1	CHAPTER 5				
2	LOOKING INTO THE FUTURE FOR KST (KNOWLEDGE, SCIENCE AND TECHNOLOGY),				
3	AGRIC	ULTURE AND AKST (AGRICULTURAL KNOWLEDGE SCIENCE AND TECHNOLOGY)			
4					
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1 Key Messages

2

3 1. Choices about agricultural knowledge, science and technology (AKST) relate to

4 paradigms, investment, governance, policy and other ways to influence the behavior of

- 5 producers, consumers and food chain actors. They will have powerful impacts on which
- 6 development and sustainability goals are achieved and where, both globally and within NAE.
- 7 There are many uncertainties of the future, and therefore a number of alternative AKST futures
- 8 can be identified. It is unlikely that all development goals can be achieved in any of these futures.9
- As Seneca wrote: "There is no favorable wind for the person who does not know where he wants to go." Depending on which development direction society chooses and how funds are allocated, different drivers will be emphasized. This will affect agricultural systems and related AKST. When making decisions, policy makers will need to consider the opinions of the local population and organizations, and the increasing number of NGOs involved in AKST. Interventions on some trends or in response to some uncertainties can be more quickly implemented and be more effective than on others.
- 17

18 The conclusion of a number of recent global and regional foresight exercises on 19 agriculture, rural development and environment is that business as usual will not be good 20 enough. Consumers, producers and information providers will have to rapidly recognize and 21 respect the physical limits of the planet and the biological equilibriums needed to ensure long-22 term survival. New responses must be found. Different kinds of approaches have been used to 23 address future changes in agriculture. Some have employed projections accompanied by limited 24 policy simulations. Others have proposed scenarios and considered a wide range of uncertainties 25 in an integrated manner. They all explore key linkages between different drivers and resulting 26 changes.

27

3. Science and technology studies stress the consequences of major technological
developments in fields not directly related to agriculture but that could have important
potential impact on AKST in the future. These relate, for example, to information and
communication technologies e.g., imaging and Radio Frequency Identification, as well as to
nanotechnologies, genomics, biotechnologies and physics.

4. NAE agrifood systems will continue to face long-standing problems to increase the
 output level of agricultural products and services without jeopardizing (a) the natural
 resource base, (b) food security through equitable access to food and stable food supplies
 for an aging NAE population and a growing global population, and (c) food safety. The

second challenge does not mean producing food to sell or to donate to other countries, but rather
 cooperating with other countries in developing and sharing AKST that meets this goal.

3

4 5. Emerging trends in agriculture are leading AKST to tackle problems that are interacting

in a dynamic, complex and mutually reinforcing way, generating long-term impacts, cross impacts and feedback loops. They are thus requiring new forms of AKST. The main trends are

7 the following:

8 Human as well as plant and animal health considerations are becoming more important. 9 Populations in North America and Western Europe, especially the poor, face alarming 10 increases in illnesses associated with inadequate diets and over-processed food. Central 11 and Eastern Europe are likely to face the same problems in the near future. Increased plant 12 and animal diseases, as well as weed and insect problems, both evolving and invasive, are 13 threatening production in certain areas and are leading to overuse of agricultural chemicals 14 and antibiotics, whose lingering residual effects in the environment is threatening human 15 health. This trend could be addressed through new AKST, more information and 16 appropriate regulations, as well as encouragement for individuals and companies to market 17 and consume organic foods.

18

Agricultural trade policies and subsidies in NAE tend to undermine the achievement of
 development goals in other parts of the world. There is uncertainty about whether the World
 Trade Organization will be effective in harmonizing approaches to internal subsidies, and
 about whom is likely to benefit, how much and for how long if NAE subsidies are removed.
 Applying AKST to agricultural policies and property regimes might help balance the needs
 of vulnerable people in other regions of the world.

25

Farms tend to specialize, as they grow in size and decline in numbers. Alternative
 agrosystems coexist with mainstream agriculture. Farmers are working in larger
 enterprises, operating through cooperative arrangements and contracts with large
 businesses. This could lead to greater complexity and monopolies that reduce resilience
 and choices. AKST is needed to devise alternative agrosystems.

31

Businesses in every sector of the food system are concentrating into integrated networks
 and exerting power by imposing standards on suppliers that challenges their ability to
 remain viable. Such standards gradually exclude small-scale producers, processors or
 other enterprises from participation in markets. The rate at which this integration is
 proceeding and the specific geographic areas and sectors that businesses will choose to
 enter are uncertain, in part because most business decisions are not transparent.

- 1 2 Rural populations are dwindling and agro-urban areas are growing. Multiple expectations on 3 farming systems are leading to the development of new enterprises such as agrotourism, 4 and are pushing the farming systems to deliver new services, such as watershed 5 development and landscape protection. But the high demands on agriculture to provide 6 energy could change this trend. AKST is needed to improve the sustainability of food and 7 farming systems, regardless of what is demanded of them. 8 9 Migrant labor represents a growing proportion of the workers in the agri-food sector, 10 especially in parts of the United States and the southern countries of Europe. An increasing 11 number of them are illegal immigrants. Enforcement of immigration law would force 12 undocumented workers to leave the countries. The impact on the labor force could be 13 solved by policy research and technological advances, but must be accompanied by 14 political and social measures. 15 16 Rising prices of energy, water, minerals and other natural resources could affect outputs, 17 costs and practices in all sectors of the food system. NAE agriculture uses large quantities 18 of natural resources such as oil, water and phosphates, although there are regional 19 differences. Decreasing availability and increasing competition for these resources boosts 20 costs to heights that can have very negative impacts on agricultural production, processing, 21 distribution, retail and purchasing. These effects could be averted by a substantial reduction 22 in the use of these resources thanks to improved management and new technological 23 developments that increase use efficiency, and hence could mitigate the consequences of 24 the current trend. 25 26 Climate change increasingly affects agriculture, which will require a wider and stronger 27 spectrum of adaptation responses as well as efforts to reduce energy needs and emissions. 28 Higher temperatures, more erratic precipitation patterns and increased risks of droughts, 29 particularly in the southwestern parts of the USA and in Europe, coupled with a northern
- shift of cropping zones, will lead to shifts in agricultural systems and production regions.
 Extreme events will severely challenge adaptive capacity. Existing AKST needs to be
- 32 applied and new AKST developed.

33

Increased demands are being laid on agriculture for providing energy and biomaterials.
 Bioenergy that includes the production of liquid fuels from biomass could meet some of the
 world's growing energy needs. It is unclear to what extent agriculture in NAE will become an
 energy producer, and how much can be achieved from other renewable energy sources

and conservation. The development of bioenergy will increase competition for land and
 water resources and could lead to higher food prices. Significant technological challenges
 still need to be overcome for the second-generation technologies to become commercially
 viable.

5

6 6. Emerging and on-going trends as well as uncertainties in Knowledge, Science and 7 Technology (KST) can be identified and are going to influence the way Agricultural 8 Knowledge Science and Technology (AKST) will be developed:

- Innovation is a strategic element in economic competition, but companies' investments
 depend on the expected return; the level private R&D varies from one country to the other.
 Large multinational companies are increasingly influencing priorities and investments in
 agricultural science and technology and are highly involved in agricultural extension. Some
 consider this trend as positive, others as negative.
- 14

15 The public funding of science and technology is starting to be insufficient to adequately 16 address agricultural problems including satisfaction of consumer demands and the need for 17 more sustainable natural resource management. The decreasing proportion of publicly 18 funded AKST means that less AKST is available in the public domain thus limiting farmers' 19 choices and restricting research on issues such as food security and safety, sustainability, 20 climate change. This also has a negative impact on partnerships with other regions of the 21 world. Halting and reversing this negative trend depends on the will of governments. A 22 reshaping of intellectual property rights and other regulatory frameworks could also modify 23 this trend.

24

The interest for science and the number of students in science and technology in most of
 NAE is declining. The population of European researchers is aging, and students tend to
 turn away from science and technology, especially when it is research oriented. Measures
 are needed to bolster school education programs and public awareness in order to draw
 public recognition to the benefits of S&T. In North America, the number of students in
 "sustainability programs" is increasing, but few have agricultural backgrounds.

- 31
- The present domination of NAE in generating formal knowledge could be challenged.
 Bigger R&D budgets and better R&D results in Asia are changing the relationship of NAE
 research with that of the rest of the world. This could lead to more networking and
 increased competition among agriculture, industry and services.
- 36

The involvement of users in research definition and execution is challenging the traditional
 research approach. Innovation is a process that integrates various forms of research and
 the knowledge it creates in a wide range of patterns. Users are increasingly expressing
 needs which challenge the traditional disciplinary research approaches but may pave the
 way to a more integrated approach that some researchers find difficult and that, potentially,
 could be an obstacle to the required innovation.

7

The capacity of universities and public research organizations, the private sector and the
 governments to make their economies competitive by defining research priorities jointly and
 funding R&D is uncertain. Collaborative research is gaining in importance and measures
 could be taken to further promote it and improve the general R&D effort.

12

13 7. There are several plausible pathways and major differences in the AKST sets of drivers;

much depends on the society's choices. The differences lead to alternative pathways for
 AKST development:

16 Economic considerations and drivers could shape a globally-oriented "market-led AKST" 17 wherein multinational corporations and other private sector actors play a major role. In that 18 case, public policies would tend to be reactive, and consumer protection would amount to 19 measures taken after serious problems have occurred. Policies would mainly focus on trade 20 liberalization and assurances of a favorable platform for free competition. The common 21 interests of transnational corporations and wealthier consumers would determine industrial, 22 KST- and capital-intensive solutions marketed under private labels. "Market-led AKST" 23 could effectively decrease hunger and poverty and improve nutrition and human health in 24 NAE and at international levels. However, it would probably contribute little to equity and 25 sustainable economic development.

26

27 Increased government intervention could lead to "ecosystem-oriented AKST" with strong _ 28 public sector input and interventions to internalize environmental externalities through 29 regulations, taxation, subsidies and international standards. In that scenario, the public 30 sector would invest in centralized, coordinated innovation systems, with few centers of 31 excellence. Education would be a priority and solutions would probably be knowledge-32 intensive, high-tech and precision oriented. "Ecosystem-oriented AKST" could make a 33 major contribution to improving environmental sustainability through knowledge-intensive 34 technologies that use resources efficiently and to sustaining economic development by 35 investing human and financial capital in the development of green technologies. It could 36 have the potential to level off global imparities. However, little emphasis on social

- viewpoints might lead to shortcomings regarding issues such as equity and enhanced
 livelihoods.
- 3

4 Cross-sectoral public-private governance platforms with emphasis on regional and local _ 5 decision making along with the subsidiary principle and bottom-up approaches could lead to 6 "local-learning AKST" system. Food system actors and both rural and urban regions would 7 participate in interactive knowledge networks that are decentralized and regionally 8 diversified. Externalities would be internalized through direct response and locally visible 9 impacts of AKST, but local standards would also be developed. "Local-learning AKST" 10 could successfully contribute to the goals of enhancing livelihoods, equity and social capital 11 and to environmental sustainability, especially within the regions. Nutrition and human 12 health would be improved through knowledge-based, safe local diets and a reduction in 13 meat consumption. Balanced urban-rural regional economic development would be 14 promoted by keeping up the added value in the region. Hunger and poverty in other regions 15 would not be a high priority. 16 A "local food-supply led AKST" system could arise if research efforts were not coordinated and if 17

budget cuts were took place. "Local food-supply led AKST" is a plausible future which would not

18 contribute to development and sustainability goals.

1 5.1 Context

- 2 Agricultural systems and land use are changing as a consequence of changes in demography,
- 3 world trade, climate, diets, political unions (e.g., enlargement of the European Union) and
- 4 technology. The degree and impact of these variations are largely unknown. Although the future
- 5 is unpredictable, some developments can be foreseen and alternatives explored. This chapter
- 6 focuses on trends and uncertainties related to the futures of the main drivers of agricultural
- 7 research and innovation systems and agricultural knowledge, science and technology (AKST).
- 8

9 5.1.1 Problem statement

The future of the agricultural research and innovation systems in North America and Europe is not certain, and current systems may be revised or new ones built. 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 utopic and may be of less value for planning the future.

16

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
(Godet, 1977; Irvine and Martin, 1984, 1989; Hatem, 1993; Martin, 1995; de Jouvenel, 2004; de
Lattre-Gasquet, 2006). Emphasizing the process can help to build strategic capabilities and to
inform research and innovation policies ("embedded foresight") (Kulhmann et al., 1999).

24

25 Identifying appropriate drivers is the first step in forecast/foresight activities. As defined in chapter 26 1, a "driver" is any natural or human-induced factor that directly or indirectly causes a change in 27 an ecosystem. Drivers are linked to decision making, as many of the drivers can be influenced by 28 policy choices. A "direct driver" unequivocally influences agricultural production and services and 29 can therefore be identified and measured with differing degrees of accuracy. An "indirect driver" 30 operates more diffusely, often by altering one or more direct drivers, and its influence is 31 established by understanding its effect on a direct driver. The tendential development of each 32 driver must be presented, and curves and potential breaks that could block the tendential 33 development should be explored (de Jouvenel, 2004). In this chapter, uncertainties about the 34 futures have been raised in the form of questions, and no hypotheses about future development 35 have been made. 36

1 As described in chapter 1, AKST is knowledge, science and technology pertaining to agriculture.

2 It is a subset of science and technology, located at the intersection of the agricultural system and

3 the knowledge, science and technology system. The futures of AKST depend on the futures of

4 agriculture, the futures of KST, and have their own dynamic. This chapter is built around four

- 5 questions:
- 6 What are the key drivers for knowledge, science and technology (KST), their major
 7 uncertainties and consequences for AKST? (see 5.3)
- 8 What are the key drivers for agriculture, their major uncertainties and consequences for
 9 AKST? (see 5.4)
- What are the key drivers for agricultural knowledge, science and technology (AKST) and
 agricultural research and innovation systems and their major uncertainties? (see 5.5)
- What are some future normative AKST systems and their potential contributions to
 sustainable development goals? (see 5.6)

For each driver, the questions show that the future is uncertain. Each driver also points to fieldswhere AKST needs to be developed or expanded.

