NAE Chapter 3

Looking into the Future for AKST

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Key Messages

3.5 Future agricultural innovation systems: Contributions to sustainable development goals

References

Key messages

The futures agricultural research and innovation systems in North America and Europe are not already decided and can be created or build. Even if a certain number of science and technologies appear to be of key importance in the future, due to financial constraints and societal situations, the weight given to each of them might differ. Therefore, there are several plausible futures, each of which can be created through the actions we choose to take today. Some futures are desirable, others are not. Among the desirable futures, some are plausible and seem feasible and can, therefore, help decision makers choose strategic options, while others are utopian.

A number of recent foresight exercises focusing on agriculture, rural development, environment, science and technology, etc. have been undertaken at global level and at regional level. Global exercises with particular relevance to IAASTD are, amongst others, the Global Scenario Group scenarios, the Intergovernmental Panel on Climate Change Special Report on Emissions Scenarios, the United Nations Environment Programme's Third Global Environment Outlook, and the Millennium Ecosystem Assessment. Additionally, other studies have prepared projections specific to agriculture: examples including OECD-FAO Agricultural outlook 2006-2015, Food and Agriculture Organization's Agriculture Towards 2020 and the International Food Policy Research Institute's Global Food Projections.

A number of foresight exercises related to agriculture and science and technology have also been undertaken at the EU level and in European countries as well as in North America. There are fewer of them in Russia. The foresight studies carried out in Europe ask questions around the Common Agricultural Policies, bio-energy and their consequences on people, planet and profit (sustainability) indicators. A limited set of 'archetype' scenarios reappears in recent scenario-based assessments (see Raskin et al., 2005; Westhoek et al., 2006; Zurek, 2006):

- *Economic optimism/ conventional markets scenarios;* i.e. scenarios with a strong focus on market dynamics and economic optimism, usually associated with rapid technology development.
- *Reformed Market scenarios*; i.e. scenarios that have a similar basic philosophy as the first set, but include some additional policy assumptions aimed at correcting market failures with respect to social development, poverty alleviation or the environment.
- *Global Sustainable Development scenarios*; i.e. scenarios with a strong orientation towards environmental protection and reducing inequality, based on solutions found through global cooperation, lifestyle change and more efficient technologies.
- *Regional Competition / Regional Markets scenarios*; i.e. scenarios that assume that regions will focus more on their more immediate interests and regional identity, often assumed to result in rising tensions among regions and/or cultures.
- *Regional Sustainable development scenarios*; i.e. scenarios, that focus on finding regional solutions for current environmental and social problems, usually combining drastic lifestyle changes with decentralization of governance.

- *Business as usual;* i.e. scenarios that build on the assumption of a continuation of past trends.

In North America, the increasing role of technology is a commonly addressed element in foresight exercises. Many reports indicate a major role for technology in agriculture as a response to consumer demands and changes in diets, ageing population, affluence, worries about environmental issues: they also discuss the importance of multifunctional agricultural systems and the fact that agriculture is going to provide new products and services, such as carbon sequestration or biofuel. The application of nanotechnology in precision agriculture is a recurring theme. A number of reports discuss the implications of dualism in NA agriculture. Agriculture will consist of almost entirely very large farms and small farms. A relatively small number of large farms will produce most agricultural products. Small farms will persist, but operators will also depend on off-farm income

When considering plausible futures, it is important to take into account uncertainties that appear in the agricultural system, in the knowledge, science and technology system, and their interactions. For example: to what extent will bio-energy develop and which drivers will determine future bio-energy use in NAE? Will AKST be able to reduce the negative impact on climate of massive development of bio-energy? Will agriculture be able to reduce substantially energy use for its production? How will agriculture in Southern Europe and Southern US deal with climate change? To what extent will consumers from North America and Europe adopt a “sustainable development” attitude, reduce their demand for non-season crops, meat and fish? Will food continue to be an instrument of cultural identity in many countries? Will it coordination of food standards be undertaken by international governmental and non-governmental organizations? What is the risk of reducing the populations’ immunity in the long term through the provision of increasingly asepticized food? Will subventions continue to focus on prices or will they shift to other areas such as resources protection? Will North America, EU and Russia improve dialogue on agricultural policies? What is the economic viability of present family farm systems? Will there be administrative and financial measures to facilitate young farmers’ training and installation? How will structural unemployment in agriculture be tackled, especially in the Eastern European countries? Will migration within NAE allow skilled labor to work in agriculture? Will there be training courses to encourage farmers, especially the younger ones to become entrepreneurs who can compete in global agricultural markets, use e-commerce opportunities as a commercial tool for worldwide trade, measure environmental impact, develop a multifunctional farming respecting the environment, etc.?

When looking into the research and innovation systems, a number of uncertainties also appear, for example: Will Eastern and Central Europe be able to reduce the digital divide with the rest of Europe? Will governments be able to develop “innovation plans” that favors interactions between universities, industries and governments? Will European universities serve the industrial economy? Or simply become more closely linked to “external” research? What kinds of relationships will North America and Europe’ science and technology systems have with Asia and with the less developed countries? How will universities deal with their missions of education of a diverse student population and of research with local industrial communities? Will the “triple-helix” model that implies university-industry-government relations, develop quickly?

All these will have consequences on agricultural research and innovation systems and AKST. This assessment has explored four different types of agricultural research and innovation systems and shown that AKST priorities will differ with each type of system. However, these systems are contrasting but not mutually exclusive. As they are intertwined in many areas, decision makers will want to assess and combine elements of each of the systems depending on values, priorities and resources. These four explored systems are:

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

3.1 Introduction

Agricultural systems and land use are changing as a consequence of changes in demography, world trade, climate, diets, political unions (e.g., expansion of the European Union), and technology. The degree and impact of these variations are largely unknown. Although the future is unpredictable, some developments can be foreseen and alternatives explored. This chapter focuses on uncertainties related to the futures of the main drivers of agricultural research and innovation systems and AKST.

In this subchapter, we define the problem and present foresight exercises related to agriculture and to science and technology in North America and Europe. Subchapter 3.2 deals with uncertainties in the futures of agriculture. Subchapter 3.3 deals with uncertainties in the futures of science and technology. Subchapter 3.4 looks at uncertainties in agricultural research and innovation systems and AKST. In subchapter 3.5, four plausible agricultural research and innovation systems are proposed with potential impact on AKST.

3.1.1 Problem statement

The future of the agricultural research and innovation systems in North America and Europe is not certain, and it is possible to revise current systems or to build new ones. There are several plausible futures, some more desirable than others. Each of them depends on the decisions and actions of today's leaders. Some of the appealing futures appear plausible and feasible and may help decision makers choose strategies to reach those futures. Other futures, although desirable, are utopian and may be of less value for planning the future.

Forecasting and foresight are methods to think about options for the future. They can have a national, a regional, or a sectoral focus. They can be based on scientific panels, the Delphi method, scenario development, investigative surveys, working groups, or scientific seminars. Foresight activities can focus on the result (e.g., projections or scenarios) or on the process. Emphasizing the process can help to build strategic capabilities and to inform research and innovation policies ("embedded Foresight") (Godet, 1977; Irvine and Martin, 1984 and 1989; Hatem, 1993; Martin, 1995; Kulhmann et al., 1999; de Jouvenel, 2004; de Lattre-Gasquet, 2006)

Identifying appropriate drivers is the first step in forecast/foresight activities. The tendential development of each driver must be presented, and curves and potential breaks that could block the tendential development should be explored. In this chapter, uncertainties about the futures have been raised in the form of questions, and no hypotheses about future development have been made.

The futures of agricultural research and innovation systems and AKST depend on agriculture and knowledge, science and technology, but AKST also influence agriculture and KST. This chapter addresses four questions.

-The optimal agricultural research and innovation system and fields where ASKT needs to be generated or developed depend on future agricultural systems. What are the major uncertainties in the drivers of agricultural systems? (Subchapter 3.2)

-KST is a key driver of AKST; what are the major uncertainties in the drivers of KST? (Subchapter 3.3)

-AKST is a key driver of agricultural systems; what are the major uncertainties in variables of future agricultural research and innovation systems and AKST? (Subchapter 3.4)

-What are some plausible futures for agricultural research and innovation systems and AKST fields, and how do they contribute to meet the development and sustainability goals? (Subchapter 3.5)

For each driver, the questions show that the future is uncertain. Each driver also points to fields where AKST needs to developed or expanded. Chapter 4 will discuss uncertainties about potential changes in institutional arrangements and policies associated with each driver.

The plausible futures comprise a number of goals for an agricultural research and innovation system, including promotion of sustainable agriculture and enhancement of nutritional security, human health, and rural livelihoods, and AKST depends on the priorities. At the same time, an agricultural research and innovation system and certain AKST could help mitigate environmental degradation and social inequities. Reaching all of these goals will be difficult; various agricultural research and innovation systems favor particular goals at the expense of others. These alternative futures expand the spectrum of possibilities and will facilitate discussions among decision makers about strategic choices.

3.1.2 Review of related studies

A number of recent global and regional foresight exercises focus on agriculture, rural development, environment, science and technology, etc. Global exercises with particular relevance to IAASTD include the Global Scenario Group scenarios (GSG; see Raskin et al. 1998), the Intergovernmental Panel on Climate Change Special Report on Emissions Scenarios (IPCC-SRES; see IPCC, 2000a), the United Nations Environment Programme's Third Global Environment Outlook (UNEP-GEO3; see UNEP 2002 and UNEP/RIVM 2004), and the Millennium Ecosystem Assessment (MA; see Millennium Ecosystem Assessment 2005). Additionally, other studies have prepared projections specific to agriculture: examples including OECD-FAO Agricultural outlook 2006-2015 (OECD/FAO, 2005), Food and Agriculture Organization's Agriculture Towards 2020 (FAO at 2020) and the International Food Policy Research Institute's Global Food Projections (IFPRI; see Rosegrant et al. 2001). These studies are reviewed in chapter 4 of the Global Assessment.

Although none the studies are identical to the IAASTD exercise in scope and time-scale, many meetings and reports have addressed one or more of the components included in the IAASTD narrative. We have collected and reviewed a number of them focusing on Europe and North America which include elements of the IAASTD exercise. Table 1 for Europe and table 2 for North America give references on these exercises.

Two recent European foresight exercises represent different approaches: Eururalis and Scenar 2020. Eururalis was launched with the aim to explore alternative future rural development options for EU-25 (Klijn & Vullings, Eds., 2005). This Dutch project is developing and analyzing a set of four long-term alternative scenarios to capture major uncertainties, Alternatively, Scenar 2020, a recent initiative of DG Agri, uses a baseline approach with varying policy options with particular focus on the impact of technological change (especially information communication technology) and food chains on agriculture and rural areas (European Commission, 2007).

EURURALIS. Based on its success of providing sound information on future rural development options during the 2004 Dutch EU Presidency, an extended version of the Eururalis toolbox (no. 2.0) is under development. The new version will be used to analyze a number of specific rural policy questions for EU-25, including issues related to bio-energy and strategic options for the CAP after 2013 and the consequences on people, planet and profit (sustainability) indicators. Such policy questions can be posed for each of the four different world views – as developed in Eururalis 1.0 – and, regionally differentiated, for different time horizons: 2010, 2020 and 2030. The aim of the Eururalis toolbox is to help policy makers formulate long-term development strategies for rural areas in Europe (EU-25).

SCENAR 2020.This study aims to identify future trends and driving forces shaping the European agricultural and rural economy (EU-27 +) on a time horizon up to 2020. Analyses of trends from 1990 to 2005 provide the basis for developing a reference scenario (baseline) that represents a trend projection up to 2020. Three variants are constructed around the baseline: the baseline with modifications of current policies that are reasonably certain to happen, a ‘liberalization’ scenario, and a ‘regionalization’ scenario. The latter two represent alternative policy frameworks with differing degrees of support to the agricultural sector. Drivers of change are grouped into those that are independent of policy influence (at least for the time horizon up to 2020) and those associated with agricultural and environmental policies.

EURURALIS has the advantage of sketching principally different alternative future directions and their consequences. The primary advantage of SCENAR 2020 is its capacity to perform a sensitivity analysis with regard to very precise policy modifications. SCENAR 2020 identifies demographic dynamics as the strongest driver, likely to continue to remain so also for the future rural world. In general, the study concludes that the economic importance of agriculture will further decline although agriculture will remain a significant land use with an increasing role in managing externalities such as landscape and biodiversity. In 2020, there will be fewer farms that are more competitive at global scale, with higher average income and higher productivity (European Commission, 2007).

A number of exercises have also been conducted for the Eastern countries of the EU and Europe, such as the Czech Republic, Hungary, Poland, etc. For example, the ForeTech project looked at Technology and innovation related to agriculture, food and drinks for Bulgaria and Romania. Another study analyses the potential evolution of agricultural income and the viability of selected farming systems in the Czech Republic, Hungary, Latvia, Poland and Romania under different Common Agricultural Policy implementation scenarios (EU-IPTS, 2006).

The UK, Finland, Germany, The Netherlands, Ireland, Norway, Sweden, Romania, France, etc. have all conducted foresight studies on the future of the agricultural sector or the future of science and technology. All the reviewed exercises have developed their assumptions about a number of underlying uncertainties and future development of key driving forces and arrived at different logics regarding the construction of alternative futures. Nevertheless, many scenarios display some similarities, and it has been argued that a limited set of 'archetype' scenarios reappears in recent scenario-based assessments (see Raskin et al., 2005; Westhoek et al., 2006; Zurek, 2006):

- *Economic optimism/ conventional markets scenarios* - strong focus on market dynamics and economic optimism, usually associated with rapid technology development.
- *Reformed Market scenarios* - similar to conventional market scenarios but include some additional policy assumptions aimed at correcting market failures with respect to social development, poverty alleviation or the environment.
- *Global Sustainable Development scenarios* - strong orientation towards environmental protection and reducing inequality, based on solutions found through global cooperation, lifestyle change and new or more efficient technologies.
- *Regional Competition / Regional Markets scenarios* – regions focus more on their more immediate interests and regional identity, often assumed to result in rising tensions among regions and/or cultures.
- *Regional Sustainable development scenarios*- focus on finding regional solutions for current environmental and social problems, usually combining drastic lifestyle changes with decentralization of governance.
- *Business as usual* - build on the assumption of a continuation of past trends.

A list of foresight institutions at European level is in the reference list.

Table 1:
References to Foresight exercises related to Agriculture, Science and Technology at European level since 2003

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- Dissemination conference. http://cordis.europa.eu/foresight/ntw_conf2004.htm

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EU Commission, 2005. Key Technologies for Europe. http://cordis.europa.eu/foresight/kte_expert_group_2005.htm, The "Key Technologies" Expert Group has approached the future of several key technologies all crucial for Europe's future: biotechnology, nanotechnology, information technologies, communication technologies, transport technologies, energy technologies, environmental research, social sciences and humanities, manufacturing and materials technologies, health research, agricultural research, cognitive sciences, safety technologies, complexity research and systemic, research in the services sector.

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Also for North America (NA), a large number of studies exist that look into the future of agriculture and/or AKST. In the following we present some of the more common views extracted from these studies. More prominently than in Europe, the increasing role of technology is a commonly addressed element in foresight exercises. More than half of the reports indicate a major role for technology advances in agriculture. The application of nanotechnology in precision agriculture is a recurring theme. Producers could have near real-time data from every plant or animal (Fletcher, 2007; Western Farm Press, 2007); computers would automatically collect and analyze the information. These data would allow producers to detect and correct disease infections, pest infestations, nutrient/water deficiencies, etc. before there is any significant effect on the plant/animal. This type of system would allow precise targeting (and tremendous reductions) of medicines, pesticides, nutrients, and water. Much of the process would be completely automated; problems could be addressed or prevented (Catlett, 2003; Lawton, 2003). Combinations of detection technology and global positioning technology would allow detection and precise location information. Pesticides, nutrients, and water could be used more efficiently and with fewer environmental effects.

The application of technology will also be a response to demographic changes in NA. Slow population growth, combined with an aging population, will reduce the labor pool available for agriculture.

However, increased mechanization of NA agriculture will reduce the number of workers needed for an agricultural operation (McCalla 2000). Although the workers will have to assess and apply much more information, computer assistance and automated responses will minimize the manpower requirements.

Consumer demands are also a common element in many of the foresight reports. In part, the application of technology will be driven by consumer demands. The NA demand for food quantity is expected to be mostly static (NMSU, 2001), but greater affluence and consumer knowledge will create a demand for product differentiation. An aging, health conscious NA population will ask for greater health benefits and fewer risks from food (Oliver, 2005). Biotechnology can be used to manipulate nutritional qualities of foods and reduce chemical inputs (e.g., pesticides) remaining on foods.

Additionally, affluent consumers are more knowledgeable about environmental issues and more likely to pay a premium for products that have been produced / processed with attention to environmental or social issues (UGA, 2000). Technology can provide the means to track individual food items or food components from the field to the table (Western Farm Press 2007). Consumers will be able to make buying decisions based a wide range of nutritional, environmental, and social factors.

Greater affluence is also associated with an increased demand for meat in the diet (Tillman et al., 2002). Because the typical diet in NA is already based on meat, the demand in NA is unlikely to change significantly. However, increasing affluence in other countries will most likely strengthen the export market for meat produced in NA. Additionally, there will be greater demand for grains to produce meat animals.

Aging and affluence will also generate greater demand for additional processing of food products (Western Farm Press, 2007). Aging consumers, in particular, are willing to pay more for convenience. Consequently, there will be a greater demand in NA for prepared foods or products that can be prepared quickly and easily.

All of these consumer factors will combine to create a broad, varied market for differentiated products. Some groups of people will be most interested in food properties (e.g., nutrition, flavor, or convenience); others will choose agricultural products based on concomitant environmental impacts of production. Technology and rapid global communication will allow consumers to evaluate a wide range of factors and to identify/track agricultural products from the field to their home (Bosserman, 2007).

Many of the reports also discuss the importance of multifunctional agricultural systems, and greater public awareness and support of multifunctionality (Tilman et al., 2002; McCalla, 2000; Oliver, 2006). Affluent consumers are not concerned about food supply, and they have greater knowledge of the environment. They are more likely to pay for environmental services (e.g., wildlife habitat or watersheds) associated with agricultural production.

Agriculture will provide new products and services. Genetically modified plants and animals will produce many different pharmaceuticals and raw materials for industry. In NA, agriculture will become a major source for energy (Ugarte et al., 2006; Sanderson, 2006). Modified plants and agricultural waste products will be converted to fuel. This industry will expand into a major market for agriculture, providing a major additional revenue stream but possibly creating resource competition between the production of food and fuel. Agriculture will become a more important source of fuel as China and India become major competitors for energy (Oliver, 2006; Vanacht, 2006). It would particularly matter whether feed grains (e.g., corn) are massively used for energy, as done currently, or lose in importance. In the first case, it will become more difficult and expensive to meet a rising demand for meat (Ugarte et al., 2006).

Carbon sequestration may be a new role for NAE agriculture (NMSU 2001, USEPA, 2005; Bosserman, 2007). As China, India, and other countries become more industrialized, it will become more critical to mediate levels of greenhouse gases. Plants can remove carbon dioxide from the atmosphere, and agriculture could provide this service. If carbon sequestration is combined with fuel production, agriculture could provide energy with little or no net gain in greenhouse gases. However, climate change is not expected to have only modest impacts on NA agriculture by 2025 (Pardey and Alston, 2004)

The scale and impetus for multifunctional agriculture will depend on locality and the services desired. Many services (e.g., watershed protection) are primarily beneficial to the local area; demand and support for these services will occur at state and local levels (NMSU, 2001). The federal government will be involved with other services, such as carbon sequestration, that benefit a much larger population and area (NMSU, 2001; USEPA, 2005; Bosserman, 2007).

A number of reports discussed the implications of dualism in NA agriculture. Agriculture will consist of almost entirely very large farms and small farms. A relatively small number of large farms will produce most agricultural products. Small farms will persist, but operators will also depend on off-farm income; it will be important to provide these opportunities (NMSU, 2001). Some small farm operators will band together to achieve important economies of scale (Manternach, 2004).

Four of the 23 reports included implications for AKST. There will be an increased trend for more public-private partnerships (NMSU, 2001;,UGA, 2000); a more affluent society will focus private research on convenience/appeal of agricultural products and public research on product safety and environmental impacts (USDA, 2003). A tiered system of research institutions will emerge (Kohl 2003). One tier will focus on basic grant-funded research. Other institutions will favour local alliances and applied research.

As knowledge increases, more companies, institutions, and individuals will have intellectual property (IP) rights for components that are necessary to further AKST (Atkinson et al., 2003; Pardey and

Alston, 2004). It is important to revise the current system of IP protection and to harmonize IPM security internationally. A new system is needed that will facilitate sharing of information without eliminating the financial incentive that drives much agricultural research.

Table 2: References to Foresight exercises related to Agriculture, Science and Technology In North America since 2000

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3.2 Agriculture: Major Uncertainties in Key Drivers

3.2.1 Food demand and consumption

3.2.1.1 On-going trends

Food demand is increasing as the world's population grows and migrates, Climate change, water shortages and soil degradation are rapidly changing the conditions of agricultural production. The Malthusian fears of a widening gap between the people's needs and food production are once more coming to the fore in debates concerning the future of the planet. The problem arises mainly in the developing countries (Smil, 2000; Raoult-Wack and Bricas, 2001; Gilland, 2002; Braun et al., 2005).

