agriculture will necessitate ongoing attention to achieving the proper balance between public and private involvement in AKST with respect to funding, property regimes, delivery and overall governance. The recent trend toward privatization of agricultural goods and services has contributed to competitiveness, innovation and efficiency in many aspects of AKST development. However, there are compelling reasons for ongoing reconsideration of how to best protect the specifically public interest aspects of AKST development.

Agricultural production has its foundation directly in the biological world. It is also rooted in particular patterns of culture and economic organization that are specific to agriculture but vary in important ways from region to region. For this and other reasons, the balance of public and private interests and investments in agriculture is different from that in other economic activities. In the last century, government agencies, public organizations and publicly-funded universities and research institutions have worked in partnerships with private organizations and firms in a way that both served private interests and protected certain key public interests, such as relatively open access to seed varieties. Shifting the balance with regard to property regimes and governance within that partnership towards stronger private control has special implications for agriculture. For example, the increasing private ownership of intellectual property rights to seed varieties and genetic material has raised profound economic, environmental and cultural issues whose implications for society bear serious examination. The same can be said for property regimes regarding access to water and other resources. This is particularly significant when the multiple functions and changing circumstances of agriculture in the future are properly taken into consideration.

The increasing globalization of property regimes and forms of public/private interaction and the strongly influential role NAE has in shaping these changes have powerful implications for the rest of the world. Upon consideration of changes that may be appropriate for the NAE region, it is proposed that NAE not impose those changes on nations and regions that may have good reasons for choosing other legal and institutional arrangements. Achieving the best balance between the value of internationally uniform arrangements and the value of arrangements adapted to place and context can be a key issue for achieving development and sustainability goals.

6.2 Future Needs and Priorities for AKST

The evolution of agricultural science and technology In NAE, during the last decades, has been largely driven by academic and disciplinary approaches with the ambition to better understand biological and agronomical mechanisms of simplified and focused systems. Such approaches have led to high-level science that has in some respects ignored organizational impacts, particularly contextual elements (from biological sciences as well as from social sciences) affected by the deployment of that science, in nonlinear and unpredictable ways. These disciplinary approaches are not sufficient to address a complex problem - as a whole – and could be supplemented with more systems and overall approaches such as “complex system”[1] approaches. These new approaches are today more developed in the ecological domain and consider all relevant sub-systems or components and their inter-relations as well as their associated social, economic and policy frameworks. They require a multiple scale approach, both from a spatial (from local to global) and temporal (from short to long term) point of view.

Putting the focus on complexity and trans-disciplinary approaches does not devalue disciplinary efforts that supply basic knowledge for some of the components of the overall complex system. But, it highlights the importance of mobilizing AKST more in this direction that has been under-developed until now and is essential for understanding both the operation and the evolution of the whole system. This will be all the more important as the number of variables and their interrelations increase, many of them being uncertain and addressing multiple scales (Box 6.1).

[Insert box 6.1]

[1] A “complex system” is a network of many components whose aggregate behaviour is both due to, and gives rise to, multiple-scale structural and dynamic patterns that are not inferable from a system description that spans only a narrow window of resolution (Parrot and Kok, 2000). It leads to emerging new features or proprieties that cannot be predicted from the components. Complexity differs from other analytical approaches in that it is based on a conceptual model in which entities exist in a hierarchy of interrelated organisational levels. The main features of complex systems are: (i) the non linearity of relationships, (ii) the occurrence of both negative and positive feedback loops, (iii) their openness (show pattern of stability, even if usually far from energetic equilibrium), (iv) their history, keeping memory of past events, (v) they may be nested, each component of a complex system may itself be a specific “complex system”.

As far as global phenomena are concerned, one of the major challenges of the next decades is to develop agricultural activities that respond better to climate change: NAE could play a leading role in this domain. NAE could also consider its role in helping to deal with the spread and emergence of disease: the anticipation and management of new and emerging diseases, the occurrence of which is partly due to climate and partly due to rapid globalization. One other area where AKST can contribute to is to reduce the dependence of the NAE region on petroleum based fuels by developing alternative sources of energy and also by developing energy efficient supply chains at the global level. The NAE region has supported the implementation and development of agricultural activities in many other regions to enrich NAE's own food and nonfood systems. Another challenge for the next 50 years will be to contribute to a sustainable economic, social and environmental development in these regions.

As far as local phenomena are concerned, future agricultural research and development must consider broadening its concerns to address explicitly and directly the multiple functions of agriculture (production of food and fiber including land conservation, maintenance of landscape structure, sustainable management of natural resources, biodiversity preservation and contribution to the socioeconomic viability of rural areas (OECD, 2001) both in Europe and North America. Several broad areas of research are required in order to move towards this goal in a deliberate and logical fashion as detailed in the following sections.

6.2.1. Responding to climate change

Greenhouse gas (GHG) emissions from agriculture are in the range of 7-20% of total country emission inventories (by radiative effect) for NAE and are a contributor to climate change. AKST could be mobilized to mitigate this change while helping agriculture adapt to these changes.

6.2.1.1 Mitigate climate change through agriculture

The influence of agriculture on climate is significant but complex. Agriculture could help in reducing the increase in greenhouse gas emissions and in some cases, through expansion of some agricultural practices and land-use changes and development of new ones, can also contribute to a decrease in GHG. Some examples of agricultural practices and their potential benefits are given below:

- increase carbon sequestration in agricultural soils for example through no or minimum tillage, cover crops and green manures leading to an increase in soil carbon levels. Additional research on the enabling conditions and the magnitude of the net effect on GHG emissions could be useful directly sequester carbon from flue gasses in intensively grown crops in closed conditions (Betts et al., 2007);

- increase carbon sequestration via land use change (Brovkin et al., 2004 ; Soussana et al., 2004). The conversion of arable lands to grasslands and afforestation is one of the important local options. Their net effect on GHG emissions in variable environments could be determined through additional research (Dupouey et al., 2006);
- analyze the effect of extreme heat or cold episodes on carbon accumulation. The long-term benefits of these changes and management systems could be further evaluated;
- manipulate livestock diet to reduce nitrogen losses from animals and/or reduce pH of excreta and to reduce methane emissions by ruminants (Lassey, 2005);
- use husbandry methods, management techniques and novel varieties to minimize the inputs of energy, synthetic fertilizers and agrochemicals on which present industrialized farming methods depend;
- reduce energy use via reduced use of fossil fuels in farming and food processing; and
- conduct high quality whole system studies and develop easy to use decision systems to ensure advantages in one area do not have ill effects in other areas (Seguin et al., 2005).

6.2.1.2 Reduce agriculture's vulnerability to climate change

A change in the climate that has been witnessed particularly over the past 50 years is likely to be reinforced in the next five decades. Some of the most prominent consequences of this change have been in the following areas: acceleration of several physiological processes accompanied by a greater demand in water and nitrogen, variations in rainfall (frequency and quantity), change in the radiative balance, increase in the frequency of extreme episodes and changes in biotic stress.

The geographic distribution of agricultural production within and outside NAE is likely to change considerably due to climate changes for the next 50 or 100 years, even if uncertainties remain in the timing and geographic details of these effects. Two strategies that could be pursued to address these uncertainties are: (i) improving the ability to predict future effects of climate change and (ii) adapting food production system to minimize adverse effects on food supply and avoid exacerbating hunger.

Improving capacity to predict future effects of climate change on the geographic distribution of agriculture and overall food production in NAE and in other regions:

One of the major challenges is to better understand better the consequences of climate change where there are still considerable uncertainties. Although there is a consensus regarding an elevation of the temperature or an increase in the concentration of greenhouse gases, there is less certainty regarding other effects including: change in the nature and timing of biotic stress due to the phenological shift of the host plant, outbreaks of new parasites and ways of combating them, variation in the rainfall, increased frequency of extreme episodes (e.g. summer of 2003 in Europe). Taking into account these uncertainties (rainfalls, biotic stress, political and economic choices etc.) as well as short and long-term effects could help in the understanding of such complex questions and dealing with them. In addition, collecting serial data through appropriate long-term observations could facilitate the construction and validation of previous models and shed more light on these unanswered questions (Seguin et al., 2006).

Reconfiguring NAE production areas to adapt and optimize available space and resources in new "environments":

Geographic shift in crop and forest production. Many studies suggest that rising temperatures could result in a shifting of crops and forests towards the north where temperatures in the future will most probably be equivalent to current temperatures in the south (Olesen and Bindi, 2002). In Europe for example cereals in Finland will shift 100-150 Km towards the pole for each 1°C rise in temperature (IPCC, 2001). Continental and mountain forests are expected to occupy less surface area in the future compared to their present distribution as they are sensitive to high temperatures and extreme drought conditions.

The NAE region could anticipate some of these profound changes in the geographic organization and utilization of agricultural lands and study (Easterling, 1996; Watson et al., 1997):

- possibilities of extending crop productive agricultural lands to Siberia and northern Canada;
- optimal shift of perennial horticultural crops by optimizing the interactions between varieties, new cultivation environment and crop management systems;
- occupation of the most sensitive regions (irregular rainfall alternated with intense droughts) by plants that are more robust and have a high plasticity; and
- new and changed species composition of forest areas and its consequence on the amount of forest biomass available.

This adaptation and preparation will be more robust if data have a higher degree of certainty than before, as with the data from IPCC used for predictions of climatic changes (IPCC, 2007).

Development of new and adapted agricultural practices and crop varieties. Simultaneous development of new varieties, either new crops or agricultural crops adapted for predicted climatic changes and agronomic practices appropriate for those crops under predicted climatic conditions may be required.

Some of the desirable traits for these new varieties are: better suited for high temperatures, with increased or stable growth with less water and and/or transient drought tolerance, longer durations of vegetative growth and grain filling periods, early budding and better frost resistance for orchard varieties and field crops (Seguin et al., 2006).

Some practices include: planting earlier so that crop development would be more advanced in the case of a summer drought, using longer-season cultivars, mixing cultivars and planting seeds deeper and harvesting earlier. Early planting might also eliminate the necessity of artificial drying of grain. Soil moisture may be conserved by using conservation tillage methods, modifying the farm microclimate for example by integrating trees as shelterbelts and changing the way irrigation, fertilization and crop-protective sprays are scheduled, so that inputs are applied according to crop needs or field conditions.

A reevaluation and adjustment of these above mentioned options may prove to be useful, for example by taking into account new rhizosphere communities that develop due to climate change and the effect of these communities and their interactions with the surrounding agroecosystem.

Development of new social systems to enable smooth transitions of rural economies and maintenance of world food supplies. Mass human migrations stimulated by scarcity are often highly disruptive and damaging. If global climate change undermines the basis for agricultural production in rural NAE, it may cause dust bowl-like migrations such as those that occurred in the US during the 1930s. New social programs could be designed to face this scenario and to help alleviate rural poverty and facilitate the economic transformation of rural NAE. Ensuring a stable production of agricultural products so that world food supplies are maintained during these transitions could be one of the main goals of these programs.

6.2.2 Facing new and emerging human, livestock and plant diseases

6.2.2.1 Human and livestock diseases

The past few decades have seen an alarming increase in new and emerging diseases such as AIDS, BSE, SARS, avian influenza, foot and mouth disease and others. These diseases are seen as a threat to global animal, plant and human health. One reason for this upsurge is the increased exposure of humans to infectious agents through changes in lifestyle, international travel and industrialization and globalization of the food industry. However, adequate understanding of the root causes of this upsurge is still lacking. Clearly it will not be possible to meet development goals unless the AKST system responds to the challenge of emerging diseases.

AKST could be used to elucidate the following aspects for a better management of these diseases through the following:

Understanding the origin of new and emerging diseases

- differentiate between “new” and “emerging” diseases: some of these diseases may be old diseases with newly recognized etiologies. Others are diseases that did not exist more than 100 years ago. This difference is important to understand to be able to project the future occurrence of new and emerging diseases (Desenclos and de Valk, 2005);
- understand the ecological and evolutionary dimensions leading to the development of new and emerging diseases.

Predicting epidemics and pandemics across both spatial and temporal scales

- identify factors that increase the risk of developing infectious diseases: new areas of risk factor research include the relationship between changes in the environment (such as climate change) and the incidence and distribution of diseases; and the influence of crop and livestock genetic makeup on their susceptibility to disease and response to treatment (Desenclos and de Valk, 2005);
- develop basic fundamental research about hosts, pathogens and their interactions at different levels (molecular, cellular and superior integrative levels) (Horwitz and Wilcox, 2005):
    - hosts: physiopathology, immune response;
    - pathogens: ecology and biology of the pathogens, vectors; and
    - host-pathogen interactions: cellular and molecular mechanisms, evolutionary potential (develop a better understanding of how pathogens mute and migrate and how they skip host species barriers) and in particular research on resistance to anti-infectious drugs.

- construct models for the system as a whole:
    - multidisciplinary groups of scientists studying the ecology of an emerging infectious disease could help in the building of these models. These models are parameterized with data from field studies and pathological and microbiological investigations. These studies enhance classic epidemiology by involving an array of medical, veterinary, health and ecologic scientists and others in a dialogue between model building, parameterization and further refinement of models (Daszak et al., 2004);
    - integrating various disciplines (evolutionary, social, anthropologic, geographic, economic and public health sciences) could help in understanding the determinants of new and emerging diseases (Daszak et al., 2004; Desenclos and de Valk, 2005).

Building surveillance and response networks

Early detection allowing a rapid response to emerging infectious diseases is essential (WHO, 1998). However, this depends upon the application of the latest diagnostic tools along with developing newer tools and appropriate, predictive epidemiological analysis (Thompson, 2000). Technological advances that require interaction between government, policy advisers and scientists could be applied as part of surveillance strategies (Hughes, 2001).

Some of the options that could strengthen the ability of veterinary and human quarantine systems to cope with the growing threats and build comprehensive, strategic and effective surveillance are to:

- set up observatories at appropriate scales to collect data over long periods as they could help understand the temporal and spatial dimensions of the epidemiology of the different diseases;
- develop diagnostic tests and systems that are reliable when the disease is rare; and
- develop new methods of disinfection to avoid propagation: assess new methods for sterilization of food and reduce contamination of water.

Other innovations that may prove essential are developing new types of cures through newer forms of drug discovery and also through immunizations using nanotechnology or biotechnology to quickly vaccinate livestock and wildlife to cure the disease and thus to lower the chances or delay the disease jumping to humans.

Building and strengthening coordination between veterinary and public health KST infrastructure and training

The coordination between veterinary and public health infrastructure is the underlying foundation that supports the planning, delivery and evaluation of public health activities and practices (Salman, 2004). Three of the main areas that could be developed to help build efficient infrastructure are listed below:

- enhance epidemiologic and laboratory capacity: the ‘new' tools of molecular epidemiology could be rapidly deployed to counteract the potentially devastating effects of emerging and re-emerging infectious diseases. In particular, accurate and sensitive DNA-based diagnostics and mathematical models can be used to provide optimum surveillance and the ability to predict the occurrence and consequences of disease outbreaks so that the necessary ‘preparedness to respond' is available and control strategies can be established (Thompson, 2000). This would play an important role to better understand the advances in investigations of outbreaks, assessment of vaccine efficacy and monitoring of disease trends;
- provide training opportunities in infectious disease epidemiology and diagnosis in the NAE region and throughout the world with the goal to train laboratory scientists to become leaders in public health laboratories, especially at the state and local levels (Hatch and Imam, 1996); and

- increase funding given that, in the future, the development of prediction and prevention programs to eradicate or minimize these emerging infectious diseases at a global level may require more global resources accompanied by a greater involvement of international nongovernmental development and aid organizations. It is vital that a coordinated global civil society rather than an exclusively governmental approach be implemented in the prevention of these diseases (Harrus and Baneth, 2005).

6.2.2.2 Insect pests, weeds and diseases of plants

Similar to new and emerging human and livestock diseases, there has been an upsurge of new insect pests, weeds and pathogens of plants in the past few decades. Recent examples with important economical or social consequences include for example epidemics of sudden oak death disease cause by *Phytophthora ramorum* (Rizzo et al., 2005), new genotypes of potato late blight in the US (Fry and Goodwin, 1997), the appearance of Phylloxera -a root-feeding aphid- on grapevines in Europe and increased parasitic weeds, especially in Europe. In each case, society and/or agricultural practices were severely affected.

Currently, weeds are the major biotic constraint on crop production and the farmers' major variable inputs are for weed control. In NAE nearly 70% of pesticide applications are of herbicides for weed control (over 50% worldwide) and much tillage to control weeds. The success of chemical control of weeds has led to a weakening of AKST in dealing with weeds, both in the public sector in dealing with ecological and physiological relations between weeds and crops and the whole ecosystem and the private sector has come up with only one new target site for herbicides in the past two decades. The result has been deleterious changes in weed spectra in ecologically preferable minimum tillage systems that reduce erosion and chemical run-off to harder to control perennial weeds.

Farmers are troubled in trying to balance the demands of multifunctionality and weed biodiversity with the needs of productivity and supplying the demands of food fiber and fuels, as the weeds that supply food to wildlife in the field are often secondary hosts of disease and insect pests as well as direct competitors with crops for resources. Weed control is the major constraint to organic agriculture, where considerable soil degrading tillage and backbreaking manual labor is required to deal with weed problems and the ensuing ethical dilemmas. Despite the present and future problems posed by weeds, both public and private sector AKST in weeds is disproportionately low compared to the AKST investment in dealing with other biotic stresses.

As far as pests are concerned although fewer studies exist compared to their counterparts affecting humans and animals, the emergence or re-emergence of these pests is considered to be linked with several, concurrent factors among which are (Anderson et al., 2004):

- increased global travel and global trade of plant materials, including crop plants but also exotic species used as garden or ornamental plants (Mack and Erneberg, 2002); this trade results in increased risks of dispersing pests onto new hosts and/or into new geographical areas;
- climatic modifications such as global warming that have already resulted in the extension of the range of some insects, including vectors of pathogens; although currently limited, this effect is predicted to see its importance increase during the forthcoming century;
- modification of farming practices, with a strong trend towards a reduced diversity of crops and an increased contribution of monoculture;
- increased occurrence of resistance to pesticides in both insects, weeds and pathogens, further reducing our ability to control these pests and resulting, in some situations, in the build-up of large, difficult to control pest populations; and
- evolution of the pests themselves, expanding host range of weeds, insects and pathogens and increasing occurrence of feral, weedy forms of many crops.

AKST could be developed and used to understand the root causes of these new and emerging pests to shift focus to pre-empting new pest emergence, rather than just responding to it. Some of the main options for action in this domain are listed below:

Better understand the origin of and the factors responsible for the invasiveness of insect pests, weeds and pathogens of plants

- study the factors that determine the invasive potential of these pests:
  - genetic factors, including genetic makeup, gene expression and its influence on the adaptation of these new pests to the new environment;
  - ecological factors, including the conditions that could either inhibit or stimulate the invasive potential of new pests.
- understand how these new pests alter ecological community structure, which in turn can facilitate the development and propagation of these pathogens;
- study weed ecology, to allow maximum biodiversity with minimum impact on productivity and crop health;
- conduct retrospective studies on biotic invasions to better understand the factors that stimulated the invasive potential; and
- increase international collaboration to facilitate the exchange of biological and ecological information associated with insect pests, weeds and pathogens with high invasive risk potential.

Build surveillance and detection networks

- Track the changing geographic distribution of potentially dangerous invasive pests with associated ecological data;
- develop improved techniques/models/strategies/frameworks for Pest Risk Analysis i.e. the capability to predict the potential risk(s) linked to the introduction of pests into region(s) where it is absent; such strategic analyses could help to focus some monitoring efforts on "high risk" agents and to de-emphasize efforts on "low-risk" agents that have nevertheless made their way to quarantine lists;
- implement surveillance and efficient alert systems:
  - develop internet databases with taxonomical and biological data on these pests and pathogens and store samples with their respective data at the regional or national level; this calls for more research in taxonomy of pests and pathogens;
  - train field workers (agricultural cooperatives, entomologists, naturalists…) to detect the presence of pests and pathogens rapidly and not only alert the other actors involved but also to contribute and supply data to regional and national databases; and
  - develop new molecular detection tools (e.g. gene chips) that could in certain cases be used *in situ* directly on the fields for cost-effective detection of potentially invasive species and rapid assessment of both qualitative (presence or absence) and quantitative (number) changes observed in affected biological communities.

Developing appropriate management and regulatory measures

- develop a database with control methods for these pests , preferably based on sustainable, ecological pest management methods coupled to surveillance and detection networks;
- build systems for effective border control to deal with risks from pests and disease-causing pathogens;
- develop adaptive management systems to be able to adjust rapidly management and regulatory measures;
- develop newer and safer pesticides as well as breed pest-resistant crops; and
- develop new biological control agents to suppress pests and replace chemical controls and tillage.

6.2.3 Contributing to a global strategy for a low carbon economy

6.2.3.1 Biofuels

The heavy dependence of the NAE during past century on petroleum is a major challenge. AKST can be deployed to develop agricultural production of biofuels while decreasing net carbon dioxide output.

Some of the sources that could be used for producing biofuels are: cereal grains and oilseeds to produce bioethanol[2] and biodiesel[3] (1st generation biofuels), cellulosic materials (2nd generation biofuels) and, algae and cyanobacteria (3rd generation biofuels). The possibility of producing biohydrogen and bioelectricity using nature's photosynthetic mechanisms (4th generation biofuels) might be explored as well.

<u>Ethical considerations – effects on food security</u>

The rapid growth of biofuels industry is likely to keep farm commodity prices high through the next decade as demand rises for grains, oilseeds and sugar from 2007 to at least 2016 (OECD/FAO, 2007). This will substantially increase meat and milk prices in the NAE and decrease the amount of grain available to the poorer parts of the world both as direct imports and food aid. Brazil's earlier diversion of cane sugar to ethanol stabilized high sugar prices, assisting farmers worldwide, but at a higher consumer price. The diversion of grain to fuel can negatively affect the millennium goal of alleviating hunger throughout the world in the short term, but might have a positive long-term effect. Because heavily subsidized NAE grain will no longer be "dumped" on developing world markets below production costs, the subsistence farmers in the developing world could quickly switch from subsistence to production agriculture, increasing yields and self-sufficiency. There are also eco-ethical considerations; putting more ecologically fragile and necessary lands into production of biofuels; whether oil palm production in Southeast Asia at the expense of jungles, or soybean production at the expense of rangeland or rain forest. It may not be morally justifiable to purchase oils for biofuels from areas where the environment is being negatively exploited. Proponents of some biofuel crops state that they will be grown on "marginal" land. Such lands may not be marginal to biodiversity and wildlife, posing another ethical issue. As discussed below, a major NAE biofuel crop, oilseed rape emits a major greenhouse gas and Jatropha, which is promoted by many NAE organizations in Africa and Asia is highly poisonous. There are ethical issues about promoting the cultivation of such crops. Thus, alternative feedstocks are needed for biofuel production, without expanding the land under the plow such as waste cellulosic material or algae and cyanobacteria.

<u>First generation biofuels (cereal grains and oilseeds)</u>

The energy, economic and environmental results of the 1st generation liquid biofuels cannot make them a substantial alternative to fossil transport fuels (IEA, 2004; Sourie et al., 2005). Co-production can improve energy and economic balance and biofuel costs will go down as the technologies improve in production efficiency and economies of scale are realized (Farell et al.,

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[2] The complex carbohydrates in plant material are hydrolyzed to simple sugars that are fermented into ethanol or butanol, which can be used in internal combustion engines.

[3] Crop oils are increasingly being used for use as biodiesel. The crop oil is de-esterified to release the fatty acids for use as biodiesel, and glycerin is a byproduct.

2006). In addition, the amounts of land that would be required to obtain self-sufficiency in biodiesel using oilseed crops alone varies from 9-122% of the global cropping area (see table below), which makes it clear that both fuel and food needs cannot be supplied by standard crop agriculture alone.

	Typical Yields	**Area necessary to meet demand**	**Arable land necessary**
	Ton oil/ha/yr	*million hectares*	*% of global total*
Oil palm	5	141	9%
Jatropha	1.6	443	29%
Oilseed rape	1	705	46%
Peanuts	0.9	792	51%
Sunflower	0.8	881	57%
Soybean	0.4	1880	122%
Algae/cyanobacteria*	52.8	4.5*	2.5%

* Yield data for 30% oil content (low), area necessary to meet 50% USA diesel demand (Chisti, 2007).