16

17 The plausible futures comprise a number of goals for an agricultural research and innovation 18 system, including promotion of sustainable agriculture and enhancement of nutritional security, 19 human health and rural livelihoods, and AKST depends on the priorities. At the same time, an 20 agricultural research and innovation system and certain AKST could help mitigate environmental 21 degradation and social inequities. Reaching all of these goals will be difficult; various agricultural 22 research and innovation systems favor particular goals at the expense of others. These 23 alternative futures expand the spectrum of possibilities and will facilitate discussions among 24 decision makers about strategic choices.

25 26

5.1.2 Review of related studies

27

A number of recent foresight exercises focusing on agriculture, rural development, environment, science and technology have been undertaken at global and regional levels. Different kinds of approaches have been used to address future changes pertaining to agriculture. Some have employed projections accompanied by limited policy simulations. Others have proposed scenarios and considered a wide range of uncertainties in an integrated manner. They all explore key linkages between different drivers and resulting changes. They all conclude that business as usual will not suffice. However, no assessment has explicitly focused on the future role of AKST.

36 5.1.2.1 At global level

1 A number of quantitative models have been developed by the International Food Policy Research

2 Institute (IFPRI), the Food and Agricultural Policy Research Institute (FAPRI), the Food and

3 Agriculture Organization (FAO), the Organization for Economic Cooperation and Development

4 (OECD), the Netherlands Environmental Assessment Agency, etc.

5

6 Partial equilibrium models (PE) treat international markets for a selected set of traded goods, e.g., 7 agricultural goods in the case of partial equilibrium agricultural sector models. These models 8 consider the agricultural system as a closed system without linkages with the rest of the 9 economy, apart from exogenous assumptions on the rest of the domestic and world economy. 10 The strength of these partial equilibrium models is their great detail of the agricultural sector. The 11 "food" side of these models generally uses a system of supply and demand elasticities 12 incorporated into a series of linear and nonlinear equations, to approximate the underlying 13 production and demand functions. World agricultural commodity prices are determined annually 14 at levels that clear international markets. Demand is a function of price, income and population 15 growth. Regional biophysical information (for land or water availability, for example) is 16 constraining the supply side of the model (IAASTD Global Chapter 5). 17 18 Computable general equilibrium (CGE) models are widely used as an analytical framework to 19 study economic issues of national, regional and global dimension. CGE models provide a 20 representation of national economies, next to a specification of trade relations between 21 economies. CGE models are specifically concerned with resource allocation issues, that is, where 22 the allocation of production factors over alternative uses is affected by certain policies or 23 exogenous developments. International trade is typically an area where such induced effects are 24 important consequences of policy choices. CGE models have sometimes been used to provide a 25 scientific guarantee in support of full trade liberalization (Boussard et al., 2006) 26 27 Beyond IAASTD, major global environmental assessments include: 28 The Millennium Ecosystem Assessment (MA, 2005). 29 The Intergovernmental Panel on Climate Change (IPCC) assesses scientific, technical 30 and socioeconomic information needed to understand climate change, its potential impacts and 31 options for adaptation and mitigation. In 2007, IPCC finalized its Fourth Assessment Report.

The UNEP-led Global Environment Outlook (GEO) project focuses on the role and impact
 of the environment for human well-being and the use of environmental valuation as a decision
 tool.

The OECD environmental outlook to 2030 focuses on environment-economic linkages to
 2030. The projections are complemented by qualitative discussions based on extensive OECD
 analytical work.

The Comprehensive Assessment of Water Management in Agriculture led by the
 International Water Management Institute (IWMI) critically evaluated benefits, costs and the
 impacts of the past 50 years of water development and looks at current challenges to water
 management.

The Global Scenario Group (GSG) was convened in 1995 by the Stockholm Environment
Institute to examine the prospects for world development in the twenty-first century. Numerous
studies at global, regional and national levels have relied on the Group's scenario framework and
quantitative analysis (Kemp-Benedict et al., 2002).

9

10 [Insert Table 5.1]

11

12 Chapters 4 and 5 of the global IAASTD report have reviewed a number of quantitative models13 extensively (see Table 5.1):

IMPACT-WATER - a partial equilibrium agricultural sector model with a water simulation
module developed by the International Food Policy Research Institute (IFPRI) (Rosegrant et al.,
2002). Using this model, IFPRI has made a number of studies, e.g., Global Food Projections to
2020 (Rosegrant et al., 2001), Global water outlook to 2025 (Rosegrant et al., 2004), Fish to
2020: supply and demand in changing global markets (Delgado et al., 2003), Food security (Von
Braun et al., 2005),

IMAGE – Integrated model to assess the global environment developed under the
 auspices of the Netherlands Environmental Assessment Agency (MNP) (Bouwman et al., 2006),
 GTEM – global trade and environment model, a computable general equilibrium model

developed by the Australian Bureau of Agricultural and Resource Economics (ABARE) (Pant,
2002),

WATERSIM – Water, Agriculture, Technology, Environment and Resources Simulation
 Model developed by the International Water Management Institute (IWMI) and the International
 Food Policy Research Institute (IFPRI) (de Fraiture et al., 2006),

GLOBIO3 – Global methodology for mapping human impacts on the biosphere, a
 consortium that seeks to develop a global model for exploring the impact of environmental
 change on biodiversity and was designed to support UNEP's activities (GLOBIO, 2001),

31 - EcoOcean – a marine biomass balance model of the University of British Columbia,

32 - GEN-CGE – a computable general equilibrium model for India,

33 - CAPSiM – a partial equilibrium agricultural sector model for China.

34

35 Since 1995, FAO has been using a World Food Model, which is a partial equilibrium model

36 capable of making projections on food demand and supply at the 2030 horizon and 140 countries

and 32 products. FAO has published the work of Collomb (1999) and more recently two reports

on world agriculture towards 2015-2030 and towards 2030-2050 (FAO, 2003, 2006). OECD and
 FAO publish the Agricultural Outlook periodically. The most recent is for 2007-2016 (OECD/FAO,

3 2007).

4

5 Quantitative projections indicate a tightening of world food markets, with increasing resource 6 scarcity, pushing prices up which especially penalizes the poor consumers. Real world prices for 7 most cereals and meats are projected to increase in the coming decades, dramatically reversing 8 trends from the past several decades. Price increases are driven by both demand and supply 9 factors. Population and economic growth in sub-Saharan Africa, together with already high 10 growth in Asia and moderate growth in Latin America drive increased growth in demand for food. 11 Rapid growths in meat and milk demand are projected to put pressure on prices for maize and 12 other coarse grains and meals. Bioenergy demand is projected to compete with land and water 13 resources. Overall growing water demands and land scarcity are projected to increasingly 14 constrain food production growth and have an adverse impact on food security and human well-15 being goals. Higher prices can benefit surplus agricultural producers, but can also reduce access 16 to food for a larger number of poor consumers, including farmers who do not produce net surplus 17 for the market. As a result, progress in reducing malnutrition is projected to be slow (IAASTD 18 global report, chapter 5). 19

Although none are identical to the IAASTD exercise in scope and timeframe, 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.

24

25 5.1.2.2 At European level

There are too many foresight activities in Europe to describe them all. We will describe a few exercises and give the references for networks and places where information can be found.

28

29 In the European Commission, foresight activities are launched and carried out in several places:

The European Technology Platforms (ETPs) which provide a framework for stakeholders,
led by industry, to define research and development priorities, timeframes and action
plans on a number of strategically important issues where achieving Europe's future
growth, competitiveness and sustainability objectives is dependent upon major research
and technological advances in the medium to long term. More than thirty platforms exist,
for example "Food for life", "Plants for the future", "Global animal health", "Forest-based
sector technology."

1	-	The Joint Research Centre's (JRC's)/Institute for Prospective Technological Studies		
2		(IPTS). The mission of IPTS is to provide technico-economic analyses to support		
3		European decision markers. It monitors and analyses S&T related developments, their		
4		cross-sectoral impacts, interrelationships and implications for future policy development.		
5	-	The European Science Foundation (ESF) which has introduced "Forward Looks" to		
6		enable Europe's scientific community, in interaction with policy makers, to develop		
7		medium to long-term views and analyses of future research developments with the aim of		
8		defining research agendas at national and European level.		
9	-	The ForSociety which is a network where national foresight program managers		
10		coordinate their activities.		
11	-	The Science and Technology Foresight Unit of the DG research whose missions are to		
12		promote cooperation in European foresight, to monitor and exploit foresight, informing		
13		European research policy developments and contributing to policy thinking in DG		
14		research, to implement S&T foresight activities, to promote foresight dissemination and		
15		experience sharing, and to prepare a foresight report. Studies are commissioned and		
16		expert groups meet. The Science and Technology Foresight Unit has commissioned		
17		studies such as 'Converging technologies. Shaping the Future of European Societies"		
18		(Nordmann, 2004), the future of Key Research Actors in the European Research Area		
19		(Akrich and Miller, 2007; http://cordis.europa.eu/foresight/home.html).		
20	-	Different directions can launch foresight activities. For example, in 2007 the Standing		
21		Committee on Agricultural Research (SCAR) commissioned a Foresight food, rural and		
22		agrifutures (FFRAF) study which is presented below.		
23	The Eu	The European Parliamentary Technology Assessment (EPTA), the European Organization for		
24	Nuclea	Nuclear Research (CERN) and the European Molecular Biology Laboratory (EMBL) all have		
25	foresig	ht activities.		
26				
27	The Eu	ropean Foresight Monitoring Network (EFMN) monitors ongoing and emerging foresight		
28	activitie	activities and disseminates information about these activities to a network of policy researchers		
29	and for	and foresight practitioners. It supports the work of policy professionals at regional and national		
30	level. 7	level. The EFMN is part of the European Foresight Knowledge Sharing Platform. It monitors and		
31	maps I	Foresight activities all over the world.		
32				
33	The Eu	The European Futures Observatory (EUFO) is a UK based not-for-profit company limited by		
34	guaran	guarantee, formed in October 2004, which aims to foster the development of a European School		
35	of Futu	of Futures Studies. It is starting to carry out studies and has looked at the strategic futures that		
36	the US	the US may encounter out to the year 2025.		

1 In Europe, a number of modeling exercises have been designed. The global economy-wide 2 dimension is covered by the economic LEITAP model (a modified version of the global general 3 equilibrium Global Trade Analysis Project, GTAP, model) and the biophysical IMAGE model 4 (developed by the Netherlands Environmental Assessment Agency, MNP). 5 6 ESIM (European Simulation Model) is providing more agricultural detail for the EU-25 countries. 7 CAPRI has been developed by the University of Bonn and is a static partial equilibrium model 8 with a dynamic recursive version to simulate policies. 9 10 WEMAC, developed by the Institut National de la Recherche Agronomique (INRA), in France, is a 11 partial equilibrium model on crops that can make projections and simulations for cereals and oil 12 crops in Europe. 13 14 MEGAAF (modèle d'équilibre général de l'agriculture et de l'agroalimentaire français) is a general 15 equilibrium model to simulate commercial policies for France and the rest of Europe. 16 17 Three recent European foresight exercises represent different approaches: Eururalis, Scenar 18 2020 and FFRAF (Foresight food, rural and agrifutures). Eururalis was launched with the aim to 19 explore alternative future rural development options for EU-25 (Klijn and Vullings, ed., 2005). This 20 Dutch project is developing and analyzing a set of four long-term alternative scenarios to capture 21 major uncertainties. Based on its success in providing sound information on future rural 22 development options during the 2004 Dutch EU Presidency, an extended version of the Eururalis 23 toolbox (no. 2.0) is under development. The new version will be used to analyze a number of 24 specific rural policy questions for EU-25, including issues related to bioenergy and strategic 25 options for the Common Agricultural Policy (CAP) after 2013 and the consequences on 26 sustainability indicators. Such policy questions can be posed for each of the four different world 27 views, as developed in Eururalis 1.0, with regional differentiation and different time horizons: 28 2010, 2020 and 2030. The aim of the Eururalis toolbox is to help policy makers formulate long-29 term development strategies for rural areas in Europe (EU-25) (Box 5.1). 30 31 [Insert Box 5.1] 32 33 Alternatively, Scenar 2020, a recent initiative of European Commission, Directorate General for 34 Agriculture, uses a baseline approach with varying policy options and particular focus on the 35 impact of technological change (especially information communication technology) and food 36 chains on agriculture and rural areas (EC, 2007). This study aims to identify future trends and

37 driving forces shaping the European agricultural and rural economy (EU-27 +) on a time horizon

1 up to 2020. Analyses of trends from 1990 to 2005 provide the basis for developing a reference 2 scenario (baseline) that represents a trend projection up to 2020. Three variants are constructed 3 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 4 5 alternative policy frameworks with differing degrees of support to the agricultural sector. Drivers of 6 change are grouped into those that are independent of policy influence (at least for the time 7 horizon up to 2020) and those associated with agricultural and environmental policies. (EC, 8 2007). In Scenar 2020, the spatially explicit land use model CLUE-s (Conversion of Land Use and 9 its Effects) (Verburg et al., 2002) is used. The CLUE-s model disaggregates the outcomes of the 10 ESIM-CAPRI-LEITAP/IMAGE suite of models to a temporal resolution of two years and a spatial 11 resolution of 1 km. CLUE-s provides a cross-sectoral approach that includes all land use relevant 12 sectors, while the ESIM, CAPRI and LEITAP/IMAGE models mainly address the land use of 13 agricultural sectors. The results indicate that the structural changes, i.e. decline of agricultural 14 contribution to total income and employment, will continue at national level. Regions with high 15 shares of agriculture and industries may be vulnerable to this process with regard to employment 16 and income growth, as the structural change process is often characterised by adjustment 17 processes and related costs. The impacts of each scenario on production, employment, land use, 18 etc. are detailed in the Scenar 2020 report.

