NAE Chapter 4

Options for action

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Key messages

4.4.4 Funding investments in research and development (R&D) for agriculture

References

Note to the reader: This document has been written essentially from a NAE perspective. Due to lack of time and parallel organization of tasks in this assessment, it has been built up:

- *A detailed analysis of the contributions from the other regions (documents written simultaneously as ours) should enable us to complete the sections that call for an interaction with the other regions. Missing points and elements will be discussed with the LA s of these regions during the meeting at Cape Town.*
- *This document focuses on a variety of options for the future and has not taken into consideration any conclusions from chapter 3 (baselines) as this chapter is not yet complete. A detailed analysis of chapter 3 might lead to some modifications in the options highlighted in this chapter.*
- This document is not entirely finalized. Certain sub sections need to be analyzed further and references provided for some others.

Key Messages

This chapter presents options for action in the AKST domain in order to contribute to the primary goals of the IAASTD which are to reduce hunger and poverty, to improve rural livelihoods and health, to increase incomes and to facilitate equitable, environmentally, socially and economically sustainable development.

Successfully meeting the IAASTD development and sustainability goals and responding to new priorities and changing circumstances will require widespread recognition of a paradigm shift. This new paradigm accords increased importance to the multiple functions of agriculture (producing food and fiber, providing environmental services, conserving resources and biodiversity, providing livelihoods and supporting the quality of rural life), and its adaptability to local environment and social contexts. This "multifunctionality of agriculture" can only be understood and achieved by developing new conceptual tools that aid in taking the complexity of agricultural systems into account and by setting agriculture in the entire context of society and ecosystems. New institutional and organizational arrangements are required that support a more integrated approach to the development, dissemination and uptake of AKST. Emphasis must be 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 much wider group of stakeholders, policymakers and the public to address these new complexities. Working successfully on this 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.

Global issues should be addressed:

AKST needs to be developed to counteract the detrimental effects of agricultural activities on climate change and to reduce agriculture's vulnerability to this phenomenon New farming systems, agricultural practices and land use changes leading to a reduction in GHG emission are necessary. In addition to effective mitigation, AKST must facilitate enhancement of rapid adaptation of the food production system and the agricultural sector at large to reduce its vulnerability to climate change. Some of the ways of reducing this vulnerability is by improving the capacity to predict future effects of climate change on geographic distribution of agriculture and overall food production in NAE and in other regions as well as reconfiguring NAE production areas to adapt and optimize available space and resources in new "environments".

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

AKST needs to carefully evaluate the advisability of biofuels production. Where appropriate, AKST needs to 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 overly cutting into the world food supply. Research needs to focus on improving the energy content of biofuel crops and other raw materials (sustainable energy crops, lignocellulosic wastes, algae…) and the overall energy efficiency these systems, increasing the efficiency of processing methods (fractionation techniques).

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

Innovative and sustainable food and farming systems should be developed:

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

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

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

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

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

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

The importance of aquatic products in food diets calls for improvement in the sustainability of the systems for coastal capture fisheries and aquaculture. Regarding coastal capture fisheries, AKST should focus on a comprehensive understanding of the marine ecosystem with systemic collection of long term data (biological and ecological as well as social and economic) and the development of tools and indicators that will help in the management of the ecosystem as a whole. In addition, technologies that facilitate selective fishing are necessary. An urgent priority in AKST for aquaculture is the need to address provision of alternative sources of fish feed, currently provided from unsustainable capture fisheries. Another priority is to continue research into reducing pollution from aquaculture units in both fresh and saltwater environments.

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

Future developments in AKST will raise profound issues about patterns of rural development and need to be designed and evaluated with such issues in mind. Such issues include questions regarding patterns of ownership and employment, effective participation, equity, development of human capital, cultural change, and ongoing education and training.

Strengthening the human capital and reconfiguring institutional arrangements:

Interactive knowledge networks involving multiple stakeholders need to be strengthened between the three components of the Agricultural Knowledge System: research, education, and extension. Providers of advisory, higher education, and research services are required become more engaged in building networks to address the more integrative approaches. Governments are required to ensure that organizational and structural arrangements encourage these cooperative efforts.

AKST needs to be developed to improve processes for involving and empowering stakeholders, women in particular, and others whose interests have hitherto been invisible to practitioners of mainstream science and technology. In this regard, the mechanisms required for stakeholders with little power to assert their interests are lacking, especially where these interests are not considered by those with power to be legitimate or urgent. There is also a need for cost-effective, participatory methods that bring together stakeholders at different scales of aggregation to identify and appraise actions that are individually and collectively advantageous. This is particularly important given the diversity of stakeholder interests in multifunctional agriculture.

Meaningful interdisciplinarity in research, educational programs, and extension/development work needs to be enhanced without compromising disciplinary excellence. Systemic barriers to interdisciplinarity like the organization, funding, and evaluation of research being biased towards work in specific disciplines should be identified and surmounted while defining criteria for assessing for high quality multi-disciplinary AKST

New skills and learning opportunities are necessary for existing and future AKST personnel and their various clients so that they can understand and function more comfortably in the context of the wider vision of agriculture. Initial education/training, multiple entry into the agricultural education system, on-going adult learning accompanied by learning materials readily available via internet and new modes of interactive learning need to be promoted.

Links between research and higher education as well as lifelong learning need to be strengthened as a key component of human capital development for the agriculture, food, and rural sectors. This entails the development of significantly expanded post-graduate level programs in NAE higher education institutions, a greater harmonization of quality among the widely differing education systems across NAE and continuing learning as part of the core mission of universities.

Strengthened information and knowledge-based systems are necessary to enable a rapid flow of information between the agricultural sector and the AKST system. The digital divide that exists between Western Europe/North America and CEE needs to be reduced. Specialized data management programs and methods that can help to extract useful knowledge from the very dense and numerous sources of information need to be developed.

Promoting appropriate organizational arrangements is necessary to guarantee the development of human capital in AKS and the creation of a learned society. Newly reconfigured and “engaged” public institutes need to be developed that provide access to a diverse student population as they reach out to "engage" the larger community and support lifelong learning.

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

Reshaping policy, governance and funding framework:

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

New proprietary regimes that define clearly the rights of use and rights of property need to be developed. The development of “common property regimes” that go beyond either purely public or private ownership need to be considered to optimally use hybrid public/private goods and resources. This would be facilitated by identifying factors conducive to the organization of these new regimes. Significant public policy discussions of the nature and implications of these new proprietary regimes for the future are needed.

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

New modes of governance are required that call for the development of innovative networks at the local level. Tools to facilitate local governance (suitable participatory approaches that involve the different stakeholders and result in the integration of their advice) need to be developed.

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

- Public investment in R&D should focus on aspects of the public good, addressing strategic issues such as food security and safety, impacts of climate change, long-term environmental sustainability of the system, social viability, protection of biodiversity, achieving strategic balance between land use for food and bio-energy, as well as other "non market" issues that do not attract private funding.
- Public investment in human capital development will be necessary to achieve widespread understanding of the complexities of multifunctionality and to develop the knowledge and skill sets necessary for effective decision making 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 is needed in the development of multi-disciplinary research and education programs that promote an articulation between research and educational goals consistent with the IAASTD 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, will continue to be an important and growing source of new AKST. It is critical that private suppliers of ASKT are given the necessary incentives and rewards to make new investments in R&D and have access to essential commercial services such as market information and credit.
- Public–private partnerships are needed to provide technical assistance and joint funding of R&D investments, especially where risks are high and where development of successful research capabilities and products/services in the private sector can significantly enhance the public good. Various forms of public-private partnerships will be relevant for advisory/information services of a near market nature. There are significant public good aspects to the development of human capital and skills relating to many pre-market, quasi-market or non-market multifunctional services, some of which may transfer to private funding at a later date.
- Non-governmental organizations are likely to become more important channels for public and private funding of technical assistance, knowledge transfer and applied research, especially at the local scale. Further support will be needed to facilitate this.

4.1 Paradigm shift and key issues for AKST to meet the IAASTD goals

4.1.1 The need to recognize a new 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. However, agriculture must now be responsive to new priorities, expectations, and changing circumstances. Many of these are stated in the IAASTD 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 will be made more complicated by a variety of foreseeable and unforeseeable changes. These challenges necessitate a new way of thinking about research, technology development, education, and knowledge exchange. The new way of thinking requires that those working in the fields affecting AKST must:

- 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 and social 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 is now a clear need for such broad anticipatory approaches to complement more narrowly focused R&D. Agriculture and AKST development must be re-conceptualized within the entire context of society and environment, introducing new levels of complexity in understanding and responding to the needs of the future. This requires recognition of a paradigm shift in the way AKST is to be produced and delivered. Elements of this shift have appeared throughout the NAE.

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

Working within the new paradigm will also require new institutional arrangements. These arrangements should 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.

4.1.2 New research approaches and the institutional change needed to support them

Universities, other research organizations, training institutions, and extension services need 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 must be done without sacrificing disciplinary excellence, which is the foundation for successful multi-disciplinary work. Much of this work needs to be focused directly on meeting the IAASTD goals.

Agricultural research and education, in all its forms, must meet 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 be much more interactive 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 need to recognize that this cannot depend on individual researchers but instead requires changes in the ways that research and educational organizations are structured. It also requires changes in the incentive systems for educators and researchers such that multi-disciplinary efforts are properly recognized and rewarded rather than ignored or punished.

The development and pursuit of research agendas also needs to 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 need 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 need to 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 need to become 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 the IAASTD goals.

4.1.3 Achieving the proper balance between the public and the private

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 some areas 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 much more directly in the biological world than do industrial and service sectors. 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 often successfully 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 much 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 in 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. NAE must be careful that changes that may be appropriate for the NAE region not be imposed 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 is a key issue for achieving the IAASTD goals.

4.2 The main fields where AKST needs to be generated or developed

In NAE, during the last decades, the evolution of Agricultural Science and Technology 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 which has ignored organizational impacts, particularly contextual elements (from biological sciences as well as from social sciences) affected by the deployment of that science, in non-linear and difficult to predict ways. These disciplinary approaches are not sufficient to address a complex problem - as a whole – and need to be supplemented with more systems and overall approaches such as "complex system"[1] approaches. These new approaches are today much more developed in the ecological domain and take into consideration 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 term to long term) point of view.

Putting the focus on complexity and trans-disciplinary approaches does not discredit more simple and disciplinary efforts that supply basic knowledge for some of the components of the overall complex system. But, it highlights the need to mobilize AKST much more in this direction which has been under-developed until now and which 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 is bound to increase, many of them being uncertain and addressing different scaling levels. Some of the potential contributions of these new complex systems to elucidate agricultural systems are enumerated in box1.

[Insert box 1]

This section will successively address AKST options (i) to address proactively global phenomena and (ii) to develop local and sustainable Food and Farming Systems (including forestry and fisheries) that would facilitate such comprehensive systems approach and its contribution to achieving the IAASTD goals.

As far as global phenomena are concerned, one of the major challenges of the next decades is to develop agricultural activities that will respond better to climate change: NAE could play a leading role in this domain. NAE should 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 globalization of exchanges. Regarding global phenomena and exchanges, one other area where AKST can contribute to is to reduce the dependence of the NAE region on fuels from crude oil by developing alternative sources of energy and green chemistry products 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 its own food and non-food 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 broaden its concerns to address explicitly and directly the multiple functions of agriculture (production of food

[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 dynamical patterns which are not inferable from a system description that spans only a narrow window resolution (Parrot and Kok, 2000). It leads to emerging new features or proprieties which 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 feedback loops both negative and positive, (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".

and fiber including land conservation, maintenance of landscape structure, sustainable management of natural resources, biodiversity preservation and contribution to the socio-economic viability of rural areas (OECD 2001)) both in Europe (Knickel et al, 2001; Hervieux, 2003) and North America (e.g. Boody et al. 2005).

Several broad areas of research are needed to move towards this goal in a deliberate and logical fashion as detailed in the following sections.

OPTIONS FOR AKST TO FACE GLOBAL PHENOMENA

4.2.1. 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 should be mobilized to mitigate this change on one hand and help agriculture adapt to these changes on the other.