Second (cellulosic substrates) and Third generation (algae and cyanobacteria) biofuels

New developments in biofuel production seem necessary. Two types of cellulosic second generation substrates for biofuel production are being considered: straws and specially cultivated material. The use of cellulosics will have a higher net energy gain than seed grains/oilseeds (Samson et al., 2005; Farrell et al., 2006), but the present technologies are less environmentally friendly than those using grain, as they use dilute sulfuric acid and heat to separate lignin from the carbohydrates. Third generation sources, such as algae, may be even more environment friendly as well as cost effective. Concentrating future R&D options on the following areas can help make second and third generation sources viable:

- *Research can help define plant ideotypes that fulfill certain criteria and respond to certain needs for instance* :
  - assimilation of carbohydrates (starch and sucrose) at the detriment of proteins. This is cost effective as the crop requires a lower quantity of inputs (particularly water and nitrogen) and has less hauling requirements; some examples are leguminous plants, as they require less fertilizer and the cultivation of C4 plants adapted to low temperatures (Heaton et al., 2004);
  - production of fermentable 5- and 6-carbon sugars that can subsequently be converted to ethanol;
  - increasing the amount of cellulose (especially at the expense of lignin), or modifying its structure such that more is available to cellulases could increase the bioethanol yield

of straws and specialty grasses, while lowering demands for acid and heat for hydrolysis (Attieh et al., 2002);

- increasing the lignin content and the digestibility of straws through transgenics. The solution to increasing digestibility without affecting important traits is to transform elite material to contain modified lignin and cellulose contents, e.g. by partial silencing of the pathway enzymes leading to lignin (Gressel and Zilberstein, 2003), or by enhancing cellulose synthesis (Shani et al., 1999);
- lowering the presence of polluting silicon in both straws and cultivated grasses;
- lowering emissions of methyl bromide from oilseed rape or Canola (Gan et al., 1998);
- developing lodging-tolerant varieties and when necessary dwarfed varieties;
- developing insect resistant varieties, as lower lignin can lead to pest infestation;
- improving the stand establishment of perennial grasses (Schmer et al., 2006);
- compensating for the reduction of soil carbon and its consequences on soil quality due to straw harvesting; and
- explore the harvesting of unwanted aquatic weeds such as water hyacinth for biofuel production.

Biotechnologies including genetic engineering could potentially achieve most of the above mentioned targets by modifying certain metabolic pathways. Development of such modified varieties requires taking into account appropriate safety concerns.

Research and technological developments could focus on increasing processing efficiency by:

- increasing the efficiency of cellulolytic enzymes, e.g.. by gene shuffling to increase activity, stability, temperature optima;
- improving the pretreatment step that disrupts the structure of the biomass and releases 5-carbon sugars from hemicellulose, hydrolysis of the cellulose to form 6-carbon sugars and the fermentation of sugars to ethanol. This remains a technical challenge due to the nature of lignocellulosic feedstocks; and
- improving fractionation technology while reducing the sulfuric acid and heat to hydrolyze lignocellulosics.

Research options for third generation algal/cyanobacterial biofuels could focus on increasing organism survival, growth and lipid content, carbon dioxide enrichment and yields:

- organism survival: the best laboratory strains become contaminated and taken over by indigenous local organisms under field conditions. Transgenes conferring herbicide resistance might overcome this problem;
- growth & lipid content: algae either grow *or* alternatively they produce lipid (fat) bodies, but not do both simultaneously. This requires batch culture or separate growing ponds

and lipid producing ponds, increasing production costs. Pathways and genes for continuous production of the best lipids for biodiesel are becoming known and could be explored (Ladygina et al., 2006);

- carbon dioxide enrichment: the algal response to added carbon dioxide is not as good as it could be; molecular research in photosynthesis could potentially increase yield (Ma et al., 2005);
- seasonal high yields: algal growth is a function of temperature - when it is too cold they grow less and most do not do well at high summer temperatures; recent and future AKST with plants will have much to offer to overcome this problem (Shlyk-Kerner et al., 2006); and
- poor light penetration to cultures requires shallow ponds and lower yields; further research in trimming photosystem antennae size could greatly increase efficiency and yields (Tetali et al., 2006)

Research is also required to establish the ecobalance and life cycle analysis for each source.

Fourth generation: producing biohydrogen and bioelectricity

Biophysicists have seen it as an intellectual and practical challenge to harvest solar energy to produce hydrogen or electricity by directly using nature's photosynthetic mechanisms, or by embedding parts of the photosynthetic apparatus in artificial membranes, or using algae to produce sugars and yeast or bacterial enzymes to produce electrochemical energy (Tsujimura et al., 2001; Chiao et al., 2006; Logan and Regan, 2006). This will necessitate considerable long term multidisciplinary efforts to become more than a laboratory curiosity. The informational gains, as well as the new fuel gains about basic biophysical processes are bound to be exceedingly important to AKST.

Biofuels and global carbon balance

The grains, oilseeds and specially cultivated grasses (switchgrass and *Miscanthus)* used for biofuels require considerable fuel in their production and processing. The straws by-products require energy only in harvest and processing and will give a much more favorable carbon balance. Algae and cyanobacteria can achieve the highest carbon balance, as they can be directly "fertilized" by industrial flue gasses, directly removing them from the environment (Brown and Zeiler, 1993).

6.2.3.2 Improve energy efficiency of supply chains: food miles and life cycle analyses

Changes in food production and marketing systems, accompanied by changes in transport technologies, have led to increased transportation of agricultural and food commodities, both in raw and processed forms. Modern food supply chains, transforming goods from field to fork, tend to have greater ‘food miles’ per unit of final consumption than in-season, locally procured items. Transportation enables producers to exploit comparative advantage in farming and food by extending the spatial distribution and size of markets for their produce, to the mutual benefit of producers and consumers, thereby enhancing overall economic efficiency. This applies to produce transported within NAE and between NAE and other regions.

High food miles, especially involving heavy road vehicles, can, however, have negative impacts on sustainability associated with energy use, congestion, pollution and accidents (Smith et al., 2005). These transport related impacts can be significant at the local and national scales. Furthermore, failure to fully attribute the costs of these impacts to transport could give unfair advantage to distant compared to local produce. A large share of total food miles, however, is attributable to shopping by car at out-of-town supermarkets, reflecting changes in retailing and in purchasing habits (Pretty et al., 2005; Smith et al., 2005).

Thus, the relationship between food miles and sustainability of food supply is complicated (Smith et al., 2005). Aggregate travel distance is not in itself a useful indicator. Shorter distances are not necessarily more sustainable due to differences in the characteristics of food and supply systems (Smith et al., 2005; Saunders et al., 2006). Much depends on modes of transport, economies of scale in transportation, complementary functions such as refrigeration and differences in the overall cost and energy efficiency of food production, processing and delivery systems as these affect their comparative advantage over time and space.

Total energy use and CO_2 per unit commodity delivered to end users are more meaningful indicators, requiring a whole life cycle perspective, including production stages (Audsley et al., 1997; Smith et al., 2005; Williams et al., 2006). Thus, while increasing transportation efficiency is a valid target, minimizing transport miles and costs in themselves are not and to do so could increase prices and reduce the range and quality of produce available to consumers and compromise the livelihoods of low cost but distant producers, especially those in developing countries.

Some of the options cited below could help guide decisions on sustainable transport throughout the supply chain and its organizations, for example:

- develop crop varieties by breeding and biotechnology that can be shipped by sea instead of air while maintaining quality.
- further develop treatment technologies (chemicals, storage conditions, irradiation, biologicals) that preserve shelf life of agricultural commodities allowing shipping by sea instead of air.

- develop and apply databases and routines to assess transport efficiency and total energy/CO_2 emissions within a whole life cycle, field to fork approach, including full environmental accounting for transport functions.
- develop methods for carbon and energy accounting, reporting and labeling for food commodities, appropriately communicated to consumers.
- develop methods to enhance consumer understanding and appreciation of sustainable food procurement and transport systems to inform consumer choice.
- develop increased efficiency in food transport technology and logistic management systems, including promotion of sustainable transport.

6.2.4 Trade, markets and agricultural policies

As a major importer of commodities, labor and resources and an exporter of products, investment and AKST, NAE has influenced food and agriculture systems throughout the world. Regardless of which scenario will play out in the future, NAE's influence on other regions will continue. It is to NAE's advantage to ensure sustainable development of the whole world's food and agriculture system as well as its own. This task includes environmental, economic and social considerations in a context of autonomy for everyone (Box 6.2)

[Insert box 6.2]

Development of competitive and viable local production systems could be based on measures to ensure food security, improve farmers' livelihoods and assure sustainable development for both NAE and the concerned regions. Since exchanges between NAE and the other countries are presently through the trade system, NAE has the potential to participate in the continued evolution of the world trading system to ensure that it becomes more fair and equitable.

Develop competitive and viable local production systems.
The diversity of agricultures throughout the world is a consequence of the heterogeneity of available natural resources and local, social and historical contexts (Mazoyer and Roudart, 2006). A role for AKST could be to analyze this diversity of agricultures, their resources and constraints and their potential in terms of production, environmental services, social contribution, public goods and externalities as well as an analysis of production systems. The development and implementation of AKST could be based on the following principles (CBD, 2005):

- focus on food security and improvement of farmers' livelihoods;
- build on previous experience and knowledge, through combining the skills and wisdom of farmers with modern scientific knowledge;

- focus on integrated holistic solutions and technical adaptation to local contexts within a clear framework that builds on the principles of the agroecosystem approach;
- promote cross-sectoral approaches to address different perspectives (social, political, environmental) through association and flexibility; and
- prioritize actions based on country goals and the wants of direct beneficiaries and locally validate such actions through the full participation of all actors.

Continued attention to family farms is important as they were the basis of agricultural development and the forerunner of industrial development in NAE (Danbom, 2006). In many countries today such farms represent a major part of the rural population. If efficient and competitive in production and trade, these small producers could significantly contribute to achieving a higher and more sustainable pace of development, thereby promoting economic growth and social cohesion (IFAD, 2001).

In order to reach development and sustainability goals, NAE's contribution to AKST in other regions could result in alleviating rural poverty by improving access to resources and improving skills and institutional support so that the rural poor can benefit from:

- improved access to natural resources, especially land and water and improved natural resource management and conservation practices ;
- improved agricultural technologies and effective production services;
- broad range of financial services;
- transparent and competitive markets for agricultural inputs and produce;
- opportunities for rural off-farm employment and enterprise development and
- local and national policy and programming processes

The principle of division of labor has been a common feature of AKST (Herman, 2001). Product specialization based on resource endowments and linked with appropriate AKST will increase productivity (Mattson et al., 2006). IAASTD can examine whether states' abilities to benefit from application of AKST depend on their alignment with practices common to prosperous countries and their effects (Box 6.2).

Develop a fair and equitable trade system.

Market forces are shaping and will continue to shape the future of the world's agriculture and food system (Brown, 2002). Private enterprise operating through the market is the main engine of sustained economic growth, but it requires that states ensure that the investment climate is conducive to growth by equitably upholding property rights and contracts, maintaining political and macroeconomic stability, providing public goods, using regulation and public services to fill gaps left by markets and investing in the education, health and social protection of its people (Wolfensohn and Bourguignon, 2004).

From a market point of view, AKST can contribute to developing a fair and equitable trade system in NAE and in the rest of the world. A better understanding of what a fair and equitable trade system is, including further examination of the potential negative effects of measures such as dumping, may be required. There are contrasting views on this (see box 2). AKST can help: (i) to better understand the market mechanisms; (ii) to improve the modeling representation of the agricultural systems and their dynamics, including all the players and their inter-linkages through the markets.

(i) To understand better the market mechanisms.

In the field of market mechanisms, the questions for research can relate to:

- institutional analysis of local, regional and international markets and their mechanisms;
- modes of cooperation and coordination between players of the food system and the distribution of the added value;
- economic, institutional and social conditions for an access to the markets for all the actors;
- promotion of fair trade through prevention of monopolistic practices;
- attributes of the quality of the products (origin, know-how, practices and manufacturing process) and the way in which markets are able to recognize the qualification process of quality;
- institutional arrangements necessary for the remuneration of the positive externalities and for an adequate level of public goods production leaving transaction costs between potential beneficiaries sufficiently low and
- public policies able to generate a fair and equitable global trade system.

AKST could also investigate whether and how comparative advantage from specialization coupled with trade really favors smaller economies more then larger economies (Anderson, 2004).

(ii) To improve the representation of complex agricultural systems in the models

Agricultural trade has been one of the most contentious issues in multilateral trade negotiations in recent years due to the effects it could have on developed and developing countries. The trend has been towards more open markets, suggesting that worldwide agricultural production is likely to become more competitive. Analyses suggest that the impact of trade on developing countries will be very uneven. Some simulations even go so far as to suggest that the effects of agricultural trade liberalization will be small, overall and are likely to be negative for a significant number of developing countries (Bureau et al., 2005; Polaski, 2006). Policy recommendations derive too often from static, perfect competitive simulation models. More emphasis could be laid on technological change-induced inequalities, missing market effects on inequalities, dynamic adjustments impact assessment (Chabe-Ferret et al., 2005).

In order to improve the representation of the models (Box 6.3) it is important to distinguish between the various groups of developing countries (net food exporters vs. net food importers, least developed countries benefiting from huge trade preferences, least developed countries with main exports severely penalized by tariff peaks). It is essential to take into account the complex effects of the various types of domestic support, trade preferences (which are presently well utilized in the agricultural sector), regional agreements and the effect of trade liberalization on them (Loyat, 2004).

[Insert Box 6.3]

A larger discussion of the specification of the trade models used for the simulations of market liberalization and policy consequences might be required. This discussion could include representation of labor markets; imperfect information; price instability; uncertainty and risk; dynamics; and environmental externalities.

6.2.5 Promoting food quality and safety in diverse food and farming systems

Research and development in the last 50 years focused mainly on a unique model of development based on an increase of productivity. This trend is changing as recent evolution of agriculture shows that more than ever consumers are emphasizing on food quality, food safety and the relationship between diet and health to combat malnutrition and obesity (WHO, 2003; EC, 2005; USHHS and USDA, 2005). AKST could be used to understand and respond to these new expectations.

In addition, a new profile for agriculture is taking shape, with two major poles (Loyat, 2006; Hubert et al., 2007): agriculture directed by the demand for products of standard quality; and agriculture directed by the supply of specific products, identified by their origin or their manufacturing process (Box 6.4). In both cases AKST could be used to support the food and fiber supply chains that connect producers to markets, provide incentives and just rewards to producers, processors and marketing agents, provide products of value to consumers and society and also support rural livelihoods. The organization and operation of these supply chains vary considerably across NAE and also among different commodity chains. Global supply chains in bulk commodities often run along side local procurement networks of highly differentiated products.

[Insert Box 6.4]

Some of the areas where AKST can intervene and help respond to the above mentioned expectations are presented below:

6.2.5.1 Improve food quality

Explore the relationship between food, diet and health by taking into account the cultural diversity of food systems and the diversity of human responses within a given food system.

Understand better the relationship between diet and health by:

- investigating basic mechanisms by which nutrients or specific food components may act on biological mechanisms (gene expression, cell signaling and cell function, integrated physiology) (Young, 2002);
- performing high throughput analysis of biological responses with techniques such as transcriptomics, proteomics and metabolomics (Afman and Muller, 2006; Trujillo et al., 2006); and
- investigating how genetic polymorphism and metabolic imprinting (influence of early nutrition) of individuals result in the variability of physiological responses to diet (Waterland and Garza, 1999; Miles et al., 2005).

Take into account the various determinants of food choices and their influence on health by:

- investigating the biological, psychological, historical and socioeconomic factors that affect food choices, as well as their interactions (Bellisle, 2003); and
- identifying the early events taking place in infancy and childhood that are critical for the development of food preferences e.g. predilection for more diversified foods, fat free foods, high protein foods etc (Hetherington, 2002).

Improve the nutritional composition of food for health purposes by (Azais-Braesco et al., 2006; Richardson et al., 2003; Roberfroid, 2002):

- developing methods of assessment of “nutritional profile” of foods that allows a comparison between various food products regarding their contribution to the overall balance of the diet;
- developing functional foods and confirming related health claims; and
- developing and applying methods to remove anti-nutrients, allergens and toxins from the food chain.

Improve the standard quality of unprocessed agricultural products and their processing

AKST could contribute to the improvement of nutritional, organoleptic and health quality of unprocessed agricultural products. The role the environment (i.e. soil, air, pathogens) and agricultural practices and their various interactions, play in determining the quality and stability of these unprocessed products (e.g. the production of mycotoxins, polluted soils and the transmission of xenobiotics to food plants and animals, pesticide application and the detection of their residues in food etc.) could be taken into account. Such improvements in unprocessed agricultural products are particularly appropriate for bulk production (standardized quality products) (Box 6.5).

[Insert Box 6.5]

The overall objective of processing is to be able to design and produce food that meets a large set of criteria (safety, nutrition) and is accepted by consumers (Bruin et al., 2003). The "Preference, Acceptance, Need" set of expected properties (PAN) is an important objective and tailor made food is one example that corresponds to these properties (Windhab, 2006). In addition to processing control, the conservation of properties on the shelf life appears to be of much importance too. This includes packaging. An important goal is to control the processes in order to simultaneously reach all the objectives: food quality and energy and environmental considerations (Dochain et al., 2005). Finally, even if the control of specific properties (nutrition mainly) is of great importance, the ability to control food safety and hygiene appears to be equally essential (Napper, 2006).

Develop quality specific products distinguished by their place of origin

Options for research on these products could include:

- study the attributes of quality (Allaire, 2002);
- develop processes for the qualification of food products according to their origin, methods of production or marketing (Bérard and Marchenay, 2004, 2007); and
- encourage the normalization of local knowledge and practices (Bérard and Marchenay, 2006).

Reinforce traceability: from raw materials to marketed products

Spurred on by recent food scares around the world, some governments are forcing the adoption of food traceability systems. The ability to trace products and their components throughout the food chain is becoming more important in markets for safety and quality assurance.

Methodological and technological developments required for efficient traceability in standardized production could include among others:

- development of new generation of analytical methods based on micro and nanotechnology solutions that comply with the requirements for ubiquity, fast response, low cost, simple use etc. (European Commission, Framework Program VI Information society technology 2005-2006: Good Food project);
- development of microsystems technology solutions for the rapid detection of toxigenic fungi and mycotoxins by natural bioreceptors, artificial receptors and nano-electrode devices;
- development and characterization of different sensors, based on innovative DNA sensing technologies for direct and real time measurement of target DNA sequences of pathogens present in the food matrix. (European Commission, Framework Program VI Information society technology 2005-2006: Good Food project); and
- promotion of innovations in DNA fingerprinting, nanotechnology for miniature machines and retinal imaging and their increased integration into plant and livestock industries for improving the speed and precision of traceability (Opara, 2003).

6.2.5.2 Develop diversified, fair and equitable food and fiber supply chains

Many NAE food supply chains operate at the cutting edge of marketing technologies and have reaped increasing profits and market-share. Trends in agricultural and food commodity markets, however, show that most NAE farmers have not only become separated from consumers, but food supply chains are dominated by processors and retailers (Fearne, 1994; Lyson and Raymer, 2000; PCFFF, 2002; Vorley, 2003). Vertical integration of successive stages in agricultural and food supply chains under the control of single corporate organizations or clusters of corporations can reduce the competitive power of farmers (Lamont, 1992; OFT, 2006; UNCTAD, 2006) who have become disadvantaged, inadequately rewarded 'price takers' facing limited market opportunities for their produce. The gap between farm and retail prices is growing and is wider in countries where transnational corporations (TNC) have concentrated market power. The farm retail price gap is costing commodity-exporting countries more than US $100 billion each year and anticompetitive behavior by agrifood TNCs is said to be a key cause (Morisset, 1997).

There is thus an urgent need to develop policy instruments to remove incentives for farm concentration and agribusiness concentration (Action Aid International, 2006; SOMO 2006; UK Food Group, 2005). These include:

- improve competition policies within agrifood markets, for instance, by monitoring corporate concentration, mergers and strategic business alliances and their anti-competitive effects across national borders;
- apply stringent anti-trust measures that dissuade global price-fixing cartels;

- develop strict monitoring and external verification systems to assess and increase the credibility and transparency of corporate social responsibility;
- develop international organizations to monitor the concentration and behavior of TNCs involved in agricultural trading and food retailing at a global level. These organizations could be given the task of collecting information, researching policy advice and developing standards of corporate behavior.

Another area of equal importance is that of improving the 'connectivity' between food producers and consumers and increasing the competitive power of farmers. Some of the measures that could facilitate this are:

- improve the market orientation and responsiveness among producers through training and technical assistance in marketing and related business management skills;
- improve market intelligence and transparency throughout the supply chain;
- extend existing and develop new supply chains within NAE and externally that distribute profits more equitably among actors through negotiated multistakeholder arrangements;
- support actions to add value on or near the farm, through on-farm processing and/or product differentiation, including for example organic and fair trade products and products distinguished by geographical origin or appellations;
- develop collective business and marketing capability among farmers, through for example farmer groups, cooperatives and trade association in order to improve their bargaining position;
- increase investments in market development and in marketing infrastructure for local and regional marketing such as storage, processing, refrigeration and transport.

6.2.6 Promoting environmental sustainability through ecological management

From an environmental perspective, the sustainability concept calls for an ecological and evolutionary approach. . The understanding of specific ecosystems and the ecological principles by which they function are key elements for the design and management of agricultural systems– simultaneously ensuring both productivity and natural resource preservation (Altieri, 1995; Vandermeer, 1995; Gliessman, 1997).

The design of such agroecosystems is based on ecological principles (Reinjntjes et al., 1992) that may be applied using a range of techniques and strategies (Altieri, 2005): *"(i) enhancing recycling of biomass, optimizing nutrient availability and balancing nutrient flow, (ii) securing favorable soil conditions for plant growth, particularly by managing organic matter and enhancing soil biotic activity, (iii) minimizing losses due to flows of solar radiation, air and water by way of microclimate management, water harvesting and soil management through increased soil cover,* *(iv) increasing species and genetic diversification of the agroecosystem in time and space and (v) enhancing beneficial biological interactions and synergisms among agrobiodiversity components thus resulting in the promotion of key ecological processes and services*."

AKST needs to fully take into account this ecological perspective on agriculture and its dynamic evolution over time and space. In this context, biodiversity –viewed as the multitude of interactions among all living organisms in the soil and water as well as on the ground and in the air - plays a central role in the preservation and the enhancement of the multiple functions of the agroecosystem (Griffon and Weber, 1996; Altieri and Nicholls, 1999; Thies and Tscharntke, 1999) and particularly with respect to productivity (Hector et al., 1999).

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6.2.6.1 Potential contribution of AKST for long term soil preservation

In the last few decades there has been an intensification of human activities on soil (industry, agriculture, urbanization, cemeteries, recreation, etc.). This has largely been achieved without considering soil diversity and its suitability to accommodate these different activities. Consequently there has been a pronounced degradation of soil with negative consequences for a range of soil functions, including the regulation of hydrological and atmospheric gas processes and the provision of habitats for flora and fauna.

In view of an ecological management of agroecosystems, there are some areas where AKST can be developed and help remedy the current situation of soils are mentioned below:

Understand soils better: including past, present and current dynamics.

- Soil is a continuous milieu wherein there are vertical as well as lateral organizations and dynamics. We are in a better position today to understand the vertical organization but more research is essential to understand the lateral organization and dynamics of pedological covers, that can in turn shed light on the different existing "pedological systems"[4] and their differentiation process (Ruellan, 2000, 2005). In particular, it is important to understand better the long distance transportation of organic matter, fertilizers, pesticides and pathogens through this milieu.
- Elucidate the relationship that exists between the "pedological systems" and the current or future social systems (Lahmar et al., 2000).
- Study the rate of evolution of the different characteristics and properties of soil. (AFES, 1998).
- Develop the notion of soil as being not just a part of the larger ecosystem but also as an ecosystem in itself (Lal, 2002).

[4] A pedological system is a portion of soil cover that, by its constituents, its structures and its dynamics (vertical and lateral distribution and functioning), constitutes a unity.

Link soils and human activity

(; AFES, 1998; Lahmar et al., 2000; Lal, 2002; Van Camp et al., 2004)

There is need of improved understanding of the influence of human activity on: rate of evolution of soils, mechanisms of soil formation, modification of biological activities and their consequence on soil formation, modification of the alteration rate of rocks etc.

- Understand the effect of climate change on soil evolution and the subsequent re-utilization of these soils in a better way.
- Understand better soil degradation and its consequences on the surrounding environment (air, water, life) and human health.
- Identify the interactions between agricultural practices and soil degradation.
- Where it has not been done, develop a portfolio of soils at the national level that would help in classifying soils according to their properties, functions and appropriate utilization. For example, certain soils can be categorized under “soils meant for agriculture” whereas others can be “sealed” (used for construction or other purposes).

Develop appropriate soil related technology and agricultural practices

Develop agricultural practices that take into account the diversity of soils, thereby matching their properties to their use and management.