Populations' requirements for food relate to three factors: quantity, quality (nutrition and safety) and cost. The NAE region is concerned with food demand from its own population and from the needs of the rest of the world, especially the less developed countries. This subchapter, 3.2.1, examines the demand from the NAE population. Chapters 4 and 5 of the global IAASTD report discuss the demand from the rest of the world. Subchapter 3.2.2 of this report reviews trade and markets.

Population growth rates, economic growth, rising incomes, and rapid urbanization in the developing economies, greatly influence the global structure of food demand (Cranfield et al., 1998; Collomb, 1999; Rosegrant et al., 2002; Schmidhuber, 2003; Smil, 2005; Griffon, 2006). Because little or no population growth is expected in NAE over the next 30 years, global composition of food demand (e.g., cereals, sugar crops, oil crops, produce, livestock, and fish) will be shaped by rising incomes and rapid urbanization in other parts of the world, particularly Asia.

The nutritional transformation reached many industrialized countries in the 19th century, and advanced to many developing countries in the last 50 years or so. In the United States, the fraction of expenditure on food was 25percent in 1930; less than 14percent in 1970; around 10 percent in 1995. In the European Union (EU 15), the fraction of expenditure on food decreased from 14.7 percent in 1993 to 12.4 percent. (Eurostat).

In NAE, in the last thirty years, diet has changed considerably. A shift towards convenience foods has been driven by changes in demographics and work patterns; fewer people want to spend time making meals from scratch. Town-dwellers eat more meat and more processed products that require more energy (e.g., packaging, pre-cooking, etc.) to be injected into the processing system. Travel and migration foster demand for ethnic and bio-foods; consumer demands are less homogeneous.

Food demand is also influenced by the cultural settings. Shapes, textures, flavors, and colors of foods help define different cultures. Consumption patterns (e.g., cooking styles, meal organization, and eating utensils) are a powerful medium for the construction of cultural identity. Moreover, food is different from other consumer products in that it passes through the body. Man is transformed by it to a greater extent than by any other product and it affects its well-being more directly. Overall food contributes to both sensory and social pleasure and also has considerable effect on Man's sense of individual and collective identity (Fischler, 1990; Raoult-Wack and Bricas, 2001).

Distribution affects food demand. In the agro-industrial age (Malassis, 1997), the food sector consists of Small or Medium-sized Enterprises (SMEs) and large groups. Mass distribution (hypermarket-type food outlets) plays a growing role and influences both food production and food consumption. This paragraph needs more explanation.

North America and Europe are in a situation of "food satiety", with an overabundance of food products on the market. Many foods have excessive fat, sugar, and sodium. Combined with unhealthy lifestyle choices (e.g., less physical exercise), the populations of both North America and Europe exhibit alarming increases in illnesses (e.g., obesity, diabetes, and arteriosclerosis) associated with diet. A number of recent crises (e.g., mad cow disease, listeria, and foot and mouth disease) have exacerbated consumer concerns about food safety. A growing health divide between rich and poor is appearing.

International regulations and social consciousness also impact food demand. , In particular, the Codex Alimentarius develops quality food standards, consumer health guidelines, fair trade practices, and internationally harmonious food standards. Also, society has become increasingly aware of environmental impacts and animal welfare associated with agriculture. These factors This appears to be causing some changes in buying and consumption habits that may decisively influence consumers' willingness to pay a premium on a product they may perceive as safer, produced in ethical conditions, or more beneficial.

In many developed countries, more than 80 kg of meat are consumed per capita every year. This high meat consumption entails a huge cereal and water demand and exacerbates some health problems (e.g., heart disease).All meats do not require the same quantity of vegetal calories for production; 11 vegetal calories produce one calorie of beef or mutton; 8 calories produce one calorie of milk; are 4 calories are needed for one calorie of pork, poultry or egg (Collomb, 1999 cited by Griffon, 2006). At present, in North America and Europe, the share of fish in the total protein consumption is relatively low (see graph 1).

3.2.1.2 Uncertainties for the future

They are uncertainties related to food demand and consumption. Here are some of them.

- <u>Demand</u>.

What will be the consequences of changing energy consumption on standard of living in NAE and food consumption patterns?

To what extent will consumers from North America and Europe adopt a “sustainable development” attitude, reduce their demand for non-season crops, reduce their consumption of meat and fish, reduce their consumption of processed (convenience) food, and consider preparing food a leisure? What consequence will a “sustainable development attitude” have on the share of food and beverages in household expenditures? Will this share considerably increase – at the expense of other categories?

If in NAE, the demand for meat does not change significantly and increasing affluence in other countries creates demand for meat produced in NAE, how will the demand be met? Where will the grains need to produce meat animals come from? Will consumers accept meat produced without animals?

To what extent will the majority of consumers from North America and Europe want to see the share of expenditures devoted to food and beverages continue to decrease, and therefore require food at cheap prices?

How fast will food diversification take place and spread in Eastern Europe?

Will food continue to be an instrument of cultural identity in many countries? Will food become completely standardized? Will local products disappear?

- Consumption.

Will meat consumption decrease as a whole, or will there be shifts towards white meat, pork and fish? To what extend will the protein demand increase and how will the demand be met? Trough increased production or imports? To what extend will there be a development of “meat and fish without animals”?

Will there be growing product diversification (i.e. food for people interested in food properties, cheap food, food produced at low environmental costs, fully prepared food, unprepared food, etc.) or reduced product diversification due to lower incomes?

- National and international food regulations.

Will it be possible to coordinate all food standards work undertaken by international governmental and non-governmental organizations?

How strict will international regulations be and will there be controls to protect the health of consumers?

- Health.

To what extent will consumers gain knowledge about the relationship between food and health, and require tailor-made food that meets individual dietary needs/profiles, functional food, and food with high safety standards?

What is the risk of reducing the populations’ immunity in the long term through the provision of increasingly asepticized food? What is the risk of creating resistant pathogens? What is the risk of

preventing the natural protection of food by its natural competitive flora? How will the balance between hygiene and too much hygiene be found?
How will improvements in analytical methods influence consumers' preferences for residue-free and environmentally friendly products? Will functional foods (EUFIC website) gain an important share of the market? Will the trend towards higher share of organic products continue as observed in Europe during the last years (EEA, 2005)?
What are the risks of terrorism related to food?

- Packaging and distribution.
  How will food packaging evolve to use in the direction of sustainable development?
  How will be the development of food purchase through internet? How will home delivery services evolve? Will local outlets develop?
  How to strengthen again the relationship between farmers and consumers?

3.2.1.3 Consequences for AKST

To achieve the goal of "nutritional security", strategic choices have to be made in the economic and social domains (lifestyles), and in the domains of international and national food regulations and modes of distribution.

According to the priorities chosen, AKST will differ. For example:

- To produce safe high quality food, plant raw material for food and feed will need to be recognized. Factors determining the shelf life of both fresh produce and processed food, or the stability of plant raw materials after harvest will also be important (Plants for the future, 2005).
- If functional food is developed, then there will be a need for analysis, measure and control, biotechnologies, biochemistry, biology, medicine… Protéonomique (as for drought resistance) will also be very useful (Technologies clés 2010, 2006).
- To create food targeted at specific consumer groups or needs, identification and characterization of the molecular structure of plant polymers, as well as the characterization of plant metabolites will be very useful. Also molecular breeding and transgenic approaches. There will need to be an interdisciplinary approach bringing together plant scientists, doctors and nutritionists (Plants for the future, 2005).
- If the accent is on food quantity rather than food quality, than genomics will be very important.
- If the accent is on food quality, than functional genomics and systems biology needs to be developed
- If allergies develop at high speed, than special work will need to be developed.
- If transformation is a priority, than microbiology will be useful to look at the nutritive qualities of food.
- If there is a market-led, globalized world, food traceability, prevention of bioterrorism and identification of sabotage will be very important. There will be a need to develop nanoscale systems, microsystems technologies, sensors…

- To produce more meat, a major effort will have to be made to produce in high quality, sufficient and sustainable feed using biochemical tools and biological assays, molecular mechanisms to decipher the plant-pathogen interaction, assessment of macro- and micronutrient characteristics and germplasm. (Plants for the future, 2005)
- To produce bio-plastics and biomaterials and use renewables, biotechnologies should be very useful.
- Etc.

3.2.2 Policies, trade and markets

3.2.2.1 Ongoing trends

Agricultural policies.

Among the major policy developments related to agricultural policies and trade that will determine the future international competitiveness of NAE agriculture and agri-food industries and the sustainability of rural regions, the following are of paramount importance:

- the reform of the EU Common Agricultural Policy
- the NAFTA trade policies;
- the negotiations under the World Trade Organization (WTO);
- the projected population growth, combined with the greater prosperity of some social groupings;
- the relationship between economic growth and environmental degradation, and the compliance with international, regional and national environmental directives (such as the Kyoto Protocol; EU water directive, the former mineral accounting system in the Netherlands).

There are three levels of policy frameworks: international (i.e. WTO, Kyoto agreement), continental-regional (i.e. CAP of the European Union, NAFTA), national / governmental. At all levels, there is a broad range of agricultural policies which relate to different types of institutional support that farmers may be eligible to receive if they comply with specific agreements. Aid, subventions, tax reductions, special tariffs etc. can be given to compensate farmers for the loss of income or price gaps, for producing certain types of crops, for taking care of the landscape, for not cultivating certain areas, for using new agricultural techniques or practices that are deemed socially or environmentally valuable by the public authorities. Agricultural policies also relate to the conservation of natural resources, to rural development, to agricultural credit, nutrition and international trade.

In the EU, the general scheme of the Common Agricultural Policy aid includes both market supporting policies in their different variants (viz. area-based subsidies, subsidies for cattle rearing, and subsidies on production, transformation and consumption), agri-environmental aid - some of which are directly related to specific alternative agrosystems or their practices - and structural policy aid (e.g. farm modernization and improvement, easier access of young people to farming). The Common Agricultural Policy (CAP) reform proposed by the Commission in 2002 introduced a major change in the income support regime: the decoupling of direct payments from production with potentially marked effects on land use. Other important reform measures have been the introduction of obligatory, modulated payments to generate funds for agri-environmental and rural development programs, and reduced price support for dairy (partly compensated by direct payments). The intention behind these reforms has been to increase market orientation of EU agriculture (through decoupling). Concern for less favored agricultural regions, has led to a complex “policy cocktail” (Britz et al., 2006). Several studies conclude, that the effect of decoupling will be that cereal and silage maize acreage as well as ruminant production in EU-15 will most likely decline. It can be expected that the economic resources devoted by the EU to rural development, food safety and environmental protection will further change.

At national level, in North America, we find that the United States, Canada, and Mexico have made some important changes to their agricultural policies over the past several years, but much remains to be done. Heeding the experience of the late 1990s and early 2000s, when commodity prices sank to unusually low levels, all three countries have institutionalized income supports that provide additional assistance to producers when commodity prices (or net farm revenues, in the case of Canada) decline. Each country also has made noteworthy reforms in other areas of agricultural policy: Canada has crafted new approaches to food safety and food quality, the environment, the role of science in agriculture, and the overall reinvigoration of the agricultural sector; and the United States is proceeding with a comprehensive buy-out of tobacco quotas while expanding its efforts in conservation, placing greater emphasis on land continuing to be used for production rather than land retirement. However, in all three countries, fiscal resources have been sufficient in recent years to allow agricultural policy to proceed in a direction that is not altogether different from its previous course. In the future, fiscal constraints could conceivably affect the size and content of agricultural policies in each country (Zahniser et al., 2005).

At national level, the interactions between ministries or states define the policy frameworks. It can go from a spectrum of little interaction to great integration. At one end, regulation is fragmented and there is little interaction between different ministries; a different ministry deals with health and food safety, another with the environment, another with agriculture, another with transport and distribution systems; inter-ministerial issues tend to feature fairly low down the agenda; each ministry has a limited knowledge of the systemic needs of a regionally based agri-commodity value-chain. At the other en, there is synchronization of public programs across the whole chain by a number of different agencies; regional authorities bring together in one region independent policy interventions so as to have the greatest impact on the regional economy; nature is planned.

Agricultural trade and markets.

Globalization means the changes in the world economy that tend to create a world market for work, capital, goods and services. It is not a new phenomena but it has markedly increased over the last thirty years. The decrease of cost of transportation and costs of communications has largely contributed to it. Globalization has not taken place in a uniform way. As a result of globalization the distance between production locations and markets has increased, thus also trade and travel. Globalization has very much affected food consumption: People from sub-Saharan Africa or from the

Lowlands of south-east Asia eat bread made from wheat which they do not produce; NAE citizens drink coffee and tea coming from tropical countries, and products such as fruits and vegetables can be eaten all year round. Globalization has also increased competition. Certain agricultural products, for example cotton, are produced in both developed and developing countries and competition is strong. As shown in table 3, in 2002, the share of agricultural products (food and raw material) in total merchandise was 9.3 percent in value (compared to 11.7 percent in 1995), and its share in primary products was 42.5 percent[1]. For many years, the USA has been the main agricultural trader. Mechanization, high use of fertilizers, subsidies and governmental food aid to developing countries have helped the farmers to keep this competitive advantage. Over the last few years, countries like Canada, Australia, Argentina and the European Union have started to erode this position of the US. More recently, Brazil has come into the game (see Table 4).

Table 3: Share of agricultural products in trade in total merchandise and in primary products in NAE regions, 2002

	Share of agricultural products in trade in total merchandise (2002)		Share of agricultural products in trade in primary products (2002)	
	Exports	Imports	Exports	Imports
World	9.3	9.3	42.5	42.5
North America	10.7	6.2	59.9	35.1
Latin America	19.3	9.8	48.7	47.4
Western Europe	9.4	10.2	57.6	48.5
C/E, Europe/ Baltic States/ CIS	8.9	10.2	22.1	43.0
Africa	15.8	15.9	22.3	59.5
Middle East	3.5	13.4	4.7	69.0
Asia	6.6	9.5	48.1	36.0

Source : WTO

Table 4: Intra and inter-regional trade 2002 (in percentage)

	North America	Latin America	Western Europe	PECO, Baltic CIS	Africa	Middle East	Asia	World
North America	40,3	16,1	17,9	0,7	1,2	2,1	21,5	100
Latin America	61,3	15,4	12,6	1	1,2	1,3	6,7	100
Western Europe	10,2	2,1	67,3	6,3	2,5	2,6	7,8	100
PECO, Baltic,CIS	4,5	1,9	56,2	25,5	1,2	2,4	7,7	100
Africa	17	3,3	50,9	0,7	8,1	2,3	16,8	100

[1] Source : WTO. http://www.wto.org/english/res_e/statis_e/its2003_e/its03_bysector_e.pdf

Middle East	15,5	1,4	16,4	0,8	3,8	7,1	47,4	100
Asia	24,3	2,4	16	1,3	1,6	3	48,9	100
World	21,3	5	40,6	4,5	2,1	2,7	22,2	100

Source : OMC, World Trade Report 2003,
http://www.wto.org/english/res_e/statis_e/its2003_e/its03_bysubject_e.htm

Agricultural trade is an important source of revenues for farmers and countries. Beyond this revenue component, trade is based on two types of demands: a demand by regions which do not produce the product(s) (for example coffee to NAE), a demand by regions which produce the products but in insufficient quantities. This second demand is the most important one; in value terms, the main agricultural products that are exported are bovine meat, wine, pork meat, wheat, poultry, maize, sugar, soybean, coffee, palm oil, cocoa, cotton and rice.

3.2.2.2 Uncertainties – questions for the future

A number of uncertainties and questions for the future can be raised relating to trade and policies:

(1) How will the EU develop, will it continue to expand with new member states (EU-30, EU-40) or will it divide? What will be the consequences of changed development policies and stronger collaboration with the Southern Mediterranean Sea countries and Russia on policies, trade and agricultural systems of NAE? What political and economic coalitions will develop outside NAE, and how will that affect agricultural markets and trade?

(2) How will increased international co-ordination in areas such as trade, commercial and consumer protection law, defense and security develop and affect policies and trade?

(3) What effects will demographic trends have on future policies? Will current trends of stagnating and declining populations in large parts of NAE continue? Can out-migration from more remote rural areas to urban centers be halted? Will there be sufficient incentives to attract investments in rural areas? In which sub-regions within NAE will agriculture vanish?

(4) Will migration of skilled labor within NAE be permitted, where will the main migrations take place, and will these help to increase economic viability of rural areas? To what extent will urban commuters and new well-to-do residents be able to contribute to sustainable rural development?

(5) Will agriculture and rural areas in NAE develop sufficient adaptive capacity to overcome threats and risks imposed by future environmental change (including climate change)? Will more stringent environmental regulations be agreed upon, together with stronger internalization of externalities. How will that affect agricultural production and production orientation in NAE? How will the impacts of climate change in other world regions affect changes in policies and trade of NAE?

(6) How will a WTO extension of the scope for the exchange of goods, services, labor and capital between countries work on agricultural systems? What will happen if almost all trade barriers for agricultural products and subventions will be eliminated? To what extent will that increase environmental risks?

(7) To what extent will producer subsidies further decline – and how fast? And, how will the money saved in that manner be spent? Will it be invested to alleviate poverty and (thereby) reduce environmental degradation, or other challenges?
(8) How will the demand for the major agricultural products of the region evolve?
(9) How will the share of agricultural products (food and raw material) in the NAE region develop – will it further drop? How will intra- and inter-regional trade evolve in the future?

3.2.2.3 Consequences for AKST

There is thus a large number of possible future pathways for agricultural policy and trade at national and supranational level within the NAE and outside, which in turn will generate different types of farming and agricultural systems.

If there is a more ecosystem-oriented future, in which externalities will increasingly be internalized, e.g. by progressive decoupling subsidies from production, more stringent environmental regulations and introduction of special taxes, and different pricing of products, then AKST should be organized to better support the development of more environmentally friendly and resource-use efficient technologies and production systems, including all kinds of "green technologies" and supportive policies that contribute adoption of such technologies to reduce resource use and emissions from agricultural activities. Such direction might certainly lead to more integration of agricultural and environmental sciences and more cooperation with the various interest groups involved in natural resource management at different levels. Such AKST would still be strongly oriented towards feasible technical solutions, and require longer term planning and investments.

If we live, however, in a market-led future, the influence of consumers and their preferences on demand for research would become larger: issues like food safety (labeling, traceability, etc.) would be in the centre and require more comprehensive attention by AKST than currently. Such AKST would be organized differently, whereby multi-national companies might have the lead. In a future that would favor regionalization and local approaches, social equity, reduction of income disparities between urban and rural areas, and more power and political influence to local people, the requirements for AKST would again be very different (Kahiluoto et al., 2006). Such a future would also very likely imply changes in attitudes towards consumption and diets, e.g. towards less meat. Though objectives, organization and funding of AKST have already drastically changed over the last 10 to 20 years (OCED, 2002; Van Keulen, 2007), further policy adjustments would be required to support development of mechanisms for increased involvement of stakeholders, and develop a more demand-driven AKST that is increasingly built on interactive knowledge networks (OECD, 1999), and serves the multiple development goals of rural areas, e.g. through supporting the development of multi-functional agricultural systems. Some recent trends, like special payments for rural development would need to be intensified. The AKST required in such future, would also need to support the realization of full participation of stakeholders in decisions concerning design and implementation in agricultural and environmental policies.

Such might be realized by harnessing the power of ICT and appropriate databases with new tools for interactive analysis of alternative land use and policy options for sustainable regional development (Di Giorgio et al; Van Ittersum et al., 2004). Furthermore, the AKST would also seek solutions through behavioral changes. AKST would also need to generate the information required to compare the environmental and social effects of integrated, local versus more specialized, world-market oriented farming systems. The type of AKST required would be fairly interdisciplinary and oriented towards locally tailored solutions and their implementation.

3.2.3 Agricultural systems and farming systems

3.2.3.1 On going trends

The term agricultural system (or agrosystem) is a concept that has been in continuous evolution over the last few decades. The great number of elements involved in its definition and their interrelations are partially responsible for this evolution. An extended definition is the one given by Dillon and Hardaker (1993). According to them an agricultural system is “the system of production used by a farmer as specified by the technology used, resources available, preferences held and goals pursued within a given agro-ecological and socio-economic environment”.

In the arena of discussion about the agricultural systems in Europe, references to the dichotomy between traditional or mainstream systems, on one side, and emerging or alternative ones, on the other side, are frequent. However, there is no clear consensus about the scope of these concepts. As a first approach (Grudens Shuck *et al.*, 1998), alternative agricultural systems could be those including non-traditional crops, livestock, and other farm products; services, recreation, tourism, food processing, forestry, and other enterprises based on farm and natural resources; unconventional production systems such as organic farming (…); or direct marketing and other entrepreneurial marketing strategies. A European prospective analysis of agricultural systems (EU-IPTS, 2004) show that the principal alternative agrosystems coexisting with mainstream agriculture are organics farming, integrated production, conservation agriculture and agriculture under guaranteed quality. Other, less widely used agrosystems in the EU include precision agriculture, short-chain agriculture, urban agriculture, *agriculture paysanne*, and permaculture.

3.2.3.2 Uncertainties

Will prices and subsidies lead to the broadening of agricultural systems, or on the contrary to their reduction? What role will the transfer of existing technologies and the development of new ones play? How will improved analytical methods, increased traceability and reduced risks of fraud in the agricultural industry develop? Will the dissemination of biotechnology facilitate the emergence of new alternative systems? What could be its impact on precision agriculture, for example?