Some of the options for action are detailed below (Easterling,1996; Watson et al.,1997; Boucher et al., 2004; Brovkin et al,2004; Falloon and Betts,2005; Lassey, 2005; Olesen,2004; Jacobson et al., Pattey, 2005; Soussana et al.,2004; Dupouey et al.,2006)

4.2.1.1 Mitigate climate change through agriculture

Agriculture's influence on climate is significant but very complex however there are ways in which agriculture could help in reducing this alarming increase in greenhouse gas emissions by developing agricultural practices and land-use changes contributing to a decrease in GHG, for instance:

- Increase carbon sequestration in agricultural soils for example through no or minimum tillage and green manures leading to an increase in soil carbon levels. Additional research is needed on the enabling conditions and the magnitude of the net effect on GHG emissions.
- Increase carbon sequestration via land use change. The conversion of arable lands to grasslands and afforestation are important local options. Their net effect on GHG emissions in variable environments needs additional research.
- Analyze the effect of extreme heat or cold episodes on carbon accumulation. The long-term benefits of these changes and management systems need to be evaluated and developed.
- Manipulate livestock diet to reduce nitrogen losses from animals and/or reduce pH of excreta and to reduce methane emissions by ruminants.
- Use husbandry methods, management techniques and novel varieties to minimize the inputs of energy, synthetic fertilizers, and agro-chemicals on which present industrialized farming methods depend.
- Reduce energy use via reduced use of fossil fuels in farming and food processing.
- 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.

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

<u>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:</u>
The major challenge will be to better understand 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 much 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 2002 in Europe). These uncertainties (rainfalls, biotic stress, political and economic choices etc.) as well as short and long-term effects should be taken into account in the understanding of such complex questions. Also, there is a need to collect serial data through appropriate long-term observations to facilitate the construction and validation of previous models and to shed more light on these unanswered questions.

<u>Reconfiguring NAE production areas to adapt and optimize available space and resources in new “environments”:</u>
Geographic shift in crop and forest production
According to some studies 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. In Europe for example cereals in Finland will shift 100-150 Km towards the pole for a 1°C rise in temperature (International Panel on Climate Change (IPCC) 2001), continental and mountain forests will occupy less surface in the future compared to their present distribution as they are sensitive to high temperatures and extreme drought conditions etc.
The NAE region needs to anticipate these profound changes in the geographic organization and utilization of agricultural lands and study:

- 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 even better if data has a much higher degree of certainty than before for e.g. data from IPCC (IPCC, 2007) used for predictions of climatic changes.

Development of new and adapted agricultural practices and crop varieties

New varieties need to be developed, either new crops or agricultural crops adapted for predicted climatic changes, and agronomic practices appropriate for those crops under predicted climatic conditions need to be developed simultaneously.

New varieties should be better suited for high temperatures, with increased or stable growth with low water and nitrogen supply, lengthening of both vegetative growth and grain filling periods, early budding and better frost resistance for orchard varieties and field crops.

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 need for artificial drying. Soil moisture may be conserved by using conservation tillage methods, modifying the farm micro-climate 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 field need.

All of these above mentioned options need to be re-evaluated and adjusted to take into account new rhizosphere communities that develop due to climate change and the effect of these communities on and their interactions with the surrounding agro-ecosystem.

Development of new social systems to enable smooth transitions for rural economies and maintenance of world food supplies

Mass human migrations stimulated by scarcity are often tremendously disruptive and damaging. If global climate change undermines the basis for agricultural production in rural NAE, it may cause dust bowl-like migrations that occurred in the US during the 1930s. To face this scenario and to help alleviate rural poverty, new social programs will be needed to aid in the economic transformation of the rural NAE. These programs should also have the aim of ensuring a stable production of agricultural products so that world food supplies are maintained during these transitions.

4.2.2 Facing new and emerging human, livestock and plant diseases

4.2.2.1 Human and livestock diseases

The last three decades have seen an alarming number of high profile outbreaks of new viruses and other pathogens, many of them emerging from wildlife. Recent outbreaks of AIDS, BSE, SARS, avian influenza, foot and mouth disease and others highlight emerging diseases as one of the threats to global animal and human health. Similar emerging diseases have been reported in wildlife populations, resulting in mass mortalities, population declines, and even extinctions.

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. The uses of pesticides, land-use change, changing nature of land-water interface and damage to the natural environment are other contributors. However, adequate understanding of the root causes of this upsurge is still lacking.

Clearly it will not be possible to meet the IAASTD goals unless the AKST system responds to this challenge in coordination with the rest of the KST system (with much closer contacts between the human and veterinary medicine).

AKST are needed in this domain to elucidate the following aspects (Salman, 2004; Thompson, 2001; Desenclos and de Valk, 2005; Center for disease control and prevention, USA; Horwitz and Wilcox, 2005; Douglas and Imam, 1996) :

<u>Understanding the origin of new and emerging diseases</u>

- 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.
- Understand the ecological and evolutionary dimensions leading to the development of new and emerging diseases.

<u>Predicting epidemics and pandemics across both spatial and temporal scales</u>

- Identify factors that influence 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 impact of crop and livestock genetic makeup on their susceptibility to disease and response to treatment.
- Develop basic fundamental research about hosts, pathogens and their interactions at different levels (molecular, cellular and superior integrative levels):
  - Hosts: physiopathology, immune response…
  - Pathogens: ecology and biology of the pathogens, vectors…
  - 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:
  - There is a need to involve multidisciplinary groups of scientists studying the ecology of an emerging infectious disease (EID). 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.

- There is also a need to consider ecological, evolutionary, social, anthropologic, geographic, economic and public health sciences. These disciplines need to be integrated in order to address determinants of new and emerging diseases.

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, 2001). There is thus a need to ensure that such technological advances are being applied as part of surveillance strategies, which requires interaction between government, policy advisers and scientists. The ability of veterinary and human quarantine systems to cope with the growing threats requires more comprehensive, strategic and effective surveillance. There is thus a need 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.
- Develop new methods of disinfection to avoid propagation: assess new methods for sterilization of food and reduce contamination of water.

There is also a need to develop new types of cures through newer forms of drug discovery, immunizations using nanotechnology or biotechnology to quickly vaccinate livestock and wild-life to cure the disease and to lower the chances of 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. In order to possess an efficient infrastructure three of the main areas that need to be developed are listed below:

- Enhance epidemiologic and laboratory capacity: the `new' tools of molecular epidemiology should 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. This would play an important role to better understand the advances in investigations of outbreaks, assessment of vaccine efficacy and monitoring of disease trends. Laboratory service has been the foundation of both improving the sensitivity and quality of surveillance data and identifying the emergence of newly identified agents.

- 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.
- Increase funding: in the future, more global resources should be allocated to the development of prediction and prevention programs to eradicate or minimize these emerging infectious diseases at a global level. There is further need for greater involvement of international non-governmental development and aid organizations. It is vital that a coordinated global broad civil society rather than an exclusively governmental approach be implemented in the prevention of these diseases.

4.2.2.2 Plant pests and diseases

Similar to new and emerging human and livestock diseases, there has been an upsurge of new plant pests and pathogens in the past few decades. Recent examples with important economical or social consequences include for example the severe epidemics of cassava mosaic caused by *East African cassava mosaic virus* (EACMV) or the sudden oak death disease cause by *Phytophthora ramorum (*Rizzo DM et al., 2005). Older examples that have had major impacts in the past include the arrival of potato late blight in Ireland, coffee rust in Ceylon, Chestnut blight in the Appalachians in the U.S. and the appearance of Phylloxera (a root-feeding aphid) on grapevines in Europe. In all these cases, the new disease severely affected the societies and/or agricultural practices used at the time.
Although fewer studies exist on plant pests and pathogens compared to their counterparts affecting humans and animals, the emergence or re-emergence of plant pests and pathogens is considered to be linked with several, concurrent factors (Anderson PK et al., 2004) among which are:

- increased global travel and global trade of plant materials, including crops plants but also exotic species used as garden or ornamental plants. This trade results in increased risks of spreading plant pests and pathogens into new hosts and/or new areas.
- climatic modifications such as global warming that has 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 (1) a reduced diversity of crops and (2) an increased contribution of monoculture.
- increased occurrence of resistance to pesticides in both pathogens and vector populations, further reducing our ability to control these agents and resulting, in some situations, in the build-up of large, difficult to control vector populations.
- evolution of the pests and pathogens themselves.

AKST needs to be deployed to understand the root causes of these new and emerging plant pests and diseases in order to shift focus to pre-empting pest and disease emergence, rather than just responding to it.

Main options for action in this domain are listed below:

<u>Better understand the origin of and the factors responsible for the invasiveness of pests and pathogens</u>

- Study the factors that determine the invasive potential of a pest or a pathogen:
  - Intrinsic factors: genetic makeup and its influence on the adaptation of a pathogen to its environment (demo-genetic models need to be developed to simulate the effect of such factors).
  - External factors: ecological conditions that could either inhibit or stimulate the invasive potential of such pests and pathogens.
- Understand how a pathogen or a pest change the behaviour and the equilibrium of the whole ecological system (namely biological communities) which in turn can facilitate the development and propagation of these pathogens.
- Conduct retrospective studies on pathogen and pest invasions in certain cases to better understand the factors that stimulated the invasive potential.
- Increase international collaboration since a significant fraction of future invasive pests and pathogens are already present (and sometimes with no detrimental effects) in other geographical regions. Working on the pest or pathogen in its "native" zone can be done more efficiently and under lower (and cheaper) containment conditions and is invaluable (and cannot be duplicated in an "invaded" zone) when it comes to studying the ecology of the agent and its interaction(s) with other biological partners. In this regard, establish an international research network which would facilitate the exchange of biological and ecological data associated with pests and pathogens with high risk potential.

<u>Build surveillance and detection networks</u>

- Establish cartography of potentially dangerous pathogens and pests with associated ecological data.
- Develop improved techniques/strategies for Pest Risk Analysis (PRA) i.e. the capability to predict the potential risk(s) linked to the introduction of known pathogen/pests in region(s) from which it is absent. Such strategic analyses are needed in order to be able 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.
  - Develop new molecular detection tools (e.g. gene chips) that could in certain cases be used *in situ* directly on the fields for a faster detection of both qualitative (presence or absence) and quantitative (number) changes observed in biological communities.

Developing appropriate management and regulatory measures

- 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.

4.2.3 Contributing to a global strategy for a low carbon economy

4.2.3.1 Biofuels

(Biofuels in the EU, 2006; Commission Européenne, SEC(2006)142 ; Biomass, Plan of action, 2005; IFP 2005; NREL; Biomass Research and Development Technical Advisory Committee, US)

The heavy dependence of the NAE during past century on crude oil is a major challenge facing the NAE. AKST can be further deployed in the future to develop an agriculture that contributes to the production of alternative energy sources or biofuels.

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) needs to be explored as well.

First generation biofuels (cereal grains and oilseeds)

The energy, economic and environmental results of the 1st generation liquid biofuels cannot make them a real alternative to fossil transport fuels (IEA, 2004; Sourie et al., 2005). Co-product production can improve energy and economic balance (Farell et al., 2006) and biofuel costs will go down as the technologies improve in production efficiency and economies of scale are realized.
Aside from obviously critical questions over whether we are actually gaining any energy from producing biofuels and question over the process' environmental impacts and sustainability, there is the ethical question of whether, in a world where more than 800 million people are seriously malnourished and many more are challenged to meet their food needs, it is legitimate to use a large percentage of our productive land to feed our vehicles? This question is complicated by the fact that under the current global economic system, foregoing raising fuel crops is no guarantee that anyone would be better fed or have easier access to affordable food. The switch from food production to biofuels should nevertheless take into consideration the consequences such an act would have on the global food production (as more land is diverted to biofuel production), the effect on world food security i.e. the availability of stored grain for emergencies and production fluctuation and ultimately on one of

[2] The carbohydrates in plant material are fermented into ethanol, 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 the glycerine is a byproduct.

the most important millennium goals of alleviating hunger in both the NAE region and the rest of the world.

In addition, the amounts of land that would be required to obtain self-sufficiency in biodiesel alone using oilseed crops 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 agriculture alone.

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

Already in the last year world grain prices have doubled due to diversion of grains to biofuels, which will substantially increase meat and milk prices in the NAE, and decrease grain available to the poorer parts of the world. This ultimately affects the millennium goal of alleviating hunger throughout the world by more than just decreasing grain availability. Because heavily subsidized NAE grain will no longer be “dumped” on developing world markets below production costs, the subsistence farmers in the developing world can engage in production agriculture possibly increasing production and self sufficiency. There are also ecological considerations; putting more ecologically fragile and necessary lands into production of biofuels; whether oilpalm 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.

Thus, alternative feedstocks are needed for biofuels production, without expanding the land under the plow such as cellulosic material or algae and cyanobacteria as discussed below.