- Design tools to improve soil productivity while promoting renewal of soils (Van Camp et al., 2004).
- Develop new methods to remediate soils like phytobial remediation, a new process that combines the best of both traditional bio and phytoremediation using microbes. Plants are grown whose roots are colonized by symbiotic microbes that degrade toxicants and assist plants in taking up toxic materials (Lynch and Moffat, 2005). Other novel bioremediation technologies include transgenic technologies where the bacterial genes are inserted directly into the plant (Mackova et al., 2006). These plants could be used to accelerate the decontamination processes to more rapidly remediate sites and bring or return contaminated areas into production or other use. More research on heavy metals sequestered in biomass could be helpful.
- Develop nanosensors for monitoring soil health.
- Develop and implement accessible information systems and extension services including remote sensing technologies for better soil management.
- Decrease soil degradation and/or increase soil fertility using technologies that permit:
    - an increase in porosity that would prevent soil compaction and promote a decrease in the rate of erosion (excluding arid areas where increased water retention is the primary focus);

- an increase in water retention and act against drought and land desertification; and
- an improvement in the retention of organic matter present in soils.

In addition to all of the above, a better integration of existing and new knowledge on soils and soil practices into the legal regimes of states or regions as well as national and international policies could be useful.

6.2.6.2 Contribution of AKST to water management

Water is an essential input for agricultural production for which there is no substitute. It is imperative that NAE achieves sustainable use of water resources in the agricultural sector within the region, as well as contributing to sustainable water management in a wider global context.

Agricultural water management is likely to become more challenging in the future due to increased human demand for water, climate change and limits imposed by available water (Evans, 1996; EEA, 1999, 2001a, 2001b; Hamdy et al., 2003; FAO, 2004a; NRC, 2004; Dobrowolski and O'Neill, 2005; OECD, 2006; Morris, 2007; Rosegrant et al., 2007). Keeping in mind the perspective of ecological design and management of agroecosystems, several options could be considered for AKST to contribute to water management (quantity as well as quality) as follows:

Water Quantity

Irrigation water management

Irrigation is critical for some areas within NAE, especially southern Europe and the western United States (Hutson et al., 2005). The EU has 9% of its agricultural production under irrigation (13 million ha), over 75% of this in Spain, Italy, France and Greece (EEA, 1999; Kasnakoglu, 2006). More than 22 million ha (18% of total cropland) are irrigated in the U.S., over 80% of which is in the West (Gollehon et al., 2006). In Europe, agriculture accounts for 30% of total water abstraction and 55% of consumptive (nonreturnable) use. In parts of southern Europe, these figures are typically over 70% and 60% respectively (EEA, 2001a; Berbel et al., 2004).

With regard to irrigation water management, the following are some of the priorities for the future:

- develop new irrigation technologies and practices (Stringham and Walker, 1987) that further increase water use efficiency (that is 'crop per drop'). including controlled water placement and use, cultivations to conserve moisture and introduction of low water demanding crops;
- promote irrigation water auditing and scheduling systems, including remote sensing to monitor crop for optimal timing of irrigation;
- increase training and incentives for farmers to adopt improved irrigation practices; and

- improve water harvesting methods including the construction of dams and water distribution systems.

Removal of excess water

In the future, under conditions of climate change, new integrated land drainage technologies will be required. These can include on-farm water treatment and storage, which can help cope with greater variation in precipitation and temperature and periods of excessive rainfall and river flows, help mitigate salinity and improve overall water resource management. (O'Connell et al, 2004; Lane et al, 2006; Morris and Wheater, 2006; Thorne et al., 2006).

Genetic developments (using conventional and transgenic technologies) to reduce drought stress

Technologies are now available to alter the metabolism of plants to make them more tolerant to water induced stress. Research could help in determining optimal water requirements of important crops and in developing new stress resistant varieties. There is need to develop crops which are tolerant to low water quality, especially associated with salinity.

Water Quality

There are major concerns in many parts of NAE about water quality and the consequences for ecosystems and human health (Costanza et al., 1989). In the EU, the Water Framework Directive sets the context for this over the next 20 years (Morris, 2007). Diffuse pollution from agriculture is of major concern in many parts of Europe (Pretty et al., 2000; EFTEC and IEEP, 2004; Bowes et al., 2005; Neal et al., 2005) and increasingly the subject of targeted control measures (EA, 2002). In this respect, some of the priorities for AKST include:

- An integrated approach to water resource management, of which agriculture is part, at the catchment scale (English Nature, 2002).
- Improved integrated understanding of pollutant behavior and transport mechanisms within the landscape (nitrates and pesticides in particular).
- Suitable measures to reduce diffuse pollution from farmland.
- Evidence of the link between land management, runoff and flood generation and options for on farm water retention and storage.
- Methods for on-site passive water treatment systems such as reed-beds, industrial or energy crops and active systems such as nano-based filtration and purification techniques using membrane systems to detect and neutralize undesirable chemical, physical and biological properties.
- Improved understanding of the link between environmental water quality and public health (Hallman et al., 1995).

Water policies and water reuse

Ownership and rights to use water are becoming more contentious as aquifers are depleted faster than they are recharged (Engberg, 2005). Water law and entitlements are typically more complex and less well defined than those for land (Sokratous, 2003; Caponera and Nanni, 2007). Water reuse is a rapidly evolving water-management tool for supplementing limited water resources around the globe (Lazarova and Bahri, 2004). In this context, future research and investment could help to:

- Better understand the agricultural use of water and the cost of providing water services.
- Better appreciate the social, economic and environmental value of water as a basis for sustainable water resource management.
- Develop water allocation and distribution schemes to balance food and agriculture with other water needs (Engberg, 2005).
- Provide water managers and policy makers with decision support tools to guide water resource management and policies that lead to behavioral change and a reduction in water conflicts.
- Understand the role of water property rights and laws, the benefits of local management of water and the role of collective action by water user groups.
- Support schemes for water licensing, pricing and, where appropriate, trading to promote water use efficiency.
- Develop integrated programs to address water reuse, conservation and wastewater reuse for agricultural, rural and urbanizing watersheds after having assessed the social and economic feasibility and impacts of water reuse projects.
- Develop technologies for the exploitation of alternative water sources (e.g. sea water after desalination, air humidity after condensation, production of drinking and irrigation water in seawater greenhouses (Pearce and Barbier, 2000).
- Develop education/outreach programs to foster the development of criteria and standards for economic and sustainable solutions that will help protect public health and the environment.

AKST will have a critical role in managing the potential benefits and risks of agricultural water use as the resource becomes more scarce and valuable. AKST is required to achieve a much greater integration of ecological land and water management as a basis for sustainable, multifunctional agriculture.

6.2.6.3 Potential contribution of AKST to biodiversity and genetic resource management

Agriculture as a whole is based on the human utilization of biodiversity: soil biodiversity, aquatic biodiversity, as well as diversity of plants, animals and microorganisms. Historically, agronomy has led to increased uniformity in the whole farming system in order to facilitate the mechanization and industrialization the whole process (from seedbed to harvest and post-harvest periods) to the detriment of biodiversity. Considering recent advances, it is now obvious that diversity and productivity are linked (Hector et al., 2000; Loreau et al., 2001; Reich et al., 2004; Van Ruijven and Berendse, 2005; Tracy and Faulkner, 2006).

AKST could play a significant role in managing and enhancing present biodiversity, which is the foundation of ecosystem services namely provisioning (e.g. food, wood, fiber, fuel) and regulating (climate and flood regulation, disease control) services (MA, 2005). There are many options for AKST to play such a role through agricultural practices and land management as well as through genetic resources preservation as long as the political and regulatory context allows it.

Biodiversity enhancement in agricultural activities and land management

To promote an ecological approach of the agroecosystems, AKST could focus on a better understanding of the impacts of different cropping and livestock systems both on the spatial distribution and the evolution of the overall biodiversity at the landscape level and, as well as the effect of biodiversity on the productivity and quality of the systems including soil and water resources. Some of the options among others are (Jackson, 1980; Soule et al., 1992; Kerr and Currie 1995; Caughley and Gunn, 1996; Johnson et al., 1996; Srivastava et al., 1996; Johnson et al, 1999; McNeely et al., 2002; Graf, 2003):

- Design rural landscapes with biodiversity enhancement in mind. This might include consideration of such critical issues as mixed and strip cropping for annual crops at the farm level, as well as the creation of migration corridors and improvement in habitat quality at the appropriate scale. It could also include enhancing knowledge of the functional role of nonagricultural biodiversity in achieving specific regulating services at the landscape level (pollination, pest and disease regulation, natural hazard protection…).
- Continue research on radical new types of agricultural production that would be based on biodiversity enhancement while increasing productivity and offering other advantages, including reduced reliance on chemical inputs, lower energy costs and reduced soil degradation and erosion for example:
    - Further research and experimentation on pesticide use and pesticide hazard reduction plans (at national and regional level) that could result in yield gains while enhancing biodiversity and safeguarding human health.
    - Changes in fertilization and tillage practices that could enhance beneficial soil flora and fauna as well as alleviate the contamination of waterways that has multiple effects on wildlife. There is wide recognition of the desirability for substantial

additional research on both technical and policy options that ensure a wide and consistent implementation of these changes.

- Improvements in water use efficiency through technical improvements and policy tools to reduce the impact of agricultural water demands on the environment and biodiversity.

▪ Better understand the role of both forests and grasslands and their management in the preservation of biodiversity and ecological processes.

AKST could also focus on the optimization of spatial and temporal management of crops and livestock biodiversity at the landscape level and as part of a global agroecosystem (Loreau et al., 2003) to contribute to the sustainability of the whole system by:

▪ Better understanding the effect of spatial and temporal distribution of varieties (for example among crop plants possessing different pest resistance genes) and the associated organizational and technical practices on the evolution of both pathogen and pollinator communities at the landscape level. This requires the understanding of the biological mechanisms of host-pathogen co-evolution and their susceptibility to a fluctuating environment;
▪ Improving knowledge on the diversification of production and associated practices and its effect on the productivity as well as on the supply of environmental services (provision of public goods, positive externalities);
▪ Better understanding the spatial organization and relative proportion of cultivated areas on the one hand and grassland and forests on the other as well as their interaction with urban areas, in the study of water and fertilizers transportation within the territory and as parts of the whole landscape living ecosystem;
▪ Developing GIS tools and Multi-Agent Systems that help farmer communities and associations determine appropriate locations of various food and farming systems (crops, animals, enterprise, grasslands) to improve production efficiency and meet environmental challenges including biodiversity preservation.

Genetic resources preservation

The global distribution of genetic diversity and the interdependency of all countries vis-à-vis genetic resources call for greatly improved cooperation and coordination mechanisms at the global as well as the local level. Much work will be required in order to upgrade, rationalize and coordinate the global design for *ex situ collections* (based on local, national and regional genebanks): the Future Harvest Centers and the Global Conservation Trust could play a major role in the coordination and support of all the components of such design. This effort has to be accompanied by a more systematic characterization, evaluation and documentation of genetic resources to allow their wide use.

Today, there is a strong scientific consensus that the viability of genetic resources in agriculture depends on *in situ* preservation efforts that allows the development of resources' adaptative capacities and acts as a complement to *ex situ* stored collections. These must be carried out in a large variety of ecological and cultural circumstances that can only be achieved through international cooperation and funding. So, in addition to the static conservation of genetic resources, more attention could be paid to the dynamic processes that allow potential evolution in changing environment through *in situ* preservation.

Considering livestock, it will be important to:

- Understand better the evolution of genetic diversity in intensive and extensive breeding populations and develop tools to monitor and control the genetic drift within such populations.
- Develop specific and breeding efforts on locally adapted populations in order to meet the challenge of specific local demand and maintain a large genetic diversity.

Considering crops, important measures include:

- Develop methods and tools to accompany the preservation of genetic diversity on farm.
- Broaden the conservation circles to establish closer collaboration with grassroots conservation movements and community seed banks.

6.2.6.4 Potential of AKST for developing energy efficient food and farming systems

Farming and food systems (FFS) in NAE are energy intensive. Even though farming in general accounts for only about 5% of total energy consumption in the most of the NAE region, this share increases to over 20% of total energy use once food processing, packaging and distribution are included (Fluck, 1992; Giampietro and Pimentel, 1993; Pimental and Giampietro, 1994; Heller and Keoleian, 2000; Heller and Keoleian, 2003; Murray, 2005; Williams et al., 2006). At the farm scale, about 85% energy inputs in NAE farming systems are carbon fossil based: other sources are relatively undeveloped. 50% of farm energy relates to agrochemicals, mainly nitrogen fertilizer, 30% to field machinery and transport and 20% to energy services linked to heating, lighting and materials handling (Box 6.6).

[Insert Box 6.6]

Current NAE farming and food systems and related livelihoods are especially vulnerable to increased energy prices and reduced fossil fuel supplies. Although high energy prices will continue to increase the scope for bioenergy crops, energy efficiency will remain a critical component of their feasibility (Stout, 1991).

AKST is a critical factor in understanding and influencing the farming-energy relationship. In the face of rising energy prices, the following possible priorities are identified:

- Enhanced understanding of energy use and efficiency in farming systems, including synergies and trade-offs with other 'performance' indicators such as yield, quality, added value and environmental impacts.
- Development of data bases and evaluation methods such as energy auditing, budgeting and life cycle analysis. Improved farmer and operator skills in energy auditing and management for field and farmstead operations.
- Adapting existing and development of new energy saving technologies for crop and livestock production addressing major field and farm operations and processes, including:
    - Improved minimum cultivation systems
    - Combination tillage and crop establishment field operations, including gantry systems
    - Precision application of fertilizers and crop protection chemicals
    - Whole crop harvesting systems
    - Handling, storage and treatment of materials and deriving energy from 'wastes'
    - Irrigation application systems
- Technology development in alternative energy sources, including on-farm wind, solar and groundwater heat and use of ambient conditions to provide energy services in drying and storage.
- Genetic development, using conventional and transgenic technologies, to improve energy conversion in crop and livestock systems and reduce agrochemical dependency as well as to increase the shelf life of agricultural products with reduced refrigeration.
- Improved design for energy efficiency in farm machinery and equipment.
- Development of energy efficient protected cropping buildings and animal housing, including heating and refrigeration systems.
- Improved methods for recovery and reuse of residues and wastes as 'resources'- including fertilizer, heat and power from farm wastes and other off farm waste (such as biosolids).
- Re-development of indigenous, energy saving technologies.
- Improved understanding among consumers of excessive energy costs of 'out of season' vegetables, in order to modify purchasing behavior.
- Development of whole supply chain energy auditing and reporting systems, including energy labeling, to inform consumers and policy makers.

- Design of suitable policy instruments to promote energy efficiency in food and fiber supply chains.

6.2.6.5 Reducing pressure on natural resources through the ecological footprint method

The ecological footprint is a method for comparing the sustainability of resource use –mainly energy- among different populations (Rees, 1992). The ecological footprint was defined in terms of land area needed to meet the consumption of a population and absorb all their wastes (Wackernagel and Rees, 1995). Although the concept has been subjected to considerable criticism, recent advances include input-output analysis (Bicknell et al., 1998; Hubacek and Giljum, 2003), land condition indicators and land disturbance analysis (Lenzen and Murray, 2001). These advances have enabled calculation and comparison of ecological footprints across widely divergent scales, from countries to families and categorization of the ecological footprint into commodities, production layers and structural paths. Such analyses provide detailed information on which to base policy decisions for reducing pressure on energy consumption of different types of populations (Lenzen and Murray, 2003).

6.2.7 Developing innovative crops and livestock food and farming systems

AKST could be mobilized at the farm level for developing innovative crop and livestock farming systems by breeding plants and animals with high quality performance both from environmental and production perspectives and breeding of under utilized species. AKST could also contribute to the development of innovative modes of production and evaluating of diversity. These new systems could facilitate better interactions among -crops or livestock, production methods and the environment.

6.2.7.1 The potential of genetics and biotechnology for crops and livestock breeding

Breeding has the potential to be a key element to contribute to the realization of development and sustainability goals, both in the areas of food security and safety and to contribute to environmental sustainability (FAO, 2004; Plants for the future, 2005; FABRE, 2006). It would be appropriate to tightly bind breeding with crop or animal system management and with the local environment. The potential of AKST to support breeding activities is enormous -due to the recent progress in genetics especially in molecular genetics and genomics whose continuation is important- and offers new possibilities for breeding methods that could be better explored. Also, these future innovations raise new concerns in terms of possible wider effects and unforeseeable consequences, (Boxes 6.7 and 6.8), calling for new ways of assessment and follow up.

Considering basic knowledge, a huge effort has been invested in the last 20 years to explore the structure and functions of the genomes of several living organisms'. It enhanced knowledge in genome sequencing of gene structure, expression and function and in genome structures (physical maps, duplications of chromosomes fragments and deletions, mobile element invasiveness; comparative genomics, etc.) through a more systematic and industrialized approach of the cell/tissue products (transcripts, proteins and metabolites).

Much previous research had been based on an understanding of genetics that has assumed "a direct path from gene to protein and to function as well as the presence of preset responses to external perturbations" (Aebersold, 2005). While it led to the accumulation of large amounts of detailed knowledge that constitutes an important data investment, its limitations have also become apparent: little is known about how cells integrate signals generated by different receptors into a physiological response and few biological systems have produced a consistent set of data that allows the generation of mathematical models that simulate the dynamic behavior of the system. Some of the priorities for research to help better understand these processes could be:

- maintain the effort in genomics data acquisition to accumulate knowledge in structure and functions of specific genes and particularly those the expression of which may contribute to development and sustainability goals (FAO, 2004; Plants for the Future, 2005; FABRE, 2006);
- strengthen the efforts of basic physiology through functional genomics and systems biology that continue to break through the major limitations inherent in previous approaches (Minorsky, 2003). This requires enormous sets of data as well as a sophisticated data infrastructure with a high level mathematical framework (Minorsky, 2003; Wiley, 2006). These efforts will also lead to a better understanding of the interactions between the metabolic pathways and of their role in the expression and the regulation of specific traits;
- explore further the role of epigenetic mechanisms (DNA methylation, histone acetylation, RNA interference) in the regulatory framework of specific gene sets (Grant-Dowton and Dickinson, 2005, 2006);
- increase the understanding of mechanisms of reproductive biology and regulation of ontogenesis that allows elaboration of methods of rapid multiplication of appropriate genotypes (cloning, apomixis etc) (FAO, 2004b; FABRE, 2006);
- develop comparative biology including comparative genomics (Sankoff and Nadeau, 2000) to ensure the dissemination of knowledge on a wide range of food species including under-utilized ones (FAO, 2004b); and
- invest in metagenomics, the potential of which is considerable considering applications in agriculture, land environmental remediation, bioenergy *etc*. (NRC, 2007).

Concerning applied research, AKST could be pursued to accompany breeding activities focused on functions and mechanisms that contribute to the adaptability of crops and animals to extreme stress –both biotic and abiotic-, to quality and safety of food as well as to the sustainability of food and farming systems (Box 6.7). It could be useful to develop these activities on a wide range of food species to maintain progress in both industrial and under-utilized species.

[Insert box 6.7]

AKST could also explore the potential of more diversified and heterogeneous variety types namely to better meet the environmental concerns: for example, it would be interesting to generate a variety of wheat that has three different leaf and stem architectures but is otherwise isogenic; such variety, planted with its mixed morphotypes, could be better at capturing sunlight and carbon dioxide and better at competing with weeds; also, a variety of wheat or maize having different types of root systems (a superficial one with a large covering area and a deep one more localized) could better benefit during restricted water availability in the different soil depth. In this case, the “uniformity” paradigm for variety registration procedures will have to change to integrate and favor diversity.

AKST could also be mobilized to develop innovative breeding strategies and technologies (marker/ “genomics”-assisted selection, gene transfer, targeted mutagenesis…) for the efficient introduction of desired traits into high-yielding crops and animals, using the vast potential available in genetic resources’ collections of both widely used and under-utilized species (crops as well as wild relatives). Among other options AKST could contribute and help (Plants for the Future, 2005; FABRE, 2006):

- Develop innovative breeding methodologies based on sexual reproduction to integrate present genetic and genome knowledge (marker-assisted selection, new mathematical models and software for genetic evaluation and selection -taking into account new data on gene regulation, imprinting, silencing, genome dynamics, whole genome sequencing *etc*.); and
- Develop technologies that can lead to “break-through innovations” through genetic engineering (for example to move needed genes and pathways from species where they exist to species where they are needed, tissue specific promoters with genes or RNAi to turn on or off genes that are needed only in specific tissues), cloned animals and other methods that do not include sexual reproduction.

It is important that the development of such innovations does not negatively affect other desirable traits or basic physiology of crops/animals and is not harmful either for the environment or for the human health and that it benefits to many people around the world, namely through their contribution to the achievement of development and sustainability goals (Box 6.8 and 6.9)

[Insert boxes 6.8 and 6.9]

Animal welfare has an important high priority place in the agenda for the future. Most livestock production (pigs, poultry, dairy cattle, beef cattle) will probably be in large-scale production systems. AKST may be mobilized to ensure that minimum standards for the protection of farm animals are set and respected (Box 6.7)

More generally, the wide development and dissemination of innovations has to be anticipated and assessed to understand how it might or might not contribute to Development and sustainability goals, considering all dimensions of sustainability and integrating appropriate spatial and temporal scales. New AKST developments could accompany this new form of innovation process through:

- a change in the evaluation process, that could move towards a more systems and dynamic approach and take into account all the potential impacts (both positive and negative) of the innovation (ACRE, 2006): (i) from environmental, health, social, ethical and economic point of views, (ii) both short and long term, (iii) at the pertinent spatial scale. The evaluation of these impacts before and after implementation through appropriate means is important. AKST research could contribute to the developments of methods and tools that could help in the renewal of this evaluation at the different steps of innovation process; and
- a renewal of policy design (associated with systems evaluation process), which call for a priori evaluation as well as follow-up designs and a posteriori analysis.

6.2.7.2 The potential of nanotechnologies in the food and fiber supply chains

Nanoscience involves the study of the characteristics and manipulation of materials at the scale of atoms and molecules (RS&RAE, 2004; BSI, 2006). Nanotechnology involves the ‘design, characterization, production and application of structures, devices and systems by controlling shape and size at the nanometer scale’ (RS&RAE, 2004). At extremely small dimensions, materials exhibit different properties and behaviors, for example possessing greater strength or tolerance, or reacting differently to physical or chemical stimulation. Nanotechnology is already incorporated into commercial products such as pharmaceuticals, chemicals, transport and energy products, packaging, coating and lubrication and electronic products. Nanotechnology is also used for environmental sensing and remediation (Zang, 2003; Kuzma and Verhage, 2006).

Nanotechnology is potentially applicable at all stages of the food and fiber supply chain (Joseph and Morrison, 2006; Kuzma and Verhage, 2006). On farm nanotechnologies have potential to:

- improve crop fertilization and protection by improving the precision of application and enabling activation of chemicals at agronomically and environmentally appropriate times;
- identify and immediately treat crop and livestock pathogens and signal contamination of food products by microorganisms;
- apply additives such as minerals in crop treatments that can be recovered on harvest; and
- enhance operational properties of farm machinery through reduced mass, improved coatings and reduced maintenance.

Nanotechnologies using 'smart devices' can help detect environmental damage and target remediation, such as water pollution and clean up. With respect to food processing and marketing, nanotechnologies have potential to enhance the nutrient and dietary properties of foods, improve packaging, detect contaminants in foods including toxic substances and extend product life.

There are, however, actual and perceived risks associated with nanotechnologies and their application in farming and food (RS&RAE, 2004; Defra, 2005a), with respect to occupational health (Aitken et al., 2004; Health and Safety Executive, 2004), public health (Warheit, 2004; SCENIHR, 2005) and environmental risk (Colvin, 2003; Guzman et al., 2006). For example in 2004, the Royal Society calls for a precautionary approach until the uncertainties associated with 'potential toxicity and persistence can be ascertained'. In this context public agencies could develop proactive approaches to nanotechnology management by reviewing potential benefits and risks, understanding and informing public perceptions of risks and benefits and prioritizing the farming and food as a pioneer sector for the beneficial use of nanotechnology (Kuzma and Verhage, 2006). For others such as Friends of the Earth and the UK Soil Association, the risks of 'nanofoods' to human and environmental health outweigh benefits especially compared to organic options.

Although most investments in nanotechnology are commercially driven, there here are important social, environmental and ethical implications that justify government participation in nanotechnology research as well as management. Furthermore, the development of nanotechnology in NAE has potential to influence its use in other regions of the world.