3.2.3.3 Consequences for AKST

The adoption of a new agricultural production system involves some changes in the way holdings are managed; this makes the presence of a science and technology transfer system capable of meeting the new requirements of farmers especially important. This factor is therefore strongly influential on the choice of production systems involving substantial changes, as is the case with organic farming —which recovers traditional practices— and conservation agriculture —which experiments with new practices. The influence of this factor on the adoption of agriculture under guaranteed quality is dictated by marketing and distribution criteria; in fact, this agrosystem facilitates a better knowledge of consumers demands and hence their meeting.

Farmers' willingness to make the transition from mainstream agricultural practices is not enough if they do not have access to the technology required. Hence, this factor is highly influential on the choice of those agrosystems whose practice calls for the use of new technologies (*e.g.* integrated farming and conservation agriculture). The choice of organic farming involves the use of natural resources, thus requires good knowledge about soils, biological pest and disease control, organic fertilizers. If conservation agriculture develops not only in large farms and with specific production types (cereals, wood crops), but also in smaller farms, substantial investments in special machinery will be necessary. Production and distribution of AKST must be carefully looked upon if alternative agricultural systems are to be developed.

3.2.4 Labor

3.2.4.1 Labor ; gender dynamics: on-going trends

The traditional hierarchy of agricultural areas around villages, located around central towns and at a certain distance from big cities, was relatively stable for large parts of NAE's agricultural regions and a relatively constant basis for the existence of rural communities, but it is not the case anymore. Recently, there has been a backward flow from the larger to the medium sized cities and rural villages, especially in EU15, involving a combination of retired persons, distance workers, and part-time farmers. The distinction between rural and urban populations is starting to blur.

Farms tend to close down or to be bought, resulting in increasing unemployment in rural areas. Farmers leave their farms or combine farming with another job. On the other hand, the larger farmers no longer find adequately skilled personnel. Better educated and skilled persons seek other opportunities, because the hard and dirty work in agriculture is unattractive. This is also the reason why many farmers are not married and farms are dying out. Complex worldwide patterns of mobility and migration are causing rapid changes in the agricultural workforce. For example, in Spain, workers from the new member states are starting to replace North Africans (FFRAF report, 2007).
The growth in the number of farms and ranches with Hispanics as principal operators is 51 percent for the 1997-2002 period in the United-States ((Dohm, 2005).

More than half of all farm holdings in the EU-15 are owned by farmers above 55 years of age, and one out of three farms are owned by farmers above the age of 65, only less than one of twelve of all farm holdings in the EU-15 is owned by farmers under the age of 35 years (1999 statistics from Eurostat).The economic transformation in countries of Central and Eastern Europe as well as Asia has resulted in a diverse picture of change in agricultural labor use. According to the data available ageing of agricultural population can be observed in certain countries like Estonia, the Czech Republic and the Slovak Republic. For the other countries, the relative importance of the oldest age group fell in the period up to 2000 (IAMO, 2003). The average migration rate varies between an emigration of up to 8 percent of the agricultural labor force (Estonia) and an immigration of up to 10 percent (Georgia) (Herzfeld et Glauben, 2006) .

Success in agriculture has been based on production skills for at least 10,000 years. Producers knew their crops and animals and understood seasonal cycles and the need to adapt to climate and pest unpredictability. Knowledge was learned by transfer from parent to child and from neighbor to neighbor. Now, farmers need a larger range of skills. They need relational skills to cooperation with input suppliers, particularly suppliers of knowledge, with markets, particularly in reaching emerging markets, and with fellow producers in new models of cooperation. They need mechanical and technical skills, financial management skills, and of course production skills (Butler-Flora, 1998). Nevertheless, there are still many poorly educated farmers in North America and Europe. For example, observing the stock of education among the agricultural population, it can be stated that particularly high shares of those active in agriculture in Poland and Lithuania have no more than a primary level educational qualification. On the other hand, in Estonia and Hungary, almost 10 percent of those active in agriculture have a university qualification or equivalent (IAMO, 2003).

Today in North America and Europe, most farms and ranches are still small (Dohm, 2005). But farms are getting larger and more concentrated. Increasingly, farmers contract with large business operations that purchase the farmers' crops and animals and produce the food put on grocery store shelves; they have a guaranteed buyer. Other farmers sell their products themselves elsewhere, such as on commodity exchanges.

3.2.4.2 Organizations: on-going trends

Farmers and their associations. There is great variation in influence among farmer organizations. In North America and most of Western Europe, some groups (e.g., cotton or apples in U.S.) are well organized politically and have a platform to directly influence resources that support their commodity. However, most crops are not well organized and have relatively little political or economic influence.

Inputs enterprises. This group includes companies that supply seed, fertilizers, pesticides, and other components necessary to produce crops. Within the last fifteen years, agricultural inputs have become largely concentrated within a small number of companies. Less than ten multinational companies control the lion's share of the global pesticide market and the global seed market. Concomitantly, these companies also control nearly all of the private sector agricultural research.

Processing/marketing enterprises. These companies buy agricultural products and process them for the marketplace or make them available to consumers without further processing. The largest of these companies are multinational in scope and wield tremendous influence on agriculture and AKST. For example, Frito-Lay controls about 40 percent of the snack food market worldwide and is the largest snack food company in more than thirty countries. If the company needs a certain type of agriculture product or refuses a certain type of commodity, agriculture and AKST will be revised to accommodate them. Even though the genetically engineered NewLeaf potato was a valuable tool for pest management, potato farmers in the United States quit growing them largely because MacDonald's corporation told their suppliers not to use NewLeaf potatoes in their french-fries.

Media. The media has a powerful influence on consumer preferences; consumers reflect their desires in the marketplace and the polling booth. For example, the tremendous growth of the organic market is largely driven by the media depiction of pesticide risks; whether or not the risks are accurately depicted is largely irrelevant. The marketplace determines what agricultural products will be produced and how they will be distributed. Elected officials determine resource allocation and a broad range of policies and regulations affecting agriculture and AKST.

Agricultural universities/colleges. Universities and colleges conduct most of the public-sector research. Researchers typically have a long career with a single institution. Hiring decisions by the university or college can have substantial implications for the direction and progress of AKST.

Although these actors have been presented individually, their influence is a much more complicated interaction. For example, a processing company may use the media to promote cotton as a clothing material. As consumer demand for cotton increases, cotton producers need to increase productivity. The university recognizes a need for a cotton AKST position to help cotton producers achieve these goals. The companies that provide inputs for cotton production introduce new plant varieties and chemicals that the cotton researcher manipulates into a more efficient production system. The cycle repeats as the media report that cotton production degrades the environment; the processing company demands more environmentally-friendly cotton; the university turns its attention to better production methods; the input companies produce less dangerous chemicals; etc.

The increasingly integrated global trade environment leads to convergence in dietary preferences and patterns across countries, and this, in turn, is stimulating the ongoing structural changes in food processing and retailing. Thus, to a large degree, multinational food companies are the cause *and* the consequence of the evolving global food system. By their nature, these multinational food companies transcend national borders and give rise to greater interdependence of economies and larger trade flows. To manage and harmonize product flows along the food chain, they also are at the basis of vertically co-coordinated marketing systems. The purpose of these systems is to ensure that product and process requirements for food products are met at all stages of the supply chain, thereby reducing transactions costs. Thus, evolving globalized systems of food production and retailing are becoming an element of increasing importance with respect to the integration of developing countries into global food markets[2].

3.2.4.3 Uncertainties for the future

They are uncertainties related to labor and gender. Here are some of them.

- Farming systems. What is the economic viability of family farm systems? Will there be a growing number of large, capital-intensive farms? Will specialty farms with an agricultural niche develop quickly?
- Farmers' age and gender. In the EU, will there be enough young people interested in farming and capable of identifying the production methods best suited to the local conditions, of respecting the environmental, animal welfare and public health standards, of reaching a suitable income in the long run? Will there be administrative and financial measures to facilitate young farmers' training and installation? Will measures be taken to formalize women's status in the farm enterprise? Will there be an increasing number of farms run by women?
- Employment. How will structural unemployment in agriculture be tackled, especially in the Eastern European countries? Will public intervention be sufficiently synchronized to solve unemployment in the rural areas? Will the educational level of farmers and the creation of non-farm jobs in rural areas be looked upon simultaneously? How will pluriactivity of men and women in rural areas be taken into account? Will it have a positive or a negative influence on benefits and resources available to farmers?
- Migration. Will political leaders of NAE allow people from outside NAE to move to rural areas for seasonal work?
- Education, skills. Will there be training courses to encourage farmers, especially the younger ones to become entrepreneurs who can compete in global agricultural markets, use e-commerce opportunities as a commercial tool for worldwide trade, measure environmental impact, develop a multifunctional farming respecting the environment, etc.?

3.2.4.5 Consequences for AKST

Decisions related to labor will have consequences on AKST. For example, if migration is permitted and people from outside NAE move to rural areas for seasonal work, the need for research on picking up crops, etc. will not be great. On the other hand, strict migration policies will lead to research on productivity improvement.

[2] OECD – FAO AGRICULTURAL OUTLOOK: 2005 – 2014. Highlights 2005. http://www.oecd.org/dataoecd/32/51/35018726.pdf

Another example: the demand for mechanization, computer assistance and automated responses will also not be the same if NAE is able to attract young, well-trained, entrepreneurial farmers, or if farmers' population continue to age, is not very well trained, and labor is not available.

3.2.5 Climate change and variability

3.2.5.1 On-going trends

Agricultural systems, forestry and fisheries are - to a large extent - sensitive to and can be strongly affected by climate change and variability. Concurrently, land use and land use change, particularly agricultural and forestry activities can exert a marked influence on the climate. There is now unequivocal evidence that the Earth's climate has demonstrably warmed since the pre-industrial era, and that most of the warming over the last 50 years is very likely to have been due to increases in greenhouse gas[3] concentrations in the atmosphere. Atmospheric concentrations of these gases are at their highest recorded levels, and continue to increase, mainly due to combustion of fossil fuels, agriculture and land-use change. It is generally not the changes in the means of weather variables that impose risks, but the increase in frequency or intensity of extreme events that pose challenges to agricultural systems The full appearance of many of the impacts of these changes is delayed by inertia in the climate system and in the behavior of ecosystems (IPCC, 2007).

While the impacts of a changing climate are complex, agriculture has demonstrated considerable capacity to reduce its emissions and adapt to climate change impacts by developing appropriate agricultural practices and systems. While mitigation measures clearly need to continue to be taken to reduce emissions from agriculture, some changes are now inevitable and will require adaptive responses. Agricultural climate change response options are often taken in the context of other stresses and objectives through a range of technological, behavioral and policy changes.
To manage current climatic risks and increase resilience to likely future changes mitigation measures such as cultivation practices that increase carbon sequestration in soils, manure management and reforestation are expected to continue. The earlier and stronger the cuts in emissions, the quicker concentrations will approach stabilization (although the effects of such measures on the climate will only emerge several decades after their implementation). However, regardless of these mitigation measures, global warming will continue and associated climate changes during the 21st century are expected to exceed any experienced in, at least, the past thousands of years over which agriculture has been practiced in the NAE region. Adaptation will continue to be an important complement to mitigation as a policy response to climate change.

While ecosystem services and goods (including agriculture) will face a number of climate change - induced risks (IPCC, 2001; Easterling III et al., 2004), there will continue to be new opportunities and potential benefits (Roetter & Van de Geijn, 1999; Carter, 2007). Throughout human history people in

[3] Greenhouse gases and clouds in the atmosphere absorb the majority of the long-wave radiation emitted by the Earth's surface, modifying the radiation balance and, hence, the climate of the Earth. The primary greenhouse gases are of both, natural and anthropogenic origin, including water vapour, carbon dioxide (CO_2), methane (CH_4) nitrous oxide (N_2O) and ozone (O_3), while halocarbons and other chlorine- and bromine-containing substances are entirely anthropogenic.

regions all over the world have learned to cope with climate variability and extreme climatic events (Lamb, 1995). However, experience with such adaptive measures differ widely among regions, countries and continents – and so do the risks involved (IPCC, 2001; Kabat et al., 2006). It is worthwhile to mention that large parts of North America and Europe in which agriculture takes place distinguish themselves from other world regions: they are located in the temperate climatic zone characterized by favorable agro-climatic conditions, i.e. neither too dry nor too hot – with ample, well-distributed rainfall, and relatively mild winters. The NAE region also includes areas in which currently climatic risks such as drought, frost and flood play a considerable role, but the risk prone areas have a smaller share than in other regions. Drought prone regions include large parts of California and the Mediterranean, while frost risk and low temperature limit agricultural activities in large parts of Canada, the Nordic European countries and Russia.

The highest emissions of greenhouse gases from agriculture are generally associated with the most intensive farming systems whereas some of the low input farming systems currently located in marginal areas may be most severely affected by climate change (IPCC, 1997; 2001). Agriculture contributes to the emissions methane and nitrous oxide. Land-use change also provides a significant contribution to carbon dioxide emissions, but that from fossil fuel use for machinery and heating is considerably larger (Rosenzweig and Hillel, 2000; UNESCO, 2006; cross-reference to chapter 2). In the NAE region, GHG emissions from agriculture are in the range of 7-20 percent of total country emission inventories (in terms of radiative forcing). Latest estimates suggest that agriculture accounts for 48 percent of CH_4 emissions and 52 percent of N_2O emissions in the EU. The role of agriculture - both as a source of and as a sink for greenhouse gases (GHGs) - varies significantly across the NAE region because of the different agricultural policies adopted and the different agricultural practices implemented. Emissions also come from changes in forests and other woody biomass stocks, forest and grassland conversion, and from the soil (UNESCO, 2006; IPCC, 2000). Insert FIGURE (GHG emission trends – missing) and TABLE [sources of emissions: UNESCO 2006 / IPCC 2007 and IPCC, 2000 Special report on LULUCF - missing.] The major sources of methane emissions are enteric fermentation and manure management. Nitrous oxide comes from the breakdown of fertilizer and from manure and urine management from livestock production.   There is a clear trend across the whole NAE region, that of markedly increased recent efforts of replacing fossil fuels with liquid bio-fuels (IEA, 2006, see, next subchapter 3.2.6). Government supports already heavily this development by paying subsidies. Such development will have significant impacts on emissions. Associated land use changes will have also have consequences on water availability and biodiversity (Fresco, 2006).

Climate change effects on agriculture (including forestry and fisheries) are already visible in different parts of NAE (IPCC, 2001). For instance, during the 20th century, the thermal growing season (with daily mean temperature above 5°C) has lengthened by about 10 days in southern Finland (Carter, 2007). This lengthening is directly attributable to spring and summer warming and also coincides with a decline in snow cover duration.

INSERT (Figure on extreme year 2003 : deviation summer temperatures as compared to long –term average in EUROPE – from JRC – MARS project)

INSERT (figure on adaptation – based on B Smit and O Pilifosofa, 2001, 2003)
Adaptation in the climate change issue: Relationships between climate change, exposure, vulnerability and adaptation – policy responses and mitigation

3.2.5.2 Uncertainties for the future

How might GHG emissions develop?

There is a number of uncertainties involved in predicting the future development of GHG emissions. Some of the uncertainties relate to the emission drivers such as the unknown speed of economic development, energy supply and use as well as consumer behavior around the World (EU, 2007; Sachs, 2006). Other uncertainties relate to the operation of the carbon cycle which is crucial in translating emissions into concentrations as well as the magnitude and behavior of vulnerable carbon pools (UNESCO, 2006): Natural carbon pools could well turn into sources as global warming and deforestation continue. Some of the most vulnerable pools are: (i) carbon in frozen soils, (ii) carbon in cold and tropical peatlands, and (iii) biomass-carbon in forests vulnerable to fire and insect infestations. Within the time horizon for our assessment (up to 2050) most of the IPCC emission scenarios are indistinguishable because of the inertia in our economic and technological systems. Furthermore, and as a result of this and the inertia in the climate system, projections of the climate in the NAE region until 2050 are quite similar

How might the climate in NAE change – and what are the possible consequences for agriculture?

During the 20th century, most of Europe has experienced increases in surface air temperature – amounting to 0.7 to 0.8 ^{o}C in annual mean temperature over the entire continent. Simulations indicate that annual temperatures over Europe will continue to warm at a rate of between 0.1 and 0.4 ^{o}C decade, whereby the greatest increases are expected over southern Europe and north-east Europe (Parry, 2000). Annual precipitation is expected to increase by 1-2 percent decade^{-1} over northern Europe; there will be little decrease (at maximum -1 percent decade^{-1}) over southern Europe, and hardly any change over central Europe. These changes will lead to different consequences in the various sub-regions of Europe. In North America, it is expected that trends of increased temperatures and changes in the frequency of heavy precipitation over most land areas will continue. Furthermore, extreme events are likely to increase in frequency and severity (IPCC, 2007).

Generally, warming in NAE will lead to a northward expansion of suitable cropping areas, a reduction of the growing period of determinate (plants develop through a pre-determined set of stages, from germination to ripening) crops (e.g. cereals), and an increase for indeterminate crops (continue to grow as long as environmental conditions are favorable) (e.g. root crops). Possible negative effects can in most cases be counteracted by choosing crops /crop cultivars that are better suited to the changed climatic conditions. While an increase of atmospheric CO_2 concentrations will directly enhance plant productivity and increase water use efficiencies (Rötter & van de Geijn, 1999; IPCC, 2001), the expected frequency of extreme weather (flooding and droughts) will possibly offset the potential benefits – this applies to Europe (Olesen and Bindi, 2002) as well as to Canada and the United States (Lemmen & Warren, 2004; Reilly et al., 2003; Easterling et al., 2004).

While it is generally expected that productivity of European agricultural systems will increase (Olesen & Bindi (2002)), because of the yield- and water use efficiency enhancing effects of higher CO_2 concentrations, it is not clear how these beneficial effects will be reduced or even reversed by higher frequency and intensity of adverse climatic phenomena (more frequent dry spells in early summer, e.g. in Nordic countries). In NW Europe, climate change may lead to positive effects for agriculture by triggering the introduction of new crop varieties and species, higher crop production and expansion of suitable agricultural land area. However, climate change may have effects on infectious diseases of plants (Chancellor and Kubiriba, 2006) and there may be a higher demand for plant protection and for measures to reduce nitrate leaching and turnover of soil organic matter (Olesen & Bindi, 2002). In Southern Europe, more disadvantages are likely. Estimated increase in water shortage and extreme weather events may result in lower yields (and harvest indices), higher yield variability and a reduction of suitable areas, for traditional and region-specific crops. Such effects will most likely aggravate the current trends of intensification of agriculture in NW Europe and extensification in the Mediterranean and SE parts of Europe. Also in the US and Canada future climate change is likely to result in shifts toward higher latitudes and elevations in the suitability for (current) agricultural production systems. Moderate increases in temperature (1 to 3 ^oC) along with elevated CO_2 and changes in precipitation will have small beneficial impacts on crops such as wheat, maize and cotton. Further warming, however, will probably have increasingly negative effects (Lemmen & Warren, 2004; Easterling et al., 2004). Some authors have reported positive crop yield responses to temperature increases of about 2^oC, but negative yield responses at increases more than 4^oC. Higher temperatures and warmer winters could reduce winterkill of insects and broaden the range of other temperature-sensitive pathogens (Rosenzweig et al., 2000). Regarding different findings with respect to changes in crop yields in response to climate change in the US, Reilly et al. (2000) found yield gains for the lake states, mountain states, and the Pacific region, whereas yield losses were predominant for the southern Plains, the southeast delta and Appalachia. Looking at the various climate change impact studies on agriculture, it is still not clear whether North America as a whole will be will be affected negatively or positively. Part of the reason for this is different assumptions on agriculture's adaptation potential - which is a function of the different exposures (wide range of climatic zones) to climate change, vulnerabilities and effectiveness of (planned) adaptation options. The beneficial effects of elevated CO_2 concentrations on plant growth and yield reported in the literature referring to open top chambers (at 560 ppm major food crops showed around 15-20 percent higher yields) and reproduced in regional impact (simulation) studies by various crop models (IPCC, 1995, 2001; Roetter & van de Geijn, 1999) have recently be confirmed by results from Free Air Carbon Enrichment (FACE) studies. The growth enhancing effects of the increasing CO_2 concentrations (currently around 380 ppm – and at an annual growth rate of 2 ppm) on crops may mask much of the negative effects of climate change on agriculture. Agriculture will likely be vulnerable to higher frequency and severity of extreme events – as was demonstrated during the summer 2003 European heat wave that was accompanied by drought and reduced maize yields by 20 percent, representing the largest yield decline since the 1960s.

Climate change impacts in relation to mitigation and adaptation in NAE

There is broad consensus among scientists that climate change impacts on agriculture will be significant. Different types of impact can be identified:

- Impacts of higher carbon dioxide concentration: While it is assumed that about 10-20 percent of the increased crop productivity (doubled over the last 100 years), may be due to the growth-enhancing CO_2 effect, it is unclear whether this will continue and to what extent this fertilization effect will be reduced by combinations of multiple biotic (pests, diseases) and abiotic (drought, heat) stresses.
- Impacts of higher temperatures: In the highest latitudes, higher temperatures should lead to higher yields using new cultivars and species. Higher temperatures will increase evaporation from plants and soil, worsening the water problems that already afflict the hotter (southern) regions of NAE. Agricultural pests and diseases may increase in certain areas, along with human diseases that already threaten rural populations. Exceeding crop-specific high temperature thresholds may result in a significantly higher risk of crop failure in the southern parts of Europe and the US, while the northern regions may be able to grow a wider range of crops than is currently possible, due to a warmer and longer growing season. Crops which are presently grown throughout Europe experience more positive impacts in northern Europe compared with southern Europe. In regions where crop production is affected by water shortages, such as in southern Europe, increases in the year-to-year variability of yields in addition to lower mean yields are predicted.
- Impact of changes in precipitation: larger year-to-year variations in precipitation are very likely. It is likely that precipitation will increase over NAE (high-latitude regions) in both summer and winter. Northern Hemisphere snow cover, permafrost, and sea-ice extent are projected to decrease further In many sub-regions, one serious impacts will be experienced by changes in the timing of water availability – more precipitation falling as rain in winter, earlier snow-melt, higher risk of flooding in winter and/or spring, and less precipitation and more frequent dry spells in summer (IPCC, 2007).
- Impacts of higher sea levels: sea surface levels will rise, which means that larger areas are susceptible to flooding in future years, with potentially disastrous effects on harvests and biodiversity (extinction of vulnerable species) and water resources (salinization, pollution). Desertification will most likely take place in Southern USA and Europe.