<u>Second (cellulosic substrates) and Third generation (algae and cyanobacteria) biofuels</u>

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 much higher net energy gain than seed grains/oilseeds (Farr, but the present technologies are less environmentally friendly than those using grain, as they ell et al.,2006; Samson et al.,2005)use dilute sulfuric acid to separate lignin from the carbohydrates. Third generation sources, such as algae, may be even more environment friendly as well as cost effective.

Future R&D options should concentrate on the following areas to make second and third generation sources viable:

- *Research is needed to 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 needs 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.
▪ 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.
▪ Increasing the lignin content and the digestibility of straws through transgenics. The solution to increasing digestibility without affecting important varietal traits is to transform elite material to have modified lignin and cellulose contents. For example, partial silencing of the phenylpropanoid pathway enzymes leading to lignin, encoded by whole gene families can be achieved by antisense or other RNAi strategies using small interfering RNAs (siRNAs) that conform to consensus sequences for the gene family.
▪ Lowering the presence of silicon in both straws and cultivated grasses.
▪ Lowering the unwanted emissions of methyl bromide from oilseed rape
▪ Developing lodging tolerant varieties and when necessary dwarfed varieties.
▪ Developing insect resistant varieties, as lower lignin can lead to higher infestation rates
▪ Improving the stand establishment of these grasses (frequencies of twenty five percent establishment are not uncommon (Schmer et al., 2006)).
▪ Compensating for the reduction of soil carbon and its consequences on soil quality due to straw harvesting.
▪ Explore the harvesting of unwanted aquatic weeds such as water hyacinth for biofuel production

Genetic engineering could be a useful tool to achieve most of the above mentioned targets by modifying certain metabolic pathways but any such transgenic varieties will need to be developed such that appropriate safety concerns—e.g., for gene flow to wild populations and related species--are addressed.

- *Research and technological developments need to focus on increasing processing efficiency by*:

▪ Identifying more efficient cellulolytic enzymes.
▪ Increasing the efficiency of cellulolytic enzymes for example with the investments in gene shuffling to increase activity, stability, temperature optima, etc.
▪ 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 step still remains a significant technical challenge due to the heterogenous nature of lignocellulosic feedstocks.

- Improving the fermentation step as lignocellulosic materials contain a greater range of sugars and other products, some of which can inhibit the fermentation process.
- Improving fractionation technology while reducing the sulfuric acid to increase the ability of the industry to utilize more variable biomass sources of lignocellulosics.

- *Research options for third generation biofuels need to focus on increasing organism survival, growth and lipid content, carbon dioxide enrichment and yields:*

- Organism survival**:** current systems are unable to maintain the best laboratory algea under field conditions. They become contaminated and taken over by indigenous local organisms. Transgenes conferring herbicide resistance might overcome this problem.
- Growth & lipid content: algae either grow <u>or</u> alternatively they produce lipid (fat) bodies, but not do both simultaneously. This would require either batch culture or separate growing ponds and lipid producing ponds, rendering substantially higher production costs. The microbial and algal pathways and genes for production of the lipids best for biodiesel are becoming known (Ladygina et al., 2006) and should be explored further.
- Carbon dioxide enrichment: the algal response to added carbon dioxide is not as good as it could be. Ongoing molecular research in photosynthesis will have much to offer this area, as it has the potential to increase yield, which sequestering fossil fuel generated carbon dioxide.
- 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, a prohibitive engineering factor is the cost of harvest via expensive centrifugation. This too may be eventually soluble through biological means.

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

<u>Fourth generation: producing biohydrogen and bioelectricity</u>

Biophysicists have seen it as an intellectual and practical challenge to harvest solar energy for hydrogen or electricity (Chiao et al., 2006; Logan et Regan,2006; Tsujimura et al., 1998) using nature's photosynthetic mechanisms, directly, 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. This will necessitate considerable long term multidisciplinary efforts to become more than a laboratory curiosity, but the informational gains about basic biophysical processes are bound to be exceedingly important AKST, as well as the new fuel gains.

4.2.3.2 Develop energy efficient supply chains at a global level: Food miles

(To be completed after having consulted with the different LA at the Cape Town meeting)

4.2.4 Trade, Markets and Agricultural Policies

As a major importer of commodities, labour, and resources and an exporter of products, investment, and AKST, NAE has influenced food and agriculture systems throughout the world. Regardless of which scenario exists 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 (see box 2)

[Insert box 1]

[Insert box 2]

Development of competitive and viable local production systems should include 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 today are through the trade system, NAE should 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 will 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. This needs to include an analysis of production systems.

Optimization of production systems requires application of available resources to produce needed products. It is suggested that both development and implementation of AKST should address 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 agro-ecosystem approach.
- Promote cross-sectoral approaches to address different perspectives (social, political, environmental) through association and flexibility.
- Prioritize actions based on country goals and the needs of direct beneficiaries and locally validate such actions through the full participation of all actors.

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

In order to reach the IAASTD goals, NAE's contribution to AKST in other regions should furthermore support the strategic objectives of IFAD that poor rural people have better access to, and the skills and organization they need to take advantage of the following (IFAD, 2007):

- Natural resources, especially secure access to 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 main objective should be that poor people no longer remain in poverty.

The principle of division of labor has been included in AKST from the beginning (Herman, 2001). Product specialization based on resource endowments and linked with appropriate AKST will increase productivity (Mattson et al., 2006). IAASTD should examine whether States' abilities to benefit from application of AKST depend on their alignment with practices common to prosperous countries (see box 2) and what are the effects.

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 should help to develop a fair and equitable trade system in NAE and in the rest of the world. Dumping practices based on distorted policies or market dominance need to be banned. But there is a need to go much further to understand what is a fair and equitable trade system. There are still contrasting views on that respect (see box 2). In all the cases there is a need: (i) to understand better the market mechanisms; (ii) to improve the modelling representation of the agricultural systems and their dynamics, including all the players and their interlinkages through the markets.

<u>(i) To understand better the market mechanisms.</u>

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

- Institutional analysis of local, regional, and international markets and their mechanisms.

- Modes of co-operation and coordination between players of the food processing 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 by the suppression of the dominant positions on the markets.
- Attributes of the quality of the products (origin, know-how, practices and manufacturing process) and the way in which markets are able to recognise 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 should also investigate whether and how comparative advantage from specialization coupled with trade really favours smaller economies more then larger economies (Anderson, 2004).

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

The agricultural sector 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 toward 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 & al., 2004, Polaski, 2006). Inequalities rise when developing countries open up their trade unless trade-induced inequalities are not anticipated and corrected from the onset. Policy recommendations derive too often from static, perfect competitive simulation models. More emphasis should be laid on technological-change induced inequalities, missing market effects on inequalities, dynamic adjustments impact assessment (Chabe-Ferret & al., 2005).

In order to improve the representation of the models (see box 3, the case of the CGEs models) the distinction between the various groups of developing countries should be made (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). The complex effects of the various types of domestic support should be accounted for and trade preferences (which are presently rather well utilized in the agricultural sector), regional agreements and the effect of trade liberalization on these should be taken into account.

[Insert box 3]

The specification of the trade models used for the simulations of market liberalization and policy consequences should be largely discussed and include a representation of:
- Labor markets,
- Imperfect information,
- Price instability,

- Uncertainty and risk,
- Dynamics,
- Environmental externalities.

AKST OPTIONS TO DEVELOP LOCAL AND SUSTAINABLE FOOD AND FARMING SYSTEMS

4.2.5 Integrating the Diversity of Food And Farming Systems (FFS) and Considering Food Quality as its Major Determinant

In spite of a tendency, in the last decades, for research and development to promote a unique model of development based on an increase of productivity, the recent evolution of agriculture shows that given society concerns AKST needs to emphasize more than ever on food quality, food safety and the relationship between diet and health to combat malnutrition and obesity. In addition, a new profile for agriculture is taking shape, with two major poles (Loyat, 2006; Hubert et al., 2007). On one hand we have an agriculture directed by the demand for products of standard quality and on the other hand agriculture directed by the supply of specific products, identified by their origin or their manufacturing process (see box 4). In both cases AKST is required to support the food and fiber supply chains that connect producers to markets, provide incentives and just rewards to producers, processors and marketing agents, thereby providing 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 amongst different commodity chains. Global supply chains in bulk commodities often run along side local procurement networks of highly differentiated products.

[Insert box 4]

4.2.5.1 Improve food quality

<u>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.</u>

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).
- Performing high throughput analysis of biological responses with techniques such as transcriptomics, proteomics, metabolomics.
- Investigating how genetic polymorphism and metabolic imprinting (influence of early nutrition) of individuals result in the variability of physiological responses to diet.

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

- Investigating the biological, psychological, historical and socio-economical factors that affect food choices, as well as their interactions.

- 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.

Improve the nutritional composition of food for health purposes by:

- 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
- 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 should focus on the improvement of nutritional, sensorial and health quality of unprocessed agricultural products. AKST should consider 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. fusarium and the production of mycotoxins, polluted soils and the transmission of xenobiotics to food plants and animals, pesticide application and the detection of its residues in food etc.). Such improvements in unprocessed agricultural products are particularly appropriate for gross production (standardized quality products). Some of the options for these improvements are mentioned in box 5.

[Insert box 5]

The overall objective of processing is to optimize the nutritional properties as well as taste and safety of unprocessed agricultural products during processing. So, AKST could be mobilized to:

- Improve the transformation processes: this includes technological innovations, mathematical modeling of processes and development of “on line” sensors and monitoring systems;
- Understand the dynamics, stability and sensory properties of complex foods.
- Use reverse engineering approaches to design tools to create food matrices with predefined functional properties.

Develop quality specific products distinguished by their origin (terroir)
AKST options for research for these products are:

- Study the attributes of quality.
- Develop processes of qualification of the food products by their origin, by methods of production or marketing.
- Encourage the normalization of local knowledge and practices.

Reinforce traceability: from raw materials to marketed products

Spurred on by recent food scares around the world, such as mad cow disease and bioterrorism fears, governments are forcing the adoption of food traceability systems. There is a real need for full and accurate traceability in the supply chain from farm to fork at every level of the food chain.
Some of the areas where more methodological and technological developments need to be undertaken for standardized production are stated below:

- Develop new generation of analytical methods based on micro and nanotechnology solutions that comply with the needs of ubiquity, fast response, low cost, simple use etc.
- Develop microsystems technology solutions for the rapid detection of toxigenic fungi and mycotoxins by natural bioreceptors, artificial receptors and nano-electrode devices.
- Develop and characterize 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.
- Promote 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.

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

Many NAE food supply chains operate at the cutting edge of marketing technologies in 'fast moving consumer goods'. Trends in agricultural and food commodity markets, however, show that NAE farmers have become separated from consumers, food supply chains are dominated by processors and retailers, and there is growing concern about food safety, bio-security and potentially unhealthy diets.
Within NAE, a key future strategy will aim to strengthen the relationship between farmers and their markets and to enhance the performance of the food and fiber supply chains in accordance with the IAASTD goals.

In this respect AKST is required to:

- Improve the 'connectivity' between food producers and consumers, by increasing market orientation and responsiveness amongst producers.
- Improve market intelligence throughout the supply chain, especially for producers and marketing and related business management skills amongst producers.
- Extend existing and develop new products, markets and supply chains within NAE and externally.
- Support actions to add value on or near to the farm, through on farm processing and/or product differentiation, including for example organic, regional and fair trade products.
- Develop collective business and marketing capability amongst farmers, through for example farmer groups, cooperatives and trade association in order to improve their bargaining position.
- Reduce actual and perceived risk in food marketing though improved food traceability, auditing, and labeling, supporting mandatory and voluntary regimes for market regulation and

product assurance, and achieving informed consumer choice through product information relating to health, environmental, worker and animal welfare issues.

- Exploit the potential of the internet as marketing tool.
- Guide investments in market development and in marketing infrastructure such as storage, processing, refrigeration and transport.
- Monitor and evaluate the performance of markets in terms of efficiency, equity and welfare consequences.

4.2.6 Positioning Food and Farming Systems (FFS) as Part of the Ecosystem with a Strong Emphasis on Natural Resources' Management

This section illustrates the complexity of FFS and identifies the different components where AKST could be mobilized in a more sustainable and multifunctional perspective. One important function is that of natural resources management that may be carried at different levels that interact with one another (at the farm or landscape level). The following discussion and the options suggested are based on the landscape level as it is at this level that most issues related to the preservation and sustainability of natural resources are tackled.