In the context of the use of nanotechnology in farming and food and related environmental management, capacity could be developed in:

- ensuring that public investments in nanotechnology are aimed at meeting critical societal needs;
- supporting fundamental studies in nanoscience to improve the understanding of nanoparticle interactions with biological materials and organisms;
- maintaining a registry of nanotechnology applications, linked to product and process information and 'labeling';
- applying appropriate methods for testing, risk assessment and monitoring of impacts, including epidemiological, occupational and environmental aspects;
- educating the public and consumers on the benefits and risks of nanotechnology, including product information, to enable informed choice;
- developing suitable regulatory frameworks for new nanotechnology applications, including specifications and commodity and trade descriptions, working with existing standards agencies;
- promoting beneficial development and use of nanotechnology in the public interest through scientific research and joint government-industry partnerships; and
- building international partnerships to promote appropriate nanotechnologies to meet the needs of developing countries (Salamanca-Butello et al., 2005).

6.2.7.3 Contribution of AKST to the development of improved pest management.

New technologies and production practices have been developed to reduce the environmentally detrimental effects of pest management in agricultural production. Many of these methods will require further research to improve both their productivity and environmental performance. Such research will continue to contribute to innovation in the development of technologies and practices. Broadly speaking, the new approaches fall under the term "ecologically-based pest management" (EPBM) as based on a working knowledge of the agroecosystem, including natural processes that suppress or reduce pest populations (National Academy of Sciences Board, 2000).

Management techniques reflecting such an ecologically-based approach can include Integrated Pest Management (IPM), conservation biological control integrated plant nutrient systems (IPNS), no-till (or minimum tillage) conservation agriculture (NT/CA), precision, spatial variable farming and livestock breeding and feeding and housing regimes that reduce environmental load (Elliot and Dent, 1995). Significant uncertainties and controversies remain to be resolved by future research regarding the nature and efficacy of many of these techniques and their many variants (NRC, 2001; Ehler et al., 2005).

As elaborated in the cited sources above, AKST can contribute to the further development and dissemination of such practices by:

- investment in pest ecology, including insect, weed and pathogen ecology, to allow maximum biodiversity with minimum impact on productivity and crop health;
- broadening and deepening the research on environmental and human health implications of pesticides. Continuing improvements in human epidemiology and environmental assessment will be useful to better identify and measure the adverse effects of pesticides and thus guide further research into their safe use;
- ensuring that research on pest management is locally appropriate and effective by drawing on the existing locally developed knowledge and developing new knowledge of local conditions;
- developing better tools for prior evaluation of the unintended effects of pesticide use and for monitoring and evaluation of negative effects after adoption; and
- developing new approaches to integrated pest management and organic agriculture (Box 6.10) based on integrating advances in ecological sciences. Better ecological understanding of both the field environment itself and the wider ecosystem will be essential in this respect.

[Insert Box 6.10]

6.2.7.4 Development of alternative resource management strategies

A variety of approaches show significant promise in improving overall resource management and environmental performance of agriculture. Many of these have incidental or significant roles in pest management strategies, but they are designed with wider purposes in mind. They include:

- optimizing integrated plant nutrient systems by maximizing plant nutrient use efficiency through recycling all plant nutrient sources within the agroecosystem and by using nitrogen fixation by legumes, balancing the use of local and external sources of plant nutrients while maintaining soil fertility and minimizing plant nutrient losses);
- adapting no till and conservation tillage technologies to environmental, social and economic conditions within specific territories, using both validation and demonstration steps in representative farms (FAO, 2002);
- setting up participatory mechanisms associating scientists, farmers and extension services to further develop the incorporation of the above technologies into location-specific sustainable resources management systems;
- developing controlled agriculture (greenhouse and hydroponics) in peri-urban areas to produce food for the ever increasing urban population (Littlefield, 1998; Savvas and Passam, 2002). Further development of new and innovative systems that are less consuming in energy and inputs is required (John, 2001; FAO, 2005a);

- developing precision farming to use real-time, site-specific information in crop management, for example:
  - accurate field mapping with information collected from soil samples, pest monitoring and harvest yield data allows farmers to target the use of plant nutrients and crop protection products, leading to an efficient and judicious use of these products (SEENET, 2007);
  - highly developed systems use computers installed in farm machinery such as harvesters, fertilizer spreaders and crop sprayers, combined with mobile satellite global positioning systems, enabling farmers in some situations to spatially vary the rate of input application and management operations, thereby optimizing the productivity of the crop based on accurate determination of soil and crop needs (SEENET, 2007).

6.2.8 Developing sustainable systems for forestry

Over the past 20 years in some parts of NAE there has been a move away from productivity as a driver of forest management, with more emphasis being put on environmental and social issues. Today awareness has emerged worldwide regarding other forest values or its “multifunctionality”. Forests, especially mixed forests, are recognized as reservoirs of biodiversity, as contributors to improved water quality and availability and as an important component of the carbon economy.

Sustainable forest management cannot be considered without taking into account the many changes that affect the environmental, societal and economic context. Competing land-uses can result in forest fragmentation and can contribute to climate change, invasive species, increase of energy prices of fossil fuels and the new cost of carbon emissions. All of these, among other factors, can have implications for social expectations of forests and forest management as well as natural areas in general (Raison et al., 2001; Houllier et al., 2005; Dekker et al., 2007).

Integrated forest management methods addressing both timber production and ecosystem management have appeared in the NAE (Rauscher, 1999). This management can lead to sustainable development of forests with overall economic, social and environmental benefits. More research will assist in better understanding the multifunctional role of forests from an economic, social and environmental perspective and promote it through appropriate sustainable management methods.

Integrating the multifunctional role of forests: The definition of forest multifunctionality has changed over the decades from a simple three-fold categorization of production of wood, protection and restoration of the environment and social functions into something more complex with multiple functions added under each category. For example, the “production” function now comprises a larger range of forest products such as wood products, bioenergy, green specialty chemicals, novel composites (Table 6.1).

[Insert Table 6.1]

In order to integrate the multifunctional role of forests better it is important to understand how forests can contribute to these functions and the extent to which these functions could be simultaneously realized through definition of optimal management methods that guarantee the provision of these functions as explained below.

<u>Characterize and understand the different functions and the potential incompatibilities between them</u>

Enhance forest productivity in a sustainable manner: Understand how the social and natural environments create, reinforce and localize the tradeoffs between the multiple functions of forestry. These understandings can constrain and guide developments in the following areas of AKST.

- breeding trees for the future (for specialized plantations): study molecular, biochemical and physiological processes determining wood and fiber properties, water and nutrition biology and interactions with insects and microorganisms; this could include the identification and functional analysis of relevant tree genes as well as the elucidation of signal pathways and components required for the expression of genes important in tree improvement. More effective breeding strategies could be developed using molecular genetics including genetic engineering in order to use them to generate new tree varieties with characteristics that fit the local multifunctional needs of forestry; these may include wood fiber characteristics that provide enhanced economic as well as environmental value (higher cellulose, lower lignin, fewer chemicals during paper manufacturing, stronger rot resistant wood (for construction), xenobiotic degraders for phytoremediation, biotic and abiotic stress tolerances to allow expansion of forests to harsher climates or more marginal lands, hypoallergenic pollen producers to enhance urban landscapes without jeopardizing health) (FTP, 2007);
- developing tools to anticipate new invasive species problems in forestry and improve tools to manage existing invasive plants, insect pests and pathogens, which are one of the major threats to forest quality in the NAE (Pimentel et al. 2000; Allen and Humble, 2002);
- enhancing the availability and use of forest biomass for products and energy and finding a balance between the increasing demand for forest biomass for energy production and an increasing demand for forest-based products; and

- accentuating the environmental assets of wood (compared to other materials) by developing innovative products for changing markets and customer needs: intelligent and efficient manufacturing processes that require little or no chemical products, reduced energy consumption, etc. (Forest-based Sector Technology Platform, Vision 2030).

Provide environmental and social services: Important areas for the development of knowledge, science and technology in forest management include:

- analyzing the role of biological diversity (both functional and heritage value) and other factors (soil, water) in maintaining the stability and primary production of forest ecosystems (UNECE-FAO, 2005);
- forecasting future dynamics of forest biodiversity and productivity, especially in relation to environmental change;
- exploring further the positive effects of forests on water quality and accordingly exploring the potential benefits of urban and peri-urban forests;
- evaluating the impacts of exurban sprawl on forest fragmentation and forest quality; and
- continuing research activities that focus on determining the effects, at various scales, of optional forest management strategies on environmental services such as carbon sequestration and social services such as amenities and recreation (UNECE-FAO, 2005).

Once these different functions are characterized a clear definition can be developed with the help of indicators. These indicators could help to better assess and quantify these incompatibilities and also help in deciding where certain functions can be compromised compared to the others.

<u>Define optimal management methods that guarantee the provision of these multiple functions</u>

Defining optimal management methods can help better address this issue of multifunctionality at the appropriate geographical scales. Currently forest management can be broadly divided into three types. The first two types are based on complete geographic segregation of the different functions: intensive production forests that are dedicated solely to production (intensively managed conifer monocultures, e.g. Southern pines in the USA, Sitka spruce in the UK and maritime pine in France) and natural reserves that are left untouched with little or no human intervention. The third type is that of semi intensive forests ensuring production, environmental and social services, often using trees more adapted to local conditions.

There are many ways of guaranteeing the multifunctionality of forests based on the above mentioned three forest types. One way would be to have all the three forest types in the same zone and the other way would be to have only semi intensive forests wherein depending on the needs one function would dominate slightly over the other.

More research can shed light on how to optimize the overall distribution of intensive, natural reserves and semi intensive forests in NAE and its sub-regions, keeping in mind that total forest stocks have remained relatively constant in most of North America and are increasing throughout Europe (Karjalainen et al., 1999).

As at the local level semi intensive forests could be viewed as a complex multifunctional system. More research can contribute to developing models of this system as a whole (one that includes the production, environmental and social services) based on a meaningful knowledge representation elaborated with the help of the different stakeholders involved.

Providing methods and tools for monitoring and improving the environmental sustainability of forests

- extending existing and promoting new and integrated forest inventory services: develop tools for monitoring forest health, nutrition, greenhouse gas absorption, evolution of populations and communities, in addition to the traditional growth and yield studies (Birot et al., 2005);
- adapting forestry to climate change (European Forest Inventory) (European Forest Institute, 2007), particularly in drought prone regions e.g. Southern Europe and Western United States; development of adaptive forest management methods comprised of heterogeneous species populations for improved resilience, improved adaptive capacity of the forest reproductive material, deciphering the buffering capacities of tree species and genetic diversity to climate change;
- developing better risk assessment, risk management methods and improved risk sharing instruments to integrate risk and other environmental and economic changes into forest management (climate change, invasive species, exurban sprawl, fires, gales, floods, pest and disease outbreaks, uncertainties regarding the economic value and abrupt changes in the market…); for example, assessing the vulnerability of various management strategies in regard to the different risks (FTP, 2007);
- monitoring genetic diversity of natural forest populations to elaborate methods to keep genetic integrity during reforestation and other forest management events; selecting areas for forest genetic reserves (*in situ* preservation); and
- better and more exhaustive mapping of forest resources in terms of quantity and quality through a wider use of present technologies (GIS, remote sensing, ground laser technique…) as well as the use of satellite imagery and modeling as a decision support tool in forest planning and management.

The future of successful forest management rests on a revision of forestry concepts in the light of climate, invasive species and other environmental changes, a recognition of new concepts of sustainability in which risk management and forest resilience are prioritized and the encouragement of an improved dialogue among scientists, managers and the public that transcends national boundaries.

6.2.9 Developing sustainable systems for fisheries and aquaculture

6.2.9.1 Coastal capture fisheries in the NAE region

With the collapse of many fisheries and the expansion of fishing efforts, improving the sustainability of coastal capture fisheries and increasing their productivity have become acute problems (Pauly et al., 2002, 2003, 2005; Garcia and Grainger, 2005). Sustainability can be achieved by: (i) broadening the focus to include the entire food web and habitats that support the target species, (ii) through efficient management systems that take into account the ecosystem and (FAO, 2003)(iii) through better fishing technologies that help in preventing overexploitation of all target species (De Alessi, 2003; EC, 2003). Productivity on the other hand can be increased by adopting new processing methods that add value to the current system, such as creating markets for by-catch (Christensen et al., 2003).

In the following text, options for research and technological development in the area of coastal fisheries have been explored within the different compartments of the system namely: sustainable marine ecosystem management, fishing technologies and fish processing. These compartments have various interactions among them. Only an integrated vision of the entire system and its different compartments as a whole would allow a fuller understanding of the functioning of the system.

Develop an ecosystems approach for a sustainable coastal marine ecosystem management

Up to now, most research has concentrated on the consequences of fishing activities on the target fish stocks. Future research is increasingly taking into account the social, economic and ecological consequences of fisheries not just at the local but also at a global level (Pauly, 2005). More research on the following may be useful to achieve this:

- further analysis of the impacts of coastal fishing drag-net methods that disturb the entire benthic community and harvest entire food webs. These methods disrupt entire communities and irreversibly alter benthic habitats, changing the reproductive potential of the target species and associated by-catch (Francis et al., 2007);
- further develop the construction of mathematical models for complex systems that help understand and predict ecosystems behavior, by multidisciplinary approaches and considering biological, ecological, economic and social driving forces (Dame & Christian,

2007). Such models and toolboxes would facilitate the study of the different effects of fisheries management, regulation and policy;

- collect long term observation data: identify a representative sample of long term observatories to collect data that can be used for the constitution of reliable and continuous series data (biological, economic and social) for use in present and future research, namely for the validation and adjustments of the above mentioned models; this activity exists but is presently inadequate because marine resources are difficult to access and not well known;
- develop tools and indicators: appropriate tools and indicators that take into account an ecosystem as a whole reflecting resource health including its economic and social components as well as integrate global phenomena such as climate change do not yet exist and will be useful now and in the future;
- develop experimental research on consequences of human activity on wild fish: effects of fishing and pollution on growth and reproduction;
- develop specific multidisciplinary research on marine ecosystems: including ecological engineering, “ecological therapy” (how to cure, restore an ecosystem), environmental economy and sociology; and
- evaluation of the effect of enforcement of territorial waters (or lack thereof) on the sustainability of fisheries. Combating illegal fishing has been identified as a crucial element (COFI, 2007).

All the above mentioned research activities will require an integrated global research effort, coupled with stronger enforcement measures throughout NAE. Focusing on selective fishing and sustainable harvest levels can prevent the overexploitation of all species. By concentrating research efforts on overcoming the barriers mentioned below it may be possible to adapt “selective” adaptation levels to the renewal capacity of fish stocks:

- develop innovative methods for direct evaluation of fish stocks (e.g. acoustics, buoys, AUV (autonomous underwater vehicles));
- promote selective fishing that takes into account the present and potentially renewable fish stocks: in this context a better quantification of the long term biological and economic benefits of selective fishing could convince the actors of its importance and urgency;
- devise new fishing techniques that are highly selective with a minimum impact on the ecosystem in coastal and high sea fisheries and/or that have a smaller ecological effect on the habitats that sustain the fisheries; and
- improve existing fishing technologies: to obtain a higher quality of fished products while simultaneously minimizing by-catch.

Fish processing for food

- focus on processing and adding value to small pelagic fishes for human consumption, usually fished to make fish food and animal foods (yearly around 18 million tonnes in the world); and
- improve processing methods and quality of the existing processing units or build new processing units that have the least environmental impact feasible.

6.2.9.2 Aquaculture

Developing countries such as China, others in South East Asia and some CEC countries will continue to expand production of low-valued fish, such as carp and will greatly expand production of some high-valued fish, such as shrimp and salmonids (Delgado et al., 2003). The NAE region will continue relatively constant production of high-valued fish, such as salmonids. Trade in aquaculture is likely to increase or at least stay the same and perhaps South-South trade will increase. However, with increasing affluence in some developing countries, this trade dynamic is likely to change with a reduction in trade due to increased home consumption. Some of the main areas with identified research gaps are listed below.

Disease and water quality: An important aspect of aquaculture is combating viruses, bacterial and parasitic diseases. It is however difficult to guarantee a strict sanitary isolation of aquaculture sites. Therapeutic options are limited and often lead to environmental problems. Research on the fish immune system can provide more therapeutic options and allow an understanding the environmental determinants of immunity. These are necessary prerequisites for the sustainable use of genetic resources for disease resistance.

The aquatic environment is subjected to pollution from both human activities (accumulation of pollutants: e.g., heavy metals, pesticides), nature (e.g. heavy metals and acids from volcanoes) as well as aquatic microorganisms (toxin production by microalgae). More research on ecotoxicology and ecopathology will provide a better understanding of these impacts on fish quality and production. It would be advantageous if such research were done in close collaboration with research in physical sciences (hydrodynamics, modeling of the pollutant flux, etc.). Also research to improve the quality of the aquatic environment could be done, through the optimization of physicochemical and microbiological quality of the aquatic environment.

Environmental impacts of aquaculture. Aquaculture can have negative impacts on the environment (SOFIA, 2006). Firstly, aquaculture activities in general can perturb and alter the surrounding environment. Secondly, wastes from intensive aquaculture often have adverse effects on the environment. Thirdly, escaped fish can destabilize nearby native fish communities.

The impact of the wastes of intensive aquaculture is due, primarily, to the quality and the quantity of fish diet (concentrated fish feed). Some of the ways to combat this is are, for example: (i) increase the efficiency of fish feed to reduce the quantity of the overall diet; (ii) substitute fish meals that are classically made of fish oil and fish meal with plant products and (iii) in closed systems, develop biofilters using biofilms that recycle wastes back to fish feed. Aquaculture can have positive effects on the environment by reducing the pressures on native fisheries, as well as increase the fertility of the water though wastes.

Reduce dependence of high value fish farming on fish meal derived from coastal capture fisheries: To reduce impacts on fisheries, fish meal made from plant products might be substituted for fish meals that are classically made of fish oil derived from coastal capture fisheries. One of the areas of research that might reduce dependence on coastal fisheries is to produce feed crops with high levels of oils and proteins required in aquaculture.

Labeling or certification for responsible fish farming: Aquaculture's future is determined not only by the market price but also by consumers' acceptance of its products. Aquaculture may find it useful to expand linkages of its impact (or lack thereof) on the environment, the type of products produced and production practices with marketing. Initiatives that integrate these aspects have already been adopted in certain areas (the global aquaculture alliance -created by shrimp farm producers- which proposes a code of good practices that would help in reducing the environmental impacts of their activities; organic aquaculture; labels certifying the quality like red label, etc.) but more research is necessary to define appropriate management strategies and establish the relevant criteria that would help in the evaluation of the efficiency of these strategies and lead to an eventual labeling or certification of the product.

Moderate intensification of extensive systems: Intensification of aquaculture seems inevitable due to increasing reduction in the area available for these activities (SOFIA, 2006). The most desired solution may be to opt for moderate intensification of current extensive aquaculture systems (often polyculture systems comprising of different species). This transition can only be successful following more research on:

- identifying optimum conditions for the different types of polyculture systems as the different species involved in polyculture systems have different ecological roles;
- the criteria for the amelioration of environmental impact of a multi-specific population under trophic constraints (e.g., increase in the growth rate, nutritional behavior). Amelioration of the impact of one species in a polyculture could be done to the detriment of others and may not result in the overall amelioration of impacts; and

- better understanding the integration of these systems in rural areas: eventual constraints (e.g., water management), opportunities, complementarities (e.g., use of agricultural by-products in aquaculture and effluents from aquaculture in agriculture) etc.

Introduction and naturalization of species: Aquaculture is currently based on a limited number of species that have been disseminated all over the world. Aquaculture populations commonly escape establishing feral populations that can adversely effect the population density, health (e.g., when one population is a pathogen carrier), or genetic diversity of native species. More research evaluating and quantifying the impacts of introductions of aquaculture species on natural populations can ensure better integration of these species in the ecosystem while avoiding harmful effects on the surrounding environment. The culture of triploid fish is one way to ensure the non-reproduction of escaped fish.

6.2.10 Ensuring socioeconomic viability of the systems and improving rural livelihoods

Changing priorities and the reform of agricultural policies recently have reduced the financial rewards for farm production in NAE with economic and social consequences for those whose livelihoods depend on it. Simultaneously, concerns have grown about the high, yet hidden, social and environmental costs of intensive agricultural systems. It is critical that, drawing on lessons from the past, socio economic mechanisms are harnessed to help achieve the new paradigm of multifunctional agriculture, securing the incentives and benefits to those engaged in its delivery and maximizing overall welfare. Doing this has major implications for the types of AKST required and how AKST can best be mobilized to meet new expectations.

6.2.10.1 Social issues

Development of AKST in agriculture strongly affects and is strongly affected by the multiple societal issues related to rural society. Ensuring social sustainability of locally dynamic economies will require AKST research on the necessary social relationships that could be reinforced or developed to meet goals for NAE (Narayan, 1999; Flora and Flora, 2004).

Social institution building

Because many of the institutions in rural NAE have been developed and maintained to support national agricultural commodities and commodity prices, it is likely that new institutions will be required to support rural economies that have a strong local component. Research can help determine how the present institutions can support and maintain a focus on a local economy and the institutional changes required. Several measures can be considered including:

- providing appropriate training and new credit systems to enable rural workers to become farm owners and operators;

- establishing locally-based market linkages between farm products and consumers;
- improving rural quality of life, including better schools, health care, recreation and food quality and availability;
- identifying and encouraging institutions to facilitate transitions to a multifunctional agriculture;
- developing instruments for the provision of new income, in particular for goods and services that are not marketed today; and
- the new paradigm of multi-functional agriculture emphasizes environmental sustainability and the provision of public goods. There will be increasing demand for collective (community) rather than individual actions (Ostrom, 2003), encouraging a new 'moral' economy in which people constrain their immediate individual freedoms in order to achieve improved common and subsequently individual, welfare (Trawick, 2004). There is a role here for AKST to devise new mechanisms for joint action especially concerning the management of scarce natural resources (Trawick et al., 2005)).

Farmer organizations: The building of producer's capacities, which is an important goal of AKST, could be reached by professional and inter-professional organizations. To be effective, agricultural development requires the participation of the farmers and their organizations in domains such as: elaboration of agricultural policies, extension and training systems, organization of the markets and the supply chains, rural credit, land policies. The roles that producer organizations play are diverse and can cover various topics such as:

- policy representation and defense of the interests of the members ;
- economic services through the supply chain organization and the collective setting in markets;
- development of technical services such as economic and technical advice, training, the use of materials owned jointly; and
- provision of public services, for instance the elimination of illiteracy, infrastructure maintenance, etc.

The current debate on the place and the role of the agricultural organizations in supporting family farms revolves around three themes (Mercoiret et al., 2001): producer support mechanisms; creating new forms of coordination between actors; building and strengthening the capacity to face global phenomena.

Supporting these professional and non professional organizations could lead to the building of new relations between the different actors, based on the partnership, dialogue and negotiation. On the economic side, strengthening the economic organization of agriculture is essential to ensure decent incomes through economic market management (MAP, 2006). It is important to accord a specific place to inter-professional organizations. They are private organizations bringing together the partners upstream and downstream of an agrifood network related to a product or a group of products. Their goal is to sign inter-professional agreements which define and promote contracting policies between members, contribute to market management (improved product adaptation and promotion) and reinforce food safety.

Organization of workforce: Demand for agricultural labor remains high in those regions in NAE that fill the increased consumer demand in domestic and export markets for vegetable, fruits, nuts, wines and juice products. Many tasks in this agricultural sector including planting, pruning, cultivating and harvest, remain labor intensive. The tendency towards more elaborate processing and packaging for all crops, including grain-based and meat products, creates continuing strong demand for workers in these agriculturally based industries. Organic and alternative agricultural practices also typically increase labor demand. The strength of the demand for agricultural hired labor in some regions and crops is often disguised by the longer term and more general decline in agriculture overall. Both changing markets and the prospect of climate change will create new needs for knowledge and skills in the agricultural labor force. Although the demand for agricultural labor remains strong in much of NAE, research shows that the inequalities created by low-paid farm labor constitute a significant share of overall income inequality in most of NAE (Alderson and Nielsen, 2002; Martin, 2003; ERS, 2007)

Development and sustainability goals have important and unresolved implications for required improvements in the welfare of agricultural workers and farm families in terms of wages, overall working conditions, health and safety problems, health insurance, job security and housing. Meeting development and sustainability goals also requires that a healthy and stable rural work force be available to agricultural employers.