19

20 EURURALIS mainly sketches different alternative future directions and their consequences while 21 Scenar 2020 performs a sensitivity analysis with regard to very precise policy modifications. Each 22 has its advantages. SCENAR 2020 identifies demographic dynamics as the strongest driver, now 23 and probable also for the future rural world. In general, the SCENAR study concludes that the 24 economic importance of agriculture will continue to decline although agriculture will remain a 25 significant land use with an increasing role in managing externalities such as landscape and 26 biodiversity. In 2020, there will be fewer farms but they will be more competitive at global scale, 27 and they will enjoy higher average income and higher productivity.

28

29 FFRAF (Foresight food, rural and agrifutures) was launched by the Standing Committee on 30 Agricultural Research (SCAR) of the European Commission to identify possible scenarios for 31 European agriculture in a 20-year perspective and priority research needs for the medium and 32 long term. FFRAF shows that the European Union is at the beginning of a major disruption period 33 in terms of international competitiveness, climate change, energy supply, food security and 34 societal problems of health and unemployment. It points to the need for a new strategic 35 framework for research planning and delivery. The framework needs to cater for four broad lines 36 of action and a fifth cross-cutting theme, respectively: sustainability challenge, security challenge, knowledge challenge, competitiveness challenge and policy and institutional challenge (FFRAF,
 2007).

3

4 A number of exercises have also been conducted for the EU's East European countries, such as 5 Czech Republic, Hungary, Poland, etc. For example, the ForeTech project looked at technology 6 and innovation related to agriculture, food and drinks for Bulgaria and Romania. Another study 7 analyzed the potential evolution of agricultural income and the viability of selected farming 8 systems in the Czech Republic, Hungary, Latvia, Poland and Romania under different Common 9 Agricultural Policy implementation scenarios (Cristoiu et al., 2006). 10 11 The UK, Finland, Germany, The Netherlands, Ireland, Norway, Sweden, Romania, France, etc. 12 have all conducted foresight studies on the future of the agricultural sector and/or the future of 13 science and technology in their countries (Table 5.2). 14 15 [Insert Table 5.2] 16 17 5.1.2.3 At North American level 18 North America (NA) has a large number of studies on the future of agriculture and/or AKST, but 19 there is no coordination or networking among organizations. There are therefore more difficult to 20 collect. More prominently than in Europe, the role of technology is a commonly addressed 21 element in foresight exercises. 22 23 Beyond the Central Intelligence Agency (CIA) which does not reveal the results of studies, the 24 National Intelligence Council (NIC) is a centre for midterm and long-term strategic thinking. The 25 "Mapping the global future" report looks at the world in 2020 (NIC, 2004). 26 27 As far as agriculture is concerned, the Economic Research Service (ERS) of the US Department 28 of Agriculture (USDA) ERS conducts a research program to inform public and private decision 29 making on economic and policy issues involving food, farming, natural resources, and rural 30 development. ERS specialists, for example, provide wide-ranging research and analysis on 31 production, consumption, and trade of key agricultural commodities and on agricultural policies of 32 countries and regions important to U.S. agriculture, as well as on international trade agreements 33 and food security issues. The Economic Research Service (USDA/ERS) has developed the 34 SWOPSIM model (Static World Policy Simulation Model) to study the interaction of US policies 35 with those of the rest of world. (See http://www.ers.usda.gov/).

36

1 Universities are also very active in trade modeling. The University of Purdue, for example, has

2 developed GTAP (Global Trade Analysis Project), a data base and a model on production,

3 consumption and trade.

4

5 The World Technology Evaluation Center, Inc. (WTEC) is a US organization conducting

6 international technology assessments via expert review. For example, report on converging

7 technologies (nanotechnology, biotechnology, information technology and cognitive science)

8 have been written for the National Science Foundation (NSF) (Roco and Bainbridge, 2002;

9 Bainbridge and Roco, 2006).

10

The Department of Interior (DOI) has conducted a study "Water 2025" which sets a framework to
 focus on meeting water supply challenges in the future (US DOI, 2005).

13

14 The application of nanotechnology in precision agriculture is a recurring theme. Producers could 15 have near real-time data from every plant or animal (Fletcher, 2007; Western Farm Press, 2007); 16 computers would automatically collect and analyze the information. These data would allow 17 producers to detect and correct disease infections, pest infestations, nutrient/water deficiencies, 18 etc. before there is any significant effect on the plant/animal. This type of system would allow 19 precise targeting (and tremendous reductions) of medicines, pesticides, nutrients and water. 20 Much of the process would be completely automated; problems could be addressed or prevented 21 (Catlett, 2003). Combinations of detection technology and global positioning technology would 22 allow detection and precise location information. Pesticides, nutrients and water could be used 23 more efficiently and with fewer environmental effects.

24

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

31

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 North American demand for food quantity is expected to be mostly static, 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. Biotechnology can be used to manipulate nutritional qualities of foods and reduce chemical inputs remaining on foods.

1 2 Additionally, affluent consumers are more knowledgeable about environmental issues and more 3 likely to pay a premium for products that have been produced / processed with attention to 4 environmental or social issues (Univ. Georgia, 2000). Technology can provide the means to track 5 individual food items or food components from the field to the table (Western Farm Press, 2007). 6 Consumers will be able to make buying decisions based a wide range of nutritional, 7 environmental and social factors. 8 9 Greater affluence is also associated with an increased demand for meat in the diet. Because the 10 typical diet in NA is already based on meat, the demand in NA is unlikely to change significantly. 11 However, increasing affluence in other countries will most likely strengthen the export market for 12 meat produced in NA. Additionally, there will be greater demand for grains to produce meat 13 animals. 14 15 Aging and affluence will also generate greater demand for additional processing of food products 16 (Western Farm Press, 2007). Aging consumers, in particular, are willing to pay more for 17 convenience. Consequently, there will be a greater demand in NA for prepared foods or products 18 that can be prepared quickly and easily. 19 20 All of these consumer factors will combine to create a broad, varied market for differentiated 21 products. Some groups of people will be most interested in food properties (e.g., nutrition, flavor, 22 or convenience); others will choose agricultural products based on concomitant environmental 23 impacts of production. Technology and rapid global communication will allow consumers to 24 evaluate a wide range of factors and to identify/track agricultural products from the field to their 25 home. 26 27 There are reports that discuss the importance of multifunctional agricultural systems and 28 underline the need for greater public awareness and support of multifunctionality (McCalla, 2000; 29 Tilman et al., 2002). Affluent consumers are not concerned about food supply and have greater 30 knowledge of the environment. They are more likely to pay for environmental services (e.g., 31 wildlife habitat or watersheds) associated with agricultural production. 32 33 Agriculture will provide new products and services. Genetically modified plants and animals will 34 produce many different pharmaceuticals and raw materials for industry. In NA, agriculture will 35 become a major source of energy (Ugarte et al., 2006). Modified plants and agricultural waste 36 products will be converted to fuel. This industry will expand into a leading market for agriculture,

37 providing a major additional revenue stream but possibly creating resource competition between

1 the production of food and fuel. Agriculture will become a more important source of fuel as China

2 and India become key competitors for energy (Vanacht, 2006). It would be particularly important if

3 feed grains (e.g., corn) were massively used for energy, as is done currently, or lose in

4 importance. In the former case, it will become more difficult and expensive to meet a rising

5 demand for meat (Ugarte et al., 2006).

6

7 Carbon sequestration may be a new role for NAE agriculture (Skaggs, 2001, US EPA, 2005). As

8 China, India and other countries become more industrialized, it will become more critical to

9 mediate levels of greenhouse gases. Plants can remove carbon dioxide from the atmosphere, a

10 service that agriculture could provide. If carbon sequestration is combined with fuel production,

11 agriculture could provide energy with little or no net gain in greenhouse gases.

12

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 (Skaggs, 2001). The federal government will be involved with other services, such as carbon sequestration, that

17 benefit a much larger population and area (Skaggs, 2001; US EPA, 2005).

18

A number of reports discuss the implications of dualism in NA agriculture. Agriculture will consist almost entirely of very large and small farms. A relatively small number of large farms will produce most agricultural products. Small farms will survive, but operators will also depend on off-farm income; it will be important to provide the related opportunities (Skaggs, 2001). There will be an increased trend for more public-private partnerships (Skaggs, 2001; Univ. Georgia, 2000). A more affluent society will focus private research on convenience/appeal of agricultural products and public research on product safety and environmental impacts.

27 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). It

29 is important to revise the current system of IP protection and to harmonize IP security

30 internationally. A new system is needed that will facilitate the sharing of information without

eliminating the financial incentive that drives much agricultural research (Table 5.3).

32

33 [Insert Table 5.3]

34

35 5.1.2.4 Relationship of scenarios in different exercises

36 All the exercises reviewed have developed assumptions about a number of underlying

37 uncertainties and future development of key driving forces and arrived at different logics

- 1 regarding the construction of alternative futures. Nevertheless, many scenarios display some
- 2 similarities, and it has been argued that the enrichment of global scenarios, often through
- 3 participatory processes, will define an important agenda for policy analysis, scientific research
- 4 and education. This will require the enhancement of the role of ecosystems in both scenario
- 5 narrative and quantification. Narratives will need to more richly reflect ecosystem descriptors,
- 6 impacts, and feedbacks. Models will need to simulate ecosystem services within global
- 7 assessment frameworks. (Raskin et al., 2005).
- 8

9 5.2 Indirect Drivers for AKST

As indicated in the conceptual framework, the AKST system does not exist in isolation. It interacts with other societal parameters of development: demography, economy, international trade, sociopolitics, science, technology, education and culture. Only some elements will be highlighted here as these indirect drivers are reviewed in detail in chapter 4 of the global report, and some of them pertaining to North America and Europe have been reviewed in chapters 1, 2, 3 and 4 of this report. The predominant drivers of AKST futures are in the KST system and in agriculture.

16

17 5.2.1 Demographic drivers

18 Population growth is an important driver of demand for agricultural products and AKST, but the 19 influence of AKST on population growth is very slow. Food demand is increasing as the world's 20 population grows and migrates. People's requirements for food are related to three factors: 21 quantity, quality (nutrition and safety) and cost. Since climate change, water shortages and soil 22 degradation are rapidly changing the conditions of agricultural production, the Malthusian fears of 23 a widening gap between people's needs and food production are once again coming to the 24 forefront in discussions on the future of the planet. The problem is most acute in the developing 25 countries (Smil, 2000; Raoult-Wack and Bricas, 2001; Gilland, 2002; Von Braun et al., 2005). The 26 global composition of the food demand (e.g., cereals, sugar crops, oil crops, produce, livestock 27 and fish) will be shaped by population growth rates, economic growth, income levels, food safety 28 scares and rapid urbanization in the developing economies, particularly in Asia (Cranfield et al., 29 1998; Collomb, 1999; Rosegrant et al., 2002; Schmidhuber, 2003; Schmidhuber and Shetty, 30 2005; Smil, 2005; Griffon, 2006).

31

32 Population size and structure are determined by three fundamental demographic processes:

33 fertility, mortality and migration. The common understanding of projections in world demography

is that the growth in world population will continue up to a maximum of 7.5 to 9 billion during the

35 second half of the 21st century, followed by a slow decrease (UN Projections).

36

1 Between 2007 and 2050, the population of the more developed regions (Europe and North

- 2 America) will remain largely unchanged at 1.2 billion inhabitants, but the population of the less
- 3 developed regions is projected to rise from 5.4 billion in 2007 to 7.9 billion in 2050 and the
- 4 population of the least developed countries is projected to rise from 804 million people in 2007 to
- 5 1.7 billion in 2050. Consequently, by 2050, 67% of the world population is expected to live in the
- 6 less developed regions, 19% in the least developed countries, and only 14% in the more
- 7 developed regions (UN, 2006).
- 8

9 The European Union no longer has a "demographic motor". Member States whose population is 10 not set to fall before 2050 represent only a small share of Europe's total population. Of the five 11 largest Member States, only Britain and France will grow between 2005 and 2050 (+8% and + 12 9.6% population growth respectively). In some countries population figures will take a downturn 13 before 2015, with a percentage drop of more than 10-15% by 2050 (CEC, 2005).