Therefore AKST can be mobilized for a better knowledge and management of biophysical interactions between soil, water, biodiversity and human activities as these interactions are essential for the sustainable development of FFS.

4.2.6.1 Potential contribution of AKST for long term soil preservation

In the last few decades we have witnessed an intensification of human activities on soil (industry, agriculture, urbanization, cemeteries, recreation, etc.). This has largely been achieved without considering soil diversity, its characteristics and its potential to accommodate these different activities. Consequently there has been a pronounced degradation of soil expressed in its functions, its potential and an alteration of the media that interact with it (air, water, flora and fauna...).

AKST should thus be developed in this domain in the next few decades, through the following ways (Lal, 2002; Lahmar et al. 2OOO; Ruellan et al., 2000; SFST-DLS-IUSS; Ruellan, 2005; Van camp et al., 2004; EUR 21319 EN/1; EUR 19723; 16th World Congress for Soil Science):

<u>Understand soils better: the past, the present and its current dynamics.</u>

- 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 needs to be done regarding the lateral organization and dynamics of pedological covers, which will help understand the different existing "pedological systems"[4] and their differentiation process. In particular, we need to understand better the long distance transportation of organic matter, fertilizers, pesticides and pathogens through this milieu.

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

- Elucidate the relationship that exists between the "pedological systems and the current or future social systems.
- Study the rate of evolution of the different characteristics and properties of soil.
- Develop the notion of soil as being not just a part of the larger ecosystem but also as an ecosystem in itself.

<u>Link soils and human activity</u>

Understand the influence of human activity on: rate of evolution of soils, modification of the alteration rate of rocks, mechanisms of soil formation, modification of biological activities and its consequence on soil formation.

- 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.
- 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).

<u>Develop appropriate soil related technology and agricultural practices</u>

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 soil renewability.
- Develop new methods to remediate soils like phytobial remediation that is 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 bioremediative 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 needs to be done on heavy metals sequestered in biomass.
- 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) and
- an improvement in the retention of organic matter present in soils.

In addition to all of the above there is a need to incorporate better the existing and new knowledge on soils and soil practices into the legal portfolios of states or regions as well as national and international policies.

4.2.6.2 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 future due to increased human demand for water, climate change and limits imposed by available water (Evans, 1996; EEA, 1999, 2001a, 2001b; FAO, 2004; National Research Council, 2004; Dobrowolski and O'Neill, 2005; OECD, 2006; Morris, 2007). AKST is needed to support the management of water resource 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. The EU has 9% of its agricultural production under irrigation (13M ha), over 75% of this in Spain, Italy, France, and Greece (EEA, 1999; Kasnakoglu, 2006). More than 22M ha (18% of total cropland) are irrigated in the U.S., over 80% of which is in the West (Gollenhon et al., 2006).

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

- Promote irrigation water auditing and scheduling systems, including remote sensing to monitor crop for optimal timing of irrigation.
- Encourage improved irrigation management, including the introduction of low water demanding cultivations.
- Develop new irrigation technologies that further increase water use efficiency (that is 'crop per drop').

Removal of excess water

In future, under conditions of environmental change, there will be a need for new integrated land drainage technologies, including on farm water treatment and storage, that can cope with greater variation in precipitation and temperature, avoid causing salinity, cope with periods of excessive rainfall and river flows, and contribute to overall water resource management (O'Connell et al, 2004; Morris and Wheater, 2006; Lane 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 needs to be further developed for the determination of optimal water requirements of important crops and in developing new stress resistant varieties.

Water Quality

There are major concerns in many parts of NAE about water quality and the consequences for ecosystems and human health. 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, 2004; Neal et al, 2005; Bowes et al, 2005;), and increasingly the subject of targeted control measures (EA, 2002) In this respect, priorities for AKST include: an integrated approach to water resource management, of which agriculture is part, at the catchment scale.

- 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 nanobased filtration and purification techniques using membrane systems to detect and neutralize undesirable microorganisms and pesticides and
- 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. Water law and entitlements are typically more complex and less well defined than for land (Camponera 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 is required 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.
- 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).
- Develop education/outreach programs to foster the development of criteria and standards for economical 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. Critically AKST is required to achieve a much greater integration of land and water management as a basis for sustainable, multifunctional agriculture.

4.2.6.3 Potential contribution of AKST to biodiversity and genetic resource management

Agriculture could play a significant role in managing and enhancing present biodiversity, which is the foundation of ecosystem services namely provisioning (food, wood and fiber, fuel…) and regulating (climate and flood regulation, disease control) services(MEA, 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.

<u>Biodiversity conservation, agricultural activities and land management</u>

AKST should focus on a better understanding of the impacts of agricultural systems on both spatial distribution and evolution of biodiversity at the landscape level and, conversely, on the effect of biodiversity evolution on both productivity and quality of soil and water resources. Some of the options among others are (Caughley and Gunn, 1996; Kerr and Currie 1995; Johnson et al., 1996; McNeely et al., 2002, Srivastava et al., 1996; Graf, 2003; Soule et al., 1992; Jackson, 1980):

- Design rural landscapes with biodiversity enhancement in mind. This should include such critical issues as the creation of migration corridors and improvement in habitat quality at the appropriate scale. It should also include the improvement of the knowledge of the functional role of non-agricultural biodiversity in achieving specific regulating services at the landscape level (pollination, pest and disease regulation, natural hazard protection…).
- Continue research on radical new departures for agricultural production that would be much more favorable to biodiversity while 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 alleviate the contamination of waterways that has multiple effects on wildlife. There is a need for substantial additional research on both technical and policy options which would 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.
- Understand better the role of both forests and grasslands and their mode of exploitation in the preservation of biodiversity and ecological processes.

AKST could also focus on the optimization of spatial and temporal management of crops and livestock on the territory, to contribute to the sustainability of the whole area by:

- Understanding better both the spatial and temporal distribution of varieties (for example possessing different pest resistance genes) and the associated organizational and technical practices vis-à-vis the evolution of both pathogen and pollinator communities within the territory. This requires the understanding of the biological mechanisms of host-pathogen co-evolution and their susceptibility to fluctuating environment,
- Improving knowledge of diversification of productions and associated practices on the supply of environmental services (provision of public goods, positive externalities), at the territory level,
- Understanding better the spatial organization and relative proportion of cultivated areas on one hand and grassland and forests on the other as well as their articulation with urban areas, in the study of water and fertilizers transportation within the territory as parts of the biodiversity maintenance within the territory,
- Developing GIS tools that help farmer communities and associations determine appropriate locations of various FFS (crops, animals, enterprises, grasslands) to improve production efficiency and meet environmental challenges including biodiversity preservation.

<u>Genetic resources preservation</u>

The global distribution of genetic diversity areas and the interdependency of all countries vis-à-vis genetic resources call for a huge solidarity and coordination mechanisms at the global as well as the local level.

A huge effort needs to be done to upgrade and rationalize the global design for ex situ collections, among which the Future Harvest Centres and the Global Conservation Trust could play a major role. 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 genetic resources in agriculture depend on *in situ* preservation efforts as a complement to *ex situ* stored collections. These must be carried out in a great variety of ecological and cultural circumstances that can only be achieved through international cooperation and funding. In this case, AKST need to focus on the maintenance of the adaptive capacities of crops and domesticated animals, through a better management of genetic diversity within and between species. In addition to the static conservation of genetic resources, more attention has to be paid to the dynamic processes that allow potential evolution in changing environment through *in situ* preservation.

Considering livestock, there is a need 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 less intensive breeding efforts on locally adapted populations in order to meet the challenge of specific local demand and maintain a large genetic diversity.

Considering crops, there is a need to:

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

4.2.6.4 Potential contribution of AKST to developing energy efficient food and farming systems (FFS)

Farming and food systems in NAE are energy intensive. Even though overall, farming accounts for a relatively small 5% of total energy consumption in the economy 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; Murray 2005, Heller and Keoleian, 2000). 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 (see box 6).

[Insert Text Box 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 have increased the scope for bio-energy crops, energy efficiency will remain a critical component of their feasibility.

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.
- 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
  - Whole crop harvesting systems
  - Handling, storage and treatment of materials and '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 bio-solids).
- Re-development of indigenous, energy saving technologies.
- Improved understanding amongst consumers of excessive energy costs of 'out of season' vegetables, in order to modify purchasing behavior.
- Scrutinize "marketing agreements" and border enforcement which promote cosmetic standards that have the effect of increasing pesticide and water use.
- 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.

4.2.7 Developing Innovative Crops and Livestock Food and Farming Systems

AKST needs to be mobilized at the farm level for developing innovative crop and livestock farming systems by breeding plants and animals with high quality performances 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 valuing of diversity. These new systems could lead to better interactions between -crops or livestock, production modes and, environment.

4.2.7.1 AKST for crops and livestock breeding

Breeding will continue to be a key element to contribute to the realization of the IAASTD goals, both in the areas of food security and safety and to contribute to environmental sustainability. In any case, it needs to be tightly articulated 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 that needs to be continued- and offers new possibilities for breeding methods that need to be better explored. Also, these future innovations raise new concerns in terms of possible wider effects and unforeseeable consequences, calling for new ways of assessment and follow up.

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

Much of previous research has been based on the theory of determinist genetics, which assumes a direct path from gene to protein and to function as well as the presence of preset responses to external perturbations (references). 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, very 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.
So, AKST needs to (references):

- Maintain its effort in genomics data acquisition to accumulate knowledge in structure and functionalities of specific genes and particularly those the expression of which may contribute to the IAASTD goals.
- Strengthen the efforts in basic physiology through functional genomics and systems' biology that offers the potential to break through the major limitations inherent in previous approaches. This will require an enormous set of data as well as a sophisticated data infrastructure with a high level mathematical framework (Wiley H.S., 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.
- 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).
- Develop comparative biology including comparative genomics to ensure the dissemination of knowledge on a wide range of food species including under-utilized ones.

Concerning applied research, AKST need to 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 FFS (see box 7). These activities should be developed on a wide range of food species to maintain progress in both industrial and under-utilized species. They should also explore the potential of more diversified and heterogeneous variety types namely to better meet the environmental concerns[5].

[Insert box 7]

AKST need to 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 others, AKST need to (references):

- 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*.).
- Develop technologies that can lead to "break-through innovations" through genetic engineering, cloned animals and other methods that do not include sexual reproduction. Such innovations need to be developed in a way that does not affect other desirable traits or basic physiology of crop/animals and which is not harmful either for the environment or for the human health but also - which benefits to many people around the world, namely through their contribution to the achievement of the IAASTD goals (see box 8 and 9)

[Insert text boxes 8 and 9].

In addition, animal welfare will occupy an important place in the agenda for the future. Most livestock production (pigs, poultry, dairy cattle, beef cattle) will probably be in large-scale production systems, though still mainly family owned. Animal welfare in this situation may become a high priority. AKST may be mobilized to ensure that minimum standards for the protection of farm animals are set and respected (see box 7)

More generally, the wide development and dissemination of innovations has to be anticipated and assessed to make sure it contributes to the IAASTD sustainability goals, considering all dimensions of

[5] 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 much 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.

sustainability and integrating appropriate spatial and temporal scales. AKST need to accompany this new form of innovation process through (references):

- A change in the evaluation process, which needs to move towards a more systems and dynamic approach, taking into account all the potential impacts (both positive and negative) of the innovation: (i) from environmental, health, social, ethical and economic point of views, (ii) both short and long term, (iii) at the pertinent spatial scale. These impacts should be evaluated before and after implementation through appropriate means. AKST needs to then look for methods and tools that could help in the renewal of this evaluation at the different steps of innovation process.
- 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.

4.2.7.2 Contribution of AKST to the development of alternative innovative modes of production

Various methods of production and technologies have been developed to minimize environmentally detrimental effects of agricultural production. Ecologically-based pest management (EPBM) as defined by the US National Academy of Sciences Committee on the Future Role of Pesticides in U.S. Agriculture is an approach based on “a working knowledge of the managed ecosystem, including natural processes that suppress pest populations.”

Other management techniques and production methods include integrated pest management (IPM), conservation biological control integrated plant nutrient systems (IPNS), no-till conservation agriculture (NT/CA), precision, spatial variable farming and livestock breeding, feeding and housing regimes that reduce environmental load.

These technologies and practices meet the dual goals of maintaining increased productivity while reducing environmental impacts: they do this through diversification and selection of inputs and management practices that foster ecological relationships and biological processes within the entire agro-ecosystem.