Addressing the problems raised by farm labor will require broad public policy initiatives over the long term in farm subsidy programs, immigration law, labor law, health policy, regulatory law, housing policy, regional planning, governmental budgeting and other complex areas. However, existing research indicates that there are measures specifically within the agricultural sector and short of the broader and deeper reforms that are required, that can work to stabilize and improve the welfare of farm workers and families, yielding numerous advantages to society and the environment. The applicability of such measures will obviously vary by region. Among them are (Findeis, 2002; Martin, 2003; Strochlic and Hamerschlag, 2006):

- value-added, on-farm activities and product diversification that allow for a more stable stream of farm and labor income while providing year-round employment, creating incentives for improvement in farm worker skills, in turn improving worker productivity and morale;

- frequent consultation with farm workers, their families and rural residents to address both the nature of rural work and worker welfare; and
- improved working conditions and higher wages, recognizing these as fundamental to maintaining a stable and skilled work force and often contributing to farm profitability.

Gender issues: The role of gender in North America and Europe is extremely varied from country to country and regionally within countries. NAE researchers and institutions have done a great deal of work on gender inequities in agriculture outside of NAE, but relatively little attention has been paid to gender issues within NAE agriculture. Discussion of gender inequities within families on what has been termed “the discourse of the family farm” initially focused on the masculine dominance of the farm family and inequities of power and welfare as a consequence. Later research has focused on the recognition and development of more complex familial relationships in terms of ownership, work roles, decision-making and welfare outcomes. In analyzing these more complex relationships researchers have more recently seen the way in which women play active roles within the family, more typically working with male family members to deal with difficulties imposed on the farm enterprise from outside the family structure (Brandth, 2002).

Gender inequities within the professions of agricultural research, education and extension are striking in much of the region and particularly in the higher reaches of academic research and teaching. Researchers have focused on the factors that lead women to choose other kinds of work and that determine the relative lack of women in agricultural research. Much of this analysis focused on gender inequities within the AKST profession a decade or more ago, setting an agenda for change. There seems to be an opportunity for reassessment of the prevailing situation and of future prospects (Van Crowder, 1997; Foster, 2001).

The last twenty years have seen a striking emphasis within rural and agricultural development work done outside NAE on gender analysis and appropriate policy responses. Much of this work is performed and/or directed by institutions based in NAE (including the World Bank and NAE national foreign assistance programs). This makes it urgent that gender imbalances among the professionals engaged in such work not undermine the quality and effectiveness of research and policy carried on abroad, as well as at home. Farm workers in NAE experience a variety of work situations involving gender that create hazards, inequities and significant stresses (Barndt, 2002; Nevins, 2002; Fox and Rivera-Salgado, 2004; VanWey et al., 2005). Among these are:

- legal and illegal immigration across international borders often makes it difficult for families to remain together, posing high levels of insecurity and resulting in large economic costs. Most typically, men migrate internationally without their families when there are high risks and/or costs associated with border crossing and residence without legal documentation; this is particularly the case for some hundreds of thousands of migrants from the Caribbean, Mexico and Central America who work in agriculture in the United States and Canada;

- gendered employment patterns, as for example women working in poultry processing plants while men work in slaughterhouses for pigs and beef cattle, often with significant gendered differences in pay and often resulting in family separation and inequities;
- sexual harassment and exploitation associated with women separated from families by gendered work situations; and
- failure to exclude women, pregnant women and children from farm chemical exposure that have in some cases been shown to pose particular risks to women, fetuses and children. Serious toxicological issues remain in the analysis of this problem and while regulatory schemes in most of NAE have attempted to address the issue, problems of measurement, accountability and enforcement remain (Castorina, 2003; Bradman, 2005, 2007; Young et al., 2005; Eskanazi, 2006; Holland, 2006).

Equity in opportunity, participation and rewards for similar work ensure the sustainability of society. Rewards and prosperity in NAE farming vary substantially according to access, whether through ownership or tenancy, to land as a productive asset, security of employment, whether permanent or casual and skills, for example whether a worker is a specialist machinery operator or a general farm laborer. In some parts of NAE, rewards and entitlements vary considerable according to social class, gender, ethnicity, age and formal education, often with adverse consequences for social and economic outcomes. More attention can be paid to the potential positive role of agriculture in promoting equal opportunities as a basis for social inclusion and sustainable development.

- local, regional, national and international institutions to promote equity could be reinforced and improved;
- local knowledge and knowledge of disadvantaged communities can be incorporated interactively into the AKST system; and
- current trends are promoting further liberalization and reform of agricultural commodity markets, increased connectivity between people and food, as well as new ‘markets’ for services previously considered un-traded and un-priced, such as water supply and access to the countryside. Market mechanisms require information and skills of negotiation and transaction to work properly. This has implications for the role of AKST in supporting economic efficiency and fairness.

6.2.10.2 Economic issues

In theory, economic sustainability requires that the most efficient means of production and consumption of goods and services be used and overall long term net welfare (benefits less costs) maximized (Begg, 2003). Sustainability also requires that agents engaging in economic activity, from farmers to plant breeders, who commit resources now with a view to enhanced benefit in the future, are justly rewarded in terms of incomes and returns on investment, creating the enabling conditions for risk-taking. This applies whether the processes are entirely driven by market forces or interventions by government. Underlying this, there must be clear signals indicating what society wants of its agricultural and rural sector, whether this is in the form of market prices for agricultural commodities, or payments for environmental services such as landscape management and flood storage.

In the past, economic growth (defined in terms of gross incomes or expenditure in the economy) was used as the dominant indicator of development. Sustainable development now requires that economic indicators be balanced with social factors associated with distributional, quality of life and ethical considerations, as well as environmental factors that reflect the state of natural systems and the beneficial services they provide (Pearce and Barbier, 2000; Hanley et al., 2001;Tietenberg, 2003). Many of these broader societal impacts are now included in so-called ‘extended’ cost/benefit analysis and sustainability appraisal of development options, including AKST (Defra, 2005b).

In this context, an economic perspective has three particular contributions to make:
(a) Assessment of the economic and institutional performance of food and fiber value chains. A more complete understanding of the process by which value is added in food and fiber supply chains is necessary as this affects the efficiency of resource use, incentives, rewards, technology change, the sharing of risks among supply chain agents and end-user choice and welfare.

Further developments in AKST in the following areas, could be helpful to:

- identify opportunities for adding value through market orientation, quality assurance, product differentiation, including the promotion of sustainable production and consumption;
- evaluate the life cycle performance of alternative value chains, developing appropriate data bases and analytical methods (such as LCA) and decision support tools;
- develop tools such as multi-agent modeling to help improve supply chain performance;
- conduct value chain analysis that can help evaluate the total contribution of agriculture. This includes analysis of the competitiveness of the whole food and non-food chain and the economics of quality;

- justify and guide investments in supply chain and logistics to improve economic efficiency; and
- develop efficient supply chains for new products and markets, such as biofuels and medicinal crops.

Specifically, there may be significant opportunities to increase the competitiveness, economic viability and contribution to economic welfare of the forestry/wood chain:

- optimization of the value chain from the forest to the end product, including recycling;
- a stronger coupling between wood producers and industrial consumers;
- analysis of all sections of forestry-wood chain (silviculture operations, sales procedures and transaction costs, harvesting and logistics costs, etc.) in order to determine how to best improve competitiveness and economic viability;
- diversification of wood and fiber-based products through technological innovations: this could apply to: packaging with new functionalities (embedded information technologies); advanced hygiene and healthcare products; “green chemicals”; new generation of composites; and
- development of logistic and decision support systems for optimized supply chain management.

(b) Identifying and valuing the costs and benefits of goods and services produced by agriculture

This requires valuation not only of marketed crop and livestock commodities but also of nonmarket outputs that have consequences for economic welfare. These include the ‘public good’ or ‘external benefits’ (e.g. food security, diets and nutrition, watershed protection, landscape management, access to the countryside, sustenance of vulnerable human communities) as well as the ‘public bad’ or ‘external costs’ (e.g. diffuse pollution, soil loss, habitat loss, displacement of people, health and safety risks) of agriculture and an understanding of how these are distributed spatially and over time (Costanza, 1997; Brouwer et al., 1999; Pretty et al., 2000; Hartridge and Pearce, 2001; Environment Agency, 2002; Eftec, 2005). AKST could be developed to:

- identify indicators that reflect or give an idea about the evolution of these external costs and benefits over time;
- identify the scale at which these external costs and benefits can be studied: farm level (identification of the individual farmer’s contribution to a specific externality), landscape level;
- design policies that take into account the external costs and benefits associated with agriculture. Policies adopted to promote some public goods could worsen, or at least fail to alleviate some external costs (Sutherland et al., 2006). Specifically, the national (or larger scale) performance of the agricultural sector can be evaluated and the

consequences analyzed at the local and farm level so that local policies do not contradict national ones; and

- develop and promote innovative entrepreneurship initiatives, such as safe water production, eco- and nature tourism, recreation, hunting, including forest, upland and wetland systems.

Estimation of the contribution of agriculture and rural services to economic welfare is inefficient and can be improved. This requires redefinition of economic efficiency beyond conventional measures of tradeable inputs and outputs, which is 'internalizing the externalities' of agriculture to obtain a comprehensive measure of the social and environmental 'footprint' of the sector and its contribution to long term welfare (Barnes, 2002; UN SEEA, 2003; Eftec, 2005).

(c) Design economic instruments to help achieve sustainability

Designing economic instruments such as fiscal measures, compensatory and incentive regimes, market support and trading systems that can help achieve sustainable development, promoting the appropriate balance of private and public goods. Examples include capital and maintenance grants for organic farming, agroforestry projects, extensive livestock systems in less favored areas, farm diversification schemes, voluntary schemes to pay farmers for environmental services, grants and subsidies for cleaner, welfare oriented technologies and tradable permits for water licenses (OECD, 2000; Defra, 2002ab). For example, further research can examine how the supply of land to agriculture might respond to the fall in output prices as a result of the elimination of farm price and income support policies in many countries. Also, research could better examine how the supply of public goods associated with agricultural land responds to payments based on land area. Specific topics include:

- cause and effects of price instabilities, including consequences for production and investments;
- effects of the different public instruments in terms of market distortions, price stabilization (e.g. intervention prices, quotas, decoupled payments);
- role of market mechanisms such as stock markets and commodity futures markets to face price risks; and
- importance and role of contracts and conventions between the players of a sector (farmers, agribusiness, retailers).

6.2.10.3 Sustainable rural livelihoods

There is continuing concern about persistent poverty and the vulnerability of individuals and families in some rural populations in NAE, whether due to increased pressure on land and water resources or economic factors associated with structural change. The concept of sustainable livelihoods is used to analyze the social and economic viability of agricultural and rural systems (Chambers and Conway, 1992; Carswell, 1997; Hussein and Nelson, 1998; Scoones, 1998; Ellis 2000; Turner et al., 2001). Whereas the term 'livelihood' focuses on productivity, income and poverty reduction, the term 'sustainability' refers to the resilience of livelihoods and the maintenance of natural resources on which they depend. This analytical framework can help to understand how households and communities cope with shocks and stresses, such as those associated with policy or climate change.

The sustainable livelihood framework concept has considerable relevance for understanding the social and economic aspects of farming systems in the NAE region (Pretty, 1998) (Figure 6.1). It emphasizes the critical relationships between high level drivers and contextual factors, resources and assets, institutional processes, farmer motivation and coping strategies and resultant welfare (Scoones, 1998; Dfid, 1999).

[Insert Figure 6.1]

It is important to better understand the diversity of livelihoods within rural households and communities as a whole and the critical synergy between rural and urban dimensions of livelihoods, especially as these affect the transfer of assets, knowledge, goods and services between the rural and urban sectors, with consequences for welfare. The critical influence of local and distant institutions (e.g. local customs regarding access to common property resources, local and national land tenure rules), social relations (e.g. based on gender, kinships, tenure) and economic, value-adding opportunities are also recognized.

In the context of meeting development and sustainability goals in the NAE region, there is considerable merit in applying the livelihoods framework to guide future development of AKST, particularly to address the needs of the most vulnerable farming and rural communities. AKST clearly interacts with and is shaped by, the factors that describe the context for rural livelihoods, such as the policy and market drivers. As these change, so will the requirement for additional AKST as it is clearly embedded within the assets of households and communities. These include the products, tools, equipment and processes (physical assets), the knowledge and skills available (human capital) and the systems of governance (social capital) available to a farming community. Changing circumstances, whether induced by global or local factors, have implications for AKST in its widest sense.

AKST is closely linked with the availability, use and productivity of natural capital such as land and water resources and financial capital as this determines access to farming and other inputs.

The livelihoods framework confirms the importance of governance systems as these influence patterns of resource use and rural development, in turn shaping the development and dissemination of AKST. Hence, AKST is central to the livelihood strategies evident in farming systems and management practices, as well as the social and economic outcomes for farming families and communities.

There are critical synergies between livelihood outcomes and the stock of ‘capitals’ on which livelihoods are based. Uncertain and declining livelihoods often result in depreciation of the capital stock, especially natural capital, further increasing vulnerability. By comparison, secure and improving livelihoods can support investment and enhancement of capital stocks, such as improved land management skills and practices.

AKST is a critical component of the stock of capital in the livelihoods framework. It is recommended that the sustainable livelihood framework, adapted to accommodate local conditions, is used to inform future development of AKST to meet the social and economic needs of farming households and communities, especially targeting the needs of the most vulnerable groups.

6.2.10.4 Understanding farmer attitudes and behavior

The development and successful application of AKST depends on the attitudes, motivation and behavior of the potential user community, especially land managers. An understanding of the processes by which land managers learn about, evaluate and adopt or reject new technologies is essential for the management of technology change and the design of appropriate AKST.

Innovation-decision models have long been used to explain technology adoption behavior among rural communities (Ryan and Goss, 1943; Rogers, 2003). Prior conditions, such as policy drivers or perceived needs, shape the disposition of potential adopters towards a new product or practice. This process is influenced by characteristics of decision makers (such as personal and contextual social, economic and cultural factors) and characteristics of innovations (such as relative advantage, compatibility with values and preferences, simplicity and ability to trial and observe benefits). These models also confirm the importance of communication channels, agents of change and contextual and cultural factors, including the relative balance of individual and collective decision making. These models have however been criticized as too rigid, seeing adoption as an externally driven, linear process. Alternative models emphasize different elements of the decision process, namely systems models, information models, models of reasoned action and learning and knowledge transfer models (Garforth and Usher, 1997; Beedell and Rehman, 1999; Morris et al., 2000; Phillipson and Liddon, 2007).

In this context, there is an urgent call for improvement in the understanding of technology change and adoption behavior, in particular to:

- improve the understanding of variation in farmer motivation and behavior with respect to new technologies and how this is shaped by policy and market drivers, personal circumstances, common practices, local and distant institutions, issues of gender and ethnicity and perceptions of risk;
- develop and appraise empirically based models of knowledge 'exchange' suited to the new agricultural paradigm, combining indigenous and new knowledge sources and linked to concepts of sustainable livelihoods;
- develop participatory methods for identifying criteria for AKST designs that meet the needs and resources of different target groups, especially as this informs the advantage, acceptability, robustness and convenience of AKST offerings to users;
- develop and mobilize new communication channels, agents of change and 'knowledge brokers' where appropriate, including, web based sources, machinery contractors and specialist advisors, respectively;
- develop a framework for the analysis and design of programs of collective action, for example in water management; and
- integrate social science research into other sciences to ensure relevance of AKST products.

6.2.10.5 Rural development

Research and development can be undertaken with a greater concern for its role in sustainable rural development. It is important to factor in differences in social and environmental contexts as well as farmers' livelihood strategies and the diverse range of stakeholder interests. A key question concerns the roles that agriculture can assume in the sustainable development of rural areas. Agricultural research can and should play an important role in the collective efforts aiming at sustainable rural development:

- the contribution of agricultural research can address the challenges of a more complex countryside. Farmers follow many different and new livelihood strategies and an increasingly diverse range of stakeholders need to be taken into account; an improved understanding of the dynamics and multifaceted nature of rural development and of the roles that agriculture can assume in a more comprehensive process of sustainable development is necessary (FAO, 2003; Knickel, 2003);
- the more recent emphasis on countryside stewardship has at least three driving forces, all related to consumption: first, the rising environmental movement; second, increasing interest in recreation in the countryside; and third, a great residential shift out from the cities to small towns and villages. Use of labor in stewardship tasks consistent with the

concept and financing structures of a policy of multifunctionality in agriculture can greatly increase the quality of community life in rural areas. A key question is how to balance the often-diverging interests or the occurrence of 'clusters of compatible and mutually reinforcing activities' (Van der Ploeg and Renting, 2000). The active construction of synergies at farm household, farm and regional level could be better understood and promoted (Knickel and Renting, 2000);

- the multifunctionality concept effectively changed the understanding of the relationship between agriculture and society in more integrative ways; it recognizes that a strict segregation of different functions (living, producing, nature conservation etc.) is less and less realistic; research approaches can be adapted accordingly (Marsden, 1995; Saccomandi and Van der Ploeg, 1995; Van Depoele, 2000; Knickel et al., 2001; Hervieu, 2003; Cairol et al., 2005);
- sufficient research is lacking on how to optimally facilitate and ease the future development of less-favored areas and of agriculture and rural areas in the NAE region and particularly in the Eastern European countries. The latter are faced with a substantial fall in the number of farms due to historical trend of consolidation and a particularly severe decline in agricultural employment. A marginalization of farm households and entire regions is predicted, the related impacts of such on rural livelihoods can be addressed in research and policy.

6.3 Development of Human Capital, Organizations and Institutions

Paradigm shifts and key issues relating to the future of agriculture within NAE and its interactions with the rest of the world, as explored in earlier Chapters, have not just simply arisen overnight. Over the past few decades, increasing numbers of individuals and groups of scientists, educators, practitioners, policymakers and a range of AKST end-users in NAE have already been identifying, exploring and increasing their understanding of multifunctionality and its implications for design and delivery of AKST. In this regard, a number of individuals, groups and organizations in some of the countries of the NAE region have initiated changes that facilitate the development of human capital and associated institutional arrangements necessary for generating, providing access to and promoting the uptake of the newer and wider forms of AKST (OECD, 1995a; Lucey, 2000). A process of change has begun but it is still in the hands of the innovators and early adopters. A number of governments have encouraged the process. There have been some individual success stories but most of the newer approaches are hardly yet mainstream or sustainable; the rhetoric exists, but the reality lags well behind. It appears that there are many barriers, not only human, but also organizational, institutional or systemic (EURAGRI, 2005).

It is proposed that the process of reconfiguring AKST activities, both within NAE and in their partnerships with other regions, be dramatically accelerated so that they are jointly enabled to contribute most effectively to meeting sustainable development goals (Schneider, 2004).

The following sections explore some of the options, on a range of fronts, for this desired development, based in part on the experiences in NAE countries and analyses conducted to date by the OECD, governments, AKST agencies and individual scholars.

6.3.1 Towards interactive knowledge networks

Agricultural Knowledge Systems or AKS (long-standing OECD-adopted term) span the three main components of research, education and extension (OECD, 1995a). There are close links between these three elements of the “knowledge system”, which now require more of a “network approach” and the development of substantially greater synergy. There is an increasing shift from a unidirectional paradigm of knowledge generation and transfer (knowledge production – enlightenment – adoption) towards a paradigm of interactive knowledge networks involving multiple stakeholders who contribute to problem definition, research conception, execution and provision of results to a range of end-users for whom the research is in some way deemed to be relevant. In this way AKS can contribute better to society’s wider agenda (e.g. increasing concern with aspects of nutritional policy, food safety, animal welfare and other ethical aspects of food production and natural resource use). It is therefore essential that providers of advisory, higher education and research services become more engaged in building networks and coalitions to address newer objectives in such areas as global competitiveness, agricultural sustainability, rural development and multifunctional systems. Moreover, governments can help ensure that organizational and structural arrangements do not impede but rather encourage these cooperative efforts among components of the AKS (OECD, 1995b).

The AKS concept was further developed in collaborative work undertaken by the FAO and the World Bank which stressed the integrative nature of Agricultural Knowledge and Information Systems (AKIS), linking people and organizations to promote mutual learning and to generate, share and use agriculture-related technology, knowledge and information (FAO and World Bank, 2000). More recently, there have been noteworthy advances in applying an “Innovation Systems Concept” to agriculture, especially in approaching hunger and poverty issues in developing countries. Like AKS/AKIS, it stresses interactive knowledge networks, but recognizes an even broader range of actors/stakeholders and disciplines in a wider set of relationships that can potentially foster innovation. Innovation system analysis recognizes that creating an enabling environment to support the use of knowledge is as important as making that knowledge available through research and dissemination mechanisms (World Bank, 2007)

6.3.1.1 Promote stakeholder interaction

Stakeholder interaction in AKST is required to reinforce two recent trends: a shift from stakeholder management strategies to stakeholder involvement strategies; and a broadening of the types of stakeholders involved. Stakeholder management strategies are aimed at recognizing ways stakeholders can influence decisions and at limiting their ability to affect the process in ways contrary to the interests of the decision-makers (Eden and Ackermann, 1998). For the public sector, stakeholder management strategies have the long-term effect of alienating stakeholders as they come to recognize that their voice is not being heard and their input ignored, further isolating decision-makers. Even in the private sector, where stakeholder management is the norm, this can have similar adverse effects (Daft, 1998). When faced with a novel, complex problem, decision-makers are often unable to assess reliably the states of consensus in disciplines, incompetent in the face of burgeoning literature and prone to mistaken agreements (Fischer, 2005). Broader stakeholder involvement reflecting the multiple functions of agriculture can help improve the decision-making process.

NAE-AKST has been particularly successful at involving the dominant pre farm-gate and farm interests within the prioritization process and in recent decades the dominant post farm-gate food processing interests have also become effectively involved. Some, in fact, would argue that farmers and their organizations have possibly been heard too well. In the development of AKST, NAE has however been less successful in involving other interests. Traditionally, stakeholders are classified into eight kinds based on the legitimacy of their claims, their power and the urgency of their claims (Grimble and Wellard, 1997). Legitimacy refers to the perceived validity of the stakeholder's claim to a stake. Power refers to the ability or capacity of a stakeholder to produce an effect. Urgency refers to the degree to which the stakeholder's claim demands immediate attention. The stakeholders successfully involved in NAE-AKST are ones with legitimacy, power and urgency and these are sometimes referred to as definitive stakeholders. This kind of stakeholder is the easiest to involve and maintain. NAE-AKST has been less effective at involving stakeholders with little power to assert their interests when the definitive stakeholders and the AKST system do not recognize their legitimacy or urgency. For many years organic farmers felt they were in this category and many other stakeholder groups in society still feel as though they are. New stakeholder involvement methods could assist in developing methods to establish standards for legitimacy for inclusion in the development of NAE AKST, especially given the increasingly multifunctional importance of agriculture and the diversity of interests that must be serviced by rural areas (De Groot et al., 2002; Chiesura and de Groot, 2003).

Stakeholder involvement strategies aim to engage stakeholders in the decision-making process, either through representative or participatory processes (Grimble and Wellard, 1997). Stakeholder involvement processes can be costly and ineffective unless appropriately focused. The use of representative or participatory processes during stakeholder analysis depends on the cultural context and specific circumstances. A participatory process is one where the relevant stakeholders are involved directly, without the assumptions or structures to ensure that they are representing a broader group of like-minded stakeholders. While participatory processes are used when there are small numbers and types of stakeholders, a representative process is generally used when the number of stakeholders is large. Cost-effective participatory processes at larger scales as well as smaller scales of aggregation can be developed. The Danish Consensus Conferences and its variants (e.g. Joss, 1998; Einsiedel and Easlick, 2000), are examples of such cost-effective, large-scale participatory processes that have been successfully exported to other places. Much can be learned from these experiences.

6.3.1.2 Recognize the importance of indigenous and traditional knowledge

In recent decades, the importance of traditional and indigenous knowledge in agriculture has been newly recognized for its present and potential value. In a sense, all agriculture and AKST is built upon the traditional and indigenous systems that developed through the domestication and development of crop varieties and through the development of myriad cultivation techniques integrated within society and culture. In this sense, the “science of agriculture” of the last two centuries or so represents innovation based on a continuing and dynamic relationship with a foundation of older knowledge, even when the consequence of innovation is to replace older practices or knowledge. Researchers have pointed out that the categorical distinctions between “scientific” or “Western” knowledge and technologies on one hand and “traditional” or “indigenous” knowledge can thus be arbitrary and confusing and more recent research usually attempts to avoid overly dichotomous categorizations (Inglis, 1993; Agrawal, 1995; Tyler, 2006).