Much uncertainty is related to lack of understanding of the effects of global warming on the climate system. This refers particularly to precipitation, its distribution over the year and its spatial pattern. Impacts of the different climate change factors will depend on their combinations and risk level in the various sub-regions:

- Higher CO_2 + moderate temperature rise + high precipitation = highest yields for rice, soy and cotton, but difficulties for maize, sugar cane and sorghum
- Higher CO_2 + moderate temperature rise + moderate precipitation = moderate growth of yields
- Higher CO_2 + high temperature rise + low precipitation = decreasing yields

Much uncertainty also remains because of our difficulties in predicting technological innovations that may greatly influence agriculture's ability to mitigate and adapt to climate change. Regarding adaptation and mitigation, for Europe, Olesen & Bindi (2002) and Metzger et al. (2006) conclude that adaptation and mitigation are necessary and complementary for a comprehensive and coordinated strategy. Adaptation to climate variability and change is not a new concept. Throughout human history, societies have shown a fair capacity for adapting – though not always successfully to changing climatic conditions (Lamb, 1995; Diamond, 2005). We may distinguish autonomous from planned adaptation. The first means the implementation of existing knowledge and technology in response to the changes experienced, while the latter means increased adaptive capacity by improving or changing institutions and policies, and investments in new technologies and infrastructure to enable effective adaptation activities. Regarding the latter, Kabat et al., (2005) provide various examples for developing appropriate strategies for the Netherlands.
Autonomous adaptation strategies include: Changing varieties/species to fit more appropriately to changed thermal and/or hydrological conditions; changing timing of irrigation and adjusting nutrient management; applying water-conserving technologies (such as conservation tillage), altering timing or location of cropping activities, etc. Some of those adaptation measures also have mitigative effects – such as applying "not tillage» practices or using cover /catch crops in spring to reduce leaching and erosion. Planned adaptations will include specific policies and provision of infrastructure that support/enable integrated spatial planning and generation and dissemination of new knowledge and technologies and management practices tailored to anticipated changes (Easterling et al., 2004; Kabat et al., 2005; Carter, 2007).

<u>Adaptive capacity and sustainability</u>
For Europe, the ATEAM project (Advanced Terrestrial Ecosystem Analysis and Modeling) constructed scenarios for a range of possible changes in socio-economic conditions, land use patterns and climate to assess the vulnerability of the human-environment system to global change (Ewert et al., 2005). Results from that assessment show that global change will have a large influence on ecosystem service provision in Europe. There is, however, a large heterogeneity in the projected vulnerability between regions: The Mediterranean region is projected to be most vulnerable, while north western European countries face the lowest impacts and show the greatest adaptive capacity (Metzger et al., 2006). For the United States, Easterling et al. (2004) have looked into adaptation strategies for coping with global climate change. It is shown that the US agriculture on the whole can adapt (with either some net gains or some costs) if warming occurs at the lower end of the projected end of magnitude (i.e. 2 – 3 degrees Celsius by the end of the century) and no change in variability; However, with a

much larger magnitude of warming, even under optimistic assumptions about adaptation capabilities, many sectors would experience higher loss and costs (Easterling et al. 2004); Lemmen & Warren (2004) come to similar conclusions for Canada. In this context, another feature that clearly distinguishes NAE agriculture from other regions is the significant high level of its current adaptive capacity. This is mainly due to the region's access to important economic, technological and other resources which is better than that of other regions (Adger et al., 2005). It is also co-determined by the fact that relatively large areas have a relatively low exposure to climate change – as compared to other regions.

3.2.5.3 Consequences for AKST

Summarizing, uncertainties remain in terms of the evolution of GHG emissions, effects on the climate system, its impacts on agro-ecosystems and the adaptive capacity available. We know, however, that some climate change will occur irrespective of the emission reduction measures we may take now. We may further conclude that:

(i) Adaptation is an important complement to greenhouse gas mitigation measures and policies. However, adapting to climate change will not be an easy and cost-free task and adaptation decisions in one sector (e.g. water resources) might have implications on others.

(ii) Managed systems are likely to do much better than natural systems and some regions will face greater obstacles than others.

(iii) The various options for dealing with the threats of climate change require due examination at regional and local scales. Questions include: how can emissions from agriculture and forestry be effectively reduced, how can agriculture and forestry best adapt under given local conditions, and what role can bio-fuels play – and, finally, what are the implications of these challenges on requirements for AKST?

Depending on future policy and societal choices, i.e. on whether to strive for more drastic emission reduction or not, whether or not energy prices increase, whether to reduce consumption or not, and whether to be proactive in climate change adaptation and enhancement of adaptive capacity of agriculture, there will be different requirements for AKST.

Some of the obvious consequences for AKST are given below. Furthermore, some suggestions are given on the efficacy of different measures in reducing the vulnerability of agriculture and rural areas to climate change:

(1) AKST needs to generate the information required to improve climate modeling and scenario development – details on this are given, for instance, in the IPCC Special Report on land use and land cover change (IPCC, 2000). This implies development of improved methods for assessing GHG emissions from agricultural activities – in particular, there is a need for improved carbon cycle models; without improved tools, it will be more difficult to decide on the most appropriate mitigation and adaptation options under given local /regional conditions

(2) Another area that requires attention is, how adaptation of agriculture actually occurs in the different regions (e.g. Adger et al., 2005); such lessons are important for better understanding vulnerabilities and what planned measures are needed for different climatic hazards.

(3) Improvement is also required in the area of climate change impact assessment methodologies – this refers to the modeling of multiple stresses as well as to the quantification of climate change scenarios on the whole range of ecosystems goods and services (Carter, 2007), i.e. also on agro-biodiversity, water resources (and agricultural landscapes at large); often a number of impacts are neglected such as on soil, weeds, pests and diseases; the same applies to climate change effects on the quality of crop and animal production;

(4) More efforts are required into the development of knowledge and tools needed to support the design and evaluation of mitigation and (mitigative) adaptation options for agriculture; this also includes more comprehensive cost-benefit analysis than now available (Stern et al., 2006; Carter, 2007); Under conditions of better informed policy choices and technology development in support of the environment, new strategic research, development of better quantitative tools and design and prototyping of energy-efficient farming systems will need to receive high priority; such AKST has a high likelihood of effectively contributing to enhanced adaptive capacity of agriculture.

(5) Likewise, more consideration needs to be given to the establishment of AKST multi-stakeholder platforms for designing and implementing feasible strategies (e.g. more energy-efficient systems) at the farm and regional (sub-national) scale in response to anticipated climate change; these need to be involved in participatory planning recognizing the interdependence between planning and adaptive capacity of rural landscapes/the agricultural sector; such positive development of AKST in terms of climate protection is not likely to be favored in a basically globalized market –led society or in a future world that is not supporting cooperation.

(6) There needs to be increased focus on regional studies of impacts and mitigation/adaptation of climate change in agriculture, including assessments of the consequences on current efforts in agricultural policy for a sustainable agriculture that also preserves environmental and social values in rural communities

(7) Related to this is the development of strategies to enhance adaptive capacity of agro-ecosystems. This relates to generation of (interdisciplinary) knowledge (in close collaboration with other disciplines and with key stakeholders) that is required to enhance adaptive capacity of existing food /agro-ecosystems so that they are less vulnerable and better manage risks related to climatic change. Such development of AKST is likely to reduce the vulnerability of agriculture and rural areas to climate change. It requires, however, willingness to better integrate different AKST activities, local learning - more cooperation across sectors and among stakeholders, as well as more effective environmental regulations.

(8) Finally, research should focus on creating productive and multifunctional land use systems in rural areas that aim at provision of sustainable ecosystem services. It includes the adaptive capacity of (agro-)ecosystems in connection with – where necessary - restoration of degraded

lands, and the integrated management of natural resources. The research work should synthesize the results agricultural and environmental studies and other disciplines - from field scales to higher scales up to global land use. Sustainability indicators at lower scale levels (plant, field), such as efficiency of input use, soil organic matter status, nutrient balances and biodiversity need to be used to understand changes and trajectories at higher scales (farm, watershed).

Under future conditions where governments and citizens assume more responsibility for the environment and are proactive in terms of alleviating the threats of climate change, AKST activities that aim at provision of better information for policy-making, green technologies and multi-functional viable agricultural landscapes will be required. But under conditions where decisions on natural resources and the environment (including the climate system) are not integrated with economic decisions, AKST will be reduced to contribute to the fulfillment of requirements regarding food and non-food products by rich and poor consumers.

3.2.6 Energy, bioenergy

3.2.6.1 On-going trends

Since World War II, global energy consumption increased more than six fold. In the same period, per capita energy demand has more than doubled. The energy demand growth rate is not slowing down in spite of record oil prices – and global primary energy demand is to grow by more of 50 percent until 2030 (Fresco, 2006; IEA, 2006: World Energy outlook). Energy is a key driver in agriculture because agriculture consumes energy (oil is used for fuel and fertilizers) and agriculture produces energy (biomass). Energy consumption in agriculture depends on the type of crop, production system and orientation (field, irrigated, greenhouse, etc.) and the agro-climatic conditions. Energy consumption in agriculture usually increases with increase in the size of farms, and irrigation accounts for the largest share. It has also been observed that though farmyard manure is locally available, its application is has been decreasing over time. Application of inorganic fertilizer at farm level for improving yield and productivity has been on the increase; however, a increasingly stringent EU policy framework (water directive) and related national level policies have led to a decline in fertilizer application in recent years (Wolf et al., 2005; European Commission, 2007). At present in the US (Konyar, 2001), for dryland crops, average direct and indirect energy costs account for 19 percent of the total variable cost, ranging from 10 percent for soybeans and up to 27 percent for cotton. For irrigated crops, the total energy cost constitutes an average of 33 percent of the total variable cost, and ranges from 26 percent for hay to 51 percent for sorghum. Irrigated crop production is especially vulnerable to changes in energy prices. These proportions could change a lot with the use of bio-based energy inputs. The availability and price of energy also influences transport of agricultural products - and thus co-determines the extent of global trade.

Biofuels are fuels – liquid or gas – coming from biomass to be used for transport : bio ethanol, bio diesel, biogas, bio methanol, bio dimethylether, bio-ETBE, bio-MTBE, synthetic bio fuels, bio hydrogen, pure vegetable oil (Schröder & Weiske, 2006). The two primary biofuels in use today are ethanol and biodiesel, both of which can be used in existing vehicles. Ethanol is currently blended with gasoline, and biodiesel is blended with petroleum-based diesel for use in conventional diesel-fueled vehicles. Ethanol accounts for about 90 percent of total biofuel production, with biodiesel making up the rest (Marris, 2006; Sanderson, 2006). Global fuel ethanol production more than doubled between 2000 and 2005, while production of biodiesel, starting from a much smaller base, expanded nearly fourfold. By contrast, world oil production increased by only 7 percent during the same period. Compared to petroleum refining, which is developed at a very large scale, biofuel production is lower volume and, currently, much more decentralized. In the case of biodiesel in particular, where a wide range of plant and animal feedstock can be used, there has been a tendency for rather dispersed production facilities.

Ethanol fuel production has tended to be more geographically concentrated than biodiesel. In the United States, this production is concentrated predominantly in Midwestern states that have abundant corn supplies, such as Iowa, Illinois, Minnesota, Nebraska, and South Dakota (Worldwatch Institute, 2006). Advanced biofuel technologies could allow biofuels to substitute for 37 percent of U.S. gasoline within the next 25 years, with the figure rising to 75 percent if vehicle fuel efficiency were doubled during the same period. The biofuel potential of EU countries is in the range of 20–25 percent (EEA, 2006) if strong sustainability criteria for land use and crop choice are assumed, and assuming that bio-energy use in non-transport sectors is growing in parallel. The various biomass feedstock used for producing bio-fuels can be grouped into two basic categories). The first is the currently available "first-generation" feedstock, which comprises various grain and vegetable crops. These are harvested for their sugar, starch, or oil content and can be converted into liquid fuels using conventional technology. The yields from the feedstock vary considerably, with sugar cane and palm oil currently producing the most liters of fuel per hectare (Marris, 2006). By contrast, the "next-generation" of biofuel feedstock comprises cellulose-rich organic material, which is harvested for its total biomass (Fresco, 2006). These fibers can be converted into liquid biofuels only by advanced technical processes, many of which are still under development – but proceeding at a rapid pace. For more details, cross-reference is made to Chapter 2.

Table 5: Bio-energy production potentials for selected biomass types

Biomass Type	Bioenergy Potential (exajoules)	Main Assumptions and Remarks
Agricultural Residues	15–70	• Based on estimates from various studies. • Potential depends on yield/product ratios, total agricultural land area, type of production system. Extensive production systems require leaving of residues to maintain soil fertility; intensive systems allow for higher rates of residue energy use.

Organic Wastes	5–50+b	• Based on estimates from various studies. • Includes the organic fraction of MSW and waste wood. • Strongly dependent on economic development and consumption, and as well as use for biomaterials. • Higher values possible by more intensive biomaterials use.
Animal Dung	5–55 (or possibly 0)	• Use of dried dung. • Low range value based on current global use; high value reflects technical potential. • Utilization (collection) over longer term is uncertain.
Forest Residues	30–150 (or possibly 0)	• Figures include processing residues. • Part is natural forest (reserves). • The (sustainable) energy potential of world forests is unclear. • Low range value based on sustainable forest management; high value reflects technical potential.
Energy Crop Farming (current agricultural lands)	0–700 (100–300 is more average)	• Potential land availability of 0–4 global hectares (Gha), though 1–2 is more average. • Based on productivity of 8–12 dry tonne/ha/yra (higher yields are likely with better soil quality). • If adaptation of intensive agricultural production systems is not feasible, bioenergy supply could be zero.
Energy Crop Farming (marginal lands)	60–150 (or possibly 0)	• Potential maximum land area of 1.7 Gha. • Low productivity is 2–5 dry tonne/ha/yr.a • Bioenergy supply could be low or zero due to poor economics or competition with food production.
Biomaterials	Minus 40–150 (or possibly 0)	• These provide an additional claim on biomass Supplies • Land area required to meet additional global demand is 0.2– 0.8 Gha • Average productivity is 5 dry tonnes/ha/yr.a • Supply would come from energy crop farming if forests are unable to meet this demand.
Total	**40–1,100 (250–500 is more average)**	• Pessimistic scenario assumes no land for energy farming, only use of residues; optimistic scenario assumes intensive agriculture on better quality soils. • More average range = most realistic in a world aiming for large-scale bioenergy use.

Notes: (a) heating value: 19 GJ/ton dry matter; (b) the energy supply of biomaterials ending up as waste can vary between 20 – 55 EJ (or 1,100-2,900 million tons of dry matter per year). Biomass lost during conversion, such as charcoal, is logically excluded from this range. This range excludes cascading and does not take into account the time delay between production of the material and its 'release' as (organic) waste. Source: Andre Faaij, Copernicus Institute, Utrecht University, report submitted to Worldwatch Institute, 17 January 2005.

3.2.6.2 Uncertainties for the future

As far as energy and bio-energy is concerned, there are two major uncertainties for the future :

- To what extent will bio-energy develop and which drivers will determine future bio-energy use in NAE?
- Will agriculture be able to reduce substantially energy use for its production?

Among the major drivers in NAE that influences the energy market will be the security aspect that means, making NAE less dependent on energy supplies from outside the region so that it becomes less vulnerable to shortages of fossil fuels and associated price increases. Secondly, there will be the increasing insight of the need to protect the Earth's climate system through reduction of Greenhouse Gas (GHG) emissions by means of less energy consumption (e.g. through more energy – use efficient technologies and changes in less-consumption oriented lifestyles). The recent (March 2007) agreement of EU leaders on enforced greenhouse reduction targets and renewable energy use policies for 2020, is a milestone that may well trigger a sea-change in energy policy and make others (namely the US, Russia, China, etc.) join a changed direction towards more reliance on renewable energy production (including biofuels). It is possible that there exists a basic misunderstanding regarding the much proclaimed trade-off between economic growth and reduction of energy use – and that increased insight in this respect influences future decisions. Some experts claim to know that energy costs will rise sharply if we use less/reduce the share fossil fuels in the energy supply mix – claiming that such additional costs are unbearable. This is just one extreme scenario, that does not consider the many opportunities for reducing the use of fossil fuel use (as has already been demonstrated by many multi-national companies, such as BP, Shell, Bayer, General Electric) (Fresco, 2006), e.g. by applying energy-saving technologies and choosing increasingly for low-emission activities. The options span a wide range from changes in energy consumption patterns (e.g. by less traveling, changing diets), improved, energy-efficient technologies (e.g. cars, heating and cooling systems in buildings) and reduced costs and more positive energy/environmental balance in producing bio-fuels and other renewable energy sources (Fresco, 2006).

The "next-generation" biofuels is based on cellulose biomass such as wood, tall grasses, and crop residues that are much more abundant than food crops and can be harvested with less interference to the food economy and potentially less strain on land, air, and water resources. Promising energy crops include fast-growing woody crops such as willow, hybrid poplar, and eucalyptus, as well as tall perennial grasses such as switch grass and miscanthus. Another potential "next-generation" feedstock is the organic portion of municipal solid waste. The use of "next-generation" cellulose biomass feedstock has the potential to dramatically expand the resource base for producing biofuels in the future (Marris, 2006; Fresco, 2006). Over the next 10–15 years, lower-cost sources of cellulose biomass, such as the organic fraction of municipal waste and the residues from biomass processing, crops, and forestry, are expected to provide the initial influx of next-generation feedstock. A lot of questions arise in this context. One is, to what extent these technological developments can be accelerated, e.g. by further bio-energy supporting policy interventions, better public – private research cooperation and investments.

For biofuels to reach their full potential in meeting future transportation needs, it is critical to develop and deploy economically competitive technologies that can convert abundant cellulose biomass resources into liquid. Development efforts to date have demonstrated that it is possible to produce a variety of liquid fuels from cellulose biomass for use in existing vehicles. As of mid-2006, however, the costs of producing liquid fuels from cellulose biomass were not competitive with either petroleumderived fuels or more conventional biofuels. The diffusion of “Flex Fuel Cars” (currently about 50 percent of the cars in Brazil) is a good example of introducing flexibility in responding to price developments. Various government and industry-sponsored efforts are under way to lower the costs of making liquid fuel from cellulose biomass by improving the conversion technologies. (Worldwatch Institute, 2006). It is unclear, how fast these developments will proceed. Clear signals about the severity of climate change impacts as well as the availability of new technologies will both influence the preferences and behavior of consumers. Likewise, the speed of technology diffusion, available energy mix and prices will influence energy consumption and demand. Much of these developments will depend on to what extent and when and how economic growth and sustainable development goals will be achieved outside the NAE region. For instance, according to recent projections it is expected that China and India account for 30to 40 percent of energy demand by 2030 (IEA, 2006).

The dual challenge (and critical uncertainty) is how to secure adequate energy at affordable process and, at the same time, limiting /reducing its consumption such that it does less environmental harm. It is unclear to what extent agriculture in NAE will become an energy producer, and how much its energy-efficiency can be increased. This depends on AKST as well as on other KST efforts. It may well be possible that more centralized and technology-intensive, renewable forms of energy outweigh agriculture as energy-producer. Such development may reduce the demand for bio-fuels.

3.2.6.3 Consequences for AKST

If it is certain that biofuels will become increasingly important in the future, there are still uncertainties about the percentage of energy use they will represent and about their origin. Nevertheless, irrespective of the future development pathway, whether more based on cooperation or competition among regions and whether societies and governments play a more proactive role in achieving the sustainability goals, AKST needs to pay more attention to the following energy –related issues:

- Research into new farming systems that are able to cover their energy needs and costs by producing biofuels, and installing wind mills and solar parks on their fields.
- Generation of knowledge that allows sustainable production of biofuels, i.e. in a economically viable, environmentally friendly and socially acceptable manner.
- Proper accounting for the full energy demand of the agricultural sector in environmental impact assessments.

Furthermore, the following issues need to be considered:

- Evaluation of investment options in the short, medium and long-term, the exploration, production and energy infrastructure
- Increasing energy efficiency, identifying measures to reduce the demand from the transport sector, promoting the development and deployment of technology.
- Assess options for next 50-100 years: e.g. potential for biofuels and other renewable sources like wind, solar, tidal, etc.

- Making use of new technologies to combine energy sources in an efficient way (e.g. photovoltaic with fuel cells or new large accumulators), especially in decentralized systems.

If the accent is put on elimination of residues and use of agricultural residues to produce bioenergy, then biochemistry, biology, study of processes, etc will need to be further developed.

3.2.7 Natural resources availability and management ; land use

The linkages between climate change, energy and natural resources availability and management are considerable. For example, the need for irrigation will not be the same if and where climate becomes dries, the frequency of major floods increases, and water gets more polluted, etc.