14

15 The average number of persons per household in EU-15 declined from 2.8 in 1981 to 2.4 in 2002

16 (UN, 2006). Most of the single person or single parent households are located in urban areas.

17 Families with children tend to move out or are pushed out of highly urbanized areas and into new

18 suburban areas (ex-urbia), but this does not change their need for services such as schools,

19 sports facilities, etc. Rural areas, with shrinking populations cannot readily sustain such services.

- 20 The general phenomenon of smaller household sizes has a number of direct implications in the
- 21 structure of the markets that are being served by the food industries: packaged food needs to
- 22 come in smaller quantities, demand for convenience food grows because singles usually spend
- 23 little time preparing food, the number of food-catering services tends to go up (Leijten, 2006).
- 24

In Europe and North America, 20% of the population is already aged 60 years or over. That

- figure, with regional differences, is projected to reach 33% in 2050. In 2025, the fertility rate per
- woman is projected to be higher in the USA (2.18) than in Western Europe (1.62) and Eastern
- Europe (1.51). (U.S. Census Bureau, International Data Base; Eberstadt, 2007).
- 29

30 [Insert Table 5.4]

In developed countries as a whole, the number of older persons (persons aged 60 or over) has already surpassed the number of children (persons under age 15) and by 2050 the number of older persons is expected to be more than double the number of children in developed countries (UN, 2006). The populations of 46 countries or areas, including Germany, Italy, most of the successor States of the former USSR and several small island States are expected to be smaller in 2050 than in 2005 (UN, 2006).

37

1 The contribution of international migration to population growth in the more developed regions 2 has increased in significance as fertility declines. During 2005-2050, the net number of 3 international migrants to more developed regions is projected to be 103 million, a figure that 4 counterbalances the excess of deaths over births (74 million) projected over the period. In 2005-5 2010, the net migration more than doubled the contribution of natural increase (births minus 6 deaths) to population growth in eight countries or areas, namely, Belgium, Canada, Hong Kong 7 (China SAR), Luxembourg, Singapore, Spain, Sweden and Switzerland. Net migration 8 counterbalanced the excess of deaths over births in eight other countries viz. Austria, Bosnia and 9 Herzegovina, the Channel Islands, Greece, Italy, Portugal, Slovakia and Slovenia. In terms of 10 annual averages for 2005-2050, the major net receivers of international migrants are projected to 11 be the United States (1.1 million), Canada (200,000), Germany (150,000), Italy (139,000), the 12 United Kingdom (130,000), Spain (123,000) and Australia (100,000). The countries with the 13 highest levels of net emigration (annual averages) are projected to be: China (-329,000), Mexico 14 (-306,000), India (-241,000), Philippines (-180,000), Pakistan (-167,000) and Indonesia (-15 164,000) (UN, 2006). 16 17 In the future, the NAE region will be concerned with food demand from its own population and the 18 needs of the rest of the world, especially the less developed countries. How will NAE respond to 19 the need to feed the growing populations of Africa and Asia and the need to ensure 20 environmental sustainability in these regions? 21 22 [Insert Table 5.5] 23 [Insert Table 5.6] 24 25 5.2.2 Economics and international trade 26 Increases in demographic and socioeconomic pressure (increases in average income and labor 27 productivity) in society are the main driving forces of technological development in agriculture 28 (Giampietro et al., 1999). 29 30 In 2005, North America represented 15% of merchandise and 17% of commercial services 31 exports. Europe represented 44% and 52%, and the Commonwealth of Independent States (CIS) 32 represented 3% and 2% (World Trade Report, 2006). 33 34 The global state of the economy, including gross domestic product (GDP), trade related issues 35 and employment has influenced agriculture and AKST. In the next fifty years, the NAE economy 36 will be mostly challenged by the prices of energy and other natural resources and the competition 37 of products from developing countries. NAE's aging population will generate high expenses and

1 might lead to a shortage of human resources. Currently, the sluggishness of the European

- 2 economy constitutes a drag on world trade and output growth. The Commonwealth of
- 3 Independent States (CIS) has strong economic growth thanks to the expansion of the energy
- 4 sector. For the US, the current account deficit is a major question (World Trade Report, 2006).
- 5

6 The annual World GDP growth rate was 2.8% during 1990-2003 broken down as follows: high-7 income countries 2.6%, middle-income countries 3.5%, low-income countries 4.7% (World Bank, 8 2005). This indicates a "catching up" process: the income growth rate is higher for countries with 9 a lower initial GDP level. For the same period, GDP growth in the EU-27 is about 2% per year; 10 this is lower than the growth in other high income countries (EC, 2007).

11

12 Future world income growth will be determined by the growth in production factors (labor, capital, 13 land) and the productivity growth of these factors. Continued economic growth is expected over 14 the coming period in almost all regions of the world. This growth will be considerably higher for 15 most of the transitional and developing countries than for the EU-15, the United States and 16 Japan, in particular for Brazil, China, India and the new EU Member States (EC, 2007). In the 17 United States, public debt levels are expected to increase over the next twenty years due to 18 significant increases in public expenditures on health care (OECD, 1995). In the reference case 19 projections, the U.S. economy stabilizes at its long-term growth path by 2010. GDP is projected to 20 grow by an average of 2.9% per year from 2004 to 2030, slower than the 3.1% annual average 21 over the 1980 to 2004 period, because of the retirement of the baby boom generation and the 22 resultant slowing of labor force growth. Canada's labor force growth is projected to slow in the 23 medium to long term, however, as baby boomers retire. The country's overall economic growth is 24 projected to fall from the current average of 2.9% per year to averages of 2.6% per year from 25 2007 to 2015 and 2.1% per year from 2015 to 2030 (IEO, 2007).

26

Over the long term, OECD Europe's GDP is projected to grow by 2.3% per year from 2004 to 2030 in the reference case, in line with what OECD considers to be potential output growth in the region's economies. According to the International Monetary Fund, (IMF) structural impediments to economic growth still remain in many countries of OECD Europe, related to the region's labor markets, product markets, and costly social welfare systems. Reforms to improve the competitiveness of European labor and product markets could yield significant dividends in terms of increases in regional output (IEO, 2007).

34

35 5.2.3 Sociopolitical drivers

The term "political" refers to factors that are related to politics, that is, to the processes of decision making on public policies at the sub-national, national and international level and to the

processes of implementing these policies. The term "social" is used here broadly to refer to
 human society. Political stability is an important factor that influences the direct and indirect
 drivers of agricultural development. Civil strife and internal and cross-border conflicts and wars

4 can have a considerable negative impact on agricultural production.

5

6 It is very difficult to assess potential changes in sociopolitical drivers. In North America and 7 Europe, the main uncertainties are the integration of Eastern European countries in the EU and 8 the situation in the CIS. How will the political regime evolve? What will be the relationships among 9 the states? One of the main problems in relations between Russia and the European Union (EU) 10 is the absence of strategic goals. Russia, having played a critical role in ending the Cold War, has 11 neither found its place in the strategy of EU expansion nor in that of NATO. In 2007, the active 12 Partnership and Cooperation Agreement (PCA) between Russia and the EU, which both sides 13 agree has become outdated and is no longer able to meet today's challenges, is due to expire. 14 The form that any new legal, contractual basis for relations between Russia and the EU may take 15 will have implications not only for stability within Europe, but also for Russia's democratic future 16 (Arbatova, 2007). The future relationship of Russia with the USA is also an important uncertainty.

17

5.3 Key Direct Drivers for Knowledge, Science and Technology (KST): Uncertainties and Consequences for AKST

20 5.3.1 Transformation in models of knowledge production: trends and uncertainties

21 5.3.1.1 Trends

22 Knowledge is defined today as a learning and cognitive capacity. Most importantly, it has to be 23 apprehended in action. This implies a fundamental distinction between information and 24 knowledge. Traditionally a distinction is made between implicit knowledge (e.g., daily life or 25 common sense knowledge, experience knowledge, local or indigenous knowledge, action 26 knowledge) and explicit knowledge (practical, theoretical or creative knowledge). Other typologies 27 emphasize the context in which knowledge is used, as defined by the knowledge itself (normative 28 and descriptive knowledge, strategic and operative knowledge, scientific and empirical 29 knowledge, past- and future-oriented knowledge). Finally, certain authors focus more on the 30 modes of inscription of knowledge, and thus distinguish between: 'embrained' knowledge (based 31 on certain conceptual and cognitive skills), embodied knowledge, 'encultured' knowledge (built up 32 in the processes of socialization that lead to shared forms of understanding), embedded 33 knowledge (in systemic routines) and encoded knowledge (which can be considered as 34 equivalent to information) (Amin and Cohendet, 2004).

35

36 New forms of knowledge production and new concepts are appearing. We will briefly mention

37 them as they are often used in discussions of future research systems:

1 Mode 1 and Mode 2. "Mode 1 refers to a form of knowledge production, a complex of ideas, 2 methods, values, norms, that has grown to control the diffusion of the Newtonian (empirical 3 and mathematical physics) model to more and more fields of enquiry and ensure its 4 compliance with what is considered sound scientific practice. Mode 1 is ... the cognitive and 5 social norm which must be followed in the production, legitimation and diffusion of 6 knowledge." "In Mode 1 problems are set and solved in a context governed by the, largely 7 academic, interests of a specific community. By contrast, Mode 2 knowledge is carried out in 8 a context of application. Mode 1 is disciplinary while Mode 2 is transdisciplinary. Mode 1 is 9 characterized by homogeneity, Mode 2 by heterogeneity. Organizationally, Mode 1 is 10 hierarchical and tends to preserve its form, while Mode 2 is more heterarchical and transient. 11 Each employs a different type of quality control. In comparison with Mode 1, Mode 2 is more 12 socially accountable and reflexive. It includes a wider, more temporary and heterogeneous 13 set of practitioners, collaborating on a problem defined in a specific and localized context." 14 (Gibbons et al., 1994). 15 Collective intelligence (or Mode 3). This concept is the subject of a lively on-going discussion, 16 but a working definition is that 'collective intelligence is the capacity of human communities to 17 cooperate intellectually in creation, innovation and invention' (Lévy, 2000). This type of 18 general definition only helps to specify the distinctiveness of how "collective intelligence" 19 produces knowledge by stressing how it differs from the lone researcher in Mode 1 or the 20 purposeful process in Mode 2 (cited by Akrich and Miller, 2007). 21 Triple Helix. The "Triple Helix" model (Leydesdorff and Etzkowitz, 1998) implies university-22 industry-government relations. It is developing, though at unequal speed depending on the 23 country. 24 Platform model. The notion of platform devised by Keating and Cambrosio (Keating and 25 Cambrosio, 2003) attempts to formalize the attributes of a network insofar as it connects a 26 set of devices, tools, instruments, technologies and discourses which are used by a

27 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, transdisciplinary built-in
- 30 innovation.
- 31 <u>Frontier research</u>. This concept has been devised by experts of the European Commission
- 32 (EC, 2005) to characterize the fast-growing space which is at the intersection between basic
- and applied research. Its position at the forefront of knowledge creation makes frontier
- research an intrinsically risky endeavor that involves the pursuit of questions without regardfor established disciplinary boundaries or national borders.
- 36

1 Questions of intellectual property are linked to the transformation of knowledge production and

- 2 are equally important. The development of the Web and electronic communication tools facilitates
- 3 the circulation and also the production of knowledge. This process can be far more flexible than it
- 4 used to be in traditional research settings and can involve non-professional researchers thus
- 5 leading to new forms of collective innovation. Yet the way in which intellectual property rights
- 6 (including contracts and transaction/payment systems) are defined and managed is going to play
- 7 a crucial part in these developments.
- 8 5.3.1.2 Uncertainties of the future
- 9 The evolution of KST could create more cooperation in AKST among NAE countries. The Lisbon
- 10 Strategy recognizes that Europe is lagging behind the United-States in terms of science and
- 11 technology. A number of studies are being carried out in Europe to find ways to catch up. The
- 12 United States and Europe are often seen more as competitors than as partners.
- 13

14 The involvement of users in research definition and execution is challenging the traditional

research approach. Innovation is a process that integrates various forms of research, and the

16 knowledge it creates, in a wide range of patterns. Users are increasingly expressing their needs,

17 thus challenging traditional disciplinary research approaches and creating the need for a more

18 integrated approach, which some researchers find difficult and which could become an obstacle

- 19 to required innovation.
- 20

As far as models of knowledge production, there are a number of uncertainties concerning the future which can be formulated with questions:

- Will the "triple-helix" model that implies university-industry-government relations, develop
 quickly?
- Will knowledge production and innovation become more user-centered? How diverse will
 the forms of knowledge be? Should knowledge be yoked strictly to industrial research
 imperatives? Will knowledge production remain 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?
- 32 Will universities remain the arbiters of what is and is not legitimate scientific knowledge?
- Will intellectual property issues evolve as quickly as production modes and new modes ofcooperation?
- 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?

1 The way these questions will be answered in the different regions of NAE will affect the AKST

- 2 systems.
- 3 4

5.3.2 Transformation in models of innovation: trends and uncertainties

5 The innovation systems concept emerged through policy debates in developed countries in the 6 1970s and 1980s. The concept of national innovation systems rests on the premise that 7 understanding the linkages among the actors involved in innovation is key to improving 8 technology performance. Innovation and technical progress are the result of a complex set of 9 relationships among actors producing, distributing and applying various kinds of knowledge. The 10 innovative performance of a country depends to a large extent on how these actors relate to each 11 other as elements of a collective system of knowledge creation and use as well as the related 12 technologies. These actors are primarily private enterprises, universities and public research 13 institutes and the people within them (OECD, 1997). These systems developed in an institutional 14 (often network-based) setting which fostered interaction and learning among scientific and 15 entrepreneurial actors in the public and private sector in response to changing economic and 16 technical conditions. Over time, the innovation concept has gained wide support among the 17 member countries of the Organization for Economic Cooperation and Development (OECD) and 18 the European Union (World Bank, 2006).