Important new developments in the study of traditional and indigenous knowledge have led to a heightened and more sophisticated recognition of:

- the fact that indigenous knowledge in agriculture is sometimes a vital element for the physical and cultural survival of indigenous groups, including some within North America and Europe (Birkes, 1999; Birkes et al., 2000; World Bank, 2004b);
- the role that indigenous and traditional knowledge plays in “adaptive management,” that is, the way in which long evolved agricultural knowledge sometimes represent advantageous adaptation to specific local conditions and response to stresses such as lack of capital, lack of reliable access to water, flood, poor soil and pest invasion (Altieri, 1995; Birkes et al. 2000; World Bank, 2004b; Tyler, 2006);

- the potential for a deeper understanding of traditional and indigenous knowledge to contribute to innovation in AKST, in areas ranging from plant breeding to water and soil management (Inglis, 1993; Birkes, 2000; Tyler, 2006);
- the important role of traditional and indigenous knowledge in biodiversity conservation and the in situ conservation of genetic resources (Mauro and Hardison, 2000);
- an understanding that valuable indigenous and traditional knowledge cannot be maintained or developed without access to land and other agricultural resources by those who use it, whether they be indigenous people or commercial farmers; the situation is especially critical for indigenous people, including some portion of the several million indigenous people of Europe and North America (Tyler, 2006);
- the difficulties that sometimes exist for those trained in the AKST academic disciplines in recognizing or understanding the existence or the underlying rationales of traditional and indigenous knowledge; such difficulties can be exacerbated by cultural or socioeconomic distance between practitioners and researchers; interdisciplinarity and special training have proven important in overcoming these difficulties (Grenier, 1998; Stephen, 2006);
- the complexity and sensitivity of intellectual property rights with regard to the actual and potential products of traditional and indigenous knowledge and practitioners (Brush and Stabinsky, 1995; Mauro and Hardison, 2000); and
- a more highly developed framework for researching and evaluating the potential of traditional and indigenous knowledge, recognizing that traditional and indigenous knowledge may have either positive or negative social or environmental consequences (Stephen, 2006).

This knowledge, as other forms of AKST, is necessarily context dependent with regard to its consequences. The new framework does not make a priori assumptions about the positive or negative value of traditional or indigenous knowledge, except in recognizing the positive value of preserving all knowledge, whether or not it forms the basis for present or future practices. In rejecting such a priori assumptions, respect among AKST researchers and educators and practitioners of traditional and indigenous knowledge widens opportunities for mutual learning and improved practices (Agrawal, 1995; Berkes et al., 2000; Tyler, 2006).

6.3.2 Toward meaningful interdisciplinarity

6.3.2.1 Enlarge the scope of agricultural knowledge systems

Improvement of AKS has the capability to make powerful contributions to newer and wider issues and, in many cases, new partnerships would benefit the general scientific community. Interrelationships are required with the life sciences and in the economic and social sciences in terms of research, educational and extension/development work. The issue of developing successful linkages is important and can be addressed across the NAE region. Moving beyond "science versus humanities" dichotomies in many national education systems and developing skills in complex systems sciences is essential. Effective interdisciplinarity should not compromise disciplinary excellence, the base from which high quality interdisciplinary approaches to AKST issues can be developed. Meaningful interdisciplinary approaches are widely recognized as essential. Systemic barriers to their implementation can be addressed and overcome (Box 6.11)

[Insert box 6.11]

If interdisciplinary approaches are to reach the required critical mass to become a centrally effective feature of AKST, it is clear that more is required than the development of individual talent or the mere allocation of extra funding. Governments and stakeholders at local, national and transnational levels could identify inhibitors and design corrective measures appropriate to their particular contexts. It would be wise for research funding bodies to further develop procedures to encourage rather than inhibit interdisciplinarity. Educational and research providers could bring their internal incentive, resource allocation and reward systems (including promotion procedures and criteria) as well as their program approval procedures to be more consistent and better reflect the broader AKST aims. Substantially enhanced funding is necessary to promote interdisciplinarity and interactive knowledge networking among AKST stakeholders. However, it is important that the systemic inhibitors to interdisciplinarity be simultaneously countered so that funding accelerates the “mainstreaming” and sustainability of the required new approach and drives it towards the “Tipping Point”. In the short run it is recommended that NAE governments, AKST providers and funding agencies take steps to identify the variety of barriers to interdisciplinarity/networking at local, national and transnational levels. It is then vital to collate and analyze examples of “good practice” designed to overcome them with a view to promoting more rapid development and wider adoption of the desired AKST interdisciplinary and networking approaches. This work could be undertaken multilaterally or could build on the earlier OECD activities in this area.

6.3.2.2 New skills for AKST personnel

In order to enable these developments, newly arisen capacity building needs for existing and future AKST personnel should be addressed so that they can understand and function more comfortably in the context of the wider vision and provide AKST services to the wider range of practitioners who will engage themselves in the enlarged vision of agriculture in NAE. Major implications arise both for providing initial education and lifelong learning opportunities for AKST personnel and for their various clients, whether “traditional” or “potentially new” groups. In addition to the “content” knowledge demanded by the wider vision, the increasingly interactive networking activities will require enhanced “process” skills on the part of participants, as they adjust from the earlier unidirectional flow-of-knowledge paradigm and learn how to build new relationships and work smoothly with various new types of partners. In this regard, the European Parliament, in the Explanatory Statement accompanying a recent report on agriculture and agricultural research, highlights the need to safeguard inter- and trans-disciplinary research in the long term and to integrate in the teaching curriculum the ability to cooperate on an interdisciplinary basis. Additional teaching posts might be created by colleges and universities in order to promote the new approach to teaching and research which this would entail (European Parliament, 2004).

Traditionally, NAE agricultural higher education has been broadly based on the multidisciplinary study of a range of sciences/technologies focused on agriculture, often with a production orientation. Disciplinary specialization tended to occur at a subsequent stage via postgraduate studies. For the future, in order to enhance the pool of persons capable of making interdisciplinary contributions, it could be advisable to promote multiple entry into the agricultural education system, such that persons with initial specialized study in various other disciplines could undertake postgraduate studies (e.g. academic Master’s) providing understanding of the wider agricultural context in which they would hope to apply their particular disciplinary education/training. Such could be fulltime (oriented to younger graduates or those who can take time out for full time studies) or part-time (oriented to mid career personnel in a range of occupations as part of lifelong learning or continuing professional development). Some tertiary educational institutions have experienced high growth in demand for such programs, which are expected to become increasingly important if the wider contextual understanding of agriculture is to be realized.

6.3.2.3 Need for new learning opportunities

Promotion of a wider understanding of the multiple functions of agriculture has to extend far beyond the AKST personnel themselves and the universities and colleges that educate them. Learning opportunities for understanding, participation, contextualization and adaptation could be fostered for a range of stakeholders. Options could be developed in initial education/training and on-going adult learning to promote better understanding of various levels of complexity in interpreting and responding in a sustainable way to the needs of the future. In particular, learning materials readily available via internet and new modes of interactive learning could be developed that could build on the experiential learning of various groups, enhance their mutual understanding and enhance their skills for developing sustainable provision of the multiple functions of agriculture in their particular contextual situations. Appropriate educational bodies could often accredit these learning opportunities, with credit accumulation and possible progression to suitable adult learning awards. Specific examples of target groups could include:

- all the players participating in the agriculture and food chain;
- environmental interest groups;
- people engaged in a range of rurally located enterprises/occupations;
- community development groups;
- local public officials (both career and elected); and
- interested local residents

6.3.2.4 Interactions with policy makers and political leaders

While agricultural, food and environmental issues have become wider and more complex throughout OECD countries, Government has, in a sense, become but one of several clients for AKS services, albeit the client who has the important responsibility for the public good (OECD, 2000). Policy makers, meanwhile, are often torn between scientific evidence on the one hand and often emotionally charged consumer/interest group concerns on the other. The urgency of promoting more open and enhanced two-way communication among AKS, the public and policy makers was of major concern to the 2000 OECD AKS Conference, which recommended that effective steps be taken as a matter of urgency to develop an ongoing two-way dialogue among those three parties not only at national level but also under the auspices of OECD on an OECD-wide basis. Two way learning opportunities for policy makers and AKST personnel are in urgent need of enhancement and a range of professional development policy-oriented learning could be developed which would enhance more productive interactions. These could involve policy makers from the Ministry of Agriculture but also other sectors like Industry, Environment, Health, Economy etc., as well as personnel from various State Agencies and AKST leaders. This would facilitate a more two-way communication between AKS and the policy makers. Also, as people are increasingly suspicious of scientists and science, it is important to consolidate an independent, trustworthy agricultural research community capable of guiding complex decision-making; this is particularly crucial when it comes to integrating the sustainability concept into policy (EURAGRI, 2000).

6.3.2.5 Public understanding of the multiple roles of agriculture

If citizens are to participate adequately in decisions about research, development and new technologies, they must be capacitated to understand the scientific issues. Conversely, scientists require communication skills and an awareness of society's needs and demands. They must take time to explain what they are doing, what they hope to achieve and how their work could benefit society. The development and delivery of messages and materials designed to enhance public understanding of the multiple functions of agriculture and to promote awareness of the related complexities and trade-offs that may be involved will become an increasing responsibility of educational research and outreach components of the AKST system. For the general public, this could lead to the promotion of a new concept of "agricultural literacy" that can be summed up as the goal of education about the new vision of agriculture. Achieving the goal of "agricultural literacy" would help to produce informed citizens able to participate in establishing the policies that will support a competitive and sustainable agricultural industry in the NAE region. Options to be considered include the development of adult learning materials and the development of material suitable for developing elements of the wider understanding during pre-kindergarten through 12th grade communities, thereby recognizing the importance of early-childhood development and creating organized ways to enhance child development.

6.3.2.6 Initial education/training for farmers

In many NAE countries, initial education/training of farmers has been conducted in specialized institutions under the aegis of their Ministries of Agriculture, as part of a general pattern in which sector training was the responsibility of the relevant sector Ministry. In other countries, vocational agriculture courses were offered as part of general second level education. In both cases, these have been largely production oriented, for which demand has been declining in many cases in line with the decline in NAE farm employment. Many NAE countries are reviewing these arrangements. In France, for example, there have been proposals for radical reform aimed at developing wider suites of programs oriented to a broad range of rurally based occupations. In Ireland, steps have been taken to integrate the specialized agricultural colleges with the national system of higher education and training awards and an increasing provision of rural development or agribusiness programs leading to these qualifications, in addition to traditional programs which are now set in a wider environmental and livelihoods context.

6.3.2.7 Stimulate links between higher education and research and facilitate the harmonization of the different education systems

The links between higher education and research could be strengthened as a key component of human capital development for the agriculture, food and rural sectors. A crucial interface between the research and education areas lies in the development of significantly expanded doctoral level studies in NAE higher education institutions that would be essential for expanding the training of adequate numbers of future researchers and higher level educators who will educate the next waves of AKST personnel. NAE higher education could develop far reaching programs at the doctoral level producing a cadre of scholars capable of seriously addressing the wider issues and new paradigms associated with the enlarged vision of agriculture in appropriate interactive knowledge networks. One example of strengthening the links between higher education and research in a European country is the promotion of special cooperative centers that must include a university (under aegis of Ministry of Education) and an agricultural research centre (under aegis of Ministry of Agriculture). This is a brave attempt to cross Ministerial boundaries in an attempt to rectify the excessive compartmentalization of research and higher education when research becomes concentrated in National Agricultural Research Institutes (NARIs), to the detriment of developing a research base at the university/college level. Another such example in the US is that of the many researchers and extension personnel of the USDA who are based on university campuses, embedded within the appropriate academic departments, with adjunct university appointments and benefit from both worlds.

Another important issue is the development of greater harmonization among the various widely differing national education systems across NAE that will have enormous implications for curriculum design and delivery, articulation and transfer arrangements, institutional 'niche marketing', international student and staff mobility arrangements and potential development of transnational program delivery not just for initial higher education but also for lifelong learning. Greater harmonization does not of course imply uniformity. The challenge is to encourage articulation and mobility, without compromising academic freedom and organizational diversity.

6.3.2.8 Promote lifelong learning and create a learning society

There is a need to ensure that the remarkable growth in demand for education throughout the lifetime of every citizen can be satisfied and to demonstrate that this demand can be filled at the highest level of quality imaginable, along with the greatest efficiency possible. More universities and colleges could consider making continuing learning a part of their core mission. This could lead to the creation of a learning society that values and fosters habits of lifelong learning, ensures that there are responsive and flexible learning programs and that learning networks are available to address all student needs. (Kellogg Commission, 2000). Such a development of a learning society could have enormous value in promoting more widespread understanding of the issues and opportunities associated with multifunctionality among a wide range of rural and urban residents. It could also enhance a wider set of skills necessary for functioning with various parts of a multifunctional agriculture. It could also stimulate the creation of new knowledge through research and other means of discovery and use that knowledge for the benefit of society and as a result could promote the wider recognition that investments in learning contribute to overall competitiveness and the economic and social well-being of nations. It is recommended that greater effort be expended on accreditation of lifelong learning courses within national or even wider mutual recognition systems so that proper credit accumulation procedures could more easily enable adult learners to progress to more advanced courses with organizations other than their original providers. Such credit accumulation and articulation arrangements could make it easier for rural residents to widen their knowledge/skills to work with the new paradigm and also to deepen their knowledge in specific areas, now set in the wider context. It would also make it easier for potential learning providers to identify opportunities for program design, learner recruitment and program provision.

6.3.3 Strengthening information and knowledge-based systems

Currently, we remain in the throes of an information technology (IT) boom that began over 30 years ago. The speed and quantity of information is still rapidly increasing and the modes of information acquisition are becoming increasingly more convenient and inexpensive. The Conversion of this information into knowledge is a process that lags considerably behind (Hassell, 2007). It is expected that these trends will continue at least for the next two decades, ushering in unprecedented flows of information. The policy framework surrounding agriculture will also lead to the delivery of standardized information to various public authorities.

These changes, when allied to the paradigm shift developed earlier in this chapter, will create several significant challenges for the NAE AKST system that will also require adjustments in institutional arrangements. If the paradigm shift is to lead to really meaningful developments, the NAE AKST information and knowledge-based systems will need to be expanded and strengthened to enable rapid flow of information both to and from the various agricultural sectors and the AKST system, including those parts of the system involved in the policy framework. For example, information-based systems have enhanced the value of literacy in the agricultural sector (Warschauer, 1999) and this trend will probably continue in the future. Some of the options to strengthen these systems are described below.

6.3.3.1 Reducing the “Digital-divide”

Currently, the availability and use of IT in AKST in the NAE is uneven among countries and sectors. Some countries, such as those in Eastern Europe and to a lesser extent, Central Europe, have lower access to the technologies (Chinn and Fairlie, 2007). In comparison to Western Europe, availability in Eastern Europe is about 20-30%. The present uneven distribution of IT sets up some short term scenarios that might be useful to avoid, as they could create conditions that favor the persistence of long-term inequities. Some of the ways to counteract this digital divide are by:

- using data and information sources that can improve production;
- increasing access to software products that assist production (expert systems) in the production sectors in Central and Eastern Europe;
- encouraging investments both by the private and state sectors in capitalization of the production sector, IT maintenance and repair infrastructure and software development to help meet production goals; and

- providing education to be able to manage these IT systems in production.

6.3.3.2 Reconfiguration of information systems

If IT development progresses as expected, in the future vastly greater quantities of more detailed information will become available by faster and more convenient means for use by the AKST system and the wider range of stakeholders and clients with whom it will need to interact. If access to the hardware, software and information continues to increase, there will be too much information to be useful. Some specific challenges will be problems associated with temporal and spatial scale matching and extraction of useful knowledge from the dense and numerous sources of information. In the future, information systems will be necessary to identify and control emerging threats all at pertinent spatial and temporal scales. To avoid potential problems associated with information overload, several changes in the NAE AKST may be required, as mentioned below:

- define collectively (active participation by farmers, extension services…) what information is necessary and would be efficient for better farm and landscape management of resources (biophysical and economic) at the different pertinent scales;
- promote, as far as possible, consistencies among data formats to be supplied for regulation purposes (control, follow-up…) and data used for farm, land and environmental management;
- reconfigure information flow and information management practices to prioritize environmental land management goals in agricultural practice, in environmental practice and in government support policies, incorporating a cross-compliance approach to agricultural land management; and
- develop specialized software and data management programs that can access and use the high volume of information.

6.3.3.3 From information systems to knowledge based systems

Information systems have been widely developed to the point that many people have access to so much information that they cannot use it effectively. In the NAE, the primary locus of knowledge generation (integration of information so that it is useful in making decisions and taking actions) in the AKST system has been educational and research institutions (Leeuwis, 2004). It is essential to promote the development of multiple loci of knowledge generation so that it will be possible to harness the vast flows of information to improve site-specific and temporally dynamic management (Hassell, 2007).

- encourage land managers to become sources of knowledge production and facilitate multi-directional flows of knowledge by the education and lifelong learning systems;

- expand the sources of knowledge-generation of AKST to go well beyond the institutional boundaries of educational institutions, especially with electronic and other distance learning systems in a lifelong learning context; and
- develop several new and structurally innovative models for turning information into knowledge.

Similarly, many developing countries will probably experience a rising flood of information, although it is likely to be more uneven and lag behind the NAE (Chinn and Fairlie, 2007). It is also probable that the availability of IT and the AKST demands for its products will vary from region to region. It will be important to evaluate these regional needs and evaluate the relevance of the NAE experience so that IT is appropriately contextualized in the development strategy.

6.3.4 Promoting appropriate institutional and organizational arrangements

6.3.4.1 Towards new and “engaged” public institutes

A new kind of public institution is one that is as much a first-rate student university as it is a first-rate research university, one that provides access to success to a more diverse student population as easily as it reaches out to "engage" the larger community. Perhaps most significantly, this new type of university will be the engine of lifelong learning in the NAE region, because it will have reinvented its organizational structures and re-examined its cultural norms in pursuit of a learning society.

Engagement, on the other hand, goes well beyond extension, conventional outreach and even most conceptions of public service. Inherited concepts emphasize a one-way process in which the university transfers its expertise to key constituents. Embedded in the engagement ideal is a commitment to sharing and reciprocity. Engagement could give rise to partnerships, two-way streets defined by mutual respect among the partners for what each brings to the table. The engaged institution can:

- be organized to respond to the needs of today's students and tomorrow's;
- bring research and engagement into the curriculum and offer practical opportunities for students to prepare for the world; and
- put its resources - knowledge and expertise - to work on problems that face the communities it serves.

Engagement, two-way outreach and civic service are all critical elements of public university missions, whether specifically included in the mission statement or not and are defining characteristics of the public university of today and tomorrow (Kellogg Commission, 1998)

6.3.4.2 Innovative education and research models

It was noted earlier that there are many obstacles, both personal and institutional, to the achievement of greater and more genuine interdisciplinary research and education in the AKST fields (box 6.12). Similarly, there are major learning experiences, both personal and institutional, to be undertaken within AKST institutions that adopt or profess a commitment to become more "engaged", if we are to ensure that really interactive two-way knowledge exchange and development actually occurs. The potential partners in the "engagement" process also require support in learning to develop their skills to participate in, contribute to and benefit optimally from the new interactive knowledge networking with the engaged institutions.

There are already numerous examples of establishing such networks, some quite formal, some informal, which can have their origins either from AKST invitations to engage, from farmers who share a common problem or from a local NGO that identifies a local public good or environmental issue, for example. Indeed, networks can arise in the context of frustrations by farmers and by researchers/educators with the more traditional unidirectional delivery of research and extension services under existing institutional arrangements.

Many of these innovative education and research models show that successful development and application of innovative agricultural knowledge, science and technologies can be significantly improved by introducing more active collaboration between farmers, researchers, extension agents and other educators. Such collaboration, if it is to be most successful, begins by dispensing with the assumption that formal researchers and educators necessarily already hold the most useful and important knowledge. There is recognition that farmers and other practitioners not only have useful knowledge but that they can participate actively in formal, scientific research. The mutual learning that can occur among groups of farmers, researchers, extension agents and teachers can result in important innovations that are more readily accepted and applied by practitioners and that form a firm basis for further research (Box 6.12).Through participation by well-qualified researchers, farmers are able to sponsor and actively participate in producing rigorously scientific research results publishable in peer-reviewed journals.

[Insert box 6.12]

It is essential that a greater level of support be provided for the more active and widespread promotion of a variety of innovative education and research models of this kind so that genuinely interactive knowledge networks can emerge. Such networks could be adapted to contextual issues and needs and to be effective they could receive the support from key people in relevant institutions required for them to become successful and sustainable relative to their purpose. It is essential that the networks always have the capacity to evolve as the needs and issues change.

This could involve dissolution if their goals are reached or reconfiguring themselves into new or transformed networks as new needs and issues emerge in their spheres of influence.

Experiences of the variety of new and innovative education and research models which have been tried in NAE AKST could, in the short term, be collated and analyzed so as to identify success and failure elements, risk factors, sustainability factors, effects of differential support mechanisms and elements of "good practice" so as to inform and guide the introduction of and to promote more widespread adoption of practically oriented interactive networking with a range of end users of AKST services.

6.3.4.3 Setting up institutional and organizational arrangements for knowledge based systems.
A continual accumulation and application of agricultural knowledge, science and technology, broadly defined as AKST, has been the necessary factor making possible the development of a global food and agriculture system. Several major changes are affecting the way this AKST is and will be made available in the future. Firstly, the political base for public food and agriculture support systems is eroding as rural populations change. Institutions once uninterested in food and agriculture are now devoting resources to food and agriculture. Secondly, there is a major shift in the generation of AKST toward private rather than public funding. Further complicating matters, the above information on any subject, is now easily available on the web and elsewhere, unrestrained by quality standards.

Considering these elements, some of the options for action that would ensure the right dissemination and adoption of AKST are:

- set up new forms of local innovation networks and efficient "value-chains" associating all concerned actors to turn science into practice. For example, review the current link between science/extension/farmers to make it more efficient and, widen the more effective involvement of end-users (e.g. private sector, suppliers of goods and services, consumers, processing) and their potential benefits; and
- set up information systems that would aid AKST users in accessing information that is clear, transparent and reliable even if this means that some categories of users will have to pay a fee for it. For certain areas of a public good where public intervention is legitimate/desirable such as food security, impacts of climate change, the long term sustainability of agricultural systems, the protection of natural resources and the environment and the livelihoods of vulnerable rural communities, large diffusion systems can be strengthened. In these areas public funding could support open and user-friendly information systems.

6.3.4.4 AKST interactions between NAE and other regions

The development of AKST in North America and Europe has had both positive and negative effects on human welfare, independence, security and environmental quality in other regions of the world. It is important that the further development of AKST in NAE serve development and sustainability goals to reduce hunger and poverty, improve rural livelihoods and health, increase incomes and facilitate equitable environmentally, socially and economically sustainable development in all world regions. The first and essential element in serving the purpose of empowering people and nations outside NAE in gaining new power to improve their own situation is the recognition that it is possible to improve the nature of the interactions of NAE with other regions. It is therefore strongly recommended that the guiding principles for people and institutions in NAE be reexamined.

The next fifty years of NAE AKST interactions with other regions could be approached from a different point of view; that of two-way sharing rather than the predominant unidirectional view in which one part of the world helps another, less fortunate part of the world.

The contributions of AKST to NAE have been partly documented in earlier Chapters. New developments in AKST have the potential to play a key role in assisting other world regions to achieve higher levels of self-sufficiency and meet the challenges that will develop in the whole world over the next fifty years as we address the IAASTD question. Sustainability issues in particular will require an increase in international cooperation and coordination.

The agriculture and food sector is the basis of economic livelihood for most developing countries and its health lies at the heart of the development process. Food security is more than food production. It is the efficient, reliable combination of access to needed food supplies (directly or through markets) and the ability to pay for them. Consequently, while agricultural development is a critical starting block for the economic development process, more is needed. No country has successfully ended rural poverty on the back of agriculture alone. However, the converse also applies: for the poorest countries, economic growth and sustained poverty reduction are unlikely to be achieved without initially stimulating sustained agricultural production growth. As agricultural development takes hold, its growth in productivity releases labor that needs to find alternative productive uses. This is both an opportunity and a challenge for development because uncontrolled migration to already overcrowded urban centers in many developing countries is equally problematic.

More effort is called for in planning and funding effective rural development strategies, including the investments in physical infrastructure and human capital that will connect a more diversified rural economy efficiently, through local and national markets, to the emerging global economy.

AKST institutions in NAE need to be ready to participate actively with AKST institutions in other regions to address the IAASTD question. It is suggested that the issues associated with interdisciplinarity and interactive knowledge networks developed in this Section may also be of fundamental importance in facilitating the development of the most appropriate working relationships between AKST in NAE and other regions. Previously articulated principles and issues could be used for developing different types of interactions between NAE and partners in other regions. Three examples of interactions are discussed more specifically below, one of them in SSA where the hunger and poverty issues are most stark and the two others through international agricultural research organizations and forums.