AKST needs to accompany the development and dissemination of such practices by (Ehler et Lester, 2005, Elliot and Dent, 1995; National Academy of Sciences Board on Agriculture Committee on the Future Role of Pesticides in U.S. Agriculture, 2000; Pimentel, 2002):

- Broadening and deepening the research on environmental and human health implications of pesticides. Continuing improvements in human epidemiology and environmental assessment will be needed to better identify and measure the adverse effects of pesticides and thus guide further research into safe use.
- Ensuring that research on pest management is local (drawing on locally developed knowledge to ensure that pest management strategies are better adapted to local conditions) and site specific.
- Developing better tools for prior evaluation of the unintended effects of pesticide use and for monitoring and evaluation of negative effects after adoption (past experiences underscore this

need for e.g. it took twenty to thirty years to identify and begin to understand and respond to the biomagnification effects of chlorinated hydrocarbons, affecting a wide range of species.

- Developing new approaches to integrated pest management and organic agriculture 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.
- Optimizing IPNS (maximizing plant nutrient use efficiency by recycling all plant nutrient sources within the agro-ecosystem and by using nitrogen fixation by legumes, make a balanced use of local and external sources of plant nutrients in a way that maintains soil fertility, and minimizes 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.
- Setting up participatory mechanisms associating scientists, farmers and extension services to develop further 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. New and innovative systems that are less consuming in energy and inputs should be further developed.
- Developing precision farming to use real-time, site-specific information in crop management, e.g.:
  - 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.
  - 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.

4.2.8 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 a possibility to improve water quality and availability and as an important component of the carbon economy. Today, sustainable forest management cannot be considered without taking into account the many changes that affect the environmental, societal and economic context of: substitution between land-uses, climate change, social expectations towards natural areas in general and more particularly forests, increase of energy prices of fossil fuels and the new cost of carbon emissions.

Integrated forest management methods catering to both timber production and ecosystem management have appeared in the NAE. This management can lead to sustainable development of forests with overall economic, social and environmental benefits. More research needs to be done to better understand the multifunctional role of forests from an economic, social and environmental perspective and promote it through appropriate sustainable management methods (Birot et al., 2004, 2005; Houllier et al., 2005; UNECE-FAO, 2005; Forest-based Sector Technology Platform, Vision 2030, 2005; European Forest Inventory, Volume 15, 2007.).

Integrating the multifunctional role of forests

The definition of 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 much more complex with multiple functions added under each category e.g. the "production" function should now take into account a larger range of forest products such as wood products, bioenergy, green specialty chemicals, novel composites etc. For a more detailed description of the complexity of these multiple functions see box below.

Functions and objectives of multifunctional forest management

Functions	**Sub-categories**	**Specific objectives**
Production	Timber products	Sawtimber, veneer, pulp and paper, panels, fuelwood, bark
	Hunting	Game management
	Other products	Mushrooms, fruits, pharmaceutical molecules
Protection and restoration	Habitats	Naturalness as an ecological heritage (reserves) Protected habitats (Natura2000) Microhabitats (ponds, peat bogs) Patches of senescent forests Deadwood material (large woody debris)
	Plant biodiversity	Endangered or rare species Ordinary biodiversity Genetic diversity
	Diversity of other taxa	Endangered or rare species Hunting and fishing Wildlife, birds, insects, etc… Microorganisms (eg soil microbes)
	Carbon storage	
	Water quality	Chemical (avoid nitrates, xenobiotics, raise up pH) Ecological (microbial and vertebrate diversity in streams)
	Soil protection	Chemical (maintenance of soil fertility) Textural (prevention of compaction) Integrity (prevention of erosion)
	Forest health	Limit sensitivity to diseases and disturbances
	Human protection	Use forest to mitigate landslides, avalanches, stones
Social function	Landscape quality	Meso-scale (forests inside landscapes) Micro-scale (managing hedges for scenery) Landscape diversity (patchiness, mixtures, canopy texture)
	Naturalness as a cultural value	Forest reserves, botanical gardens, arboreta Undisturbed or low-impacted landscapes
	Tourism	Hiking, bicycle paths
	Other cultural values	Trees, flowers, fruits, animals of high cultural relevance

		Religious high sites
	Educational value	Forests as support for education (ecology, environment)

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 realized simultaneously and to define 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 should 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 micro-organisms. This needs to 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 need to be developed using molecular genetics including genetic engineering and 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, less chemicals during paper manufacturing, stronger rot resistant wood (for construction), xenobiotics 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).
- 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.
- 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.

Provide environmental and social services
Some areas where AKST needs to focus on are:

- 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.
- 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 of urban and peri urban forests.
- 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.

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

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

Optimal management methods need to be defined to 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.

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 needs to be done to optimize the overall distribution of intensive, natural reserves and semi intensive forests in NAE and its sub-regions.

As at the local level semi intensive forests could be viewed as a complex multifunctional system. More research needs to be done on 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.
- Adapting forestry to climate change (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, fires, gales, floods, pest and disease outbreaks, uncertainties regarding the economic value and abrupt changes in the market…): for e.g. assessing the vulnerability of various management strategies in regard to the different risks.
- 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).
- 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 and other environmental changes, a recognition of new concepts of sustainability in which risk management and forest resilience are prioritized and an improved dialogue among scientists, managers and the public that transcends national boundaries is encouraged.

4.2.9 Developing Sustainable Systems for Fisheries and Aquaculture

4.2.9.1 Coastal capture fisheries[6]

There is an urgent need to concentrate more than ever on the sustainability of coastal capture fisheries and increase their productivity. Sustainability can be achieved (i) through efficient management systems such that take into account the ecosystem and (ii) through better fishing technologies that help in preventing overexploitation of all target species. Productivity on the other hand can be increased by adopting new processing methods that add value to the current system. 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 (Christensen V. S et al., 2003; De Alessi M.,1998; EC, 2003; FAO 2003; FAO 2005; Garcia et Grainger,2005; Ifremer, 2004; NOAA-NMFS 1999; National Council for Agricultural Research 1998. Fisheries and Aquaculture; Rey et al., 1997; Royal Commission on Environnemental Pollution, 2004; Troadec et J. Boncoeur, 2003). These compartments have various interactions between them. It is imperative to keep in mind that only an integrated vision of the entire system and its different compartments as a whole would allow a better understanding of the functioning of the system.

<u>Develop an ecosystem approach for a sustainable coastal marine ecosystem management</u>

[6] This assessment only covers coastal capture fisheries in the NAE region.

There is a need to surpass the classical approach, which is restricted to fishing activities vs. target resources. Up until now, research has mainly concentrated on the consequences of fishing activities mainly on the fish stocks. Now, research should also take into account the social, economic and ecological consequences of fisheries not just at the local but also at a global level. More research needs to be performed on the following aspects to achieve this:

- 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. Such models and toolboxes should facilitate studying the different ways of fisheries management and governance.
- Collect long term observation data: choose 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 needs to be reinforced by further investments as marine resources are difficult to access and not very well known.
- Develop tools and indicators: there is a need to develop appropriate tools and indicators that take into account an ecosystem as a whole including its economic and social components as well as integrate global phenomena such as climate change. There is also a need to develop indicators or descriptors that reflect the health of the resources and ecosystems.
- Develop experimental research on consequences of human activity on wild fish: effects of fishing, of pollution on growth and reproduction etc.
- Develop specific multidisciplinary research on marine ecosystems: including ecological engineering, “ecological therapy” (how to cure, restore an ecosystem), environmental economy, sociology.

All the above mentioned research activities need to be developed while keeping in mind that an integrated global research effort is required, coupled with much 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 should 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 the need for selective fishing.
- Devise new fishing techniques that are highly selective with a minimum impact on the ecosystem in coastal and high sea fisheries.
- Improve existing fishing technologies: to obtain a higher quality of fished products whilst simultaneously minimizing discards and incidental catches.

Improve fish processing

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

4.2.9.2 Aquaculture

Aquaculture involves the managed reproduction and growth of aquatic animals and plants under controlled conditions. Production from aquaculture has intensified throughout many regions of the world. Aquaculture's contribution to global supplies of fish, crustaceans and mollusks continues to grow, increasing from 3.9 percent of total production by weight in 1970 to 27.3 percent in 2000 (FAO statistics). Aquaculture is growing more rapidly than all other animal food producing sectors. This explosion in aquaculture production has been led by China, which now accounts for more than 50% of all cultured seafood products (Delgado et al., 2003).

Some of the main areas with identified research gaps are listed below:

Sustainability of production systems

Reduce dependence of high value fish farming on fish meal derived from coastal capture fisheries

There is an urgent need to substitute fish meals that are classically made of fish oil derived from coastal capture fisheries with fish meal made from plant products. One of the areas of research which could potentially eliminate dependence on coastal fisheries and vastly increase sustainability of NAE aquaculture is by using transgenic technology to increase in crops the levels of oils and proteins needed by carnivorous fish such as salmonids.

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 should thus be conscious of its impact on the environment, the type of products bred (local species, non-indigenous species, GE organisms, etc), work conditions etc. Initiatives that integrate these aspects have already been adopted in certain areas (global aquaculture alliance7, organic aquaculture, labels such as “red label” certifying quality etc.) but more research needs to be done on defining appropriate management strategies and establishing 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. The most desired solution is to opt for moderate intensification of current extensive aquaculture systems (often polyculture systems comprising of different species), which is a complex

[7] Created by shrimp farm producers which proposes a code of good practices that would help in reducing the environmental impacts of their activities

issue and needs to be dealt with in the near future. This transition towards moderate intensification can only be successful following more research on:

- Optimum specific equilibriums 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 the performance of a multi-specific population under global trophic constraints (increase in the growth rate, nutritional behavior…). Polyculture systems contain different species and that the amelioration of one species alone could be done at the detriment of others and will not result in the overall global amelioration of the milieu.
- Better understanding the integration of these systems in rural areas: eventual constraints (water management…), opportunities, complementarities (use of agricultural by-products in aquaculture and effluents from aquaculture in agriculture…) etc.

<u>Introduction and naturalization of species and its impacts</u>

Aquaculture is currently based on a limited number of species that have been disseminated all over the world. There is a close link between the aquaculture populations and the natural population that can impact on the natural populations demographically (reduction in their number), on their health (when one population is a pathogen carrier) and genetic.

More research evaluating and quantifying the potential impacts of introduction of new species on natural populations can ensure better integration of these species in the ecosystem while avoiding harmful effects on the surrounding environment.

<u>Environmental impacts of aquaculture</u>

Aquaculture has negative impacts on the environment as firstly, the set up of aquaculture activities could perturb and alter the surrounding environment. Secondly, wastes from intensive aquaculture often have adverse effects on the environment. The impact of the wastes of intensive aquaculture is due, primarily, to the quality and the quantity of fish diet (concentrated fish feed). One of the ways to combat this is via a change in the nutrition 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) develop biofilters using biofilms that recycle wastes back to fish feed.

4.2.10 Ensure socio-economic viability of the systems and strengthen positive relations between agriculture and rural development

Changing priorities and 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 multi-functional 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 needs.

4.2.10.1 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 need to be reinforced or developed to meet the IAASTD goals for the NAE.

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 needed to support rural economies that have a strong local component. Research will be needed to determine how the present institutions can support and maintain a focus on a local economy and what institutional changes will be needed. Several issues 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 multi-functional agriculture.
- Developing instruments for the provision of new income, in particular for goods and services that are not marketed today.
- The new paradigm of multi-functional agriculture emphasizes environmental sustainability and the provision of public goods. There will be increasingly demand for collective (community) rather than individual actions (Ostram, date), 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)).

Equity

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 should 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 need to be reinforced and improved.

- Local knowledge and knowledge of disadvantaged communities need to be incorporated interactively into the AKST system.
- 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 untraded and unpriced, 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.

<u>Organization of workforce</u>

Increased consumer demand in NAE and export markets for fresh vegetables, fruits, and plant based beverages has meant that the demand for agricultural labor remains high in regions producing such commodities. Many tasks in this agricultural sector remain labour intensive. The tendency towards more elaborate processing and packaging of all crops - including grain-based and meat products - also creates continuing strong demand for workers in these agriculturally related industries. Organic and alternative agriculture typically increase labor demands. The prospect of climate change will create demands for new knowledge and skills as farming is required to adapt to changing circumstances. How the multiple policy and technical issues involved in ensuring a reliable and qualified work force in agriculture, and on improving the welfare of agricultural workers and farm families in terms of work wages, health, job security, safety, and housing is an open question worthy of study. The IAASTD goals for agriculture require a healthy and stable rural work force composed of both hired labor and farm families.