19

20 The innovation system perspective brings actors together in their desire to introduce or create 21 novelty or innovation in the value chain, allowing it to respond in a dynamic way to an array of 22 market, policy and other signals. Innovation capacity is sustainable only when a much wider set 23 of attitudes and practices comes together to create a culture of innovation, including a wide 24 appreciation of the importance of science and technology in competitiveness, business models 25 that embrace social and environmental sustainability, attitudes that embrace a diversity of 26 cultures and knowledge systems and pursue inclusive problem solving and coordination capacity. 27 institutional learning as a common routine, and a forward-looking rather than a reactive 28 perspective (World Bank, 2006).

29

30 The main sources of information on innovation systems are UNESCO, OECD, OST (Observatoire

31 des Sciences et Technologies) and ISNAR (International Service for National Agricultural

32 Research). For North America, the National Science Foundation is a source of information. For

33 Europe, Cordis provides a lot of information. The Institut Français des Relations Internationales

34 (IFRI) has a research program on the Russian innovation system. These sources show that

innovation systems vary in different regions of North America and Europe.

1 5.3.2.1 Number of researchers: trends

2 There were about 4.9 million researchers in the world in 2001. In Europe there were about 1.67

3 million (952,000 in the EU 15 and 503,000 in Russia) and 1.361 million in North America (1.271

4 million in the USA and 90,000 in Canada) (OST, 2006a). Between 1996 and 2001, the number of

5 researchers decreased substantially in Canada and Russia. In Russia, the most worrying problem

6 seems to be that the average age of researchers is going up. There seems to be an increase in

7 the number of doctoral students, but this does not necessarily mean increased interest in science

8 as a career. Doctoral studies in Russia fulfill several functions e.g., dodging military service and

9 obtaining a scientific title that can also be useful in the business sector (Dezhina, 2005).

10

11 The situation has been summarized as: "the population of European researchers is currently 12 facing a demographic problem. As in most sectors, this population is aging, in line with the

13 general trend over the past sixty years. Consequently, huge numbers of researchers are

14 expected to retire over the next few years. It will be necessary to rapidly recruit new researchers,

15 whose numbers will obviously depend on the resources allocated to R&D, which are in part

16 contingent on public policies. This recruitment challenge poses a number of problems. First,

17 students in Europe tend to be turning away from science and technology, especially when it is

18 research oriented. Some see this as a consequence of the more critical attitude that has

19 developed towards technical 'progress', which is perceived as bringing as many threats as it does

20 hopes. Others stress the lack of attractiveness of careers in these fields in terms of workload,

21 status and pay. In Europe researchers' salaries are relatively low when compared to industry or

- 22 the service sector" (Akrich and Miller, 2007).
- 23

24 In the context of internationalization of higher education and research, the question of 25 remuneration is crucial. In the absence of European policies that take into account stiff 26 competition to recruit the best PhDs and post-docs, many young European researchers are 27 attracted abroad, especially to the US. For the same reasons, this outward migration is not 28 compensated for by sufficient inward migration, both quantitatively and qualitatively. The research 29 job market in Europe is fragmented, organized on a national or even local scale, with a low level 30 of competition. Selection takes place in a relatively opaque way that often favors local candidates. 31 This mode of functioning does not promote international openness and leads to unequal levels of 32 quality. Many authors agree that the broader a market is, the greater its specialization and the 33 higher the overall level of quality. The low level of internationalization of the European research 34 job market is not offset by intra-European mobility. It remains limited due to the rigidity of statuses 35 and organizations and the absence of systems for managing scientific careers on a European 36 scale, even if young researchers are becoming more mobile thanks to a strong European policy. 37 Scientific dynamics and the capacity to innovate, strongly based on the possibility of establishing

1 original links between separate research currents, would undoubtedly be enhanced by active

- 2 policies to promote mobility (Akrich and Miller, 2007).
- 3

4 In the USA, according to a report of the National Science Foundation (NSF, 2003), the future 5 strength of the US science and engineering workforce is imperiled by two long-term trends: (a) 6 global competition for science and engineering (S&E) talent is intensifying, such that the United 7 States may not be able to rely on the international science and engineering labor market to fill 8 unmet skill needs; (b) the number of native-born S&E graduates entering the workforce is likely to 9 decline unless the Nation intervenes to improve success in educating S&E students from all 10 demographic groups, especially those that have been underrepresented in S&E careers (NSF, 11 2003). Indeed, foreign students account for about one-third of the total number of doctoral 12 degrees in the natural sciences and engineering in the United States. Many foreigners stay in the 13 United States after completion of their degrees to work in industry or as postdocs at American 14 universities (Eliasson, 2004). The composition of the American population and the American 15 workforce is changing. The minority populations, African-Americans, Hispanics, Asians and 16 Native Americans, will increase. More of these people will be entering college and subsequently 17 the labor force in the next decade. Today minority groups represent 24% of the American 18 population and only seven percent of the total labor force in science and engineering (Eliasson, 19 2004). According to the Third International Math and Science Study, American fourth graders did 20 relatively well in both subjects, but by the time they reached their senior year in high school, U.S. 21 students ranked very low compared to students in other countries (NSF 2003). There is a great 22 need for mathematics and natural sciences teachers in U.S. secondary schools.

23

24 5.3.2.2 Research and technology organizations: trends

"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 includes both

private resources (via contracts, patents and licenses) and public funds; they increasingly

29 straddle applied and basic research, and are thereby engaged in 'frontier research', and their

30 work has a distinct multidisciplinary dimension that includes the economic and social sciences.

31 This particular positioning is a source of tension, so that the specificity of RTOs depends on a

32 balance being maintained between their diverse components" (Akrich and Miller, 2007).

33

34 Historically and by construction RTOs have tended to encourage multidisciplinarity projects and

have been less constrained by the boundaries between basic and applied research.

36 Consequently, they have many assets conducive to playing a strategically important role in the

37 current context. With links to fundamental research, RTOs have expertise in the development of

1 tools and concepts (mathematical modeling, complex systems theory, etc.) that allow them to

2 articulate and blend the sets of heterogeneous knowledge and technology that are major sources

- 3 of innovation. RTOs are also well configured to take advantage of the increasing number of
- 4 actors involved in research and the intensified relations between the scientific community and its
- 5 environment
- 6

There is comparatively little information about R&D laboratories in the United States. Government
laboratories or federal laboratories have typically been established to serve a mission of a
particular government agency. They include government-owned but contractor-operated labs and
federally-funded R&D Centers. In 2002, government laboratories received about 25 of a total of
81 billion dollars of total federal investments in R&D (31%), which can be compared to
approximately 10 billion dollars for the academic sector. The biggest recipients are those under

13 the Department of Defense (Eliasson, 2004).

14 5.3.2.3 Universities: trends

15 Universities across Europe reflect a multitude of realities. In certain countries they are the main 16 source of research and higher education. In other countries they coexist with large research 17 organizations and even, as in France, with other types of higher education institutions (Grandes 18 Ecoles) that are increasingly engaged in research. On the whole, there is less investment in 19 higher education in Europe than in other countries such as the US. Funding is primarily from the 20 public sector, and students pay a relatively low share of the education costs. However, funding for 21 university-based research has increased substantially over the last 15 years. There has also 22 been a diversification of the sources of funding for research institutions that now include national 23 governments, supranational bodies (e.g., the European Commission), regional governments, 24 business enterprises and civil society. The respective weight of teaching and research and the 25 mechanisms through which research activities can be financed and encouraged vary 26 considerably among countries and universities. In general, universities in Europe currently face 27 similar challenges: offering courses to young adults, meeting the demand for on-going education 28 and training, and participating in knowledge production in increasingly diverse contexts and with 29 an ever-greater variety of partners. The juxtaposition of these different tasks generates strong 30 tension within universities, in part due to limited resources. The situation is exacerbated by the 31 fact that the main missions of universities are often ambiguous; additionally, key stakeholders and 32 managers may not agree on priorities. (Akrich and Miller, 2007).

33

There are about 4200 universities and colleges in the U.S., and most of the research is carried out at about 263 doctoral / research universities. Universities perform about 13% of total R&D, and 82% of federal support goes to 100 universities. Twenty of them receive about 34% of the government support (Eliasson, 2004).

1 2 In 2004, Russia had 1071 higher education establishments (40% more than in 1993). They are 3 starting to be involved in research (OST, 2006a). 4 5.3.2.4 Multinational enterprises and small and medium enterprises: trends 5 Today's multinational corporations (MNCs) see innovation as a strategic element in economic 6 competition. The life cycles of products are increasingly short, and firms are encouraged to 7 produce returns on investments more and more quickly. Consequently, an R&D race has 8 developed among multinationals. R&D activities enable firms to build up knowledge about 9 technologies to support their key activities. R&D is also critical to the firm's long-term 10 competitiveness, by enabling them to identify, acquire and apply knowledge that has been 11 developed by others. 12 13 MNCs have been expanding R&D outside their home countries in recent decades. R&D 14 investments by MNCs, within their affiliates or with external partners in joint ventures and 15 alliances, support the development of new products, services and technological capabilities. 16 These investments also serve as channels of knowledge spillovers and technology transfer that 17 can contribute to economic growth and enhance competitiveness abroad. International R&D links 18 are particularly strong between USA and European companies, especially in pharmaceutical, 19 computer and transportation equipment manufacturing. More recently, certain developing and 20 newly industrialized economies are emerging as hosts of US-owned R&D, e.g., China, Israel and 21 Singapore (NSF, Science and Engineering Indicators, 2006). 22 23 Small and Medium Enterprises (SMEs) are extremely heterogeneous, ranging from high-tech 24 start-ups to small building contractors to the local companies However the sectoral coverage 25 narrows considerably when the focus is on research related issues. Technology based SMEs 26 account for around 10% of all SMEs (NSF, Science and Engineering Indicators, 2006). 27 28 5.3.2.5 International, national and regional governments: trends 29 A variety of actors, including advisory bodies, national agencies, ministries and specialized 30 institutes are involved in making and implementing national science, technology and innovation 31 policies. These actors engage in a wide range of activities, including planning, forecasting, 32 strategic intelligence and consultation with stakeholders. The national level actors are involved 33 throughout the process, which covers needs identification, agenda-setting, policy implementation,

34 policy evaluation and benchmarking results. The forms of intervention of regional powers in

35 research and technology policies vary.

36

1 The defining characteristics of the US public R&D policy are an even stronger impact of the 2 economic factors than in other geographical areas, the enormous influence of defense-related 3 research activities, and the importance given to the high potential areas made up of converging 4 technologies (EU Commission, 2006). North American policies emphasize research support for 5 regional and local universities. Regional authorities have policies for attracting and developing a 6 qualified local workforce; these policies spurred the creation of technology clusters and parks. In 7 the USA, 60% of all R&D is concentrated in six states, with California alone accounting for 20% 8 (UNESCO, 2006b).

9

10 In Europe, national authorities generally retain the leading role in policy formulation and 11 implementation, but there are very wide differences among countries in the extent and nature of 12 this leadership (Akrich and Miller, 2007). Europe is much more influenced by societal, i.e. social 13 and environmental, factors than the U.S. as far as R&D policy setting is concerned. Ecological 14 and quality of life issues generally provide a unifying and defining element of European public 15 R&D support policy. Nevertheless, the European landscape is characterized by important inter-16 country differences. A number of factors account for this, such as GDP, political environment and 17 scientific position. Europe is also faced with policy rigidities that strongly affect the efficiency of 18 public support, influencing both the form in which support is being administered and the research 19 organization itself (EU Commission, 2006). The distribution of prerogatives between regional, 20 national and European government varies from country to country, e.g., the länders are very 21 influential in Germany, and regionalization is being introduced in Spain and the United Kingdom.

22 5.3.2.6 Uncertainties of the future

There are a number of uncertainties related to the future and the way these questions will beanswered in the different regions of NAE will affect the AKST systems. These questions are:

25

26 -The capacity of universities and public research organizations, the private sector and the 27 government to jointly define research priorities and fund R&D in order to make their 28 country's economies competitive is uncertain. Collaborative research is gaining ground, 29 and measures could be taken to further promote it and improve the general R&D effort. 30 Will governments be able to develop "innovation plans" that favor interactions between 31 universities, industries and governments? Will the public and the private sector reach a 32 consensus on priorities? Since the KST system is composed of both the public and the 33 private sector, working with the whole system could lead to a consensus on priorities. 34 This would allow the public sector to take better account of the private sector and 35 consumer needs and concentrate on the development of public goods.

36

1 Innovation is a strategic element in economic competition, but companies make 2 investment decisions according to their expected returns. The level of private sector 3 contributions to R&D varies among countries. Large multinationals are increasingly 4 influencing priorities and investments in agricultural science and technology and are 5 heavily involved in agricultural extension. Some see this trend as positive, others as 6 negative. Will policies that enable firms to pursue the 'best quality according to 7 international standards' clash with policies aimed at ensuring that 'research is a means 8 for local economic development'? Will enterprises be able to earn money from research, 9 invest massively in research and produce significant industrial innovation? How does the 10 internationalization of science interact with the internationalization of industrial R&D? 11 How do innovation systems adapt to maximize benefits and lower costs of 12 internationalization? How will the potential contradictions between local development and 13 internationalization be addressed?