The Framework for African Agricultural Productivity (FAAP)

Africa is a region in critical need of new directions in agricultural research and development. Africa's leaders see agriculture as an engine for overall economic development. Sustained agricultural growth at a higher rate than in the past is crucial for reducing hunger and poverty across the Continent, in line with Millennium Development Goals. The African Union's (AU) New Partnerships for African Development (NEPAD) has issued a Comprehensive African Agriculture Development Programme (CAADP) that describes African leaders' collective vision for how this can be achieved. It sets a goal of 6% per annum growth for the sector.

A key component of the vision calls for improving agricultural productivity through enabling and accelerating innovation. CAADP Pillar IV constitutes NEPAD's strategy for revitalizing, expanding and reforming Africa's agricultural research, technology dissemination and adoption efforts. Currently, chronic shortcomings afflict many of the Continent's agricultural productivity programs. This explains the historical underperformance of the sector and the current plight of African farmers. Consultations with agricultural leaders, agricultural professionals, agribusiness and farmers shows substantial agreement that institutional issues such as, capacity weaknesses, insufficient end user and private sector involvement and ineffective farmer support systems persist in most of Africa's agricultural productivity programs and organizations, hampering progress in the sector. These problems are compounded by the fragmented nature of support and by inadequate total investment in agricultural research and technology dissemination and adoption. So, restoring and expanding Africa's agricultural innovation capacities requires radical modifications and changes in human and institutional capacity building (Youdeowei, 2007).

Despite the enormous challenges facing African agriculture, there are reasons for optimism. The African Union (AU), in establishing NEPAD and formulating CAADP, has given its unequivocal political backing for this effort. In setting up the Forum for Agricultural Research in Africa (FARA/AU/NEPAD, 2006), Africa has created a way of bringing technical leadership into play.

The FAAP brings together the essential ingredients suggested for the evolution of African national agricultural productivity programs. A number of guiding principles have been derived from consultation with Africa’s agricultural people and with their development partners. The FAAP indicates how such best practice can be employed to improve the performance of agricultural productivity in Africa. Beyond improving the performance of individual initiatives, the FAAP also highlights the importance of replicating and expanding such programs through increased levels of investment. It also stresses how increased funding must be made available through much less fragmented mechanisms than has been the case in the past. If these efforts are to have their desired effect, the harmonization of Africa’s own resources with those of development partners will therefore need to be placed high on the agenda.

The FAAP has been developed as a tool to help stakeholders come together to bring these political, financial and technical resources to bear in addressing problems and strengthening Africa's capacity for agricultural innovation. The Heads of State and Governments of the African Union (AU) endorsed the ‘Framework for African Agricultural Productivity (FAAP)’ at its Heads of State Summit in Banjul in June/July 2006. Specifically, the AU urges regional economic communities and member states to realign their regional and national research priorities to the FAAP with the support of the FARA.

The FAAP, in its detailed discussion of the evolution and reform of agricultural institutions and services, has several proposals regarding the future strengthening of extension, research training and education, several of which resonate loudly with the proposals of this section:

- end-users should be actively engaged in the processes of agricultural research priority setting, planning and work program management;
- the quality of tertiary agricultural education is critical because it determines the expertise and competencies of scientists, professionals, technicians, teachers and civil service and business leaders in all aspects of agriculture and related industries. It raises their capacities to access knowledge and adapt it to the prevailing circumstance and to generate new knowledge and impart it to others; there is a consensus among recent studies, such as those by the Inter-Academy Council and the Commission for Africa, that urgent action must be taken to restore the quality of graduate and postgraduate education in Africa;

- establishment of national agricultural research strategies through participatory and multi-disciplinary processes and the endorsement of these at national level through inclusion in the poverty reduction strategies;
- breakdown of the institutional and programmatic separation between universities and NARIs which results in inefficient use of capacity and unproductive competition; and
- create synergies among institutions and curricula in education, research and extension.

The FAAP document suggests that international contributions could be in the following principal areas, among others:

- bringing best practices, data, knowledge and expertise from other regions of the world to bear on African issues;
- providing research-based, relevant information and data for training and curricula and course development;
- providing specialized expertise in cutting-edge sciences including biosciences, social sciences and policy analysis;
- creating critical mass and building capacity through collaborative research; and
- enabling cross-country and cross-continent replications and comparisons to inform African research and development.

Already then, at this stage, there is an articulated set of measures to which NAE AKST institutions can be enabled to respond, not solely through the International Organizations/Institutes, but also through national and international consortia or networks of NAE AKST institutions that could link with similar networks of AKST institutions in other regions or sub regions. One such European Network is NATURA, a network of about 30 European universities and research complexes which have agricultural partnership links with developing countries. In the US, the National Association of State Universities and Land-Grant Colleges (NASULGC), is similarly placed for appropriate networking.

It is recommended that initially, development funding could be made available for a number of pilot partnerships involving networks of NAE institutions and AKST institutions in developing countries in order to address the issues of generating, providing access to and promoting the uptake of AKST to address the IAASTD question. In the medium term the results from such pilots could be scaled up and outwards to regional level such as those visualized in the FAAP and the BASIC program aimed at Building African Scientific and Institutional Capacity (FARA/ANAFE, 2005).

The contribution of NAE to the CGIAR

Guided by NAE countries and the Green Revolution concept as the general horizon for research in the 1960s, the CGIAR agenda initially focused on food supply, mostly through the breeding of high yielding cultivars that were highly responsive to agrochemical inputs and could express their full potential only when provided with sufficient fertilizer and water. Because 70% of the poor are living in rural areas, reducing poverty in developing countries will require that more food be produced by the poor and thus should consider the present context of their socioeconomic and ecological environments (It will also be necessary to reduce poverty among the growing numbers of urban poor). As poor farmers have limited access to inputs, sustainable improvements of their farming systems and family incomes will be achieved (a “doubly Green Revolution”) through (1) better use of locally available resources like biological diversity, ecosystem services and diversification of income-generating products, (2) increased access to credit, agricultural inputs as well as empowerment through training and capacity building in ways that do not jeopardize the livelihood of the poor, (3) decreased food costs, especially of staples, (4) overall economic development in nonagricultural sectors that stimulates the agricultural sector, or (5) some combination of these. Without question, there have been important contributions such as new maize, cassava and rice varieties. However, the CGIAR/NARS relationships have, for some time, been “festering“ (Eicher, 2001) and there exists a great challenge for the CGIAR to build genuine partnerships with developing-country NARS (World Bank, 2004).

Despite the fact that NAE countries have the major part of the AKST resources of the world, their research and educational agenda’s barely consider major technological spillovers and the ecological, social and economic footprints produced by agrifood systems with regard to development and sustainability goals. This suggests a strong awareness effort is required to encourage politicians to accept that poverty will not disappear without a strong financial commitment of NAE AKST to agricultural development. This must be based on a wide societal and global view about the role of agrifood systems and the scope of AKST and on a strong, concerted research and educational effort to find and implement solutions that are well adapted to the conditions of the poor and take into account the many impacts of technological change.

The CGIAR centers have a unique position and enormous challenges. Taking the relatively low proportion of world R&D resources CGIAR centers directly use, even if it were substantially increased, the most effective option to use these resources is as a mediator affecting and utilizing NAE AKST, thereby simultaneously supporting the human and organizational capacity building in developing country NARS, including universities. CGIAR centers, which are research organizations, could evolve to assume an additional role as facilitators or honest brokers to support development networks that will bring together the key decision makers at different levels of public and private AKST organizations. The different stakeholders from national and regional systems include research, education, development, socioeconomic actors, including farmers' organizations, local and national authorities, NGOs and civil society as well as the best and most useful parts of the upstream science conducted in and outside the NAE countries. Summing up, partners from the NAE countries can help the CGIAR better contribute to the IAASTD agenda by:

- raising public awareness (particularly among youth, politicians, donors) and strong financial support of both development and sustainability goals and the role of research, education and innovation to address the issues (such as the Davos Economic Forum that is organized every year. "Research for Development (RforD)", under CGIAR coordination, can have an annual forum putting RforD high in the news on a regular basis);
- including a global perspective on agriculture and food systems as part of common basic education of all agricultural, food and environmental university programs utilizing expertise from developed and developing countries mediated by the CGIAR system: (i) encouraging youth in industrialized countries to work in agricultural research and for developing countries; from regular lecture programs in high schools and universities to increasing attractive scholarship and fellowship programs to encourage young scientists to do their thesis or post-doctorate work in developing countries; (ii) encouraging CG scientists to co-advise more students in NAE institutions and even participate in their teaching programs, while encouraging university personnel to participate more fully in the design and implementation of CGIAR activities;
- allocating special financial resources to the intensification of agricultural education and knowledge systems in developing countries;
- working together to building a concerted, global effort for training and capacity building in poor countries; these programs can aim to strengthen the capacity of NARS (including universities) to undertake collaborative scientific research and educational activities to realize development and sustainability goals; this could include more targeted training with policy makers, intensified training partnerships of CGIAR centers with local universities and recognizing the importance of informal learning which takes place in the course of joint activities, seminars and other events (Stern et al., 2006);
- developing more efficient ways to group experts, intermediaries and end-users in different regions, so more aid money goes directly to improvement rather than administration; and
- continuing work on targeted research programs that have a strong impact on development and sustainability goals (for e.g. challenge programs (Box 6.13) and which call for new patterns of interaction; this leads to the development of wider networks and consortia with members from the other CG centers or NARS -including universities- private sector and the NGOs.

[Insert box 6.13]

- working on common research issues, among them food diversification and its role in reducing malnutrition, plant adaptation to climate change, or more specifically plant tolerance to drought and other biotic and abiotic stresses, sustainable farming systems and practices to provide niche products for solvent markets and staples for local markets, relying on local resources and ecosystem services, developing new environmentally friendly agricultural technologies, developing more effective post harvesting market arrangements; and
- ensuring that international funding for AKST does not perpetuate donor dependence and undermine efforts to develop domestic political support for sustainable funding, especially for the smallholder sector.

Making international agricultural research work better for the poor implies developing well targeted research activities, but this research must, more so than in the past, be able to promote appropriate research carried out in NAE countries. Hence a major question for the CGIAR is how to optimize this evolution, or how to initiate, sustain and mobilize appropriate research in NAE that contributes to the international efforts of the CGIAR centers, which are now trying to orchestrate and strengthen the sustainable cooperative capacity of NARS -including universities- in developing countries.

This new way of working can mark a shift in how research for development activities is designed, monitored and evaluated in CGIAR centers and NAE country institutions altogether. All contributors, from upstream science to delivery systems and impact assessment must work effectively together from day one to ensure that the expected outcomes and impacts on food security and poverty alleviation are oriented to poor communities, farmers and other relevant food system actors with less voice and that practical solutions are developed that can be realized and sustained for generations to come.

The Global Forum on Agricultural Research (GFAR): GFAR is a joint undertaking of all agricultural research stakeholders at the global level built through a bottom-up process from the National Agricultural Research Systems (NARS) through sub-Regional and Regional Fora (SRF/RF) in the different geographical regions of the world. The GFAR goals are to:

- facilitate the exchange of information and knowledge in all agricultural research sectors: crop and animal production, fisheries, forestry and natural resources management;

- promote the integration of NARS from the south and enhance their capacity to produce and transfer technology that responds to users' needs;
- foster cost-effective, collaborative partnerships among the stakeholders in agricultural research and sustainable development;
- facilitate the participation of all stakeholders in the formulation of a truly global framework for development-oriented agricultural research; and
- increase awareness among policymakers and donors of the need for long-term commitment to and investment in, agricultural research.

In the NAE region, the stakeholders involved in Agriculture Research for Development (ARD) have organized themselves in different ways:

- in Europe, EFARD[5] provides a platform for strategic dialogue among European stakeholder groups in order to promote research partnerships between European and Southern research communities; up to now, EFARD has developed a strategic research agenda, set up an ERA-ARD and established a strategic alliance with the Forum for Agricultural Research in Africa (FARA); and
- in North America, progress is still underway to link NA Agricultural Research Institutions (ARIs) with a vested interest in Agricultural Research for Development to GFAR; also, the PROCINORTE[6] cooperative program could join the other "PROCIs" (PROCIANDINO, PROCISUR, PROCITROPICOS and PROCICARIBE) under the umbrella of the Latin American and Caribbean Forum: FORAGRO (http://www.iica.int/foragro/).

Therefore, GFAR provides an ideal platform for addressing issues of global concern, where the participation of a broad and diverse set of actors is required. One of its obvious added values is the increased exchange of information, experience and best practices between regions. This relatively recent initiative can rightly claim significant results in AKST (identification of knowledge needs; knowledge generation, dissemination, access, adoption and use) within and between the less developed regions in the world. The best evidence of GFAR success was the official support it received at the G-8 Summit of Evian in 2003, seven years after its official launching.

[5] EFARD, the European Forum on Agricultural Research for Development, represents the various stakeholders through National Fora on ARD in European Union (EU) Member States and applicant countries, as well as Norway and Switzerland. EFARD's mission is to strengthen the contribution of European ARD to three major worldwide challenges (i) alleviating poverty and hunger, (ii) achieving food security, and (iii) assuring sustainable development.

[6] PROCINORTE is a cooperative programme in research and technology for North American countries (Canada, United-States and Mexico) that aims to strengthen the capacity of the three countries to carry out agricultural research and technology transfer through exchanges and partnership in a cost effective way. This program is under the leadership of the Inter-American Institute for Cooperation on Agriculture (IICA).

However, despite previous efforts in NAE, it seems more difficult and challenging to mobilize the different categories of stakeholders in the NAE region:

- in Europe, EFARD has succeeded to mobilize the different stakeholders for some specific tasks but its legitimacy is based on the existence of an active and truly representative national forum; however the situation varies greatly from one European Member State to another: for example, Denmark and Switzerland have established active and successful national fora (http://www.sfiar.ch/ and http://www.netard.dk/) whereas Germany, after a strong launching phase, could not maintain its national ARD forum; France, in spite of being the first ARD contributor in Europe, has yet to establish its national ARD forum; and
- in North America, the different categories of ARD stakeholders seem to be working even more in isolation than in other regions, particularly universities. So far, NAFAR has not succeeded in convincing stakeholders of its added value and PROCINORTE is currently more a research program than a multi-stakeholders forum.

Lessons have to be drawn from this innovative, bottom-up, highly participative multi-stakeholder mechanism and its impact on AKST after 10 years of existence. The second external evaluation was completed in February 2007. Options for action can be discussed in the light of this last evaluation and focused on two major issues:

- the building up of two or three strong and active ARD forums in the NAE region (North America, Western Europe, Eastern Europe including Russia) to significantly help the work at the global level in collaboration with other regions; and
- the analysis of strength and weaknesses of the major past projects to identify the conditions for success of the future projects supported by the GFAR, both at the regional and global level and taking into account regional specificities and diversities in the analysis.

It would be worthwhile if cooperation at the academic level be made between NAE and south AKST with strong political support but without political interference, in an effort to gain mutually useful knowledge firmly oriented towards development and sustainability goals.

6.4 Reshaping Policy Environment and Governance Systems

The agenda for agricultural and rural development policies nowadays is broader than in previous decades. The agricultural sector is being exposed to a more diversified set of demands, not only from consumers, who are increasingly concerned over issues such as food quality and safety, but from wider society, whose expectations increasingly involve territorial, social, environmental and cultural matters. This may require a wider and more coherent policy framework, the establishment of new proprietary regimes as well as the reshaping of IPR. In addition, governance options particularly at the local level can also be reconsidered.

6.4.1 Developing a coherent policy framework

The intricate complexity of the development of agriculture and rural areas, the multifaceted linkages with policy, the diversity in agricultural and rural systems and the important dynamics of changes in the overall system mean that policies are typically formulated on the basis of a partial knowledge of the overall situation. The guiding principles in any intervention and in the supporting research simultaneously consider the economic, social and environment dimensions of sustainability (FAO, 2005b; Martin, 2005):

- economic, implies that production is profitable and demand-driven and contribute to the livelihoods of the citizens;
- social, implies that production concentrates on product safety and quality, contributes to better health of all the citizens and is transparent and responsible, etc; and
- environmental implies that production processes should respect environmental carrying capacity, respond to climate change, participate in improving the energy policies, etc.

The adjustments in policy issues and regulatory frameworks have implications for research to tackle some of the main challenges, such as:

- to provide a trans-ministerial/ interagency approach for better coherence of the complex overall framework (e.g. between agricultural, economic and health ministries that would result in the production of diversified and healthy foods, at the local, national and global levels) as well as collaborations between governmental departments and private sectors and NGO actors;
- define the criteria for balancing between these different policies; and
- identify ways that ensure the articulation of these policies at the local, regional and global levels.

For example formulating new policies to improve current policies in order to integrate the sustainability and multifunctional aspect of agriculture and facilitate the development of sustainable food and farming systems. Such possibilities include:

- adoption of policies that facilitate rapid uptake of technologies that maintain or increase productivity and have a smaller environmental footprint than current technologies;
- elaboration of policies that consider the holistic approach of agriculture (Bryden, 2001). This would lead to more encompassing policy instruments for the achievement of multiple objectives that are more efficient than separate policies for each of the multifunctional attributes of agriculture;
- development of new policies while keeping in mind the transaction costs (other than administrative costs) involved and determining if these costs could be reduced through

policies aimed at selective targeting of farms subject to the programs, by using agricultural price and income support programs etc (Abler, 2004); and

- elaboration of policies to reduce the negative and promote the positive externalities or public goods at the farm level (identification of the individual farmer's contribution to a specific externality) and the landscape level (INRA et al., 2004).

6.4.2 Developing AKST in response to International Agreements.

Implementation and development of international treaties and conventions on various matters can be facilitated by innovations in agricultural science, knowledge and technology. In many cases, successful implementation of international agreements will require changes in the use of agricultural technologies. Many agreements offer opportunities for scientific, technological and policy innovation. Policy responses to international agreements can often be made practicable or facilitated by accompanying scientific and technological change (Kiss, 2003; Mitchell, 2003; Porter et al., 2006; Anton et al., 2007).

The Kyoto Protocol signed in 1997 and the subject of continuing development since that time requires the reduction of Greenhouse Gas Emissions (GHE) in NAE and presents challenges in all sectors, including agriculture. As discussed elsewhere in this report, methane production deriving from agriculture, the use of agricultural chemicals that contribute to the greenhouse effect, energy use in agriculture and deforestation for agricultural production are among the most important areas where innovations may help in meeting the goals of the agreement. Agricultural techniques that improve rates of carbon sequestration may prove important and the development of biofuels that meet other environmental and social criteria and result in net reduction of GHE may also make an important contribution.

The fact that the United States is not signer of the Kyoto Protocol presents its own set of policy challenges and by implication, challenges for both policy and science among all nations. Adherence of the United States to Kyoto and/or the creation of new international agreements that adequately address global climate change and that enlist the commitment of all nations in NAE must be considered essential. The development of existing and new agricultural technologies and policies or their novel application should be considered important tools not only in achieving compliance with existing agreements but also in removing obstacles to the design of effective new agreements (Tamara, 2006; Eyckmans and Finus, 2007).

Similar issues arise with respect to the non-ratification by the United States of the Convention on Biological Diversity and the Law of the Sea Treaty. Both of these agreements have important implications for agricultural production and for the development of AKST. The fact that the United

States remains one of the few nations in the world that have not ratified them presents challenges to further developments in AKST and related policies, with particular significance within NAE. Resolution of the problems standing in the way of ratification by all NAE countries could clear the way for more straightforward and coordinated responses to the efforts needed to meet the goals and provisions of the agreements at the global scale.

The Montreal Protocol, first adopted in 1987, continues to challenge agriculture and other sectors to achieve full compliance. For example, the full phase-out of methyl-bromide as an agricultural fumigant has yet to be achieved and has led to the search for and/or development of substitute technologies and practices (for current regulatory status and actions, see http:www.epa.gov/ozone/mpr).

Similarly, the 1998 Rotterdam Convention for the Application of Prior Informed Consent for Trade in Hazardous Chemicals and Pesticides and the 2001 Stockholm Convention on Persistent Organic Pollutants create the demand for technologies to substitute for those that may be used less widely or eliminated by implementation of these treaties. These treaties in some of their implications may create a potential imbalance between wealthier and poorer nations, as poorer nations may have a more difficult time finding substitutes for older and cheaper technologies disfavored by the treaties, which in many cases include tools or techniques with expired patents. The higher cost of newer substitutes with patent protection may make it difficult for many countries to comply with the provision of the treaties. Research and innovation in NAE, possible compensatory schemes and the application of features of intellectual property rights may be critical in identifying viable alternatives that can be made practical and affordable to all (Nakada, 2006).

International agreements are not always entirely consistent with one another, as appears to be the case with provisions of the Convention on Biological Diversity and the World Trade Organization’s TRIPs (trade-related intellectual property rights) agreement. It will be important to forge agreements that create clear and consistent property rules, or that create ways in which inconsistencies among international agreements and among international agreements and national legal regimes, may be mediated (Chiarolla, 2006; Rosendal, 2006).

Many other treaties have implications for agriculture. In general, the credibility and effectiveness of international efforts to improve agricultural knowledge, science and technologies for development and meet development and sustainability goals will partially depend on the consistency and effectiveness of international conventions and agreements. Increasingly, agricultural scientists will find their own work shaped by such agreements and will find opportunities in the ability to provide innovations that facilitate their implementation.

6.4.3 Enlarging the range of proprietary regimes

6.4.3.1 General issues concerning proprietary regimes and IPR

A continuing reconsideration of the legal and cultural definitions of property is necessary as agriculture faces the challenges of a changing world. In the late 20th century, international institutions and most national governments promoted relatively simple property rules based on either the private ownership of goods or public ownership (goods that were considered as a public utility and were either publicly owned or heavily regulated by the government). There have been counter-trends in the definition of property that have been more compelling and many of them are likely to become critical pieces of the response agriculture will have to make to global economic, social and environmental challenges over the next half-century. At a minimum, a critical re-assessment is advised while allowing for more research and experimentation in the area of property regimes. In order to better understand the different property regimes a quick review of the classification of the different goods that determine their property regime, based on their consumption and access, is essential (see figure below).

Consumption	Access	
	Exclusive	NonExclusive[1]
Rival	*Private* (e.g. food, clothing, cars)	*Common pool* (e.g. air, water, soil and ocean fisheries[2], landscapes)
NonRival[3]	*Club/Toll* (e.g. toll-roads INTELSAT, Suez Canal, Panama Canal, private schools, theatres, professional associations)	*Public* (e.g. public roads, sunshine, national defense…)

[1] Non exclusive: once available, it is not possible to prevent free access to it by all.
[2] In some cases, soil and ocean fisheries access may also be viewed as exclusive
[3] Non rival: one person's consumption does not diminish its availability to others.

As mentioned above, there has been a tendency so far to simplify the concept and attribute only two kinds of regimes: public or private. In reality of course not all goods can be classified under these two categories as there are few goods that are purely public or purely private. For example, air used to be thought of as a public good, but as a result of pollution, this has come to be considered as somewhat of a hybrid public good, because it's erstwhile non-rival nature has been eroded due to technology and policy (Box 6.14).

[Insert box 6.14]

This has lead to the emergence of a new category of goods called “impure public/private goods,” which can be further divided into: club/toll or common pool goods. These goods may call for a double approach: partly legitimizing privatization of these goods and partly seen as a global common good by the society. A new proprietary regime can be established for these “hybrid” goods that would do more justice than either purely public or private ownership. This type of regime could allow a sustainable management of the commons and avoid over-exploitation or loss of associated resources as is expected in the “tragedy of the commons” (Hardin, 1968).

Such a vision of “hybrid” goods has been established with the concept of “common property regimes,” developed for natural resource management projects. Common property regimes can be defined as those resource management systems in which resources or facilities are subject to individual use but not to individual possession or disposal, where access is controlled and the total rate of consumption varies according to the number of users and the type of use (Forni, 2000).

Thus, proprietary questions undoubtedly raise many complex issues of which more research would allow a better understanding, so that they could be used to maximize benefits. Such research might concentrate on the identification and analysis of the factors conducive to the organization of common-property regimes as opposed to a private-property regime (Orstrom, 2003). The greatest value might be gained from such research if it associates agricultural scientists with social scientists, philosophers, ethicists, public policy practitioners and lawyers, with the participation of the public at large and of public institutions in the evaluation and implementation of research results. Significant and sustained promotion of interdisciplinarity, public forums and public policy discussions of the nature and implications of property and property law for the future could be useful.