Existing research indicates that there is a variety of ways that policy and technological development could work together to both stabilize and improve the welfare of rural workers and farm families, yielding numerous advantages to society and the environment. The applicability of such measures will obviously vary by region. Among them are:

- Value-added activities that take place on and near the farm and product diversification, both allowing for a more stable streams of rural income while providing year-round employment , creating incentives for improving farm worker skills, in turn improving worker productivity and morale.
- Frequent and serious consultation with rural agricultural actors to address both the nature of rural work and worker welfare to stabilize the workforce and improve the quality of working conditions.
- Improved working conditions and higher wages play a substantial role in improving welfare of farmers, farm workers and their families, consistent with the millennium goals.

4.2.10.2 Economic issues

In theory, economic sustainability requires that the most efficient means of production and consumption of goods and services are used and overall long term net welfare (benefits less costs) is maximized (Begg, 2003). It also requires that agents engaging in economic activity, from farmers through to plant breeders, who commit resources now with a view to enhanced benefit in future, are justly rewarded in terms of incomes and return on investments, allowing for the risks taken. 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. Of late, these signals have been confused or incomplete.

Whereas 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 this is 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 (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 (Ref on CBA, Defra, 2005).

In this context, an economics perspective has three particular contributions to make:

<u>(a) Assessment of the economic and institutional performance of food and fiber value chains</u>. There is a need for a more complete understanding of the process by which value is added in food and fiber supply chains as this affects the efficiency of resource use, incentives, rewards, technology change, the sharing of risks amongst supply chain agents, and end-user choice and welfare.
AKST is required to help

- 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.
- Develop efficient supply chains for new products and markets, such as bio-fuels 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:

- Optimisation of the value chain from the forest to the end product, including recycling,
- A stronger coupling between wood producers and industrial consumers,
- Analysis of the all sections of forestry-wood chain (silvicultural 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, etc.
- Development of logistic and decision support systems for optimized supply chain management.

<u>(b) Identifying and valuing the costs and benefits of goods and services produced by agriculture</u>

This requires valuation not only of marketed crop and livestock commodities but also of non-market outputs that have consequences for economic welfare. These include the ‘public good’ or ‘external benefits’ (such as 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’ (such as 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; Pretty et al, 2000, Hartridge and Pearce, 2002; Environment Agency, 2002, Eftec 2004). AKST needs to be developed to:

- Identify indicators which 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 should be studied: farm level (identification of the individual farmer’s contribution to a specific externality), landscape level…
- Design policies that take into account both 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. Specifically, the national (or larger scale) performance of the agricultural sector needs to be evaluated, and the consequences analyzed at the local and farm level so that local policies do not contradict national ones.
- Develop and promote innovative entrepreneurship initiatives, such as safe water production, eco- and nature tourism, recreation, hunting, including considering forest, upland and wetland systems.

<u>There is a clear need to revise estimates of the contribution of agriculture and rural services to economic welfare.</u> This requires redefinition of economic efficiency beyond conventional measures of tradeable inputs and outputs, that 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.(UNSEAC, ? ; Barnes, 2000, Eftec, 2004).

<u>(c) Design economic instruments to help achieve sustainability</u>

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, agro-forestry projects, extensive livestock systems in less favored areas, farm diversification schemes, voluntary agri-environment schemes to pay farmers for environmental services, grants and subsidies for cleaner, welfare oriented technologies, and tradable permits for water licenses (OECD, 2000, Defra, 2004, others).

For example, further research can examine how the supply of land to agriculture might respond to the fall in output prices that the elimination of farm price and income support policies in many countries would entail. 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 (eg intervention prices, quotas, decoupled payments.
- Role of market mechanisms such as stock markets ("bourses de commerce"), futures markets (marchés à terme) to face price risks.
- Importance and role of contracts and conventions between the players of a sector (farmers, agro industries, retailers).

4.2.10.3 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 analyse the social and economic viability of agricultural and rural systems. (Chambers and Conway, 1992; Carswell, 1997; Hussein and Nelson, 1998; Scoones, 1998; Carney, 1998; Ashley and Carney, 1999; Ellis 2000; Goodrich, 2001; NRI 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 for example 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 (Figure 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).

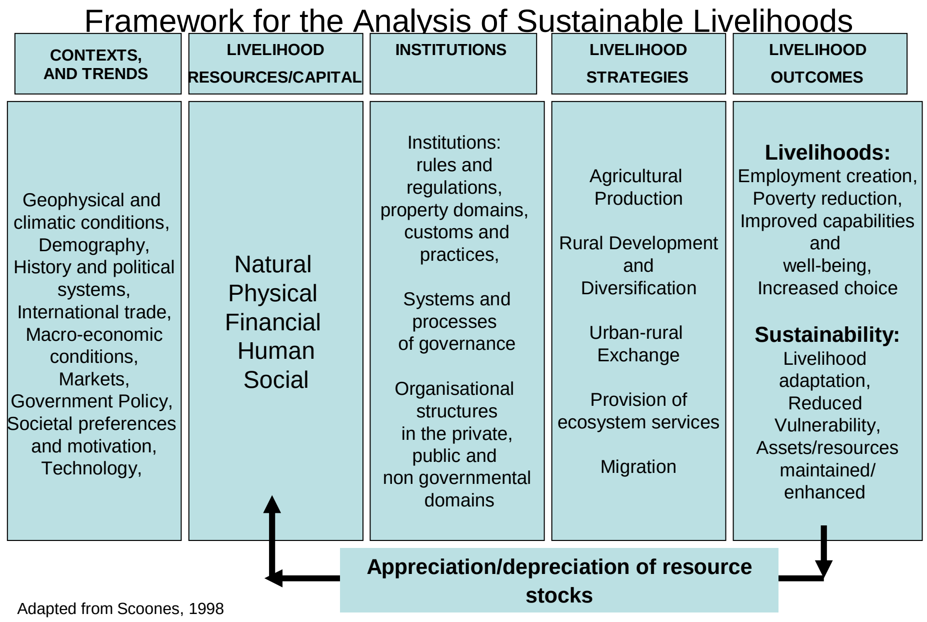

Figure 1: The Sustainable Livelihoods Framework (adapted from Scoones, 1998)

There is a need to better understand the diversity of livelihoods within rural households and communities as whole, and the critical synergy between rural and urban dimensions of livelihoods, especially as these affect 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 IAASTD 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 which describe the context for rural livelihoods, such as the policy and market drivers. As these change, so will the need for AKST change. AKST 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.

4.2.10.4 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 amongst rural communities (Ryan and Goss, 1943; Rogers, 2003). Here, 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, learning and knowledge transfer models, and models of reasoned action *(*Garforth and Usher, 1997, Beedell and Rehman, 1999; Morris et al., 2000; Phillipson et al, 2006).

In this context, there is an urgent need, integrated with many of the ASKT themes alluded to elsewhere in this chapter, to improve 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 which meet the needs and resources of different target groups, especially as this informs the advantage, acceptability, robustness and convenience of ASKT offerings to users.
- Develop and mobilize new communication channels, agents of change and 'knowledge brokers' where appropriate, including, for example, 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.
- Integrate social science research into other sciences to ensure relevance of AKST products.

4.2.10.5 Rural development

Research and development of AKST needs to be undertaken with a greater concern for its role in sustainable rural development. As has been emphasized in the introductory section, there is urgent need for a paradigm that considers the value of high productivity within the context of other functions of agriculture. Differences in social and environmental contexts need to be considered as well as farmers' livelihood strategies and the diverse range of stakeholder interests. A key question is the roles that agriculture can assume in a 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 needs to address the challenges of a more complex countryside. Farmers follow many different and new livelihood strategies and an increasingly diverse range of stakeholders needs 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 a sustainable development is needed (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. Van der Ploeg and Renting (2000) refer to the occurrence of 'clusters of compatible and mutually reinforcing activities'. The active construction of synergies at farm household,

farm and regional level could be better understood and promoted (Knickel and Renting, 2000; Walford et al., 1999; Wolters and Hoffmann, 1999).

- 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 realizable. As for research the concept means that agriculture and, more generally, the potential of rural areas, should no longer be evaluated in monofunctional terms (Cairol et al., 2006; Hervieux, 2003; Knickel et al., 2001; Marsden, 1995; Saccomandi and Van der Ploeg, 1995; Van Depoele, 2000).
- 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 as well as a marginalization of farm households and entire regions is predicted. The related impacts on rural livelihoods can be addressed in research and policy.

4.3 Development of human capital and associated institutional capacities/arrangements

(OECD,1995; OECD, 2000; Lucey,2000; EURAGRI,2002; Europe's standing Committee on Agricultural research; The Kellogg Commission in the US, 1996-2000; Assessment, 2005; US academic Summit, 2006)

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 the above section, 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 these wider issues and their 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. A process of change has begun; 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 institutional or systemic. It is proposed that the process of reconfiguring AKST activities be dramatically accelerated so that they are enabled to contribute most effectively to answering the overall IAASTD question: "How can we reduce hunger and poverty, improve rural livelihoods and health, increase incomes and facilitate equitable, environmentally, socially and economically sustainable development?"

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, by governments, by AKST agencies and by individual scholars. This material will be supplemented later in light of interactions with the analyses to come from other Regions.

4.3.1 Towards Interactive Knowledge Networks

Agricultural Knowledge Systems (to use an OECD term of about ten years standing) span the three main components of research, education and extension. There are close links between these three elements of the "knowledge system", which now require much 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 much more engaged in building networks and coalitions to address new objectives in such areas as global competitiveness, agricultural sustainability and rural development. Moreover, governments need to ensure that organizational and structural arrangements do not impede but rather encourage these cooperative efforts among components of the AKS.

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 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 and isolating decision-makers; even in the private sector, where stakeholder management is the norm, this can have similar adverse effects (ref). When faced with a novel, complex problem, decision-makers often are 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 been heard possibly too well. NAE AKST has however has 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 were in this category, and many other stakeholder groups in society are still in this category. New stakeholder involvement methods are needed to include these interests in the development of NAE AKST, especially given the increasingly multi-functional importance of agriculture and the diversity of interests that must be serviced by rural areas (Chiesura and de Groot., 2003; De Groot et al., 2002).

Stakeholder involvement strategies aim to engage stakeholders in the decision-making process, either through representative or participatory processes (Grimble, R. and Wellard, K, 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. There is a need to develop cost-effective participatory processes at larger scales as well as smaller scales of aggregation. The Danish Consensus Conferences (e.g. Einsiedel and Easlick, 2000; Joss, 1998?), and its variants, are one such cost-effective, large-scale participatory process that has been successfully exported to other places, and much can be learned from these experiences.

4.3.2 Towards meaningful interdisciplinarity

4.3.2.1 Enlarge the scope of agricultural knowledge systems

AKS has the capability to make powerful contributions to newer and wider issues but, 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 should be addressed across the NAE region. There is a need to move beyond "science versus humanities" dichotomies in many national education systems and to develop skills in complex systems sciences, for example. Effective interdisciplinarity can only be achieved without compromising the further development of disciplinary excellence, which is essential as the base from which high quality interdisciplinary approaches to AKST issues can be developed. Meaningful interdisciplinarity of approach is therefore widely recognized as essential and systemic barriers to this interdisciplinarity need to be addressed and overcome (see box 10)

[Insert box 10]

If interdisciplinarity is to reach the required critical mass to become a centrally effective feature of AKST, it is clear that much more is needed than the development of individual talent or the mere allocation of extra funding. Governments and stakeholders at local, national and transnational levels need to 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 need to bring their internal incentive, resource allocation and reward systems (including promotion procedures and criteria) as well as their program approval procedures into greater consistency or resonance with the broader and more lofty AKST aims that increasingly feature in their mission statements and/or strategy documents. Substantially enhanced funding needs to become available for interdisciplinarity and interactive knowledge networking among AKST stakeholders but, simultaneously, the systemic inhibitors to interdisciplinarity must be countered so that the funding will accelerate the "mainstreaming" and sustainability of the needed new approach and drive 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 and 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 interdisciplinarity and networking approaches. This work could be undertaken multilaterally or could build on the earlier OECD activities underpinning this area.

4.3.2.2 New skills for AKST personnel

To enable these developments to occur, new capacity development needs arise for existing and future AKST personnel so that they can understand and function more comfortably in the context of the wider vision, providing KST services to the wider range of practitioners who will engage themselves in the enlarged vision of agriculture in NAE. Major implications arise both for the provision of initial education and lifelong learning opportunities both for AKST personnel and for their various clients, be they "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 to work smoothly with various new types of partners.