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3.2.7.1 Ongoing trends

Land and water.

Agriculture has a complex relationship with natural resources and the environment. It is a major user of land and water resources yet needs to maintain the quantity and quality of those resources in order to remain viable. Agriculture generates waste and pollution, yet it also conserves and recycles natural resources, and it can significantly contribute to enrich landscapes and create habitats for wildlife. Many of the environmental effects are confined to the sector itself, but off-farm effects are also important. The impacts are often concentrated locally and regionally, although some are of national and international significance. Land, water and other natural resources are limited. Resource scarcity, and competing claims for scarce resources, such as land and water, between agriculture and other land uses are increasing. That competition is currently very alarming in the very densely populated agricultural lowlands of Asia (Van Ittersum et al., 2004); under current climatic conditions, water is at times, (and increasingly) scarce in parts of NAE such as in the Mediterranean region.

In its study “The Limits to Growth” more than 30 years ago, the Club of Rome showed how population growth and natural resources interact and impose limits on industrial and economic growth. As an example, in the first global assessment of soil degradation it had been found that 38 percent of currently used agricultural land has been degraded. Such phenomena are signs of an ‘overshoot’[4] or, an imbalance between availability, quality and claims on the earth’s natural resources beyond what can be sustained over time. A core question of the various “limits to growth” scenarios was: How may the expanding global population and economy interact with, and adapt to the earth’s limited carrying capacity over the next 100 years? The simulation model applied to that end has been criticized for underestimating the power of technology, and for not adequately representing the adaptive capacity of the free market. In its “30 years update” (Meadows et al., 2004, p.3) conclude : “We are still drawing on the world’s resources faster than they can be restored, and we are releasing wastes and pollutants faster than the Earth can absorb them to render them harmless.” Wackernagel et al. (2001), for instance, show that for each year since 1960 the ‘number of planets’ required to provide the resources

[4] Means: to go too far, to grow so large so quickly that limits are exceeded (after Meadows et al., 2004; p 4)

used by human society and to absorb their emissions, that human demand starts to exceed nature's supply from the early 1980s. And it exceeds that supply by about 20 percent since 1999. Although the method of calculating the ecological footprint just using one single measure has its limits and may be criticized[2], the basic message has been confirmed by the MA (2006).

Agriculture utilizes natural processes to produce the goods (food and non-food) that we need to support the demand of an ever growing population (Verhagen et al., 2007). While acknowledging that population trends and projections for NAE show stagnation and decline, the region will most likely continue to produce for and export to other world regions to satisfy part of their needs and requirements. Both, renewable resources, like agricultural soils, and non-renewable resources, like the world's fossil fuels, have their limits. The most limiting resources to food production and other goods provided by agroecosystems in NAE are land and water. A definition *of Ecosystem services* has been given in Chapter 2, following Daily (1997). Agricultural systems are typically managed to maximizing provisioning services to provide food, but they require several other supporting and regulating services to support production. Agriculture both depends on ecosystem services and generates them. Agricultural ecosystem services have been grouped into three categories: services that directly support agricultural production (such as maintaining fertile soils, nutrient cycling, pollination), services that contribute directly to the quality of life of humans (such as cultural and aesthetic values of the landscape) and services that contribute towards global life-supporting functions (such as carbon sequestering, maintenance of biogeochemical cycles, supply of fresh water, provision of wildlife habitats) (e.g., Björklund, 2004) (cross-reference to Chapter 2).

As in any economic activity, in the farm various production factors are combined in different proportions with the aim of producing foods and raw materials. This process, which visibly varies between the different existing systems, arises from specific techniques or production practices which could be defined as an ensemble of knowledge, resources and proceedings used by a system to obtain a particular product.

In many of the densely populated parts of North-western Europe, and, since the late 1980s also in the new member states, fertile land is lost and soil is sealed by urbanization, with increasing demand for built-up area per capita, roads, industrial terrain, etc. In the Netherlands, the land covered by built-up area is already around 10 percent (Klijn & Vullings, 2005). In its communication on soil protection the Commission states that there is evidence that soil may be increasingly threatened by a range of human activities, which may degrade it and its functions vital for life thus undermining sustainability (European Communities, 2005; CEC, 2002;). In the EU, estimated 52 million hectares, representing more than 16 percent of the total land area, are affected by some kind of degradation process. In the new member states this figure rises to 35 percent. Soil degradation in dry areas is also known as desertification. Areas under desertification risk include central and southeast Spain, central and southern Italy, southern France and Portugal and large parts of Greece (European Union, 2005). The major threats to soil functions in Europe have been identified to be erosion, a decline in organic matter, local and diffuse contamination, sealing, compaction, a decline in biodiversity and salinisation (European Union, 2005; CEC, 2002; Van Lynden, 2000) (cross-reference to chapter 2). These threats are complex and interlinked and although unevenly spread across the Europe, their dimension is continental. The biggest threat is soil erosion by water. Within EU25 it is most serious in central Europe and the Mediterranean region, where 50-70 percent of agricultural land is at moderate to high risk.

Water

In NAE, agriculture absorbs more than 70 percent of water resources (against 20 percent for industry and 10 percent for households). It takes about 13,000 liters to produce one kilo of meat and about 700 to 1000 liters to produce a kilo of wheat. Water efficiency (water used after leaks, evaporation, etc. / water taken out) depends upon agricultural practices and water management techniques. In agriculture the amount of fertilizers and animal manure applied often by far exceeds crop demands (Wolf et al., 2005). Nutrient surpluses cause problems for human beings, plants and animals. Only very slowly the excesses or nutrient emissions to the environment are being reduced – for instance, through implementation of EU's nitrate directive. In North America in an increasing number of watersheds, water supply limits have already been exceeded. In the Midwest of the US, the Ogalallah aquifer in Kansas is overdrawn by 12 km3 each year. So far, its depletion has caused 2.5 million acres of farmland to be taken out of cultivation.

Irrigation is also very important for some areas within NAE, especially Southern Europe and the Western United States. The EU has 9 percent of its agricultural production under irrigation (13M ha), over 75 percent of this in Spain, Italy, France, and Greece (EEA, 1999; Kasnakoglu, 2006). More than 22M ha (18 percent of total cropland) are irrigated in the U.S., over 80 percent of which is in the West (Gollenhon et al., 2006).

Fisheries and aquaculture. In a little more than half a century, the situation of the world fisheries showed a dramatic evolution. After the Second World War, fisheries saw quadrupling their landings from 20 to 80Mt. This progression was due to the successive opening of new resources to exploitation, while fishing capacities were increasing. In the 70s-80s came a slowing down, and for the last two decades the world production has stagnated. Fleets are on over-capacity and the state of many stocks degrades. Since the 1970s, the proportion of overexploited stocks increases, that of the under or moderately exploited stocks decreases, and that of fully exploited stocks is stable at a high proportion (50 percent). There is probably not a new resource (underexploited or unexploited stock) anymore. The overexploitation settled down more quickly in zones exploited by developed countries (Northern Atlantic, Northern Pacific) but it affects now, in various degrees, all the oceans. The North-western Atlantic fisheries has known one of the most spectacular collapses with that of cod stocks, whose exploitation however lasted five centuries. Since the moratorium for cod fishing in 1993 in Canada, stocks were not reconstituted. The commercial fisheries of the Northeast Atlantic are fully exploited, overexploited or depleted. If the total captures are seemingly stable, it is because of the transfer of fishing from the traditional and high trophic level species (cod, haddock) towards species of less level (blue whiting, sandeel) or temporarily productive stocks but threatened of depletion in the short-term (deep-sea species).

Forestry: Forests, the services, goods and products they provide affect the daily lives of most, if not all citizens. Within the EU 25 countries, forests cover 140 millions hectares, or about 36 percent of land area. Europe's forests are extending in area, increasing in growth rate, and expanding in standing volume due to under-exploitation. Forests cover 549 million hectares in North and Central America and 850 in former USSR. In EU 25, there are about 15 millions forest owners, and over 4 million people directly or indirectly employed in forestry and forest-based industries, mainly in rural areas. Europe produces 28 percent of the world's paper supply and is a major operator in wood-based panels and engineered wood products; the contribution of the forest sector accounts for 8 percent of the Europe's added value (i.e. 600 billions euros). With 5 percent only of the world forest area, Europe produces 25-30 percent of world production of forest-based products. The forest sector's main asset is based on the renewable natural resources, and the use, to a large extent, of environmentally friendly processes. Forest-based industries are very efficient in recovering, reusing and recycling their materials and products, for the manufacturing of new products as well as for energy production. Rigorous life cycle assessments of forest products have shown that they have a strong comparative advantage vis-à-vis other materials. More utilization of forest biomass as a source for energy will be of high importance for a more environmentally friendly energy secure and sustainable Europe.

3.2.7.2 Uncertainties – questions for the future

While progress has been made in terms of developing new technologies, new institutions and creating awareness of environmental problems, the outlook today on natural resources is not better than in the early 1970s. There are a number of uncertainties involved concerning the future availability and quality of natural resources, land use and environment in NAE, some of them arising from or being aggravated by global trends such as liberalization of trade and climatic change.

- Among the major factors influencing natural resource availability and land management in NAE, is the development of consumption for food, feed, fiber and fuel in and outside the region. How will demand for these goods develop in the next decades, and what can and will the NAE supply in order to meet the demands. Will growth in production continue as in the past?
- How will the demographic and economic development within the different regions of NAE affect the severity of the different claims on land, water and other natural resources and the competition between agriculture and other land uses?
- More specifically, related to the supply of food and non food by agriculture, is the question of future availability of water, especially in the face of climatic change. How will water availability develop, and to what extent will it restrict agricultural production, and/or increased environmental degradation? How polluted will water be and what kind of efforts will be made to de-pollute or de-salinize and reuse such water?

- How much suitable agricultural land will be lost for other land uses, will cultivation take place on less suitable land and what effects will that have on the use of agrochemicals, biodiversity and environmental risks?
- Within agriculture, what will be the share of biofuel crop cultivation in the future, and what implications will expansion of biofuel crops have on the supply of other agricultural products, and on natural resource quality in the different (sub-)regions of NAE?
- In what way will the required goods be produced, and how will that affect the quality of water, soil, air and land use?
- What gains in efficiency increases in water, land, energy and labor use for agriculture would be needed to not jeopardize future environmental sustainability? What gains could be achieved by new, improved production technologies and better water resources management? Can such knowledge be generated and adequately and timely disseminated and implemented? What other means (e.g. policy interventions) are required to effectively overcome expected shortages?
- What will happen to natural resource quality if the viability of rural areas in NAE will decline?
- Will current trends continue such as more consumer concerns for environment and health increased demand for food safety (labeling and traceability), organic products and less meat and towards convenient solutions continue? What will be the implications on natural resource use, land use practices and environmental quality?
- In order to improve the sustainability of coastal capture fisheries and increase their productivity, will there be research on efficient management systems taking into account the ecosystem and improved fishing technologies?
- Will NAE develop its aquaculture production? Will there be more research on the aquatic environment for aquaculture?

Agricultural land use has the potential to damage or destroy the natural resource base and in so doing undermine future needs and development. It also has the potential to conserve agricultural landscapes. Most often, it is the focus on short term economic gains disregarding long term impacts and needs that lead to environmental degradation. Clearly part of the solution lies in a change in demands from society, e.g. via changes in dietary preferences and lifestyle, but also the agricultural sector has a responsibility to find ways to reduce the negative environmental impacts by development of appropriate AKST.

3.2.7.3 Consequences for AKST

Agriculture is a major user of land and water resources and is in competition with other users for these limited resources. The sustainable development challenges for agriculture are strongly related to this competition and the role agriculture has in rural development. The pleas made 15 years ago and expressed in Agenda 21 are also valid for today:

Major adjustments are needed in agricultural, environmental and macroeconomic policy, at both national and international levels, in developed as well as developing countries, to create the conditions for sustainable agriculture and rural development. (Agenda 21, UN 1993)

Enhanced production technologies and supportive policies. The concepts of production ecology are very helpful in structuring the interrelationships between agriculture, natural resources and environmental quality (Van Ittersum & Rabbinge, 1997). For instance, cropping activities are defined by the mix of inputs to produce given target yields. The level of undesired outputs (i.e. nitrate leaching, pesticide leaching or unproductive evaporation) associated with a given target yield will critically depend on the production technology (i.e. the various resource management practices and their use efficiencies) applied. Nutrient, pesticide and water loss will critically depend on the timing and splits of fertilizer application, type of crop protection and tillage. Policies need to support the diffusion of improved or 'best practices' by environmental regulations that aim at reducing nitrate and pesticide leaching. The rigorist approach of such regulations depends on the choices of society, which in turn, also co-determines the preferred production orientation and farming systems.

Striving for food security and responding to the consequences of globalization of markets and global environmental change (including climate change) are some of the major challenges of our time (Roetter et al., 2007; CGIAR Science Council, 2005). In the future, particular attention needs to be given to climate change and possible (mitigative) adaptation options, as it is superimposed on and will influence other major challenges for agriculture such as the provision of sufficient, affordable and safe food (of high quality), as well as feed, fiber and bio-based fuel. So far, the climate-induced risks and opportunities for agricultural systems have not been sufficiently addressed by AKST.
One of the challenges for AKST is to enhance its adaptive capacity. This will be required and beneficial for the sector irrespective of precise impact of global environmental change.
Closely related to this is the development of modern, resource-use efficient and low emission farming systems and agricultural practices. For the design and *ex ante* evaluation of such systems, the development of better tools like crop models, farm household models and regional land use (optimization) models – linked to GIS - can be very helpful. Such tools will be crucial for analyzing the consequences of possible alternative development pathways on agricultural production and natural resource use. Improved methods and tools together with appropriate stakeholder participation have a high potential to support and promote well-informed policy design and implementation of effective policy interventions.

Directly related to this, is the challenge for AKST to generate the means that can contribute to conflict resolution regarding competition for scarce natural resources. During the 1990s some public AKST systems (CGIAR and NARS partners world-wide) have tried to respond to that challenge seriously, for instance by developing ecoregional research methodologies (Bouma et al., 2007). Both, top down and bottom up approaches to Natural Resource Management (NRM) have been developed (Van Ittersum et al., 2004), whereby top down approaches were more directed to policy makers and regional resource managers and bottom up approaches more towards participatory technology development and decision making support on optimizing resource use at local level. Both approaches are required and need to be interlinked in the future to effectively support NRM by improving decision making on land/resource use issues. If we live in a future world that opts to achieve sustainability goals mainly through technological solutions and will not assume a different attitude towards consumption and dietary changes, AKST will have to be organized differently than in a world that considers solutions only sustainable if these increase equity, are owned and acceptable by local resource managers and contribute to environmentally sustainability. In the first case, AKST should be organized such that local solutions can be found by linking local knowledge networks tightly to global networks of excellence. Whereas, in the latter case, a local learning approach should be promoted to better integrate the different local knowledge centers and link them to global centers of excellence for tapping the relevant disciplinary knowledge. Likewise, in a world that favors technological solutions above behavioral changes, AKST will have to care more about technology improvements in precision agriculture and conventional, specialized, agriculture to restrict negative environmental effects than about integrated systems of organic agriculture that minimize emissions through recycling and avoidance of agrochemicals. Also it will matter a lot for the focus of AKST if choices are clearly made for a bio-based economy in which biofuels play a big role. Given the threats of global environmental change, a AKST that directs its efforts towards the development of sustainable, (energy-, water- nutrient- and labor use efficient), economically viable farming and land use systems that serve the multiple development objectives of rural areas will be beneficial for natural resources quality and the environment under different plausible futures. Finally, if society decides to make a serious effort to overcome environmental degradation and resource depletion, tools such as more adequate technologies will be effective in supporting sustainable development.

To enhance the aesthetical value and sustainability of the landscape, they will need to have research on ornamental plants, genetic exchanges with wild species, improved management strategies to preserve natural biodiversity of local crops as well as wild species, and to contribute to sustainability issues, such as recycling strategies, energy production, and fire prevention. (Plants for the future, 2005)

Last, whereas there has been research on farming systems, little research has been carried out on the sustainability of coastal fishing production systems which are still intensive. Aquaculture production systems, on the contrary need to be intensified and new species introduced. The priority given to fisheries and aquaculture will differ according to the type of agricultural research and innovation system. Ecosystem-oriented AKST will favor sustainability of coastal fishing and local-food supply led AKST should favor aquaculture. Market-led AKST will probably put little priorities on these themes as it is right now.

3.3 Knowledge, Science and Technology: Major Uncertainties in Key Drivers

3.3.1 Transformation in models of knowledge production

Knowledge is a distributed resource, not restricted to what is produced through R&D activities, but diffused throughout society across boundaries between scientists and non scientists that are now more permeable. Even in the realm of industry oriented R&D and innovation activities, the closed and linear model of knowledge creation and use is definitively outdated. The old model no longer corresponds either to the conceptualization of research activities or the way in which most research activities are actually organized. Many analyses have demonstrated that, first there is no one-way move from fundamental research to application but continuous movements back and forth, and second, that there is (or at least there should be) a strong integration between basic research, applied research, development and marketing. Innovation thus appears as a process that integrates various forms of research and the knowledge it creates, in a wide range of patterns.

New forms of knowledge production and new concepts are appearing. We will briefly mention them as they will are often used in discussions of future research systems:

- Knowledge. Knowledge is defined today as a learning and cognitive capacity. Most importantly, it has to be apprehended in action. This implies a fundamental distinction between information and knowledge. Various authors have proposed different typologies of knowledge. Some are based on the source of the knowledge and its format. Traditionally a distinction is made between implicit knowledge (e.g. daily life or common sense knowledge, experience knowledge, local or indigenous knowledge, action knowledge) and explicit knowledge (practical, theoretical or creative knowledge). Other typologies emphasize the context in which knowledge is used, as defined by the knowledge itself (normative and descriptive knowledge, strategic and operative knowledge, scientific and empirical knowledge, past- and future-oriented knowledge). Finally, certain authors focus more on the modes of inscription of knowledge, and thus distinguish between: 'embrained' knowledge (based on certain conceptual and cognitive skills), embodied knowledge, 'encultured' knowledge (built up in the processes of socialization that lead to shared forms of understanding), embedded knowledge (in systemic routines), and encoded knowledge (which can be considered as equivalent to information) (Amin et Cohendet, 2004).

- Mode 1 and Mode 2. These “modes” have been presented by Gibbons et al. (Gibbons et al., 1994). “Mode 1 refers to a form of knowledge production – a complex of ideas, methods, values, norms – that has grown up to control the diffusion of the Newtonian (empirical and mathematical physics) model to more and more fields of enquiry and ensure its compliance with what is considered sound scientific practice. Mode 1 is … the cognitive and social norms which must be followed in the production, legitimation and diffusion of knowledge.” “In Mode 1 problems are set and solved in a context governed by the, largely academic, interests of a specific community. By contrast, Mode 2 knowledge is carried out in a context of application. Mode 1 is disciplinary while Mode 2 is transdisciplinary. Mode 1 is characterized by homogeneity, Mode 2 by heterogeneity. Organizationally, Mode 1 is hierarchical and tends to preserve its form, while Mode 2 is more heterarchical and transient. Each employs a different type of quality control. In comparison with Mode 1, Mode 2 is more socially accountable and reflexive. It includes a wider, more temporary and heterogeneous set of practitioners, collaborating on a problem defined in a specific and localized context."

- Collective intelligence (or Mode 3). This concept is the subject of a lively on-going discussion, but a working definition is that 'collective intelligence is the capacity of human communities to cooperate intellectually in creation, innovation and invention (Lévy, 2000). This type of general definition only helps to specify the distinctiveness of how "collective intelligence" produces knowledge by stressing how it differs from the lone researcher in Mode 1 or the purposeful process in Mode 2 (cited by Akrich and Miller, 2006).

- Triple Helix. The "Triple Helix" model (Leydesdorff and Etzkowitz, 1998) implies university-industry-government relations. It is developing, though at unequal speed according to countries.

- Platform model. The notion of platform devised by Keating and Cambrosio (Keating and Cambrosio, 2003) attempts to formalize the attributes of a network insofar as it connects a set of devices, tools, instruments, technologies and discourses which are used by a heterogeneous group of people, ranging from basic scientists to engineers and users, to pursue a specific goal. The heterogeneity of this grouping may lead to the production of new research 'entities', new technologies and new practices, in short, trans-disciplinary built-in innovation.

- Frontier research. This concept has been devised by experts of the European Commission (European Commission, 2005) to characterize the fast-growing space which is at the intersection between basic and applied research. Frontier research, because it is at the forefront of creating new knowledge, is an intrinsically risky endeavor that involves the pursuit of questions without regard for established disciplinary boundaries or national borders.

As important as the transformation of knowledge production and linked to it are questions of intellectual property. The development of the Web and electronic communication tools facilitates not only the circulation of knowledge, but also its production. This process can be far more flexible than it used to be in traditional research settings and involve non-professionals in research, leading to new forms of collective innovation. Yet the way in which intellectual property rights (including contracts and transaction/payment systems) are defined and managed is going to play a crucial part in these developments.

3.3.2 Transformation in models of innovation

The innovation systems concept emerged through policy debates in developed countries in the 1970s and 1980s. Several investigators observed that the more successful economies possessed what they described as an effective "national system of innovation" (Freeman, 1989; Lundval, 1991). These systems developed in an institutional (often network-based) setting which fostered interaction and learning among scientific and entrepreneurial actors in the public and private sector in response to changing economic and technical conditions. Over time, the innovation concept has gained wide support among the member countries of the Organization for Economic Cooperation and Development (OECD) and the European Union (World Bank, 2006).