14

15 How far will the current regionalization trend go in Europe? Will excessive competition 16 between regions, in the absence of coordination at the European level, lead to a 17 fragmentation of efforts and the absence of a coherent strategic vision? Will Europe be 18 able to reinforce excellence, especially in new, fast-growing research areas and areas 19 where science and technology are closely interlinked? Will the strengthening of large-20 scale pan-European projects concentrate and integrate research without accommodating 21 local concerns and context? Will European universities serve the industrial economy, or 22 simply become more closely linked to "external" research? Will there be a more open and 23 dynamic European market for funding post-doctoral researchers, including opening 24 access to non-academic research? Will greater importance be given to service sector 25 activities and SMEs? Will the Russian Federation manage to transform its R&D system 26 and attract young people to R&D?

- 27
- 28

29 5.3.3 Information technology: trends and uncertainties

30 5.3.3.1 Trends

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 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

- 36 structures hindering innovation, and do so in harmony with cultural, social and natural heritage.
- 37 There is a trend towards modeling more and more of reality in computational systems. There is

1 literally no part of reality which might not be subject to such modeling, including intelligent human

2 beings as the most challenging goal. Information Technology is a cross-sectoral discipline par

3 excellence. Its applications virtually cover any sector and any discipline (Bibel, 2005).

4

5 New forms of expertise are emerging, facilitated by the development of information and 6 communication technologies (ICT) that allows both access to content and contact amongst 7 actors. ICT will play a part in all fields of science and technology and in agriculture, especially by 8 providing images, real-time data wherever needed (Cuhls, 2006). Imaging will be available very 9 soon (NISTEP, 2005) and will contribute to precision farming and to making agriculture, 10 especially the related resource and land management, more efficient. Radio Frequency 11 Identification (RFID) could replace common barcodes and have a huge impact on agriculture and 12 the marketing of products (Cuhls, 2006). Models and simulations will improve and support crop 13 management, weather forecasts, etc. 14 15 Currently, IT availability and use in NAE is uneven among countries and sectors. Europe, in 16 general, is behind North America. Within Europe, there are major differences. Some countries of 17 Eastern Europe and to a lesser extent, Central Europe, have relatively low access to information 18 technologies. 19 5.3.3.2 Uncertainties of the future 20 There are a number of uncertainties related to the future and the way these questions will be 21 answered in the different regions of NAE will affect the AKST systems. These questions are: 22 23 Will drastic cost reduction in ICT-based Microsystems and artificial intelligence and _ 24 knowledge management software lead to widespread self education, training and research 25 generation tools? 26 Will Eastern Europe be able to reduce the digital divide with the rest of Europe? _ 27 As far as Information Technology is concerned, will Europe manage to catch up and keep 28 pace with North America? 29 30 5.3.4 Evolution of KST with potential impact on AKST 31 Beyond what is happening in the ICT sector, other developments in the knowledge, science and 32 technology systems could have important consequences for AKST. Technology forecasting and 33 foresighting activities have been carried out at the European (EC, 2006) and national levels 34 (Technologies Clés in France: Futur in Germany: National Intelligence Council's 2020 project in 35 the USA, etc.) to identify emerging priority technologies that will be of paramount importance for

36 Europe in the future. At the European level, forty technologies have been grouped within four

37 main scientific fields (EC, 2006):

1 _ Nanotechnologies, knowledge-based multifunctional materials, new production processes, 2 Information society technologies, 3 Life sciences, genomics and biotechnology for health, -4 Sustainable development, global change and ecosystem. _ 5 6 Two different rationales support the selection of these technologies. The first one is that they are 7 emerging and have been identified through a questionnaire sent to a panel of about 1300 experts 8 in all the countries of the enlarged Europe. The second one is the results of the foresight literature 9 review both in the European and the main competitor countries (EU Commission, 2006). 10 However, if Gross Expenditures for R&D (GERD) stay at the present level and if there is no 11 coherent European or NAE policy, it is unlikely that all of the research can be done. The AKST 12 investments will not be the same if the main drivers are life sciences, sustainable development 13 and economic factors or if they are societal motives. 14 15 In the USA, a technical foresight study (Global Technology Revolution 2020) undertaken by Rand 16 Corporation (Rand Corporation, 2006; EFMN, 2007) has identified applications: 17 Cheap solar energy: Solar energy systems inexpensive enough to be widely available to 18 developing and undeveloped countries as well as to economically disadvantaged populations that are not on existing power grids. 19 20 Rural wireless communications: Widely available telephone and Internet connectivity 21 without a wired network infrastructure. 22 Communication devices for ubiquitous information access: Communication and storage 23 devices - both wired and wireless - that provide agile access to information sources 24 anywhere, anytime. Operating seamlessly across communication and data storage 25 protocols, these devices will have growing capabilities to store not only text but also 26 meta-text with layered contextual information, images, voice, music, video and movies. 27 Genetically modified (GM) crops: Genetically engineered foods with improved nutritional 28 value - e.g., through added vitamins and micronutrients, increased production - e.g., by 29 tailoring crops to local conditions and reduced pesticide use - e.g., by increasing 30 resistance to pests. 31 Rapid bioassays: Simple, multiple tests that can be performed quickly and simultaneously 32 to verify the presence or absence of specific biological substances. 33 Filters and catalysts: Techniques and devices to effectively and reliably filter, purify and -34 decontaminate water locally using unskilled labor. 35 Targeted drug delivery: Drug therapies that preferentially attack specific tumors or 36 pathogens without harming healthy tissues and cells.
1	-	Cheap autonomous housing: Self-sufficient and affordable housing that provides shelter	
2		adaptable to local conditions as well as energy for heating, cooling and cooking.	
3	-	Green manufacturing: Redesigned manufacturing processes that either eliminate or	
4		greatly reduce waste streams and the need to use toxic materials.	
5	-	Ubiquitous radio frequency identification (RFID) tagging of commercial products and	
6		individuals: Widespread use of RFID tags to track retail products from manufacture	
7		through sale and beyond, as well as track individuals and their movements.	
8	-	Hybrid vehicles: Automobiles available to the mass market with power systems that	
9		combine internal combustion and other power sources.	
10	-	Pervasive sensors: Presence of sensors in most public areas and networks of sensor	
11		data to accomplish widespread real-time surveillance.	
12	-	Tissue engineering: The design and engineering of living tissue for implantation and	
13		replacement.	
14	Biotech	nologies and nanotechnologies are two technologies that are quite controversial in some	
15	countries, especially in Europe. They both elicit fear, and their costs and benefits depend on how		
16	they are	e incorporated into societies and ecosystems and whether there is the will to fairly share	
17	benefits	s as well as costs. They may have important potential impacts on agriculture and food	
18	system	s (Scott and Chen, 2003).	
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20	5.3.5	Financial resources devoted to science and technology: trends and uncertainties	
20 21	5.3.5 5.3.5.1	Financial resources devoted to science and technology: trends and uncertainties Trends	
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Draft—not for citation 23 March, 2008

in R&D capacities between the EU Member States. Even if the new Member States will attract
 R&D investments, the R&D budget of the European Commission represents just five percent of

3 public expenditure on R&D by Member States. In 2001, Europe accounted for 46.1% of the

4 world's R&D publications (OST, 2006b).

5

6 Since the disintegration of the USSR more than a decade ago, the R&D systems of all these 7 states have been seriously reduced, yet they remain important. The proportion of GDP spent on 8 R&D by the Federation of Russia, for example, was 1.17% in 2004 (OST, 2006a). Moreover, the 9 number of researchers in Russia, 3,400 per million inhabitants, is the third highest in the world 10 after Japan (5,100) and the USA (4,400) (UNESCO, 2006b). Almost 3,650 organizations 11 represent science and research in today's Russia (OST, 2006a).

12

13 The evolution of science and technology is increasingly expensive. Each answer gives rise to 14 new questions. Although nations are very much aware of the importance of science and 15 technology for their economy, there are limits to the amounts of money they are willing to spend 16 on it. Consequently, nations and businesses must choose which areas of science and technology 17 they will support. As a result of competition for resources, researchers must account for the 18 activities much more than in the past. Research must increasingly justify the resources that 19 support their programs; additional funding is often linked to applied solutions for societal 20 problems.

21 5.3.5.2 Uncertainties of the future

The present domination of NAE in generating formal new knowledge could be challenged. The growth of gross expenditure on R&D and R&D results in Asia is changing the relationship of NAE research with the rest of the world. This could result in new networks and increased competition among agriculture, industry and services.

26

27 Public funding of science and technology is insufficient to adequately address and provide

28 solutions for agriculture that better fulfill the needs of consumers and better respond to the

29 requirements of more sustainable natural resource management. Less AKST is available in the

30 public domain, limiting farmers' choices and the achievement of sustainable agriculture and rural

31 development. This also has a negative impact on partnerships with other regions of the world.

32 Halting and reversing this negative trend depends on the will of governments. Reshaping

intellectual property rights and other regulatory frameworks could also modify this trend.

34 Questions concerning options for the future are:

Will financial efforts and administrative measures break down barriers between the public
 and the private sectors where such barriers still exist?

37 - How will the increased productivity of industrial systems affect resources devoted to KST?

1	- Since budgetary resources are limited, should the public sector support technologies in		
2	areas of strength or, on the contrary, areas of specific weaknesses? Should the public		
3	sector leave the market and support targeted R&D firms through tax incentives, mobility,		
4	etc.? Should it fund most of the research and leave only accompanying measures for the		
5	private companies?		
6	- Will Europe be able to mobilize extra financial and human resources for KST to keep pace		
7	with the United States and Japan or be taken over by fast-developing Asian countries? Will		
8	Europe become attractive for young researchers, irrespective of their country of origin,		
9	providing them with the resources needed to develop their full research potential and retain		
10	them in Europe? Will a pan-European approach for investing in high-quality frontier		
11	research be established?		
12	- What kinds of relationships will North American and European science and technology		
13	systems have with Asia? And with the less developed countries?		
14			
15	5.3.6 Attitudes towards science and technology: trends and uncertainties		
16	The NSF Science and Engineering Indicators 2006 reports that although Americans express		
17	strong support for science and technology, most people are not very well informed about these		
18	subjects. The public's lack of knowledge about basic scientific facts and the scientific process		
19	may discourage government support for research, the number of young people choosing S&T		
20	careers and the public's resistance to miracle cures, get-rich schemes and other scams.		
21			
22	Americans have more positive attitudes about the benefits of S&T than Europeans and Russians.		
23	In recent surveys, 84% of Americans compared with 52% of Europeans (EU-25) and 59% of		
24	Russians, agreed that the benefits of scientific research outweighed any harmful results. Most		
25	Americans and Europeans know little about genetically modified (GM) foods and related issues.		
26	Although attitudes were divided, opposition to introducing GM food into the US food supply		
27	declined between 2001 and 2004. This was not the case in Europe. However, the majority of		
28	Americans believe that GM food should be labeled (NSF, 2006).		
29			
30	Relations between researchers and society have become stronger during the past few years. The		
31	development of a number of controversies in the public sphere has undermined the illusion,		
32	harbored by many, that science is able to eliminate all uncertainties.		

33

34 Researchers can no longer be treated as a population subject to homogeneous organization,

35 structured according to disciplinary divisions, with ties to the social world mediated by

36 administrative and political authorities. On the contrary, they are now a multitude of groups that

- 1 interact in varied ways, re-arranging or even partially erasing boundaries between disciplines and
- 2 different forms of knowledge, science being only one of these forms (Akrich and Miller, 2007).
- 3 Future uncertainties:

How will the "precautionary principle" affect scientific advances?
How will religious fundamentalist groups affect the development of research and technology?
How will social values influence interventions on nature?

- 7 What role will civil society organizations play in the determination of research agendas?
- 8 Will there be greater investments in anticipatory processes (e.g., foresight activities, citizen's
 9 summit, etc.)?
- 10

11 5.3.7 Education in science: trends and uncertainties

Trends: 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 science and technology has risen too, but the proportion of university students in S&T has steadily decreased during the same period. Some disciplines, such as mathematics and physical sciences, show particularly worrying trends. Nevertheless, higher education with professional objectives (engineers, technicians, etc.) remains attractive.

18

19 Image and motivation surveys show that young people continue to have a largely positive 20 perception of science and technology. S&T are considered important for society and its evolution 21 despite concerns in specific areas often linked to their negative environmental and societal 22 consequences. Scientists are among the professionals the public trusts most, even though their 23 prestige has declined (senior management or government positions are rarely held by scientists 24 or engineers, and media reports on S&T events do not focus on the researchers themselves, who 25 are thus very rarely known by name). Yet parents encourage careers in S&T for their children. 26 There is a sharp difference between the positive opinion of young people towards S&T and their 27 actual wish to pursue S&T careers. S&T professions continue to generate great interest among 28 youth in developing countries, but not in industrialized countries, where especially girls find it 29 unattractive. Many young people have a negative perception of these careers and lifestyles. 30 Incomes are expected to be low relative to the amount of work involved and the difficulty of the 31 required studies.