Traditionally, NAE agricultural higher education has been broadly based on 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 will be advisable to promote multiple entry into the agricultural education system, such that persons with initial specialized study in various other disciplines can undertake postgraduate studies (e.g. academic Master's) providing understandings 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 will become increasingly important if the wider contextual understanding of agriculture is to be realized.

4.3.2.3 Need for new learning opportunities

Promotion of a wider understanding of the multiple functions of agriculture has, of course, to extend far beyond the AKST personnel themselves and the universities and colleges that educate them. Learning opportunities for understanding, participation, contextualization and adaptation needs to be fostered for a range of stakeholders. Options can be developed in initial education/training and in 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 (and the present). 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. These learning opportunities could often be accredited by appropriate educational bodies, 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)
- Interested local residents

4.3.2.4 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. Policy makers, meanwhile, are often torn between scientific evidence on the one hand, and consumer/interest group concerns which may often be largely emotionally based, 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 better 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. To quote the EURAGRI President in 2002: the interface between agricultural research and policy: Public debate and hearings where scientists support different political attitudes make people increasingly suspicious of scientists and science. It is therefore important to reflect on how to maintain 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.

4.3.2.5 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 facilitated to understand the scientific issues. Conversely, scientists need 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 designed to enhance public understanding of the multiple functions of agriculture and to promote awareness of the related complexities and trade-offs which may be involved will become an increasing responsibility of educational research and outreach components of the AKST system. For the general public, this would 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” will 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 the development of all children

4.3.2.6 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 sectoral training was the responsibility of the relevant sectoral 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 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.

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

The links between higher education and research should 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 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 needs to 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 co-operative 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 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.

4.3.2.8 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 virtually every citizen can be satisfied and to demonstrate that this need can be met at the highest level of quality imaginable, along with the greatest efficiency possible. Universities should consider making continuing learning a part of their core mission. This would 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. It also stimulates the creation of new knowledge through research and other means of discovery and uses that knowledge for the benefit of society and as a result recognizes 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 may more easily enable adult learners to progress to more advanced courses with organizations other than the original providers. Such credit accumulation and articulation arrangements would make it easier for rural residents to widen their knowledge/skills associated with the new paradigm and also to deepen their knowledge in specific areas, though 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.

4.3.3 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 increasing rapidly and the modes of information acquisition are becoming increasingly more convenient and inexpensive. Converting this information into knowledge lags considerably behind. It is expected that these trends will continue at least for the next two decades, ushering in an 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. Specifically, 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 policy framework, if the paradigm shift is to lead to really meaningful developments. The options to strengthen these systems are described below:

4.3.3.1 Reducing the "Digital-divide"

Currently, the availability and use of IT in the NAE is uneven among countries and sectors in AKST. Some countries, such as those in Eastern Europe and to a lesser extent, Central Europe, have lower access to the technologies. 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.
- Providing education to be able to manage these IT systems in production.

4.3.3.2 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 very dense and numerous sources of information. In the future, information systems will be needed 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 needed, as mentioned below:

- Define collectively (active participation by farmers, extension services…) what information is needed and would be efficient for better farm and landscape management of resources (bio-physical and economic) at the different pertinent scales.
- Promote, as far as possible, consistencies between data 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.
- Develop specialized software and data management programs that can access and use the high volume of information.

4.3.3.3 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. There is a need 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.

- 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
- Develop several new and structurally innovative models for turning information into knowledge.

NOTE: 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. 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. This Section will be developed further following interaction with other regions and the Global Assessment.

4.3.4 Promoting Appropriate Institutional and Organizational Arrangements

4.3.4.1 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 much 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 must:

Be organized to respond to the needs to today's students and tomorrow's**;**

Bring research and engagement into the curriculum and offer practical opportunities for students to prepare for the world they will enter;

Put its resources - knowledge and expertise **-** to work on problems that face the communities it serves

Engagement, 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.

4.3.4.2 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 interdisciplinarity in research and education in the AKST fields (box 11). Similarly, there are major learning experiences, both personal and institutional, to be undertaken within AKST institutions which 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 need 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 very informal, which can have their origins either from AKST invitations to engage or from farmers who share a common problem or from a local NGO which identifies a local public good or environmental issue, for example. Indeed many 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 the most useful and important knowledge is necessarily already held by formal researchers and educators! 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 (see box 11).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 11]

It is essential that a much 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, which are adapted to contextual issues and needs, and that they receive the soft supports needed 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 dissolving 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 should, 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 to promote much more widespread adoption within NAE of practically oriented interactive networking with a range of end users of AKST services.

4.3.4.3 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 development of a global food and agriculture system. Several major changes are affecting the way this AKST is and will be generated and 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. In addition to the above information on any subject, unrestrained by quality standards, is now easily available on the web and elsewhere.

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 needed actors to turn science into practice. For example, review the current link between science/extension/farmers to turn it in a more efficient way and, widen the more effective involvement of end-users (private sector, suppliers of goods and services, consumers, processing…) and their potential benefits.

- 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 nature where public intervention is legitimate/desirable 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, for example, large diffusion systems need to be strengthened. In these areas open and user-friendly information systems should be supported by public funding.

4.3.4.4 AKST interactions between NAE and other regions

It is hard to imagine a more worthy cause for North America and Europe than helping to bring people in other places out of the hopeless cycle of poverty and hunger, with its whole family of miseries, into the light of security, independence, self-reliance, and progress. However, as we look fifty years into the future, and address the core IAASTD question: How can we reduce hunger and poverty, improve rural livelihoods and health, increase incomes and facilitate equitable, environmentally, socially and economically sustainable development?, it is essential to realize that to rise from hunger and poverty and become self-sustaining, people must be empowered to acquire the ability to stand on their own feet. It is therefore strongly recommended that the guiding principles for NAE institutions should be:

- The next fifty years of NAE AKST interactions with other regions be approached from a sharing point of view rather than from the predominant current unidirectional view of one part of the world helping another, less fortunate part of the world.

The contributions of AKST to NAE have been partly documented in earlier Chapters. AKST has brought us to where NAE is now and has the potential to play a key role in bringing the rest of the world to similar level of self-sufficiency and meeting the challenges that will develop in the whole world over the next fifty years as we address the IAASTD question, especially in the context of the sustainability issues an increase in international cooperation and coordination will be necessary to do so.

The agriculture and food sector is the basis of economic livelihood of 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. 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 needed 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.

[NOTE: The underneath Section is very preliminary at this stage, as specific recommendations will have to be developed for the next draft in harmony with views emerging from other Regions, especially SSA]

AKST institutions in NAE need to be ready to participate actively with AKST institutions in other regions in addressing 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 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. Underneath are discussed more specifically 3 examples of interaction, one on them in SSA where the hunger and poverty issues are most starkly obvious. Though this is a very preliminary proposition (which has to be shared with other regions), recent omens are encouraging.

<u>The Framework for African Agricultural Productivity (FAAP)</u>

Africa's leaders see agriculture as an engine for overall economic development. Sustained agricultural growth at a much 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 New Partnerships for African Development (AU-NEPAD) has issued a Comprehensive African Agriculture Development Programme (CAADP) which describes African leaders' collective vision for how this can be achieved. It sets an ambitious 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, agri-business, 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.

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), Africa has created a way of bringing technical leadership into the frame. The Framework for African Agricultural Productivity (FAAP) brings together the essential ingredients needed 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 need to replicate and expand 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. Harmonization of Africa's own resources with those of development partners therefore needs to be placed high on the agenda (see box 12).

[Insert box 12]

Already then, at this stage, there is an articulated set of needs to which NAE AKST institutions should 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 subregions. One such European Network is NATURA, a network of about 30 European universities and research complexes which have agricultural partnership links with developing countries.

It is recommended that initially, development funding 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 pilot should be scaled upwards and outwards to regional level such as FAAP and the BASIC program aimed at Building African Scientific and Institutional Capacity, for example.

<u>The contribution of NAE to the CGIAR</u>

Guided by NAE countries and the Green Revolution concept as 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, the IAASTD goal of reducing poverty in developing countries will require that more food is produced by the poor, and this should consider the present context of their socio-economic 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 non-agricultural sectors that stimulates the agricultural sector, or (5) some combination of these.

Despite the fact that NAE countries have the major part of the KST resources of the world, support major technological spill-overs and the ecological, social and economic food prints its agrifood systems produce IAASTD goals only barely feature, if at all, in these countries' research or educational agenda today. This suggests a strong awareness effort is needed, 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 upon a wide societal and global view about the role of agrifood systems and scope of AKST, and on a strong, concerted research and educational effort to find and implement solutions that take into account impacts on and are well adapted to the conditions of the poor.

The CGIAR centers have a unique position and enormous challenges. Taking the negligible 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. These centers which are research organizations, must evolve to assume an additional role as facilitators or honest brokers to support development networks that will bring together the key decision makers on different levels of public and private AKST (the different stakeholders from national and regional systems include research, education, development, socio-economic actors, including farmers' organizations, local and national authorities, NGOs and civil society (Fischer 2000) as well as the best and most useful parts of the upstream science conducted in the NAE countries (as well as outside NAE). Summing up, partners from the NAE countries can help make the CGIAR better contribute to the IAASTD agenda by:

- Raising public awareness (general public especially youth, politicians, donors) and strong financial support of both IAASTD goals and the role of research to address the issues. Like the Davos Economic Forum that is organized every year, "Research for Development (RforD), under CGIAR coordination, should have an annual forum in one NAE country, 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 mediated by the CGIAR system. Encouraging youth in industrialized countries to work in agricultural research for developing countries. From regular lecture programs in high schools and universities to increasing attractive, specific scholarship and fellowship programs to encourage young scientists to do their thesis or post-doctorate in developing countries, a wide range of inciting projects could be implemented. Also, CG scientists could be encouraged to co-advise more students in NAE institutions and even provide instruction.
- Allocating special financial resources to 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 should aim to strengthen the capacity of NARS (including

universities) capacity to undertake collaborative scientific research to realize the IAASTD goals. This needs to 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.
- Continuing work on targeted research programs that have a strong impact on the IAASTD goals (for e.g. challenge programs (see box 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 13]

- Working on common research issues, among others - food diversification and its use to reduce 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 etc.
- Ensure that international funding for AKST does not perpetuate donor dependence and undermine efforts to develop domestic political support for sustainable funding, especially fro the smallholder sector.

Making international agricultural research work better for the poor implies developing well targeted research activities, but this research must – better and more than in the past – be able to promote for and interlink with appropriate research carried out in NAE countries. Hence a major question for the CGIAR is how to optimize this 'development', or how to initiate, ensure shaping up and mobilize appropriate research in NAE for contributing to international efforts the CGIAR centers are now trying to orchestrate with a view to strengthen the sustainable cooperative capacity of NARS (including universities) in developing countries.
This new way of working should mark a shift in how research for development activities is designed, monitored, evaluated in the CGIAR centers and NAE countries institutions altogether. All contributors, from upstream science to delivery systems and impact assessment must really, effectively work together from day one to secure 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 building practical solutions that can be realized and sustained for the generations to come.

<u>The Global Forum on Agricultural Research (GFAR)</u>

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.
- Increase awareness among policymakers and donors of the need for long-term commitment to, and investment in, agricultural research.

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

- in Europe, EFARD[8] 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 and ERA-ARD, and established a strategic alliance with the FARA[9];
- In North America, progress is still underway to link NA ARIs10 with a vested interest in ARD to GFAR; also, the PROCINORTE[11] cooperative program could join the other "PROCIs" (PROCIANDINO, PROCISUR, PROCITROPICOS and PROCICARIBE) under the umbrella of the Latin American & Carribean 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 very 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

[8] 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 hun8ger, (ii) achieving food security, and (iii) assuring sustainable development.

[9] FARA is the Forum for Agricultural Research in Africa

[10] Agricultural Research Institutions

[11] 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).

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, 7 years after its official launching.
However, despite previous efforts in NAE, it seems more difficult and challenging to mobilize actively 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 active and truly representative national forum but the situation varies greatly from one European Member State to another[12].
- In North America, the different categories of ARD stakeholders seem to be working even more in isolation than in other regions especially universities. So far, NAFAR has not succeeded in convincing them of its added value and PROCINORTE is currently more a research program by nature than a multi-stakeholders forum.