The innovation system perspective brings actors together in their desire to introduce or create novelty or innovation into the value chain, allowing it to respond in a dynamic way to an array of market, policy and other signals. Innovation capacity is sustainable only when a much wider set of attitudes and practices comes together to create a culture of innovation, including a wide appreciation of the importance of science and technology in competitiveness; business models that embrace social and environmental sustainability; attitudes that embrace a diversity of cultures and knowledge systems and pursue inclusive problem solving and coordination capacity; institutional learning as a common routine; and a forward-looking rather than a reactive perspective (World Bank, 2006).

The innovation systems vary in different regions of North America and Europe as we will try to show.

3.3.2.1 Researchers

The situation is quite different in North America on the one hand, EU25 and the Federation of Russia on the other hand.

For Europe, a recent report on "The future of key actors in the European Research Area" (Akrich and Miller, 2006) reviewed by a number of experts, synthesizes the situation. They state that "the population of European researchers is currently facing a demographic problem. As in most sectors, this population is aging, in line with the general trend over the past sixty years. This leads to the expectation that huge numbers of researchers will retire over the next few years and that as a consequence it will be necessary to rapidly recruit new researchers, whose numbers will obviously depend on the resources allocated to R&D, in part contingent on public policies. This recruitment challenge poses a number of problems: First, students in Europe tend to be turning away from science and technology, especially when it is research-oriented. Some see this as a consequence of the more critical attitude that has developed towards technical 'progress', which is perceived as bringing as many threats as it does hopes. Others stress the lack of attractiveness of careers in these fields in terms of workload, status and pay. In Europe researchers salaries are relatively low when compared to industry or the service sector".

In the context of internationalization of higher education and research, the question of remuneration is crucial. In the absence of European policies that take into account stiff competition to recruit the best PhDs and post-docs, many young European researchers are attracted abroad, especially to the US. For the same reasons, this outward migration is not compensated for by sufficient inward migration, both quantitatively and qualitatively. The research job market in Europe is fragmented, organized on a national or even local scale, with a low level of competition. Selection takes place in a relatively opaque way, which often favors local candidates. This mode of functioning does not promote international openness and leads to unequal levels of quality. Many authors agree that the broader a market is, the greater its specialization and the higher the overall level of quality. The low level of internationalization of the European research job market is not offset by intra-European mobility, which remains limited due to the rigidity of statuses and organizations, and the absence of systems for managing scientific careers on a European scale, even if young researchers, typically post-doctoral, are much more mobile than they used to be, thanks to a strong European policy. Scientific dynamics and the capacity to innovate, strongly based on the possibility of establishing original links between separate research currents, would undoubtedly be enhanced by active policies to promote mobility (Akrich and Miller, 2006).

3.3.2.2 Research and technology organizations

Research and technology organizations (RTOs) are generally non-profit organizations that provide innovation, technology and R&D services to a variety of clients (firms, public services, administrations). This makes them 'in-between' organizations: their financing is comprised of both private resources (via contracts, patents and licenses) and public funds; they increasingly straddle applied and basic research, and are thereby engaged in 'frontier research'; and their work has a distinct multidisciplinary dimension that includes the economic and social sciences. This particular positioning is a source of tension, so that the specificity of RTOs depends on a balance being maintained between their diverse components.

Historically and by construction Research and technology organizations have tended to encourage multidisciplinarity and have been less constrained by the boundaries between basic and applied research. Consequently they have many assets conducive to playing a strategically important role in the current context. With links to fundamental research, RTOs have expertise in the development of tools and concepts (mathematical modeling, complex systems theory, etc.) that allow them to articulate and blend the sets of heterogeneous knowledge and technology that are considered to be major sources of innovation today. RTOs are also well configured to take advantage of the increasing number of actors involved in research and the intensified relations between the scientific community and its environment

3.3.2.3 Universities

Universities across Europe reflect a multitude of different realities. In certain countries they constitute the preponderant share of the research and higher education system; in others they coexist with large research organizations and even, as in France, with other types of higher education institutions (*Grandes Ecoles*) which are also increasingly engaged in research. On the whole, there is less investment in higher education in Europe than in other countries such as the US, funding is primarily from the public sector, and students pay a relatively low share of the costs of their education. However, it must be noted that the funding of university-based research has increased substantially over the last 15 years. There has also been a diversification of the sources of funding for research institutions to include: national governments, supranational bodies such as the European Commission, regional governments, business enterprises, and civil society. The respective weight of teaching and research, and the mechanisms through which research activities can be financed and encouraged vary considerably, depending on the country and the university. In general, however, universities in Europe currently face the same challenges: offering courses to young adults; meeting the demand for on-going education and training; and participating in knowledge production in increasingly diverse contexts and with an ever-greater variety of partners. The juxtaposition of these different tasks currently weighs on universities, generating strong tensions, in part due to limited resources. A situation exacerbated by the fact that the main missions of universities are not always defined in unambiguous ways nor do key stakeholders, such as the managers of universities or governments, always agree on the same priorities. (Akrich and Miller, 2006)

3.3.2.4 Multinational Enterprises and Small and Medium Enterprises

Today's multinationals see innovation as a strategic element in economic competition. The life cycles of products are increasingly short and firms are encouraged to produce returns on investments more and more quickly. This has resulted in the development of an R&D race in concentrated in multinationals. R&D activities enable firms to build-up knowledge about the technologies at the heart of their activities. R&D also plays a crucial role, essential to the firm's long-term competitiveness, by enabling firms to identify, acquire and apply knowledge that has been developed by others.

Multinational corporations (MNCs) have been expanding R&D outside their home countries in recent decades. R&D investments by MNCs, within their affiliates or with external partners in joint ventures and alliances, support the development of new products, services, and technological capabilities. These investments also serve as channels of knowledge spillovers and technology transfer that can contribute to economic growth and enhance competitiveness. International R&D links are particularly strong between U.S. and European companies, especially in pharmaceutical, computer, and transportation equipment manufacturing. More recently, certain developing or newly industrialized economies are emerging as hosts of U.S.-owned R&D, including China, Israel, and Singapore (Science and Engineering Indicators, 2006).

SMEs are obviously an extremely heterogeneous group, ranging from high-tech start-ups to small building contractors to the local pizzeria to sub-contractors in the car industry to computer service firms. However the sectoral coverage tends to narrow considerably when the focus is on research related issues. Technology based SMEs only account for around 10 percent of all SMEs.

3.3.2.5 International, National and Regional Governments

A variety of actors are involved in making and implementing national science, technology and innovation policies: advisory bodies, national agencies, ministries and specialized institutes. These actors engage in a wide range of activities, including planning, forecasting, strategic intelligence, and consultation with stakeholders. The national level actors are involved throughout the process, which covers identification of needs, agenda-setting, implementation of policies, monitoring and evaluating the effects of policies, and benchmarking. The forms of intervention of regional powers in research and technology policies vary.

The defining characteristics of the US public R&D policy are an even stronger impact of the economic factors than in other geographical areas, the enormous influence of defense-related research activities, and the importance given to the high potential areas made up of converging technologies (EU Commission, 2006a). In North America, considerable emphasis has been put on supporting research in universities which are regional and local. Regional authorities have policies for attracting and developing a qualified local workforce and spurred the creation of technology clusters and technology parks. In the USA, 60 percent of all R&D is concentrated in just six states, with California alone accounting for 20 percent. (UNESCO, 2006)

In Europe, national level authorities generally retain the leading role in policy formulation and implementation, but there are very wide differences in the extent and nature of this leadership, depending on the country (Akrich and Miller, 2006). Europe is much more influenced by societal, i.e. social and environmental factors, than the United-States as far as R&D policy setting is concerned. Ecological and quality of life issues generally provide a unifying and defining element of European public R&D support policy. Nevertheless, the European landscape is characterized by important differences between the different countries. A number of factors account for this, such as countries GDP, their political environment, their scientific position. Europe is also faced with policy rigidities that have an important impact on the efficiency of public support, influencing both the form in which support is being administered and the research organization itself (EU Commission, 2006). The distribution of prerogatives between regional, national and European government varies from countries to countries. The länders are very influent in Germany; regionalization is also occurring in Spain and the United Kingdom.

3.3.3 Human and Financial Resources Devoted to Science and Technology

The world devoted 1.7 percent of gross domestic product (GDP) to R&D in 2002. In 2001, this proportion was 2.74 for the United States, 1.91 for EU15, 1.85 for EU25, 1.9 for Canada, and 1.29 for Russia (OST, 2006).

	North America	EU 25	Federation of Russia
percent of GDP devoted to R&D (2003)	2,4 %	1.8%	1.29 %
Share of gross expenditures on R&D (2003)	36,1 %	24,3 %	1,9 %
Share of gross expenditures on R&D coming from private sector (2003)	62,8 %	53,7 %	30,8 %
Share of world scientific publications (2004)	36.2%	34,2 %	2,4 %
Ratio of researchers to total population	4,4 %	2,6 %	3,4 %

Source : OST 2006

The USA, Europe and Japan continue to dominate knowledge production, but there has been a remarkable growth of gross expenditure on R&D in Asia (world share of 27.9 percent in 1997 and 31.5 percent in 2002).

In the United States, industry contributes to about 64 percent of gross expenditures on R&D and in Canada to 48 percent, in EU-25 to 54 percent and in Russia to 31 percent.

With 25 Members, since the accession of ten new countries from Central, Eastern and Southern Europe in May 2004, the European Union now accounts for 90 percent of European gross domestic expenditure on R&D. But there is not truly a European R&D market. There are great discrepancies in R&D capacities between Member States even if the new Member States will attract R&D investments; the R&D budget of the European Commission represents just 5 percent of public expenditure on R&D by Member States. In 2001, Europe accounted for 46.1 percent of world's publications.

Since the disintegration of the USSR more than a decade ago, the R&D systems of all these states have become a shadow of their former selves, yet their size still stands out. The proportion of GDP spent on R&D by the Russian Federation, for example, was 1.17 percent in 2004 (OST, 2006). Moreover, the number of researchers in Russia, 3,400 per million inhabitants, is the third-highest in the world after Japan (5,100) and the USA (4,400) (UNESCO, 2006). Almost 3650 organizations represent science and research in today's Russia (OST, 2006).

The evolution of S&T is constantly becoming a more costly affair. Each answer gives rise to new questions. Although nations are very much aware of the importance of science and technology for their economy, there are limits to the amounts of money they are willing to spend on it. This, more than has ever been the case in the past, leads to nations and businesses having to choose for which knowledge development they wish to invest in. In contrast with the past, this development leads to organizations for applied research and universities to being asked to account for themselves more specifically. Justification is often expected in terms of contributing to solutions to societal problems.

3.3.4 Information technology

The information technology boom started over thirty years ago. Information technology is the most important among the key technologies because of its dominant role in all other areas and in the convergence of technologies. It deserves a continued special attention due to its economic and societal relevance not least for innovation. Information and Communication Technologies, especially Artificial Intelligence and Cognitive Science can help breaking up rigid organizational structures hindering innovation, and do so in harmony with cultural, social and natural heritage. There is a trend towards modeling more and more of reality in computational systems. There is literally no part of reality which might not be subject to such modeling, including intelligent human beings as the most challenging goal. Information Technology is a cross-sectoral discipline par excellence. Its applications virtually cover any sector and any discipline (Bibel, 2005).

Currently, the availability and use of IT in the NAE is uneven among countries and sectors. Europe, in general, is behind North America. Within Europe, they are major differences. Some countries of Eastern Europe and to a lesser extent, Central Europe, have relatively low access to the technologies.

3.3.5 Attitudes towards science and technology

The NSF Science and Engineering Indicators 2006 reports that although Americans express strong support for science and technology, most are not very well informed about these subjects. The public's lack of knowledge about basic scientific facts and the scientific process may adversely affect on the level of government support for research, the number of young people choosing S&T careers, and the public's resistance to miracle cures, get-rich schemes, and other scams.

Americans have more positive attitudes about the benefits of S&T than are found in Europe or Russia. In recent surveys, 84 percent of Americans compared with 52 percent of Europeans (EU25) and 59 percent of Russians, agreed that the benefits of scientific research outweigh any harmful results. Most Americans and Europeans know little about genetically modified food and related issues. Although attitudes are divided, opposition to introducing genetically modified food into the U.S. food supply declined between 2001 and 2004. This is not the case in Europe. However, the majority of Americans believe that genetically modified food should be labeled (NSF, 2006).

The relations between researchers and society have also intensified in the past few years. The development of a number of controversies in the public sphere has undermined the illusion, harbored by many, that science is able to do away with all uncertainties. New forms of expertise are emerging, facilitated by the development of ICT that allows both the access to content and contact amongst actors. Researchers can no longer be treated as a population subject to homogeneous organization, structured according to disciplinary divisions, with ties to the social world mediated by administrative and political authorities. On the contrary, they are now a multitude of groups that interact in varied ways, re-arranging or event partially erasing boundaries between disciplines and different forms of knowledge, science being only one of these forms (Akrich and Miller, 2006).

3.3.6 Education in science

Over the past 15 years, most OECD economies have experienced a large increase in the number of students in higher education. The absolute number of students in S&T fields shows an overall increase too, but the proportion of S&T students in universities has steadily decreased during the same period. Some disciplines, such as mathematics or physical sciences, show particularly worrying trends. Nevertheless, higher education with professional objectives (engineers, technicians, etc.) remains attractive.

Image and motivation surveys show that the perception of science and technology remains largely positive among young people. Science and technology are considered important for society and its evolution despite concerns in specific areas, often linked to negative environmental and societal consequences of S&T. Scientists are also among the professionals the public trusts most, even though their prestige has declined (higher management or government positions are rarely held by scientists or engineers, and media reports on S&T events do not focus on the researchers themselves, who are thus very rarely known by name). Careers in S&T are still recommended by parents. However, there is a sharp difference between the positive opinion of young people towards S&T and their actual wish to pursue S&T careers. Although S&T professions continue to generate great interest among youth in developing countries, this is no longer the case for industrialized countries, with an even stronger distaste expressed by girls. Many young people have a negative perception of these careers and lifestyles. Incomes are perceived as low relative to the amount of work involved and the difficulty of the required studies. Few pupils have a full or accurate understanding of science-related professions, and many are largely unaware of the range of career opportunities opened up by S&T studies.

Students often lack knowledge about what S&T professionals really do. What they do know often comes from personal interactions (mostly S&T teachers, or someone in the family), or through the media. Scientists are usually portrayed as white men in white coats, and engineers as performing dirty or dull jobs. As S&T professions evolve quickly, S&T teachers and career advisors often lack up-to-date information to convey to their students. Young people therefore have few opportunities to learn what S&T professionals actually do and what their lives are like. The careers of S&T professionals as a whole have suffered from reports in the media of poor prospects and funding and increased job insecurity, despite the fact that these phenomena apply primarily to researchers. In addition, the possibility of having a proper balance between a successful career and a fulfilling family life is important to young people, and is perceived as difficult in S&T professions.

Many initiatives have been launched at different levels to promote S&T careers and studies. Government action has often targeted the image of science and scientists in society (science weeks, science days, etc.), and many more undertakings come from professional scientific organizations. Communication tends to focus on science itself, not on the reality of S&T professions. The actual impact of the various actions on both young people's attitudes and their choices of studies or careers is poorly evaluated, however. Furthermore, communication between the various stakeholders is often inadequate.

3.3.7 Uncertainties for the future

- Knowledge production and innovation.

  Will knowledge production and innovation become more user-centered? How diverse will the forms of knowledge be? Will knowledge be yoked entirely to industrial research imperatives? Will knowledge production remains highly conventional, with a strong hierarchical and disciplinary structure? Will research be harnessed to solving specific problems like health and environmental conditions? Will knowledge production become highly "socialized" with many institutions being involved?

  Will intellectual property issues, use and ownership of knowledge, evolve as quickly as production modes and the new modes of cooperation?

  Will universities remain the arbiters of what is and is not legitimate scientific knowledge?

  Will Europe be able to reinforce excellence, especially in new, fast-growing research areas, and areas where science and technology are closely interlinked?

  How will the governance of the whole research and innovation chain adapt to a systemic approach? Will policies take into account the new forms and producers (including individual researchers) of knowledge looking at quality, trust and transparency?

- Innovation systems.

  How do the internationalization of science and the internationalization of industrial R&D interact?

  How do innovation systems adapt to maximize benefits and lower costs of internationalization?

  How far will regionalization go in Europe, which is strongly present in current trends? Will excessive competition between regions in the absence of coordination at European level, lead to a fragmentation of efforts and absence of a coherent strategic vision? Will current regionalization reverse and a strengthening of large-scale European level projects that concentrate and integrate research without taking into account the concerns of local authorities and local context take place?

  How will the potential contradictions between local development and internationalization be dealt with?

To what extent might policies that enable firms to pursue the 'best quality according to international standards' conflict with policies aimed at ensuring that 'research is a means for local economic development'?

Will governments be able to develop “innovation plans” that favors interactions between universities, industries and governments? Will European universities serve the industrial economy? Or simply become more closely linked to “external” research?

Will enterprises make huge investments in research and produce a great deal of industrial innovation?

How will universities deal with their missions of education of a diverse student population and of research with local industrial communities?

Will the “triple-helix” model that implies university-industry-government relations, develop quickly?

Will there be a more open and dynamic European market for post-doctoral researcher funding, including opening access to non-academic research? Will more importance be given to service sector activities and SMEs?

- Resources.

Will Europe be able to mobilize extra financial and human resources for KST to keep pace with the United-States and Japan and not be taken over by fast-developing Asian countries? Will Europe become attractive for young researchers, irrespective of their country of origin, providing them with the resources needed to develop their full research potential, and retaining them within Europe?

Will a pan-European approach for investing in high-quality frontier research be set up?

In the countries where boundaries between the public and the private sectors remain, will financial efforts and administrative measures break them?

Will the Russian Federation manage to transform its R&D system, stop brain drain and attract young people?

What kinds of relationships will North America and Europe’ science and technology systems have with Asia? and with the less developed countries?

What impact will the increase of productivity of industrial systems have on the resources devoted to KST?

Taking into account the limited resources in budgetary terms, does the public sector has to support technologies in areas of strength or, on the opposite, does it have to support technologies in areas of specific weaknesses?

Taking into account the limited resources in budgetary terms, what should be the nature of public support? Should it leave the market and support targeted R&D firms through tax incentives, mobility, etc.? Should it fund most of the research and have only accompanying measures for the companies?

- Information technology

Will Eastern and Central Europe be able to reduce the digital divide with the rest of Europe?

Will Europe manage to keep pace with North America?

- Attitudes towards science and technology.
  Will the "precautionary principle" prevent scientific advances? How strong will be groups of fundamentalists to prevent research development? Will values influence intervention on nature and in which direction?
  Will there be more systematic use and consultation of civil society organizations for the determination of research agendas?
  Will there be greater investments in anticipatory processes (e.g. foresight, citizen's summit…)?

- Education.
  Will scientific careers become attractive again?
  Will there be a spread of self education, training and research generation tools thanks to drastic cost reduction in ICT-based Microsystems and artificial intelligence and knowledge management software? Will there be concentration of education in the hands of a global knowledge oligopoly made of a small number of US, European and Asian giant firms?
  Will universities turn to problem-solving?
  Will North America and Europe continue to play an important role in the training of scientists from developing countries?

3.3.8 Consequences for AKST

There are three important consequences for AKST.

The first one relates to the relation between the public and the private sector. There needs to be consensus on priorities between the public and the private sector. For the moment, the relationship between these two sectors is not always optimal. A consensus on priorities is needed. The public sector needs to take better account of private sector and consumer needs, and also it needs to concentrate on the development of public goods (de Lattre-Gasquet, 2006).

Second, there needs to be more cooperation among countries of NAE. It is important to note that the Strategy of Lisbon has been developed recognizing, among other factors, the fact that Europe is lagging behind the United-States in terms of science and technology. A number of studies are therefore carried out in Europe to identify ways of improving the situation. The United-States and Europe are often more seen in terms of competitors than partners.

The third one relates to technologies. Studies have been carried out at European (EU Commission, 2006) and national levels (Technologies Clés, 2006) to identify emerging priority technologies that are of key importance for Europe in the future. At European level, forty technologies have been grouped within four main scientific fields:
- Nanotechnologies, knowledge based multifunctional materials, new production processes,
- Information Society Technologies,

- Life-Sciences, genomics and biotechnology for health,
- Sustainable development, global change and ecosystem.

Two different rationales support the selection of these technologies. The first one is that they are emerging and identified through a questionnaire sent to a panel of about 1300 experts in all countries of the enlarged Europe, while the second one is the results of the foresight literature review both in the European and the main competitor countries (EU Commission, 2006).

However, if Gross Expenditures for R&D (GERD) stay at the present level and if there is no coherent European or NAE policy, it is unlikely that all of it can be done.

For example, AKST investments will differ if life sciences and sustainable development if economic factors are the main drivers or if societal motives are the main drivers.

3.4 Agricultural Knowledge, Science and Technology and Agricultural Research and Innovation Systems: Major Uncertainties in Key Variables

Agricultural R & D is not conducted in isolation but strongly influenced by the rest of science. In 2000, the world invested $ 725 billion (in international dollars) in all the sciences, including both public agencies and private firms – that is about one third more than in 1995 - with the biggest increases in the Asia and Pacific region. However, there is evidence of a huge, and partly growing, divide between the “scientific haves and have nots”. The total amount spent on sciences is approximately 1.7 percent of the world’s GDP worldwide. Public agricultural R&D funds amounted to $ 23 billion in 2000 – just about 3 percent of the total science spending (Science Council, CGIAR, 2005).