32

Students often lack knowledge about what S&T professionals really do and many are unaware of
the range of career opportunities stemming from S&T studies. 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

1 dull jobs. As S&T professions evolve quickly, S&T teachers and career advisors often lack up-to-

- 2 date information to convey to their students. Young people therefore have few opportunities to
- 3 learn about the lives of S&T professionals. The careers of S&T professionals as a whole have
- 4 suffered from media reports of poor prospects and funding and increased job insecurity, despite
- 5 the fact that this applies primarily to researchers. Furthermore, the possibility of reaching a proper
- 6 balance between a successful career and a fulfilling family life, which is important to young
- 7 people, is perceived as difficult in S&T professions.
- 8

9 Many initiatives have been launched at different levels to promote S&T careers and studies.

10 Government actions have often been designed to improve the image of science and scientists in

11 society (science weeks, science days, etc.) and more has been done by the professional

12 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
- 14 choices of studies or careers is poorly evaluated, however. Furthermore, communication between
- 15 the various stakeholders is often inadequate.
- 16

17 Uncertainties of the future: The interest for science and the number of students in science and 18 technology in most of NAE is declining. The population of European researchers is aging, and 19 students tend to turn away from science and technology, especially when it is research oriented. 20 Measures relate to school education programs and public information to change the public's 21 attitudes about the benefits of S&T. In North America, the number of students in "sustainability 22 programs" is increasing, but fewer have agricultural backgrounds. What will be done in primary 23 and secondary schools and in universities to interest students in scientific research? What will be 24 done in terms of remuneration to attract and keep researchers? How will universities deal with 25 their missions to educate a diverse student body and to carry out research with local industrial 26 communities? Will universities turn to problem solving? Will education become concentrated in a 27 global knowledge oligopoly comprising a small number of giant US, European and Asian firms? 28 Will North America and Europe continue to play an important role in training scientists from 29 developing countries?

30

31 5.4 Key Direct Drivers for Agriculture, Uncertainties and Consequences for AKST

32 AKST will be greatly influenced by changes in agriculture, and can also influence changes in

agriculture. At present and for at least the next twenty years, North American and European

- 34 policies, trade and markets will greatly influence the world agriculture. In this chapter, policies,
- trade and markets have been considered a key driver of agriculture. Land use change and natural
- 36 resources have been dealt with together.
- 37

1 5.4.1 Food consumption and distribution: trends and uncertainties

2 Human as well as plant and animal health considerations are becoming more important. 3 Populations in North America and Western Europe, especially the poor, face alarming increases 4 in illnesses associated with inadequate diets and over-processed food. Central and Eastern 5 Europe are likely to face the same problems. Increased plant and animal diseases, as well as 6 weed and insect problems, both evolving and invasive, are threatening production in certain 7 areas, and lead to overuse of agricultural chemical and antibiotics, whose lingering residual 8 effects in the environment are threatening human health. This could lead to changes in food 9 production and processing. The growing organic food market could counter this trend. The 10 problem could be addressed through well-target information and appropriate regulations, as well 11 as changes in the behavior of individuals and companies.

12

13 5.4.1.1 On-going trends

14 Consumers' food preferences cannot be understood or predicted by simple models: food 15 preferences arise from a combination of different factors and drivers; e.g., income, household 16 size, age, ethics such as on animal welfare, influence of policies or media (EC, 2007). Changes in 17 food consumption can be assessed over the years using indicators such as food budget, calorie 18 intake, categories of foodstuffs, home or out-of-home consumption, home-made or precooked 19 meals, guality of food products. Changes in dietary patterns influence food systems, agricultural 20 products and services, (both food and non-food products) and other ecosystem services. While 21 changes in food demand directly affect the types and quantity of food being produced, and thus 22 affect the AKST used in producing this food, changes in AKST driving food supply can also 23 influence food consumption patterns indirectly.

24

25 Growing incomes, reduction in household size, increasing number of women in the workforce,

changes in the lifestyle with more time constraints, food scares, growing concerns for health and
 well-being and ethics have influenced food consumption in recent years (EC, 2007)

28

29 For the future, the most important trends that can be influenced by AKST seem to be: dietary

30 patterns, increased illnesses associated with inadequate diets and over-processed food,

31 consumer attitudes with increased consumption of processed and convenience food, and the

32 effects of mass distribution on food consumption.

33

34 The nutritional transformation reached many industrialized countries in the 19th century, and

35 advanced to many developing countries in the last 50 years or so. In the United States, the

36 fraction of expenditure on food was 25% in 1930, less than 14% in 1970, and around 10% in

37 1995. In the European Union (EU-27), the fraction of expenditure on food decreased from 14.5%

1 in 1995 to 12.8% in 2006 (Eurostat). North America and Europe are in a situation of "food satiety", 2 with an overabundance of food products on the market but a growing health divide between rich 3 and poor. In countries of NAE, 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 4 5 problems (e.g., heart disease). All meats do not require the same quantity of vegetal calories for 6 production; eleven vegetal calories produce one calorie of beef or mutton; eight calories produce 7 one calorie of milk; four calories are needed for one calorie of pork, poultry or egg (Collomb, 1999 8 cited by Griffon, 2006). At present, the fish/seafood food group is relatively unimportant as a 9 source of daily protein in Europe (7.2 g/day/person) although its contribution almost matches the 10 average share of beef and veal (7.6 g/day/person). However, the fish/seafood group registers 11 large variations between countries (de Boer et al., 2005). Many foods have excessive fat and 12 sugar, and too much red meat is consumed, partially as a consequence of subsidies given to 13 some agricultural products (Fields, 2004; Birt, 2007).

14

15 Growing concerns for health and well-being are influencing consumers' food choices. Consumers 16 are increasingly looking for health foods and "natural" products, which are often associated with 17 organic production. They are looking for food that provides benefits other than just basic needs 18 (functional food), Consumer concern for obesity has created a market for fat-reduced or sugar-19 reduced products. Consumers are increasingly buying fresh food all year round from all over the 20 world (EEA, 2005), and are switching to chill-cooked meals made from fresh ingredients. These 21 trends are strongly influenced by the double-income households, the decreasing household size 22 and the aging population.

23

24 Food demand is also influenced by the cultural settings. Shapes, textures, flavors and colors of 25 foods help define different cultures. Consumption patterns (e.g., cooking styles, meal organization 26 and eating utensils) are a powerful medium for the construction of cultural identity, but 27 globalization is flattening differences. Moreover, food is different from other consumer products in 28 that it passes through the body. Man is transformed by it to a greater extent than by any other 29 product, and it affects his well-being more directly. Overall food contributes to both sensory and 30 social pleasure and also has considerable effect on Man's sense of individual and collective 31 identity (Fischler, 1990; Raoult-Wack and Bricas, 2001).

32

The populations of both North America and Europe exhibit alarming increases in diet-related illnesses (e.g., obesity, diabetes and arteriosclerosis). For example, the UK has included studies on "tackling obesities: future choices" in its foresight program. A number of recent crises (e.g., mad cow disease, listeria and foot and mouth disease) have exacerbated consumer concerns about food safety.

43

1 2 Distribution affects food demand. In the agroindustrial age (Malassis, 1997), the food sector 3 consists of Small or Medium-sized Enterprises (SMEs) and large groups. Mass distribution 4 (hypermarket-type food outlets) plays a growing role and influences both food production and 5 food consumption. Supermarkets are playing a major role in determining food consumption 6 patterns and have shaped North American and EU tastes. In Central and Eastern Europe, 7 massive inflows of foreign direct investment and domestic investments are changing the 8 consumption patterns. 9 10 The following trends have recently been observed with respect to food distribution (Anania, 2006; 11 Fulponi, 2006; Henson and Reardon, 2006): 12 an increasing share of food sold to consumers in large stores everywhere in the world, 13 i.e., in cities in the industrial countries and in rural areas in the developing countries 14 (Dries, Reardon, Swimmen, 2004); 15 a rapid increase in the (already extremely high) rate of concentration of the food retail 16 sector: 17 the setting, by the retail sector, of more private food safety and quality standards implying _ 18 more stringent minimum standard requirements than those defined by existing public regulations (such as EurepGap, enforced today for fresh products); 19 20 the "decentralization", by the retail sector to its suppliers of food products, of an _ 21 increasing number of functions (such as packaging, pricing and logistic tasks needed to 22 guarantee just-in-time deliveries); 23 the imposition of increasingly more restrictive requirements as a necessary condition for 24 suppliers to be considered as potential sources, such as the capacity to deliver a "basket" 25 of goods (rather than a single one) or to provide large volumes and do so over extended 26 periods of time throughout the year, all aimed at reducing the number of suppliers and, 27 hence, transaction costs; 28 an increase in the imbalance in the distribution of market power along the food chain, 29 with the highly concentrated retail sector holding significant and increasing market power 30 vis a vis its suppliers. 31 32 These trends could be undermined if consumers in North America and Europe adopted a 33 "sustainable development" perspective, for example by reducing their demand for non-seasonal 34 and non-local crops, meat and fish and adjusting food portions to human needs. A number of 35 NGOs and local organizations are pushing in this direction, and some supermarkets in the EU are 36 also active in that direction. National and international regulations could also have an effect on

37 food demand. Food processing companies are increasingly encouraged to reduce the portion of

1 sugar and starch in their products. There is an increasing demand from consumers for labeling,

- 2 traceability and other information. Media publish messages on diets. The Codex Alimentarius
- 3 develops quality food standards, consumer health guidelines, fair trade practices and
- 4 internationally harmonious food standards. Furthermore, society has become increasingly aware
- 5 of environmental impacts and animal welfare associated with agriculture. This appears to be
- 6 causing some changes in buying and consumption habits that may decisively influence
- 7 consumers' willingness to pay a premium on a product they may perceive as safer, produced in
- 8 ethical conditions, or more beneficial.
- 9 5.4.1.2 Uncertainties of the future
- 10 Many uncertainties could greatly affect the food marketplace of the future. This section provides a
- 11 list for further discussion:
- 12 Food demand at global and NAE levels.
- 13 Will food continue to be an instrument of cultural identity in many countries? Will food
- 14 become completely standardized?
- 15 Will NAE have to contribute to the changes in meat and cereal consumption that will take
- 16 place in the other regions of the world?
- 17 How will the consumption of off-season crops evolve? How will the consumption of meat and
- 18 fish evolve? If there are increases in meat and fish consumption, will the increased demand
- 19 be met through increased local production or imports? Can increased demand be met though
- 20 "meat/fish" produced without animals?
- 21 What will be the changes in the consumption of processed (convenience) food? What will be
- 22 the consumer attitudes towards preparing food at home?
- 23 In the past fifty years, there has been a decrease in the real prices of food. Will consumers be
- 24 ready to pay a premium for "quality" products or will they continue to see the share of food
- 25 decrease in the share of household expenditures?
- 26 In Eastern Europe, how fast will food diversification take place?
- 27

28 - <u>Health</u>.

- At the global, NAE and European level, will there be coordination and harmonization of
- 30 international food standards? How strict will consumer protection be? Will human health be
- 31 adequately protected?
- 32 In NAE, will governmental measures be sufficient to make consumers aware of links between
- food and health? Will consumers demand foods tailored to specific health needs? Will
- 34 consumers recognize and demand functional foods? What food safety measures will
- 35 consumers demand? Will improved analytical methods increase the demand for organic
- 36 foods or foods free of chemical residues? Will consumers pay a premium for these food
- 37 services? Will increasingly aseptic foods reduce human immunity? Does increased hygiene

1 increase the risk of resistant pathogens? How to strike a balance between necessary hygiene 2 and excessive hygiene? 3 Food manufacturing, processing and distribution. 4 5 In NAE, will horizontal and vertical integration of the whole food industry continue? Will the 6 development of niche markets influence the on-going trend of integration? Will farmers be 7 able to choose their production or will they become even more dependent on the food 8 distribution and manufacturing industries? Will home delivery replace conventional food 9 shopping? Will local distribution points be created for food ordered through the internet? Can 10 the relationship between farmers and consumers be strengthened? 11 5.4.1.3 Consequences for AKST 12 To achieve nutritional security strategic choices have to be made in the economic and social 13 domains (lifestyles) and in the domains of international and national food regulations and modes 14 of distribution. As far as food consumption is concerned, as in other topics, AKST choices will not 15 only be technical but will also be influenced by actors and their ideologies. The following 16 illustrates the choices that will have to be made: 17 To produce safe high quality food, animal and plant genetic resources will need to be 18 evaluated and preserved. Factors determining the shelf life of both fresh produce and 19 processed food, or the stability of plant raw materials after harvest will also be important 20 (ETP, 2005b). 21 If functional food is developed, then there will be a need for analysis, measure and 22 control, biotechnologies, biochemistry, biology, medicine. 23 To create food targeted at specific consumer groups or needs, the identification and 24 characterization of the molecular structure of plant polymers, as well as the 25 characterization of plant metabolites will be very useful, together with molecular breeding 26 and transgenic approaches. This will need an interdisciplinary approach that brings 27 together plant scientists, physicians and nutritionists (ETP, 2005b). 28 If the emphasis is on food quantity rather than food quality, genomics will be very important. 29 30 If the emphasis is on food quality, functional genomics and systems biology will need to 31 be developed. 32 The rapid development of allergies will require the development of special research.) 33 If transformation is a priority, microbiology will be useful to look at the nutritive qualities of -34 food. 35 If a market-led, globalized world develops, food traceability, prevention of bioterrorism 36 and agroterrorism and identification of sabotage will be very important. There will be a 37 need for nanoscale systems, microsystems technologies, sensors, etc.