6.4.3.2 Intellectual property rights

Intellectual property rights (IPR) have clearly benefited agriculture and the environment. Much of the harmful and contaminating pesticides, insecticides or herbicides have been replaced by generation after generation of proprietary, IP-protected products. Each generation was safer than the previous, both to humans and to the environment and all generations safer than the materials initially used. This enhanced safety was due to stiffer regulation coupled with the knowledge that there would be IP (Intellectual Property) protection that would cover investments in producing subsequent generations. But the downside to this IP protection, due to the pioneering nature of the applications, is the broad coverage that the patent offices granted that often extended beyond the enabling information in the applications. This has led to a few companies obtaining broad coverage, to the point of cornering areas and making it exceedingly hard for others to have freedom to innovate. While patents are most important to reward the discoveries of astute inventors, there can indeed be problems in getting wanted and novel products to market, especially from the public sector. For instance, the inability to obtain the license on any one element in developing a transgenic crop can prevent a crop from getting to market, which can be to the detriment of agriculture. Also, patents controlled by large agricultural companies have protected certain enabling technologies essential to agricultural sciences, such as transformation methods, constitutive promoters and selectable markers.

Reshaping IPR and its associated regulatory environment can facilitate the generation, dissemination, access and use of AKST. Some of the options are listed below:

- the patent offices can continue the trend to issue narrower patents even on pioneering technologies;
- University groups and the private sector could be encouraged to pool patents through cross licensing (and free licensing to the developing world). Several interesting public initiatives are now coordinating collective networks for the management of patents and other exploitable assets (know-how, software, etc.) held by public research organizations in the field of agricultural biotechnologies (e.g. CAMBIA[7] in Australia, PIPRA[8] in USA, EPIPAGRI[9] in Europe)**.** They may also ensure common development and patenting of novel biotechnological techniques, vectors, genes, etc. They make them available by royalty-free license on the proviso that improvements be immediately made available to all other licensees. Having the technologies as "open source" leads to what they call "collaborative invention", as all the different players working with the open source material further develop it for all and innovations are quickly disseminated, instead of remaining proprietary knowledge within a company. This is an excellent rationalization of the system, for the common good, with adequate economic incentives for the developer.
- consider legislation to allow compulsory licensing, if and when necessary for agriculture and food security (So far this measure has been used or threatened only for pharmaceuticals in relation to critical health issues); and
- address the trend wherein patent offices are limiting what had been known as the "American unwritten exemption for not for profit research" on using patented intellectual property, which is being eroded by the courts. As patent law was written to optimize the

[7] CAMBIA is an independent, international non profit institute that has been creating new technologies, tools and paradigms to foster collaboration and life-sciences enabled innovation: www.cambia.org.
[8] PIPRA (Public Intellectual Property Resource for Agriculture) is a non profit initiative that brings together intellectual property from over 40 universities, public agencies, and non profit institutes to help make their technologies available to innovators around the world: www.pipra.org.
[9] EPIPAGRI is a European project (specific support action) that aims to set up a collective network for the management of patents and other exploitable assets (know-how, software, etc.) held by European public research organizations in the field of agricultural biotechnologies.

acquisition of new knowledge and its being put to use while rewarding inventors, it is time for the legislators to codify research exemptions so as not to stifle research.

In conclusion, it would be advisable to have more uniformly accepted and coherent IPR regimes in order to encourage research and other endeavors that would facilitate the achievement of the MDG's.

6.4.3.3 Access to genetic resources for food and agriculture

The current international basis for the exchange of genetic resources was established in 1992 – 1994, with the quasi-universal adoption of two international agreements: the Convention on Biological Diversity (CBD) and the Trade Related Intellectual Property Rights agreements (TRIPs) of the World Trade Organization. The former qualification of genetic resources as human heritage was then replaced by the principle of national sovereignty over natural resources and patentability extended to any domain of invention applied to living organisms. This framework has been further developed with the adoption in 1994 of the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA), that adapts the CBD principles to the specific field of agricultural plant genetic resources and establishes a multilateral system for facilitated access and benefit-sharing arising from the use of resources: it allows the use of PGRFA in a multilateral way through the conclusion of a "standard" material transfer agreement, but the funding strategy of the IT still shows some gaps. The PGRFA treaty also states that the responsibility for realizing farmers' rights (including, when appropriate, the protection of traditional knowledge, the sharing of benefits arising from the use of PGRFA, the right to participate in making decisions at national level on matters related to PGRFA) rests with national governments. Thus, a reflection is also going on since 2001 at the World Intellectual Property Organization on the relationship between intellectual property, genetic resources and traditional knowledge.

Stakeholders are being increasingly challenged by this continuously evolving and complex legal framework (Visser et al., 2000). There are several options to consider for AKST to contribute to the clarification of the regulatory framework in the context of more systemic governance approaches linking global, national and local levels on the one hand and conservation, knowledge, utilization on the other. Among others:

- ensure a better coherence of national, community and private rights systems over genetic resources and traditional knowledge relevant to agriculture, while encouraging the implementation of effective dialogues between agricultural communities and governments; and
- encourage intellectual or other property rights that increase easy access to genetic variability and associated knowledge, while ensuring that the royalties associated to such

rights will effectively permit the maintenance and regeneration of the genetic resources and their trustees.

6.4.4 Setting up new modes of governance

6.4.4.1 General governance issues in food and farming systems

New modes of governance can contribute to the sustainable development of food and farming systems. This calls for the development of innovative networks at the local level (both terrestrial and marine). It is advised that some of the research concentrate on:

- area required to ensure a good balance between diagnostic and action as well as between action and needed resource mobilization: in most cases, the size of an environmental space (e.g. a watershed) will not fit either the economic or policy space of action, suggesting compromise as a tool to define the optimal boundaries;
- development of methods and processes to create innovative networks at local levels to solve problems: mobilization of stakeholders to be part of the network, collective identification of potential conflicts among stakeholders to face and solve the problems, relevant collective organization and resource mobilization for action and follow-up; and
- development of common tools to facilitate local governance: local databases, easy to use integrated software packages to model complex systems and build up indicators to compare response strategies.

A systematic exploration and scientifically sound examination of practical experience could facilitate in fulfilling these needs. Such research would be effective if it is trans-disciplinary, i.e. also involving stakeholders using suitable participatory approaches (focus groups, expert panels, etc.). Stakeholders are the farming sector, consumers, taxpayers, citizens with food safety, environment and animal welfare interests, the food industry as well as regional level decision-makers and administrators (World Bank, 2008). A challenging question is how to combine qualitative and quantitative research to effectively support the related decision processes. The aim must be to effectively bridge different research paradigms and to embed the analyses within a process of stakeholder interactions.

Examples of such new modes of governance include:

a) Food policy councils: A food policy council is a coalition of food system stakeholders who advise a city, county, or state government on policies related to agriculture and food. These councils focus on areas such as using agriculture and food systems as an economic development tool, protection for farmland and farming, prevention of hunger, fostering the processing and local marketing of food and agricultural products, reducing producer risk, enhancing food safety and promoting nutrition education. They develop legislation, recommendations to departments of agriculture and other policymakers, support and promote state and regional food marketing programs and promote education about local food issues. One of the key functions and benefits of these councils is the increased coordination between state agencies. They also serve as a venue for communication between food and agricultural businesses, consumers and policymakers. The work of Food Policy Councils across the United States of America has so far engaged a large number of stakeholders from food businesses, agriculture, government, consumer groups, non-governmental advocates, nutritionists and institutions in a dialogue about how to promote food and farm businesses for the well-being of the current and future residents of their respective states (Lipstreu, 2007).

Food policy councils could provide a crucial forum to encourage more creative and lasting solutions to food system issues. Based on their ability to bring together diverse organizations and interests to develop win-win solutions, food policy councils can have a significant influence, even with modest resources. They have proven to be a voice for the critical role of food issues in public policy, both at the municipal and state level. Food policy councils can help put healthy food on the radar screens of local and state governments (Food Security Learning Center, 2007).

b) European Water Framework Directive - integrated river basin management for Europe:
This is the most substantial piece of water legislation ever produced by the European Commission and will provide the major driver for achieving sustainable management of water in the Member States for many years to come. It requires that all inland and coastal waters within defined river basin districts must reach at least good status by 2015 and defines how this should be achieved through the establishment of environmental objectives and ecological targets for surface waters.

Success will depend on close cooperation and coherent action at community, member state and local level as well as on information, consultation and involvement of the public. Public participation in “River Basin Management” projects is deemed to be crucial and the framework states clearly that caring for Europe’s waters will require more involvement of citizens, interested parties and non-governmental organizations. To that end the Water Framework Directive will require information and consultation when river basin management plans are established: the river basin management plan must be issued in draft and the background documentation on which the decisions are based must be made accessible. Furthermore, a biannual conference is said to be important to provide for a regular exchange of views and experiences in implementation. The Framework Directive underlines the need for establishing very early on a network for the exchange of information and experience between water professionals throughout the Community (Directive 2000/60/EC of the European Parliament and of the Council, 2007).

To facilitate the implementation of the EU Water Framework Directive, the Department of the Environment, Heritage and Local Government in Ireland as well as The Environment Agency (EA) in England and the Scottish Environment Protection Agency (SEPA) are promoting the establishment of river basin management projects by local authorities for River Basin Districts in relation to all inland and coastal waters that will facilitate participation by all stakeholders and lead to the identification and implementation of effective measures for improved water management. The overall objective of these projects is to develop a River Basin Management System, including a program of measures designed to maintain and/or achieve at least good water status for all waters and to facilitate the preparations of River Basin Management Plans. In order to implement this Directive the government of France has for instance established the “Rhine Network” for a better participatory management of the Rhine River. This network’s primary role is to identify and encourage water management based on local participatory practices as well as reinforce European cooperation at the watershed scale.

6.4.4.2 Fisheries issues

One of the main areas where research can be developed in this domain concerns the regulation of the access to marine resources and their exploitation, for instance:

- better define the rights of use and the rights of property of marine ecosystems: the regulation of the access to marine resources and their exploitation leads to the separation of the rights of property and the rights of use. The inadequacies of many present regimes and particularly where the property of the resources is declared common, results mostly from the absence of a clear regime of access and rights of usage. The evolution of access and property regimes is an essential condition for the establishment of a sustainable exploitation of fisheries resources. Alternatives for resource management could be built on scenarios allowing for the testing of various property regimes (e.g. private / collective), various systems of rights exchange, at various resources levels (stock / ecosystems).

In addition, in this area the importance of local governance and the integration of stakeholders’ advice in governance could be underlined. Models where stakeholders’ advice is taken into account could be developed to help build scenarios of sustainable fisheries management. This could be done by either strengthening or improving existing institutions (e.g. Regional Advisory Councils in the EU). In this context, the creation of localized Territorial Use Rights in Fisheries (TURF) and the granting of the TURFs to fishing communities offer new opportunities to provide local control over the resources within a territory with local determination of the objectives to be derived (Christy, 1982). The community would be in a position to choose whether it wishes to extract resource rents, to increase the income levels of its fishermen, to increase employment opportunities, or to achieve some combination of these goals. It could also determine the kind of gear to be used, the technological innovations to adopt, the time and seasons of fishing and other management measures. Exclusive territorial rights could be a strong incentive for ensuring that the management measures are respected. Further studies are necessary to develop this TURF concept such as: (i) detailed examinations of the conditions permitting the creation of localized TURFs or the maintenance and enhancement of traditional territorial rights; (ii) define the ways in which the benefits of traditional systems are shared or distributed and identify the kinds of controls over newly created TURFs that would ensure equitable distribution of benefits both within communities acquiring the rights and among neighboring communities of fishermen.

6.4.4.3 Forestry issues

The forest sector has been affected by important changes in terms of modes of governance and management since the beginning of the 1990's (Tikkanen et al., 1997). The conventional mode of decision-making in the forestry sector is basically a top-down, command-and-control, centralized system, where the technical expertise of the state forest administration staff is exclusive. With time, this framework has slightly moved towards new modes of governance and management, where participation (in fact consultation in most of the cases) and deliberation among stakeholders (mostly production-based ones) are becoming more prominent (FAO/ECE/ILO, 1997; GoFOR, 2007).

The main changes identified in the forest sector are highlighted below:

Schemes of certification: Under strong pressure from some major environmental NGOs, the idea has been introduced that the evaluation of the sustainability of forest management could work completely differently from what has been the case, where forest managers were more or less their own evaluators. It is admitted today that a certification procedure carried out by neutral actors is the only way to ensure a label of sustainable forest management (Viana et al., 1997).

Three main certification schemes are coexisting today: The FSC (Forest Stewardship Council): promoted by environmentalists (mainly WWF) and based mainly on performance indicators; the PEFC (Program of Endorsement of Forest Certification schemes), promoted by producers, including private forest owners in Europe and based on system indicators; and Smartwood, basically a North American joint initiative of an environmental NGO (the Rainforest Alliance) and industry. The effectiveness of those certification schemes is still questioned: multiplicity of labels creates confusion (still a battle among certifiers); chain of custody controls are unclear in some cases (example of PEFC); labels are used as market instruments more than tools promoting sustainability; and labels are unknown to customers (Burger et al., 2005). But the changes in the forest sector are promising, because the introduction of certification schemes has boosted both the participation among actors and the development of a more accountable expertise. An increasing share of the wood products on the market is certified through these various schemes (Rametsteiner, 2000).

National Forest Programs (NFPs): A NFP is a strategic document, established within a timeframe of 10-15 years and provides the rationale and directive for public action in the forest sector. It is established through a formal participatory process associating the stakeholders and the public and gives guidance on the establishment of partnerships and share of responsibilities in carrying out the activities. This new way of formulating forest strategies has replaced the conventional, technical top-down mode of planning of the forest administration (Glück et al., 1999; COST E19, 2000). The NFPs are based on several elements: participation (all stakeholders and sometimes the public are strongly invited to be involved in the designing and implementation of forest activities (FAO/ECE/ILO, 2000; FAO/ECE/ILO, 2003; IUCN, 2001)); links across sectors (programming of forest activities is elaborated in connection with other sectors, especially environment and land use (Tikkanen et al., 2002)); coordination between various levels of governance (to ensure comprehension between international, national and local actions) Niskanen and Väyrynen, 1999; Slee and Wiersum, 2001); accountable expertise (from various sources and subject to public debate); iterative processes (to promote adaptive management based on collaborative learning).

During the last 10 years, there has been a significant increase of NFPs, especially in Central and Eastern Europe, as this was an informal requirement before becoming integrated within the European Union (Glück and Humphreys, 2002; Glück et al., 2003). As for Western European countries, the NFPs elaborated are more formal documents, except in Finland and Scotland (Gislerud and Neven, 2002; Humphreys, 2004). In the US, where decision makers are more results, than process-oriented, NFPs are not yet part of the culture.

Although those changes are significant in a very traditional sphere such as the forestry sector, it can be noted that all the characteristics of these new modes of governance and management are far from being present in all national frameworks: participation is used as an alibi, cross-sector approaches are advocated only when they reinforce the sector and the accountability of expertise is diverted by the conventional experts, etc. (Buttoud et al., 2004).

6.5 Funding Investments in Research and Development (R&D) for Agriculture

Research and Development are key elements of technology change. R&D needs and priorities will vary among plausible futures. From an investment viewpoint, decisions are required on how much to spend on R&D, who should pay for it, who should do it and on issues of governance.

6.5.1 Spending on R&D

Spending on R&D is worthwhile if it gives a satisfactory return in absolute terms (extra benefits are greater than or equal to extra costs) and relative to other investment opportunities. The benefits of R&D are multiple and diverse, some being immediate and others long term. Some benefits of agricultural R&D accrue directly and exclusively to the users of research products (private benefits/goods) while others generate indirect benefits for society at large (public benefits/goods). Investment in crop genetics, for example, can deliver private benefits to farmers who use the research products, as well as public benefits associated with increased food security. Extra costs include the costs of resources committed to R&D activities. They may also include public costs associated, for example, with unwanted social or environmental side effects.

Methodologies to evaluate investments in R&D are available but there are theoretical and practical challenges (Alston et al., 1995). Previous investments in agricultural R&D in NAE have shown relatively high rates of return (Alston et al., 1999, 2000, 2001; ADAS, 2002; Marra et al., 2002; Thirtle, 1999, 2003; Sylvester-Bradley and Wiseman, 2005), perhaps suggesting a degree of under-investment. However, it is claimed that that some estimates are liable to errors associated with overestimation, double counting, over-attribution of benefits to individual R&D programs (Alston et al., 2001) and possible omission of some of the negative social and environmental effects of improvements in productivity due to use of R&D products (Julian and Pardey, 2001; Barnes, 2002; Koeijer et al., 2002). In some cases, it has been suggested that R&D might not have been the best way of achieving the desired outcome.

6.5.2 Paying for agricultural R&D

Generally, the criteria for payment is that the beneficiary pays, moderated by ability to pay. Broadly, providers of R&D products should be remunerated by those who derive private benefits from their use. In this way, the researchers recover their costs and are given incentives to invest in R&D. Where potential users of R&D products cannot afford to pay and yet it is considered that overall social welfare is enhanced if they use R&D products, there may be a case for public funding. This could be to help finance the R&D process or the acquisition of research products by users. Here, government intervention is addressing the failure of R&D markets to deliver a socially optimum R&D spend. Some R&D may also provide public goods by reducing the negative externalities of agriculture such as diffuse pollution; in this case, it is sometimes questionable whether remedial R&D of this kind constitutes the most economically efficient approach: other policy interventions might be better, including removing incentives which cause the externalities in the first place, such as production subsidies.

Definitions of public goods associated with agricultural R&D vary over time and space, as does the justification for Government funding. In post war Europe, food production to feed nations was regarded as a public good, justifying major commitments of public funds for crop, livestock and agricultural engineering research. Much of the fundamental R&D that underpinned the gains in agricultural productivity in NAE was publicly funded between the 1950s and early 1980s. Much of this stock of R&D knowledge and the research capability that provided it, has now either been used up or depleted. Less is available for future needs.

Government funded research is now largely confined to addressing non-market social, environmental and strategic issues as well as supporting fundamental research that would not attract private funding. Examples include research into livestock systems to reduce environmental burdens and research programs to assist farmers in disadvantaged, upland areas. Under the new paradigm of multifunctional, sustainable agriculture, it is clear that there will be a continued need for Government funding of R&D in the public interest.

Spending on private sector agricultural research has grown relatively rapidly over the last 25 years and now exceeds public spending in many developed countries (Alston, 2000). An additional and growing source of funding is that of nongovernmental, not-for-profit organizations that sponsor research in pursuit of an organizational agenda, mostly associated with social, environmental, ethical or political objectives. They also provide a conduit for private or government funds. Private benefactors also channel funds into trusts that pursue selected themes. In the future, increased emphasis on the multiple functions of agriculture is likely to call on a greater range of funding sources.

The paradigm shift in agriculture towards multi-functionality and the concomitant shift in AKST have major implications for the provisioning of R&D in terms of priority setting, funding and delivery mechanisms. Continuing reform of agricultural policy throughout the NAE region is likely to promote greater market orientation for agriculture, implying that governments will further retract from R&D that is ‘near market’, leaving this largely to the private sector.
Government funding of R&D is likely to focus on aspects of public good, addressing strategic issues such as food security, impacts of climate change, the long-term sustainability of agricultural systems and the protection of natural resources, the environment and the livelihoods of vulnerable rural communities.

Where private R&D initiatives fail to respond to market potential because of high costs, high risks or long investment periods, Governments can collaborate with private partners to underwrite commercial risks if they perceive a potential net gain in social and economic welfare.

Collaborative funding of R&D to support bioenergy cropping and processing systems is a case in point. Where technology change is policy-induced, there is a strong case for collaborative public – private funding mechanisms for R&D. The EU Integrated Pollution Control Regulations and the Water Framework Directive are cases in point, justifying collaborative R&D ventures that share the burden of costs associated with new regulations.

6.5.3 Undertaking agricultural R&D

There has been a recent tendency to separate R&D funding and delivery mechanisms, with increased ‘contracting out’ of Government-funded research, diversifying the range of organizations engaged in research. As agricultural enhancement has become less important as a policy goal, direct government involvement in R&D to improve productivity has declined: it is now regarded as too ‘near market’. As a result, the number and size of government research institutes in some parts of NAE have decreased. In other cases, specialist government research institutes and universities have increased their share of private and NGO funded research, utilizing specialist skills and facilities. Funding and delivery regimes come together to provide a range of options for R&D management, considering the three main players: Government, NGOs and private organizations (Table 6.2). Universities are a key delivery agent.

[Insert Table 6.2]

There is now much greater diversity in the provisioning of agricultural research, especially regarding biosciences, with a growth in public-private funding partnerships among industry, NGOs and government, often involving universities as research contractors. Potential complementarities include joint funding, pooling of facilities and expertise (including research management), economies of scale and learning, risk sharing and dissemination and commercialization of research products into research outcomes.

6.5.4 Deciding on R&D

Regarding public goods, this is clearly a role for government and intergovernmental development agencies, engaging the key stakeholders in the process. Most NAE governments have R&D priority setting regimes in place and these will be increasingly linked to strategies to promote sustainable agriculture (e.g. Defra, 2002b, 2005b).

Regarding private good aspects, decisions rest on the commercial considerations of business enterprises. Public–private partnerships can help to underwrite private R&D investment costs where risks are high and the development of successful research capabilities and products can significantly enhance the public good. At a national level, this may include improving international competitive advantage (Gopinath et al., 1997; Ball et al., 2001).

6.5.5 Institutional Arrangements and Collaboration

The organizational arrangements for identifying, prioritizing, funding and carrying out R&D and, not least, the transposition of research outputs into knowledge, products and processes for adoption by end users, are critical to the overall successful outcomes of R&D. Again, this will reflect the dominant purposes to be achieved and, as far as serving the public good is concerned, it is a responsibility of Government to provide an institutional framework within which various stakeholders can interact.

R&D management includes arrangements for identification of needs, priority setting, pre-investment appraisal, research procurement, dissemination and follow-up. As mentioned in earlier sections, it is imperative that key stakeholders are involved throughout this process to ensure R&D is relevant to end-user constituencies. The latter also implies full integration with the processes of 'knowledge exchange', including those of advisory and extension services. There are also important links with other services that affect technology adoption, notably credit and marketing.

The further development of funding arrangements could be designed to promote enhanced cooperation not only among AKS components but also between AKS components and the more general scientific and higher education communities (life sciences and economic/social disciplines) as well as policy makers, stakeholders and the general public.

Funding for cooperation across AKS institutions has led to the emergence of new partnerships and networks providing cross institutional and cross-disciplinary synergy in some NAE countries. Open dialogue, joint planning and fair sharing of credit are key success features in the promotion of these partnerships. It is now vital to design mechanisms for scaling these partnerships up and outwards, not only nationally, but also across the NAE region, both in research and in human capital development.

It is noteworthy that a recently published OECD study on Human Capital Investment concluded that "human capital seems to offer rates of return comparable to those available for business capital" (OECD/CERI, 1998). Allied to this conclusion is the increasing acceptance by many OECD governments that investment in the development of a knowledge based society can be a powerful stimulant to promoting innovation and competitiveness. Many governments have increasingly been prepared to give extra public funding for innovative research (especially interdisciplinary ones) to promote competitiveness and for human capital development through higher education designed to achieve competitiveness and life-long learning/re-education to maintain competitiveness. The experiences over several decades of AKST institutions linking research, higher education and extension/development in an integrated manner offers a valuable model for AKS to play a central role in addressing the wider societal issues including food safety, the food chain, sustainability of natural resource use and rural development. New partnerships, networks and relationships will be required for this potential to be realized and AKS institutions could be encouraged to take action accordingly.

6.5.6 Funding mechanisms and enablers of AKST

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 continuing need for public funding to serve the public interest, as well as new investments by private organizations responding to market needs and opportunities. Funding arrangements can promote cooperation among all stakeholders. Open dialogue, joint planning and fair sharing of rewards are key success features in the promotion of these partnerships. Depending on circumstances, the following will be required:

- public investment in R&D to serve the public good, addressing strategic issues such as food security and safety, 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 bioenergy, as well as other “non market” issues that do not attract private funding;
- public investment in human capital development to achieve widespread understanding of the complexities of multifunctionality and to develop the knowledge and skill sets necessary for effective decision making 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) involved in rural livelihoods;
- public investment to support the development of multi-disciplinary research and education programs that promote an articulation between research and educational goals consistent with development and sustainability goals and judge the research and educational outcomes 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, as 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 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 at a later date; and
- nongovernmental organizations to act as channels for public and private funding of technical assistance, knowledge transfer and applied research, especially at the local scale. Further support will be required to facilitate this.

With respect to the above, there is need for a framework that can support the cost-benefit analysis of future AKST investments under the new paradigm for agriculture.
It is clear that a range of enabling conditions are required to support new forms of AKST investment in support of development and sustainability goals (Box 6.15).

[Insert box 6.15]