In this subchapter, we will look at what are the major uncertainties in variables of future agricultural innovation systems, AKST being a key driver of the agricultural systems.

3.4.1 Organizations for Agricultural Knowledge, Science and Technology

The futures of organizations for Agricultural Knowledge, Science and Technology (AKST) are going to be influenced by changes in the Agricultural System and in the KST systems. In this subchapter, we will briefly describe these organizations in the different regions of North America and Europe, and shed light on a number of uncertainties for the future.

AKST organizations in North America and Europe include all the formal and informal organizations controlling, generating, distributing or utilizing agricultural knowledge, science, technology, inputs, markets, credits, capital and assets. This implies primarily research, education and extension organizations, but also government agencies, administrative and political decision-making bodies, NGOs and associations, and private enterprises acting within the food chain and interacting with it e.g. in regulation, input production, waste management, on markets and in financing. They form the agricultural research and innovation system. The North American and European agricultural innovation systems have also had a major impact on shaping of a broad range of AKST organizations outside the region, for example of trans-national private companies and NAE-based and -dominated international organizations, and the Consultative Group for International Agricultural Research (CGIAR), but also many national organizations from Africa, Asia and Latin America.

3.4.1.1 On-going trends

Formal AKST structures started to form in late 1800s. In USA, contrary to most of Europe, these activities were integrated among each others (Huffman and Evenson, 1993), while in Russia they were separate with no public extension service (Miller et al., 2000). In USA, decisions on AKST were taken at state level which fostered innovation and diversity, while in Eastern Europe a strictly centralized top-down model dominated (Miller et al., 2000). The governmental responsibility of AKST was in NAE traditionally in an agricultural ministry, but is increasingly been brought into closer connection with the general public KST and innovation policy (OECD 1999; OECD, 2005a,b,c). To counteract consequent disintegration among components of AKST, cooperation of them across institutes (especially between research institutes and universities), disciplines and territories, is increasingly encouraged also by specific funds. This has been more successful among research and extension. The organizational structure chosen for AKST components seems to have profound influences, and effective cooperation across ministry boundaries seems to be very challenging (OECD, 1999).

During the first half of the 1900s, and accelerated after WWII, AKST expanded. The share of public AKST funds to universities increased from the 1970s onwards. Since 1980s there occurred decline, privatization, and rationalization of facilities (Alston et al., 1998). The share of agriculture of all the R&D funding declined, but the agricultural research intensity ratio (agricultural public R&D relative to agricultural GDP) rose more than the average science and technology research intensity ratio (Alston et al., 1998). The model for international research centers was introduced after World War II, and in 1970s they formed CGIAR and expanded, with a stagnation or decline in funding in the 1990s, but recovering in the 2000s. In 2000, CGIAR represented 1.5 percent of the global public sector investments in agricultural R&D and 0.9 percent of all public and private agricultural R&D spending (CGIAR Science Council, 2005a). NAE governments are now prepared to fund higher education with an increasing tendency towards tuition fees, and also “basic” and “pre-competitive” sectoral research, but economic sectors are increasingly encouraged to fund sectoral research, and extension/development costs are addressed to clients (OECD, 1999). Farm subsidies are increasingly questioned and linked to multifunctionality.

The on-going trend of decline in public funding of AKST since the 1980s was linked with increase in private sector in North America and the European Union (Alston et al., 1998), and in Eastern Europe since 1990s. Investments of the private sector were by 2000 around 55 percent of all agricultural R&D in developed countries, but in low-income countries negligible (CGIAR Science Council, 2005). The involvement of the private companies in agricultural extension has also increased (Umali and Schwartz, 1994), while public extension services have become increasingly chargeable and down-sized (Read et al., 1988; OSI, 2006) apart from some European countries with small farm -dominated agriculture or a conscious choice for independence of commercial interests (OECD, 1999). However, this proportion of private funding is about the same as the general repartition of private funding of R&D (cf. subchapter 3.3.1).

Food chain organizations developed towards global, linear and centralized structures with regional specialization (McFetridge, 1994; Royer, 1998; Cook and Chaddad, 2000; Reardon and Barrett, 2000; Hendrickson et al., 2001; Harwood, 2001). Also farms specialized, increasing in size and declining in number. In Eastern Europe, farms were industrialized first after WWII, and also private small-scale farming continued to exist.

<u>Drivers</u>

Major drivers for expansion of formal AKST organizations were industrialization, advances in technology and knowledge, and an optimistic view of societal benefits, affected by demand and mediated through policy (Alston et al., 1998; Van Keulen, 2007). Privatization was fostered by introduction of IPR, advances in genetics (see 2D1.5.1), and by research policy (Alston et al., 1998) (see also 3.4.3). Decline occurred since the mid of 1970s due to paradigm shift towards policy having less role in society, increasingly due to the view of less societal benefits along with deletion of food insufficiency and decline in the share of GNP in NAE despite evidence of no change in high returns to investments in public AKST (Alston et al., 2000), and due to consequent budget cuts. However, many governments start again to give an opportunity to AKST to show comparative advantage in contributing to the emerging wider societal interests, through innovative, interactive AKST, even if rewarding mechanisms still need further development (OECD, 1999). The limited contribution of AKST to public debate and policies during the recent decade is seen as a major challenge (OECD, 1999).

Increase in size, specialization, and consolidation of food chain organizations and increasing domination by multinational corporations was driven first by industrialization and later by liberalization of international trade, mobility of capital and people, new technologies (Galizzi and Pieri, 1998), and by regulatory barriers discriminating small enterprises (2D1.5.1). Public AKST had at least as much importance as private R&D and market forces, for change in livestock specialization (but not in crop specialization), farm size, and farmers' off-farm work participation (Busch et al., 1984; Huffman and Evenson, 2001), which intentional agricultural policies contributed to (Van Keulen, 2007). Differences among NAE regions have been mainly due to differences in political-economic history.

3.4.1.2 Uncertainties for the future

<u>Funding to develop AKST organizations</u>

Success in meeting the challenge of changing societal demand, whether public or private, will crucially affect public and societal support for development of AKST in the future. Will the solely economic view to returns of AKST widen? Will AKST get public acceptance for its funding, if the notion for multifunctionality and sustainability for AKST, increasing demand for public goods and immaterial services, as well as interest in multidimensional food quality and ethical consumption becomes fully acknowledged? Do AKST organizations succeed in proactively convincing the public opinion of its comparative advantages in meeting crucial present and future challenges of societies? Will AKST adjust its paradigms, image and identity, adopting a wider, more diverse and flexible agenda to meet the changing societal demand? Can organization structures become flexible enough to promote changes in scopes and targets? Will the notion of world food insecurity, the impact of NAE AKST beyond its boarders, as well as drastic spatial inequity in AKST resources of the world (CGIAR, 2005) turn the view of the societal potential of NAE AKST positive? What consequence will it have on investments in public AKST and reconsideration of their spatial allocation?

Role of public and private AKST organizations

What impact will technological development (such as functional foods, gene-tailored diets, photosynthesizing microbes, GMO, nanotechnologies and information technologies) have on the role of private companies in science and technology? Will they meet development and sustainability goals through diversifying product development and segmenting supply for different demands and markets, including services, public goods and food security? Policies determine, whether there will be internalization of externalities so that public goods would become economically rewarding to develop, produce and purchase through private AKST. Will public and private AKST organizations develop separately within their own domains, or do efforts to synergy and intermediate spaces succeed? Or will AKST be divided to private sector providing products for solvent markets and to public AKST, which develops public goods and sets regulations to constrain private sector? Or will public goods including food security and multifunctionality more generally, at all get space? The answers to above questions depend crucially upon whether "laissez-faire" policies continue to dominate or whether pro-active policies will be adopted.

Dis/integration of organizations at global, national and AKST level

There is a wide consensus about the need to integration in AKST on and among different levels, starting from policy coherence on level of ministries and administrative bodies, inter- and transdisciplinarity within the formal knowledge systems with integration of stakeholders, till increased communication within the food chains and multifunctionality of food systems and agriculture. However, also risks in integration are seen and opposing views presented (OSI, 2006; Sumberg et al., 2003). Will integrative approaches in structural development of AKST organizations take over? Will incentives and tools, possibly based on modern information technologies, be created for public NAE science and technology organizations to intensify links among them and with CGIAR and NARS organizations and stakeholders in low-income countries, to integrate global/regional/local scales and thus meet food security goals in conditions of unequal resources? Will sufficient measures be taken to expand the U.S. success story of integration among research, education and extension (see 2D.1.4), but without realizing the present concerns about isolation from KST (OECD, 1999)?

Structural dis/integration of disciplines and stakeholders

Paradigms and policies will have a crucial role also in determining, whether science and expert systems will continue to develop according to their own fragmentary logics (Bruun et al., 2005) directed by expert value systems, or whether integration among disciplines, and among societal demands and diverse value-systems, will be introduced and reflect in structure and management of organizations.

If disciplinary integration will be the goal, will new disciplines be born applying the unifying and expanding ‘rhizome model’ (ecological economics and industrial ecology as examples), often seen just creating new barriers for integration (e.g., Heemskerk et al., 2003; Lele and Norgaard, 2005), or (b) through interaction of disciplines utilizing their perspectives, methodologies and cumulated knowledge (e.g., Lockeretz and Anderson, 1993; Bruun et al., 2005; Kahiluoto et al., 2006), or (c) forgetting disciplines and thinking in terms of scientific community (Lele and Norgaard, 2005), or (d) additionally integrating non-scientific knowledge systems? Will the challenge for high-quality disciplinary knowledge generation seen as a valuable basis for integration, or will that crumble away? And will the dominant way be integration of organizations/structures, such as predicted for universities by Väyrynen (2006), possibly based on flexible models of interacting scientific communities (Lele and Norgaard, 2005)? Or do structural friction and other barriers (see 2D.1.3.3) lead to additional hierarchical structures and bureaucracy, or limit integration, such as until now, to integrative approaches and methodologies only, with scarce organizational/structural changes?
Will local/experiential/traditional knowledge and beneficiaries with least voice be structurally integrated to ensure appropriateness and adoption of technologies? Is modern communication and information technologies creatively utilized to establish organizations to alleviate problems of distance and undeveloped infrastructures?

<u>De/centralization and consolidation</u>
Physical distancing in food chain and regional specialization has, besides economic benefits, caused negative environmental and social impacts. Will this and the notion for multifunctionality cause paradigm shift turning development towards diversification and integration within regions, or will farm and regional specialization continue, by half of new tools to meet the environmental and social challenges? Multifunctionality could reduce the competitive scale of an organizational unit in comparison to industrialization as a driver. But do policies, demand and formal AKST lead to diversification of supply on farm, or only on regional or even at national or international level, through economic comparative advantages, and where does the lower limit for economic scale accordingly set? Will food and product chains and marketing channels diversify, due to more varied product combinations and demand segments?

Will paradigms and their operationalization in policies and demand lead to centralized trans-national organizations, which will generate knowledge, technologies and products segmenting their activity for diverse markets, or does contextuality and local adaptation proceed through decentralization and regionalization of AKST? Does the on-going centralization of organizations and decision-making continue, and possibly lead to - as an extreme - few discipline-based international centers of excellence in the whole world?

Contextualization of AKST organizations

There are means to adjust the societal and organizational situation to the requirements of capital-intensive agricultural technology, which is less appropriate for resource-poor farming communities as such. One example is the Grameen Bank by the Nobel Prize laureate 2006, economist Muhammad Yunus. The Grameen Bank provides micro-loans for the poor, not requiring guarantees. Will such models for more diverse and contextualized organizational structures, e.g., banking systems, be developed and distributed?

3.4.1.3 Consequences for AKST

To achieve the development and sustainability goals, thorough reconsideration of appropriate organizational structures for AKST is required. Societal support for development of AKST and relevance for the crucial challenges requires in any case wide scope, broad dialogue and a broad range of perspectives implied in flexible, diverse, integrative organizational structures. The share of public and private sectors in AKST is decisive for the kind of public regulatory arrangements that best meets the goals. Regulatory regimes can either only take care of transparency and communication, or set economic incentives for the mainly private organizations to promote the goals, or directly regulate their activity. The latter can take place through rules and legislation or through maintaining a public organizational structure. In any case, proactive policies are required to shape AKST organizations and their activity.

Integration of organizations of knowledge generation and dissemination promotes the goals. However, focus on either globally coherent and centralized or on the other hand locally coherent and decentralized policies and AKST organizations create societies with very different strengths and weaknesses. Global models with few centers of excellence and top-down approaches in science might be better in meeting global environmental problems, while locally horizontally integrated models and bottom-up approaches might have social and cultural benefits. Integration among organizations representing AKST components might produce more traditional solutions but with high relevance for present actors, while linkages to KST components foster more substantial changes and innovations with higher risks and opportunities for meeting the D&S goals. Relevance and contextuality of the latter case might depend on degree of embracing social sciences.

3.4.2 ***Proprietary regimes***

3.4.2.1 On-going trends

The assignment of intellectual property rights to living things is of relatively recent origin in developed countries. Vegetative propagated plants were first made patentable in the US only in 1930. And the protection of plant varieties (or plant breeder's rights - PBRs), a new form of intellectual property, only became widespread in the second half of the 20th Century. Intellectual property laws vary from jurisdiction to jurisdiction, such that the acquisition, registration or enforcement of IP rights must be pursued or obtained separately in each territory of interest. However, these laws are becoming increasingly harmonized through the effects of international treaties such as the 1994 World Trade Organization (WTO) Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPs), while other treaties may facilitate registration in more than one jurisdiction at a time.

If the aim of plant variety protection is to provide incentives to breeders, one of the questions that arises is how the contribution of farmers to the conservation and development of plant genetic resources should be recognized and preserved. Building on the principles embodied in the Convention on Biological Diversity (CBD), the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA), seeks to establish principles for facilitating access to plant genetic resources and establishing fair and equitable mechanisms of benefit sharing. The International Union for the Protection of New Varieties of Plants (UPOV) aims to encourage the development of new varieties of plants for the benefit of society by codifying intellectual property for plant breeders. In 2005, 58 countries had signed UPOV. For plant breeders' rights to be granted, the new variety must meet four criteria under the rules established by UPOV. The new plant must be novel, which means that it must not have been previously marketed in the country where rights are applied for. The new plant must be distinct from other available varieties. The plants must display homogeneity. And the trait or traits unique to the new variety must be stable so that the plant remains true to type after repeated cycles of propagation. Protection can be obtained for a new plant variety how ever it has been obtained, e.g. through conventional breeding techniques or genetic engineering.

In 2001, the FAO Conference adopted the International Treaty on Plant Genetic Resources for Food and Agriculture. This legally-binding Treaty covers all plant genetic resources relevant for food and agriculture. It is in harmony with the Convention on Biological Diversity. The Treaty is vital in ensuring the continued availability of the plant genetic resources that countries will need to feed their people. Through the Treaty, countries agree to establish an efficient, effective and transparent Multilateral System to facilitate access to plant genetic resources for food and agriculture, and to share the benefits in a fair and equitable way. The Multilateral System applies to over 64 major crops and forages. The Governing Body of the Treaty, which will be composed of the countries that have ratified it, will set out the conditions for access and benefit-sharing in a "Material Transfer Agreement" (MTA).

There have been several extensions of patenting, especially in the direction of patenting gene sequences, totally or partially. The United States has now issued patents on protein co-ordinates (i.e., on the result of physical measurements of proteins to define their precise shape). The monopoly that is actually claimed in these patents is the use of the measured co-ordinates in computer programs to attempt to model the interaction of the protein with other chemicals that might be candidates for therapeutics (Knoppers and Scriver, 2004) .

3.4.2.2 Uncertainties for the future

Bits of information or research tools are contributions to product development, but economically, there is little or no independent value in these inventions or discoveries. The economic value derives from the final product. How can firms or public research not rely completely on biotechnology firm to improve their products? What kinds of incentives must be set up to develop new research tools in public research? What will be the impact on industry of products coming off patent? Will industry continue to be interested in high-risk low-payoff products or will it concentrate on blockbusters? Will the public procurement model develop, especially for products such as vaccines?

How far will the World Intellectual Property Organization go to harmonize international patent Law? Will there be a harmonization of patent law? Will there be a world patent? How far will the collective networks in the field of agricultural biotechnologies manage to get common development and patenting of novel technologies?

3.4.3 Access, control and distribution of Agricultural Knowledge, Science and Technology

In this subchapter we look at what kind of major arrangements are there for access, control and distribution of AKST, how did they evolve until now and why: which were the main drivers? How do they differ among North American, the European Union, and non EU Eastern European countries and Russia and why: what kind of differences were there in drivers?

Generation and utilization of research results must be coordinated and parallel processes (The World Bank, 2006). Access, control and distribution of AKST covers issues of funding and management of formal AKST structures; participation of different stakeholders and beneficiaries in agenda setting, R&D processes, interpretation and application of results; dissemination, extension and communication processes; and relevance of solutions, appropriateness of technologies, and options for spillovers, for different beneficiaries. The futures of access, control and distribution of AKST is very much influenced by the futures of actors of the KST systems (subchapter 3.2), models of production (subchapter 3.3).

3.4.3.1 On-going trends

Access of farmers was arranged in USA through decentralized, integrated AKST (see 3.4.1), and in Russia and in part of CEE through top-down "chain-of-command" with no public extension service (Miller et al., 2000). Decline in public funding has been linked with even higher decline in public control of AKST since the 1980s. The role of private sector has increased in the management of public funds, publicly funded and performed R&D, and in performing R&D using public funds, with a decreasing net flow of public funds to private research (Alston et al., 1998). Due to privatization, less focus is given on farm-level technologies and on equity and distributional issues as well as on public goods (Alston et al., 1998; BANR, 2002), and less of AKST is available in the public domain. According to Pretty et al. (2005), only £219 million of the annual UK government subsidy of £3,102 millions to agriculture (not including the additional subsidies for foot and mouth disease) was used to create positive externalities. After decline since WWII, recently farmer's influence and participation has increased (Romig et al., 1995; Walter et al. 1997; Wander and Drinkwater, 2000; Dik, 2004; Groot et al., 2004; Morris, 2006; Ingram and Morris, 2007). Power of retail in the food chain has increased, while increase in influence by consumers is debated (e.g., Buhler et al., 2002; 2B). Technologies have been biased towards

increase in size of food chain actors and industrialization of the farm sector, and they are less appropriate for poor farming communities (BANR, 2002; Alston et al., 1998). The voice of NAE policies and organizations and later of large-scale industry and NGOs has increased, and regulatory policies are reducing the extent to which spill-overs of NAE R&D are feasible also outside NAE (CGIAR Science Council, 2005a). CGIAR funds are for a major part provided by NAE countries and NAE-based organizations, funds being increasingly restricted (World Bank, 2003).
Since 1970s, competition and short-termism has been increasingly introduced to the public AKST to broaden the scope, and to increase transparency and efficiency (Alston et al., 1998; Buhler et al., 2002). However, increase in economic efficiency might have failed (Buttel, 1986; Huffman and Just, 1999, 2000), and extreme competition and lacking safety is, according to creativity research, most serious threat to creativity and true innovations (). Recently, governments are shifting towards funding multi-annual programmes and long-term thematic areas with a considerable stakeholder involvement in the process, and stronger links among AKST components, to increase efficiency and reduce fragmentation of solutions (OECD, 1999). The target is seen in innovative, interactive AKST, and becoming partner in contributing to the decision-making processes rather than prescribing optimal solutions (OECD, 1999).

<u>Drivers</u>

Major driver for privatization (see also 3.4.1) was paradigm of superiority of markets as regulators in comparison to policies. The consequent "laissez-faire" policies led, besides budget-cuts, to protection of space to act for large-scale private companies through regulations like pesticide regulations and IPR (see 2D1.5.1; Bauer and Gaskell, 2000). Trade liberalization contributed to increase in voice of trans-national companies. Advances in genetics (see 2D1.5.1) and intentional research policy (Alston et al., 1998) enhanced control by private sector. Fails of public AKST to serve all the target groups might have left empty niches for private companies, too. Increase in voice of NAE policies after WWII was due to empowering trans-national firms, and due to the role of NAE in trade negotiations, regulations and setting increasingly targets for low-income countries as a precondition for support (e.g., the increase of restricted funding for CGIAR; World Bank, 2003). Increase in voice of NGOs in AKST since the 1970s was reaction to negative externalities, which besides the increased role of agri-business again contributed to short-termism and competitive grants. Re-emergence of longer term and bigger programs was fostered by strive for governmental efficiency. Also a paradigm of “new public management” increased stakeholder participation in the 1990s: no more less government, but better government, implying more enlightened regulation, improved service delivery, devolution of responsibility, openness, transparency, accountability and partnership (OECD, 1999).

3.4.3.2 Uncertainties for the future

There are a number of uncertainties for the future of access, control and distribution of AKST in North America and Europe and their impact on development and sustainability goals at global level.

<u>Privatization</u>

Public goods, the poor and hungry, and rural livelihoods are target groups with least voice on the market at present, and private sector is led by markets. Markets can be directed to work for the social optimum through internalization of externalities, i.e., through including the negative and positive externalities, in prices. Instruments include penalties (Jackson, 2005), reallocation of all taxes, subsidies and incentives, and institutional and participatory mechanisms (Pretty et al., 2001). Regulation can be used to set limitations.