Lessons have to be drawn from this innovative multi-stakeholders, bottom-up and highly participative mechanism and its impact on AKST after 10 years of existence. The second external evaluation has been completed in February 2007. Options for action should 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 fora in the NAE region (North America, Western Europe, Eastern Europe including Russia), that could help significantly the work at the global level in collaboration with other regions for a and sub-for a.
- 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 NAE/south AKST cooperation would be made at the academic level with strong political support but without political interference, in an effort to gain mutually useful knowledge firmly oriented towards the IAASTD goals.

4.4 Reshaping policy environment and governance systems

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

4.4.1 Developing a coherent policy framework

[12] For example, Denmark and Switzerland have established very active and successful national fora (http://www.sfiar.ch/ and http://www.netard.dk/) when 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 not yet succeeded to establish its national ARD forum.

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 very 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:
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;
Environment implies that production processes should respect the environmental carrying capacity, its respond to climate change, participate in the energy policies, etc.
The challenge is (i) to find a sustainable balance between the production of food, an efficient use of natural resources, the promotion of economic development and the maintenance of the associated cultural values, and (ii) to articulate these policies at the local, regional and global levels.

The adjustments in policy issues and regulatory frameworks have implications for research to tackle the following main challenges:

- To provide a transministerial approach for a better coherence of the complex overall framework (e.g. between agricultural, economic and health ministries that would result in the production of diversified foods, healthy and of a certain quality, at the local, national and global levels).
- Define what the “right balance” should be between these different policies, the criteria used to determine this balance.
- Identify ways that ensure the articulation of these policies at the local, regional and global levels.

For example formulating new policies or work upon the current policies that would integrate the sustainability and multifunctional aspect of agriculture could facilitate the development of sustainable food and farming systems. Such possibilities include:

- Institution of policies that facilitate rapid uptake of technologies that maintain or increase productivity, which have less environmental footprint than current technologies.
- Elaboration of policies that consider the holistic approach of agriculture. This would lead to more encompassing policy instruments for achieving multiple objectives that are more efficient than separate policies for each of the multifunctional attributes of agriculture.
- Develop new policies while keeping in mind the transaction costs (other than administrative costs) involved and determine if these costs could be reduced through policies aiming at selective targeting of farms subject to the programs, by using agricultural price and income support programs etc.

- Policies are required 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.

4.4.2 Enlarging the range of proprietary regimes

4.4.2.1 General issues concerning proprietary regimes and IPR

There is a need for a continuing reconsideration of the legal and cultural definitions of property 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 need to make in response 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, which determines their property regime, based on their consumption and access is essential (cf. figure below)[13].

CONSUMPTION	ACCESS	
	Exclusive	**Non-Exclusive**[14]
Rival	***Private*** (e.g. food, clothing, cars)	***Common pool*** (e.g. air, water, soil and ocean fisheries[15], landscapes)
Non-Rival[16]	***Club/Toll*** (e.g. toll-roads INTELSAT, Suez Canal, Panama Canal, private schools, theatres, professional associations)	***Public*** (e.g. public roads, sunshine, national defense…)

As mentioned above, so far there has been a tendency 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-rivalrous nature has been eroded due to technology and policy. See the example of water in Box 14.

[Insert box 14]

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[13] International pubic goods and the CGIAR Niche in the R for D Continuum: concepts; Jim Ryan; November 2005.
[14] Definition: once available, it is not possible to prevent free access to it by all.
[15] In some cases, soil and ocean fisheries access may also be viewed as exclusive
[16] Definition: one person's consumption does not diminish its availability to others.

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. There is thus a need to establish a new proprietary regime 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).

In order to address these “hybrid” goods there is need for an enlarged vision of proprietary regimes that goes beyond just public or private ownership. Such a vision has been established with the concept of “common property regimes” which has been developed for natural resource management projects as shown in box 15. Indeed, it may be necessary to consider ways in which a single good may belong to several property rights regimes depending on how it is used.

[Insert box 15]

Thus, proprietary questions undoubtedly raise many complex issues and more research would allow a better understanding of the issues, so that they could be manipulated to maximize benefits. Such research might concentrate on the identification and analysis of the factors conducive to the organization of a common-property regime 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. There must be significant and sustained promotion of interdisciplinary work, public forums, and public policy discussions of the nature and implications of property and property law for the future.

4.4.2.2 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 protection that would cover investments in getting the next generations. But the downside to this IP protection is the broad coverage that the patent offices granted due to the pioneering nature of the applications 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 needed 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, certain enabling technologies essential to agricultural sciences, such as transformation methods, constitutive promoters and selectable markers, have been protected by patents controlled by large agricultural companies. Many of these technologies were invented at public institutions and licensed exclusively to private industry, thus making them unavailable to the scientists that created them.

There is a need to reshape IPR and its associated regulatory environment to facilitate the generation, dissemination, access and use of AKST. Some of the options are listed below:

- The patent offices should continue the trend to issue narrower patents even on pioneering technologies.
- University groups and the private sector should be encouraged to pool patents through cross licensing (and free licensing to the developing world). Several interesting public initiatives are now coordinating and mutualizing (or just initiating) the setting up of 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 (CAMBIA in Australia, PIPRA in USA, EPIPAGRI 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 (see box 16). 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.

[Insert box 16]

- Promote laws that allow the courts to force a license, under court-mandated terms, if and when necessary for agriculture. (So far this measure has been used or threatened to use, only for pharmaceuticals).
- Reverse a disturbing 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 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 millennium goals.

4.4.2.3 Access to genetic resources for food and agriculture

(To be completed)

4.4.3 Setting up new modes of governance

4.4.3.1 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 concentrates 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 economical or policy space of action, suggesting compromise as a tool to define the optimal boundaries;
- Development of methods and process to create innovative networks at local level 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;
- 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, etc.

A systematic exploration and scientifically sound examination of practical experience could facilitate in fulfilling these needs. Such research would need to be 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. A challenging question is how to combine qualitative and quantitative research to effectively support the related decision processes. The aim must be to really bridge different research paradigms and to embed the analyses within a process of stakeholder interactions.

4.4.3.2 Fisheries issues

The main area where research needs to be developed in this domain is that which concerns the regulation of the access to marine resources and their exploitation.

For instance there is a need to:

- Define better 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 dysfunction of a lot of present regimes, and particularly in Europe where the property of the resources is declared as 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 in the establishment of a sustainable exploitation of the fisheries resources. Alternatives for resource management should be built on scenarios allowing testing of various regimes of property (e.g. private / collective), various systems of exchanging rights, at various resources levels (stock / ecosystems).

In this domain the importance of local governance and the integration of stakeholders' advice in this governance should be underlined. There is a need to develop models where stakeholders' advice is taken into account while building 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 derived17. 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. With exclusive territorial rights it would have a strong incentive for ensuring that the management measures are respected. Further studies will be needed to develop this TURF concept: (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.

4.4.3.3 Forestry issues (To be completed)

The forest sector has been affected by important changes in terms of modes of governance and management since the beginning of the years 1990. The conventional way of taking decisions in the forestry sphere 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 (basically productionist ones) are becoming prominent.

The main changes brought in the forest sector are the following:

- Schemes of certification:

Under a strong pressure of some major environmentalists NGOs, the idea has been introduced that the evaluation of the sustainability in forest management should work completely differently from what

[17] Christy, F.T.Jr., *Territorial use rights in marine 1982 fisheries: definitions and conditions*, FAO Fish.Tech.Pap., (227): 10 p.

was the case before, when the forest managers were more or less systematically their own evaluators. It is admitted today that only a certification procedure, carried out by neutral actors (or supposed so) is able to give a label of good management.

Three main certification schemes are co-existing today: The FSC (Forest Stewardship Council): promoted by environmentalists (mainly WWF) and based mainly on performance indicators; the PEFC (Programme of Endorsement of Forest Certification schemes), promoted by productivists, including private forest owners in Europe and basing on system indicators; Smartwood, basically in North America, on a joint initiative of an environmentalist NGO (the Rainforest Alliance) and industrials. The effectiveness of those certification schemes is still questioned: multiplicity of labels create confusion (still a war among certifiers); chain of custody control is unclear in some cases (example of PEFC); labels used as market instruments more than as tools promoting sustainability, labels unknown from the customers. But the changes occurred 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. A more and more important share of the wood products offered for sale on market are certified through these various schemes.

- National Forest Programs (NFPs):

A NFP is a strategic document, established in a timeframe of 10-15 years giving the rationale and the directions of the 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. 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); inter-sectoral links (programming of forest activities is elaborated in connection with other sectors, especially environment and land use); co-ordination between various levels of governance (to ensure comprehension between international, national and local actions); accountable expertise (from various sources and subject to public debate); iterativity (to promote adaptive management based on collaborative learning). During the last 10 years, there was a significant increase of those NFPs, especially in Central and Eastern Europe, because it was an informal requirement before being integrated within the European Union. As for the Western European countries, the NFPs elaborated are more formal documents, except in Finland and Scotland. In USA, where the decision makers are more result- than process-oriented, NFPs are not part of the culture yet.

Although those changes are significant in a very traditional sphere such as the forestry sector, it should be noted that all the characteristics of those new modes of governance and management are still far from being always present in all national frameworks: participation used as an alibi, intersectorality advocated only when it can reinforce the sector, accountability of expertise diverted by the conventional experts, iterativity resumed to only hierarchical evaluation, etc.

4.4.4 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 amongst plausible futures. From an investment viewpoint, decisions are required on how much to spend on R&D, on who should pay for it, on who should do it, and on who should make sure all this happens in practice.

4.4.4.1 How much to spend on R&D?

Spending on R&D is valuable 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, and some are immediate and some are 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; 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; Graham 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 (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.

4.4.4.2 Who should pay for Agricultural R&D?

Generally, the criterion 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, for a variety reasons, 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 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[18].

[18] Some R&D may provide public goods by reducing the negative externalities of agriculture such as diffuse pollution. 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 during the 1950s to 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 multi-functional, 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 non-governmental, not-for-profit organizations that sponsor research in pursuit of organizational agenda, mostly associated with social, environmental, or religio-political objectives. They also provide a conduit for private or government funds. Private benefactors also channel funds into trusts that pursue selected themes. In future, increased emphasis on multi-functionality 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.

However, where private R&D initiatives fail to respond to market potential because of high costs, high risks or long investment periods, Governments will need to 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 bio-energy 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.

4.4.4.3 Who should do 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 doing 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. Table 1 shows how 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. Universities are a key delivery agent.

Table 4.1: Agricultural Research: Who Pays and Who Delivers?

		Who Pays?		
		Government including parastatal organizations	**Non-governmental, organizations**	**Private, commercial**
Research Objectives		Public good e.g. food security, environmental protection	Organizational Agenda, e.g. poverty alleviation, animal welfare	Private good, e.g. profits, increased utility of consumers
Who delivers?	**Government, including parastatal organizations**	Government funded research institutes	Government research institutes conducting external research contract	Government research institutes conducting external research contract
	Universities*	Govt funded research programs in Universities	University research under contract to NGOs	University research under contracts to commercial companies
	Non-governmental, organizations	NGOs undertaking research on contract to Government	NGOs funding and operating own research programs	NGOs conducting research on contract to private companies
	Private, commercial	Commercial research organizations on contract to Government	Commercial research organizations on contract to NGOs	Market driven, research for competitive advantage, conducted ‘in house’ or contracted out

*Universities also fund their own research programs, but this usually draws indirectly on external funding sources, such as trust funds.

There is now much greater diversity in the provisioning of agricultural research, especially regarding biosciences, with a growth in public-private funding partnerships amongst 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.

4.4.4.4 Who decides on R&D?

Regarding public good aspects, 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, 2002, 2005).

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).

4.4.4.5 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 should 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 co-operation across AKS institutions has led to the emergence of new partnerships and networks giving 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 up and scaling outwards these partnerships, not only nationally, but also transnationally 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". 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; for human capital development through higher education designed to achieve competitiveness and for 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 entire food chain, sustainability of natural resource use and rural development. New partnerships, networks and relationships will be needed for this potential to be realized and AKS institutions should be encouraged to take action accordingly.

4.4.4.6 Cost benefit Appraisal of AKST Investments

Different plausible futures will place different emphasis on development priorities and the roles of private and public sector. As a result, the funding and organization of R&D and the relative roles of Government, NGOs and private companies will vary accordingly. There is a need for a framework that can support the cost-benefit analysis of future AKST investments under the new paradigm for agriculture. This is itself a valid research theme.

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