Will private sector control in NAE AKST continue to grow? Or will the public sector take more control, either through direct funding and control, or through helping the market forces to work for social optimum, in terms of sustainability and food security? How will incentives for public good supply of increasingly multifunctional farming be created: through regulations, internalizing externalities through reallocated subsidies and taxes, through creating new markets like for GHG emission quotas, or through consumer certificates and price premia?

<u>Integration of perspectives</u>

Access, control and distribution of AKST is not only depending on, who pays. It is also depending on, which perspectives and competences are represented in processes of AKST. Will barriers for competent implementation of systems-oriented, interdisciplinary, transdisciplinary and participatory approaches be successfully alleviated, or will these approaches be increasingly seen as competitors to existing disciplinary basic sciences and expert-values, in the potential situation of declining resources? There is evidence of reduced efficiency due to excessive introduction of competition and short-termism in management of formal public science and development structures (Huffman and Just, 2000). The risks of short-termism are especially serious concerning learning-intensive integrated approaches, and sustainability objectives with an inherent long-term perspective. Do these lessons cause reconsideration, or is there lack of good alternatives? Will time-consuming and learning-intensive integration become impossible in increasing competition based on disciplinary quality and merit criteria? Thus, will contextuality and integration win or loose the fight for paradigm shift, and which perspectives will dominate in the future?

<u>Control by beneficiaries</u>

Multifunctionality could increase independence, and thus voice, of farmers or of supply chain. But do policies, demand and formal AKST lead to diversification of supply, and thus increased independence from retail, mainly on farm, regional or national level? Will diversifying marketing channels and actor networks increase power of consumer and producer? Will the perspective of solvent large-scale industry get continuously more emphasis in the knowledge networks, in the situation of decline in public funding, or will there emerge creative solutions to diversify perspectives?

Will certificate and control system with the required information and education to citizen-consumers be introduced, to enable individual consumers, small-scale farmers and other food system actors with less power on the market, to control AKST and promote achieving D&S goals, or will more emphasis be put on the public control? Or will the options to synergy among these approaches be utilized? Or, as an extreme, will no public action to enable AKST to promote development and sustainability goals be taken? Locally oriented AKST might require less public support for equity in influence and outcomes than globally oriented one. But will the competence and viewpoint of the poor and hungry, of different dimensions of sustainability, of health and nutrition, and of rural livelihoods be integrated in knowledge and technology generation in the world-wide influential NAE AKST, to prevent past failures and to shape future food systems to meet D&S goals?

<u>Dissemination of information</u>

In a situation of increasing transfer of control from political decision-makers to the market, adequate, accessible information is essential. Well-informed choices by consumers and other food system actors through education of “food competent citizens”, standards, and price premiums, can promote D&S goals. They do, however, represent lower equity in influence than public internalization of externalities. Existing social and psychological barriers for consumption underline policy interventions in the social and institutional context, including market structures, business practices, helping communities to help themselves and the environmental and social performance of governments (Jackson, 2005).

Does the dominant trend to down-sized and client-charged information to farmers continue, or will the different example of some countries (Austria, Denmark, Poland) prioritizing equal access and independence, lead to reconsideration of the trend? Will the increasing niche for commercial advice be filled in by agri-business companies, perhaps increasingly trans-national ones, leading to homogenization of practices and less competitiveness by resource-poor farmers? Or will there be a demand for independent extension enterprises? Will the increasing niche lead to a changing role of the publicly funded research to cover also distribution of knowledge and technologies? Or will increasingly integrative approaches and structures extensively incorporate clients in interactive communication networks to generate and utilize knowledge and technologies, and thus decrease significance of separate extension services?

Will development of open, continuous, reflexive and democratic processes that also allow for a respectful, productive disagreement, succeed, instead of new forms of exclusion (Hinrichs, 2000, 2003; Winter, 2003; DuPuis and Goodman, 2005)? Will the opportunities offered by modern communication and information technologies be successfully utilized to increase communication, and enhance access to knowledge, technologies and markets, and will increase of the "digital barrier" be avoided? Will this increase equity in influence of beneficiaries, including those outside NAE? And will the diverse and rapidly changing demands of consumers, farmers and other food system actors for life-long learning and wider understanding be met?

3.4.3.3 Consequences for AKST

Equity in influence and access to knowledge, technology and resources, and consequently to food, fiber and fuel requires participation. Participation of varied beneficiaries with their value systems, perspectives and competence in AKST processes through equal dialogue requires shift from technology transfer approaches to interactive social learning networks. This shift is less demanding to realize in locally than globally oriented agricultural innovation systems. On the other hand, experience of equity in the daily environment might hide consequences of global disparities. Global equity would require effective global communication networks through modern technologies, and global regulatory frameworks among regions. For meeting D&S goals more broadly, integration of varied perspectives of sustainability dimensions, system levels and scales, disciplines and stakeholders is a necessity, but there are alternative means to make that operational. More emphasis on policies allows effective internalization of externalities also in terms of D&S goals, while less regulation requires more emphasis on education, information and standards and tends to lead to lower equity on the market. Regionally and locally oriented AKST systems enhance transparency and direct feed-back from consumers, citizens and communities, as well as from local ecosystems and thus compensates or complements regulatory and information systems.

3.4.4 Access, control and distribution of inputs, markets, credit, capital and assets

3.4.4.1 On-going trends

In AKST, access, control and distribution of inputs, markets, credit, capital and assets is a function of the general economic situation, the economic situation in the agricultural system and the role of subventions and trade policies (subchapter 3.2.), and resources devoted to KST (subchapter 3.3).

Such developments tend to overlook important functions of agriculture (such as provision of certain ecosystem services) and to decouple demand for research from supply (or questions and answers). Public funding must identify the gaps and support responding to research gaps that private sector funding and research does not deal with.

Participation of stakeholders to ensure effectiveness of demand-driven research requires higher volumes of funding, as well as different mechanism for prioritization of research themes and allocation of funds. In Europe especially, highly participative and interactive foresight studies are important tools for formulating future-oriented research programs.

3.4.4.2 Uncertainties for the future

3.4.5 Traditional knowledge ; generation and advances in knowledge

3.5 Future Agricultural Innovation Systems: Contributions to Sustainable Development Goals

3.5.1 Four plausible agricultural innovation systems

3.5.1.1 Market-led AKST

There is convergence of S&T policies between North America, the European Union and Russia and the non EU Eastern European countries which all favor the private sector.

Market-led AKST contributes to decreased hunger and poverty and improved nutrition and human health in NAE and at international levels. However, it does not contribute to equity and sustainable economic development.

Due to the predominance of economic issues, R&D is mainly driven by economic factors and most Agricultural Knowledge Science and Technology (AKST) is developed and funded by Multi-National Corporations (MNCs) in association with a few universities and small innovative firms. Elite research groups throughout North America and Europe form technology clusters with firms. Research is not location specific. It is done where human resources are the best. MNCs and a few universities control and sell most AKST. Important research investments are made in relation with two markets: the market for functional food for the high revenue consumers, and the market for cheap and safe food for the low revenue consumers. Public research is mostly done in international agricultural knowledge centers. The European Research Space is a great success. Centers of excellence at international level associate R&D public institutes and major firms with the objective of developing new activities or market through innovation.

Private companies benefit from strong intellectual property rights and privatization of living organisms. Legislation makes it possible for universities, non-profit organizations and small businesses to keep ownership of intellectual property developed with the support of public funds. Common regulations and standards are designed which facilitates generation and distribution of knowledge. Tax incentives encourage companies to invest and to link up with each other and with universities.

Access, control and distribution of inputs and capital is also controlled by the large firms which are highly vertically integrated and own farm enterprises.

As far as the generation of knowledge is concerned, production and problem-oriented multidisciplinary work is encouraged. Despite managerial discourses on sustainable development, the AKST generated by MNCs which does not prevent certain areas, such as marine ecosystems and biofuels, to be left out of research agendas. Therapeutic successes, huge application of nanotechnologies leads progressively to a global conception of nature and life. There are no more frontiers between the different worlds of human beings, animals and plants.

3.5.1.2 Ecosystem-oriented AKST

In the ecosystem-oriented AKST, there are no clear demarcation lines between university science and industrial science, between basic research, applied research and product development, or even between careers in the academic world and in industry. The ecosystem-oriented AKST can make a major contribution to, at least three, of the IAASTD development & sustainability goals:

(1) to environmental sustainability by development of novel, knowledge-intensive and resource use efficient technologies,

(2) to sustainable economic development, by investing human and financial capital in the development of "green technologies", and

(3) to enhance livelihoods and equity by developing a broad range of technologies (both low and high cost) and by making these widely accessible so that also poor and small farmers can benefit from them.

Many subventions and most trade barriers are eliminated. Support payments now reward farmers for the provision of services other than food. In the EU and North America, agricultural policies are based on the multi-functional nature of agriculture and the improvement of natural resource quality by adhering to stricter environmental regulations. In Eastern European countries and Russia, governments and farmers' associations are conscious of the disasters created by the high (often excessive) usage of agro-chemicals, poor infrastructures etc. Drastic reforms ensure improved environmental policies.

Laws facilitate the ownership of knowledge by all those that have contributed to this ecosystem-oriented AKST. Policies support increased scientific cooperation among NAE countries. Special emphasis is on strengthening cooperation within NAE: especially EU and North America with Eastern European countries and Russia. Innovation, public – private interactions, as well as scientific collaboration and partnerships with the less developed countries is also encouraged. The range of organizations researchers deal with the colleagues with whom they collaborate and the topics/disciplines considered have enlarged. Problem-oriented, demand-driven approaches prevail and there is a great deal of research integration (multi and inter-disciplinary work, systems approach). Huge efforts are made to attract young students towards science and technology, especially in environmental and agricultural sciences. Efforts are made to promote new scientific fields in universities and to renew interest in fields that have been forgotten but are important.

AKST serves increasingly homogeneous consumer preferences and diets. The trends of decreasing household sizes, increased household budgets, lifestyles with less time spent for preparing food, and more traveling, increasing concerns for health, animal welfare and environment continue and result in an increased demand for convenience and functional food. While there is also increased demand for organic products, the new technical, convenience-led food solutions (e.g. ready-meals) clearly predominate. As far as access, control and distribution of inputs and capital is concerned, efforts are made to increase national and international budgets for more research and cooperation world-wide. Research investments are concentrated on global and regional centers of excellence performing both curiosity–driven and applied research. Emphasis is on investments that support a knowledge- and bio-based economy.

In the field of climate change mitigation and adaptation, policy measures related to spatial planning stimulate the reduction of greenhouse gas emissions and make NAE climate proof. This has led, for instance, to diffusion of new technologies such as floating greenhouses (e.g. in the Netherlands in response to rising sea level), meat without animals or low-emission stables (to avoid pollution) and, crop cultivation on roofs (natural cooling in urban areas). At the same time, conventional agricultural techniques are further improved and much effort is put on increasing resource use efficiencies, especially for water, nutrients and energy (precise provision in time and space). In many regions, farms specialize in either specific livestock or arable farming according to their local soil and climatic conditions.

Low efficient cultivation of biofuel crops (oilseed rape, barley, sunflower, for example) has been replaced by second generation biofuel production. Agriculture is an energy producer and consumes energy efficiently. But other, more centralized and technology-intensive, renewable forms of energy outweigh agriculture as energy-producer. For instance, artificial photosynthesis (combining sub-processes of photosynthesis) is increasingly utilized in large-scale energy labs. Many farms are able to cover their energy needs and costs by producing biofuels, and installing wind mills and solar parks on their fields. New knowledge allows sustainable production of biofuels and innovative, environmentally friendly farming systems.

Results from research into knowledge-intensive technologies supported by information technologies (such as GIS, remote sensing, GPS-controlled robots, detailed soil databases, etc) allow wide implementation of precision type farming. Food processing takes place in new energy- and /or labor saving forms, such as intelligent greenhouses (with virtually no labor) and multi-story food factories - as developed in the Netherlands (agro-metropoles). GMOs are widely accepted (but less in EU-15 than in America and Eastern Europe) and play a significant role in reducing pesticide use and emissions from agriculture to the environment.

Research is also done to better understand the concerns and circumstances that are forming consumer attitudes and choices, to develop models of consumer preferences, to improve the nutritional balance of foods, to optimize nutritional and genotype interactions in crops and livestock, and to improve regulatory frameworks.

3.5.1.3 Local food-supply led AKST

Local food-supply AKST is a multi-actor system with little coordination between organizations. It is also a local system, as the North American AKST system, the AKST system in the European Union, and the AKST systems in Russia and non EU Eastern European countries are very different from one another. The AKST systems manage to contribute to improved nutrition and human health at national level, but most rural areas are driven by urban economies and the importance of agriculture in rural activity differs between regions. At international level, the AKST systems have little impact on hunger and poverty nor environmental sustainability.

No coherent research, innovation and IPR policies are designed in NAE, and they are not even always coherent at national level. Each country keeps its educational and cultural specificities. Efforts are made to improve secondary education and to put students through the first years of universities, but there is very little training of scientists. Quality and quantity of research personnel tends to deteriorate.

In most countries, the access, control and distribution of knowledge, science and technology remains linear: fundamental research, applied research, extension and education are done in separate organizations. As many different types of organizations are involved, there is little synergy among them. A few large private companies have their own research capacities and are highly integrated. However, as their investments are relatively small, they cannot influence the global research agenda. In the USA and Canada, there is a disintegration of land grand universities because of the competition for scarce funding. In the countries of the European Union, governments continue to provide some funding for public research to avoid conflicts with farmers and researchers, but funds given to KST in real terms are below what they were at the beginning of the century. Local universities and public research organizations continue to provide public goods; however they are often in conflict with private companies and accuse them to privatize knowledge. In Russia and non EU Eastern European countries, AKST is not at all a priority; the little research that is done focuses on the large scale cereal-vegetable farming systems.

Size holdings vary greatly and therefore there are great inequalities in access, control and distribution of inputs and capital. Family farms are still prevalent but their access to inputs and capital is very difficult.

Generation of knowledge focuses on conventional food production and protection. Compared to North America, little research and use is made of genetically modified crops and animals. Research tends to ignore growing problems such as water scarcity, soil depletion, and socio-economic viability of agricultural systems.

3.5.1.4 Local learning AKST

Local learning AKST is regionally focused and proactive in meeting the various development and sustainability goals. It is a well coordinated multi-actor system, which integrates successfully the different goals at regional and local level. It successfully contributes to the goals of enhancing livelihoods, equity and social capital, and environmental sustainability. Nutrition and human health are improved through knowledge-based sustainable, fresh and safe local diets and a reduction in meat consumption. Balanced regional economic development and stewardship of natural resources are promoted through keeping added value and employment of input production, processing, transportation and marketing in the region, and through investing in quality growth and welfare services. Due to the regional orientation, hunger and poverty are not fully addressed, but more resources of low-income countries are left untouched by NAE so they can serve other purposes including provision of food, fiber and fuel for their own consumption. Many technologies developed for NAE are appropriate for resource-poor rural communities also in low-income countries.

Policies and governance are arranged based on cooperation among different sectors, utilizing trans-ministry and public-private platforms. E.g., regional food, agriculture, health, environment, rural, trade, and KST policies are fully integrated. Development is knowledge-intensive and the importance of science policies is widely recognized. Environmental policies are increasingly focused on local and regional issues rather than on global change issues. Agricultural policies allocate subsidies to internalize positive and negative ecological, socio-cultural and economic (widening of spatial and temporal scales) externalities (see below). Diverse and flexible financing and credit systems flourish, and rural capital is primarily addressed to serve local/regional rural needs. Systems to balance regional imparities in capital supply are created. Global issues are addressed enhancing understanding through world-wide regional networks, and learning from and developing local solutions. Intellectual protection is not strict and therefore many research results are available for less developed countries, and gene resources are owned by local communities. National and international trade is open, but internalized climatic and resource consequences of energy use increase price effects reducing transportation. Intensive use of modern communication technologies and rural and nature tourism compensate long-distance traveling in widening of perspectives and in entertainment. Regarding development collaboration each sub-region of NAE has close links to its own (neighboring) South. Universities and the private sector are encouraged to pool patents through licensing and there is free licensing to the developing world. Venture capital is set up and distributed.

The agrifood system actors (producers, traders, processors, waste managers, input producers, financers, institutional kitchens and private consumers), together with citizens, NGOs (representing public goods), municipality, county agencies and scholars form an interactive, open learning network with different platforms designed for different needs. These networks are connected to the networks of other regions of the world both based on interests/needs/goals and on actor groups/professions/competences. The regional networks are cooperating tightly with regional, decentralized university system developing the local and regional agrifood systems. They utilize the international knowledge networks and carry out disciplinary and interdisciplinary research. The networks are linked with the boards of universities, fund them and participate forming the agendas, planning and performing knowledge and technology generation, and interpreting and evaluating results. The interactive networks make sure that the knowledge and technology generation is highly relevant, locally adapted and socially contextual. They also ensure that agrifood system actors have full access to the results and get the necessary underlying understanding and technical knowledge from the universities.

Within the universities, disciplinary science communities, and cross-cutting interdisciplinary science communities utilizing the developments of disciplinary work, systematically interact with trans-disciplinary stakeholder platforms. The conception of the object and coverage of AKST and its methodology is very broad, to contribute to agrifood systems meeting the development & sustainability goals in different local socio-ecological contexts. Solutions for collaborative, reflexive, democratic processes to develop sustainable, local food systems are created through research, as well as means to internalize externalities of food, fiber and fuel, and to make conscious choices. In education, which is open for all citizens, there is special emphasis on increasing understanding about different values and goals, multiple impacts of food choice, and communicational and team working abilities. In scholars' education attention is given to systems, interdisciplinary and participatory approaches, and robust science philosophic base and conceptual tools to promote understanding for and communication across different disciplinary paradigms. Advanced communication technologies are consequently utilized. All universities interact also with various actors from low-income countries to integrate their views in generating knowledge and to strengthen capacity development.

AKST serves diverse, locally and regionally adapted, sustainable diets and food, fiber and energy systems. Health and nutrition are rather based on knowledge-based composition of local diets, based on fresh, seasonal foods and design of farming systems, than on gene-tailored, functional food ingredients. They appreciate cultural heritage and are based on reliance and conserving the local and regional ecosystems with their goods and services. Local bioenergy and renewable energy -based, energy-efficient and integrated agrifood systems are developed and continuously improved. Predominant farming systems are based on biologically fixed nitrogen and recycling material (nutrient cycling) and energy flows within local agriculture and back from the local demand-chain including processing, and from watercourses. Thus, bio-energy, food and also wood production are integrated and waste is used for energy and fertilizers. Small-scale solar and wind energy sources are connected in the regional electrical network. New varieties are developed, appropriate for the integrated systems and often carrying a significant amount of diversity within them, thus being adaptive for different locations. Urban agriculture is an inherent part of spatial and city planning. Regional and local food processing and retail utilize farm- and waste-based energy and have their local contract networks for input purchase. Life-cycle and sustainability assessments are carried out on the impacts of land-use changes and features of production and food systems, but the emphasis is on direct communication and feed-back from local communities and ecosystems.

Local and regional markets are developed putting special attention to communication through the chain in the learning networks, and on energy-efficient logistical arrangements. Different forms of community-supported agriculture with shared risk and labor between producers and consumers, food circles, farmers' markets and direct selling flourish besides the horizontally integrated production-trade-consumption chains. Use of fossil energy for transportation is thus reduced, and added value of the food chain is kept in the region. Externalities are internalized, but that relies not only on public regulation, taxation and economic incentives with regional variation. For an important part internalization relies on proximity of different actors, trust relations and social capital, and thus on direct communication and feed-backs from the local socio-ecological context. Local labels embracing the whole chain are successfully introduced, and regional marketing ensures a sufficient scale.

3.5.2 Matching AKST systems with priorities within and outside NAE

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Useful websites of national and international foresight exercises:

Austria	http://www.oeaw.ac.at/ita/welcome.htm
Belgium	http://www.la-swep.be/page.php?name=monde_prospective_v
	http://www.la-swep.be/out.php?www.viwta.be/
Canada:	http://strategis.ic.gc.ca/epic/internet/intrm-crt.nsf/en/Home
European Commission	http://cordis.europa.eu/foresight/platform.htm
	www.jrc.es/welcome.html
	http://foretech.online.bg/
ERA-NET SKEP	http://www.skep-era.net/site/2.asp
Finland :	http://www.tekes.fi/eng/innovation/foresight.htm
	www.tukkk.fi/tutu/default_eng.asp
France:	www.operation-futuris.org
	http://www.tc-2010.fr/ http://www.ecologie.gouv.fr/article.php3?id_article=5642
	http://www.inra.fr/l_institut/l_inra_en_bref/l_essentiel_en_documents/prospective_pilotage_et_programmation_de_la_recherche
	http://www.inra.fr/l_institut/l_inra_et_le_cirad_lancent_la_prospective_agrimonde
The Netherlands:	http://www.eururalis.nl
UK Technology Foresight:	http://www.foresight.gov.uk/
PREST – Manchester	www.les1.man.ac.uk/PREST
OECD:	http://www.oecd.org/department/0,2688,en_2649_33707_1_1_1_1_1,00.html
European Commission, DG Research:	www.cordis.lu/foresight/home.html
European Commission, Institute for Prospective Technological Studies:	
Foresight Nanotech Institute	http://www.foresight.org/challenges/agriculture.html
Global Business Network	www.gbn.org
Groupe Futuribles:	www.futuribles.com
Institute for Alternative Futures:	www.altfutures.com
Rand Corporation:	www.rand.org
World Future Society:	www.wfs.org