To produce more meat, a major effort will have to be made to produce high quality,
 sufficient and sustainable feed using biochemical tools and biological assays, molecular
 mechanisms to decipher the plant-pathogen interaction, the assessment of macro- and
 micronutrient characteristics, germplasm, etc. (ETP, 2005b)

- 5 To produce bioplastics and biomaterials and use renewables, biotechnologies should be 6 very useful.
- 7

8 5.4.2 Policies, trade and markets

9 Agricultural trade policies and subsidies in NAE tend to undermine the fulfillment of development
10 goals in other parts of the world. There is uncertainty about whether the World Trade

11 Organization will be effective in harmonizing approaches to internal subsidies, and additional

12 uncertainty about whom is likely to benefit, how much and for how long if NAE subsidies are

13 removed. Applying AKST could potentially help to balance the needs of vulnerable people in

- 14 other regions of the world.
- 15 5.4.2.1 Ongoing trends
- 16 <u>Agricultural policies</u>.
- 17 The following agricultural policy/trade developments will be paramount in determining the
- 18 international competitiveness of NAE agriculture/food industries and the sustainability of rural
- 19 areas:

20

- reform of the EU Common Agricultural Policy;
- 21 NAFTA, CAFTA and other similar trade policies;
- 22 negotiations under the World Trade Organization (WTO);
- Convention on Biological Diversity (CBD) and International Treaty on Plant Genetic
 Resources for Food and Agriculture (ITPGRFA)
- projected population growth, combined with the greater prosperity of some social
 groupings;
- relationships between economic growth and environmental degradation, and the
 compliance with international, regional and national environmental directives (Kyoto
 Protocol; EU policies, etc.).
- 30
- 31 There are three levels of policy framework: international (i.e. WTO, Kyoto agreement, CBD),
- 32 regional (i.e. EU-CAP, NAFTA), and national / governmental. At all levels, a broad range of
- 33 agricultural policies relate to different types of institutional support that farmers may be eligible for
- 34 by complying with specific agreements. Aid, subsidies, tax reductions, special tariffs etc. could be
- 35 given to compensate farmers for loss of income opportunities or price gaps they suffer if they
- 36 produce certain types of crops, tend to the landscape, rest certain areas and/or use new
- 37 agricultural techniques or practices that authorities deem socially or environmentally preferable.

Agricultural policies also relate to natural resources conservation, rural development, agricultural
 credit, nutrition and international trade.

3

For Europe, in the next 20 years, there could be a number of trade policy developments, such as
the reduction of border barriers to trade, both within the European Union and elsewhere, the
enlargement of the European Union, the liberalization of trade in agricultural and food products
within the Euro-Mediterranean Association Agreement framework, the liberalization of trade for
agricultural and food products resulting from the EPAs (Economic Partnership Agreements)
between the EU and the ACP (African, Caribbean and Pacific) countries, etc.

10

11 In the EU, the general scheme of the Common Agricultural Policy aid includes market supporting 12 policies and structural policy aid. Examples of market policies include area-based subsidies, 13 production/processing subsidies, consumption subsidies, and agri-environmental aid. Some 14 market policies are directly related to specific alternative agrosystems or their practices. 15 Structural policy aid focuses on elements like modernizing/improving farms and facilitating young 16 people's access to farming. The Common Agricultural Policy (CAP) reform proposed by the 17 Commission in 2002 introduced a major change in the income support regime: the decoupling of 18 direct payments from production with potentially marked effects on land use. Other important 19 reform measures have been the introduction of obligatory, modulated payments to generate 20 funds for agri-environmental and rural development programs, and reduced price support for 21 dairy (partly compensated by direct payments). The intention behind these reforms has been to 22 increase the market orientation of EU agriculture (through decoupling). Concern for less favored 23 agricultural regions, has led to a complex "policy cocktail" (Britz et al., 2006). Several studies 24 conclude that the effect of decoupling will most likely be a decline in cereal and silage maize 25 acreage and in ruminant production in EU-15. A further change can be expected in the economic 26 resources devoted by the EU to rural development, food safety and environmental protection. 27

28 Although the IAASTD report does not include Mexico in the NAE assessment, Mexico's trade 29 policies are closely tied to policies in the United States and Canada. All three countries have 30 institutionalized income supports that provide additional assistance to producers when commodity 31 prices (or net farm revenues, in the case of Canada) decline. Additionally, Canada has crafted 32 new approaches to food safety/quality, protection of the environment, the role of science in 33 agriculture, and the overall reinvigoration of the agricultural sector. The United States is 34 proceeding with a comprehensive buyout of tobacco quotas while expanding its efforts in 35 conservation, placing greater emphasis on the continued use of land for production rather than 36 land retirement. However, in all three countries, ample fiscal resources allow agricultural policy to 37 proceed in a direction that is not altogether different from its previous course. However, fiscal

1 constraints could affect the size and content of future agricultural policies in each country

2 (Zahniser et al., 2005).

3

4 Interactions between ministries or states often define the policy framework at the national level. At

- 5 one extreme, regulation is fragmented with little interaction between different ministries. One
- 6 agency is responsible for health and food safety; another deals primarily with the environment.
- 7 Other agencies focus on agriculture and transportation/distribution. Interagency issues are often
- 8 given low priority; consequently, each ministry has limited knowledge of the systemic needs of a
- 9 regionally based agri-commodity value-chain. At the other extreme, different agencies
- 10 synchronize public programs. Regional authorities bring independent policy interventions together
- 11 in one region so as to have the greatest impact on the regional economy; nature is planned.
- 12

13 Agricultural trade and markets.

Globalization means changes in the world economy that tend to create a world market for work, capital, goods and services. It is not a new phenomenon but has increased over the last thirty years, largely because of lower transportation and communications costs. Globalization has changed production areas, markets, trade and travel with concomitant effects on food consumption. In many countries, global imports mean that seasonal agricultural products can be eaten all year round.

20

Globalization has also increased competition. Some crops, such as cotton, are produced in both
industrial and developing countries, but American cotton producers receive much higher
subsidies than cotton producers elsewhere in the world. Competition is strong, and countries try
to develop policies that favor their growers.

25

26 The share of agricultural products (including processed products) in world merchandise exports 27 has decreased steadily over the last six decades, from over 40% in the early 1950s to 10% in the 28 late 1990s, as both volume and price trends have been less favorable than for other merchandise 29 products. Among manufactured goods, it is estimated that the largest value increases were for 30 iron and steel products and for chemicals (WTO, 2006). There are three explanations for this 31 trend: the increase of manufactured products in trade coming from developing countries, the 32 decrease of agricultural prices and the late opening of the agricultural sector to world markets 33 (IFRI, 2002).

34

Nevertheless in 2005 agricultural products represented an important share of exports of primary
 products for North America and Europe, less for CIS (Table 5.8). It represented an important

share of imports of primary products for Europe and CIS. Significant market changes would have
 important implications for agriculture and AKST in these regions.

3

4 [Insert Table 5.8]

5

6 Exports of agricultural products and agroindustrial products are extremely concentrated in North 7 America and Europe (IFRI, 2002). Over the last few years, new actors have entered the game 8 and changed the rules. For example, in the wheat market, there is increasing competition 9 between traditional world leaders (USA, Canada, EU, Australia) and the Black Sea region 10 countries (Ukraine and Kazakhstan). Volumes of world wheat imports are expected to increase 11 further due to ever-growing demand for wheat in Third World countries (Egypt and Nigeria), Brazil 12 and Mexico (Garnier, 2004; FAO, 2006). 13 5.4.2.2 Uncertainties of the future A number of uncertainties and questions for the future can be raised relating to trade and policies: 14 15 16 What will be the impact of the increase of commodity prices on the rural poor and 17 developing countries' farmers, and how will it affect their capacity to take advantage 18 of AKST? 19 If there is further liberalization of agriculture, how can the effects of subsidies in NAE 20 be offset for the small producers of the rest of the world? 21 What role will some NAE countries play to improve the governance of trade and 22 markets, to make negotiations more transparent and participatory, to strengthen the 23 negotiating capacity of developing countries, to promote regional integration and 24 negotiation from shared platforms? 25 What will be the consequence of the new use of agricultural products on agricultural 26 trade? 27 How much will the countries of the Black Sea region change NAE's agricultural 28 market? 29 How will the EU develop? Will it continue to expand with new member states (EU-30, 30 EU-40) or will it divide? What will be the consequences of changed development 31 policies and stronger collaboration with the Southern Mediterranean countries and 32 Russia on policies, trade and agricultural systems of NAE? What political and 33 economic coalitions will develop outside NAE, and how will that affect agricultural 34 markets and trade? 35 How will increased international coordination in areas such as trade, commercial and 36 consumer protection law, and defense and security develop and affect policies and 37 trade?

1	-	What effects will demographic trends have on future policies? Will current trends of			
2		stagnating and declining populations in large parts of NAE continue? Can out-			
3		migration from more remote rural areas to urban centers be halted? Will there be			
4		sufficient incentives to attract investments in rural areas? In which sub-regions within			
5		NAE will agriculture vanish?			
6	-	Will migration of skilled labor within NAE be permitted? Where will the main			
7		migrations take place, and will they help to increase the economic viability of rural			
8		areas? To what extent will urban commuters and new well-to-do residents be able to			
9		contribute to sustainable rural development?			
10	-	Will agriculture and rural areas in NAE develop sufficient adaptive capacity to			
11		overcome threats and risks imposed by future environmental change (including			
12		climate change)? Will more stringent environmental regulations be agreed upon,			
13		together with stronger internalization of externalities? How will that affect agricultural			
14		production and production orientation in NAE? How will the impacts of climate			
15		change in other world regions affect changes in NAE policies and trade?			
16	-	How will a WTO extension of the scope for the exchange of goods, services, labor			
17		and capital between countries affect agricultural systems? What will happen if almost			
18		all trade barriers for agricultural products and subventions are eliminated? To what			
19		extent will that increase environmental risks?			
20	-	To what extent will producer subsidies further decline - and how fast? And, how will			
21		the money saved in that manner be spent? Will it be invested to alleviate poverty and			
22		(thereby) reduce environmental degradation, or for other challenges?			
23	-	How will the demand for the major agricultural products of the region evolve?			
24	-	How will the share of agricultural products (food and raw materials) in the NAE region			
25		develop – will it drop further? How will intra- and inter-regional trade evolve?			
26	5.4.2.3 Cor	nsequences for AKST			
27	There are the	nus a large number of possible future pathways for agricultural policy and trade at			
28	national and supranational level within NAE and outside, which in turn will generate different				
29	types of far	ming and agricultural systems.			
30					
31	If the future	is more ecosystem oriented, with externalities increasingly internalized, e.g., by			
32	progressively decoupling subsidies from production, more stringent environmental regulations,				
33	the introduction of special taxes and different product pricing methods,, then AKST should be				
34	organized to better support the development of more environmentally-friendly and resource-use				
35	efficient technologies and production systems, including all kinds of "green technologies" and				
36	supportive p	policies that contribute to the adoption of such technologies to reduce resource use			
37	and farm emissions. Such direction would certainly lead to more integration of agricultural and				

1 environmental sciences and more cooperation with the various interest groups involved in natural

- 2 resources management at different levels. AKST in this setting would still be strongly oriented
- 3 towards feasible technical solutions and require longer term planning and investments.
- 4

5 If we live, however, in a market-led future, the influence of consumers and their preferences on 6 demand for research would become stronger: issues like food safety (labeling, traceability, etc.) 7 would be in the center and require more comprehensive attention by AKST than currently. Such 8 AKST would be organized differently, and multinational companies might have the lead. In a 9 future that would favor regionalization and local approaches, social equity, reduction of income 10 disparities between urban and rural areas, and more power and political influence to local people, 11 the requirements for AKST would again be very different (Kahiluoto et al., 2006). Such a future 12 would also very likely imply changes in attitudes towards consumption and diets, e.g., less meat. 13 Though objectives, organization and funding of AKST have already drastically changed over the 14 last 10 to 20 years (Van Keulen, 2007), further policy adjustments would be required to support 15 the development of mechanisms for increased involvement of stakeholders, and a more demand-16 driven AKST that is increasingly built on interactive knowledge networks (OECD, 1999), and 17 serves the multiple development goals of rural areas, e.g., through supporting the development of 18 multi-functional agricultural systems. Some recent trends, like special payments for rural 19 development would need to be intensified. The AKST required in such a future, would also need 20 to support the realization of full participation of stakeholders in decisions concerning the design 21 and implementation of agricultural and environmental policies.

22

This 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., 2004; Van Ittersum et al., 2004). AKST would seek solutions through behavioral changes. It 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.

30

31 5.4.3 Farming systems and farm structures

Farmers are increasingly operating in larger enterprises and within cooperative arrangements as well through contracts with large businesses. This could lead to greater complexity and monopolies which could reduce resilience and choices. There is uncertainty about how long this trend will last. It could be altered, for example, by changes in organizational practices and consumer demand and socioeconomic research.

37

1 Population figures in rural areas are declining and agro-urban areas are growing. Multiple

2 expectations on farming systems are leading to the development of new enterprises such as

3 agrotourism and are placing emphasis on farming systems that can deliver new services, such as

4 watershed and landscape protection. High demands on agriculture for providing energy could

5 change this trend.

6 5.4.3.1 On going trends

7 The term agricultural system (or agrosystem) is a concept that has been in continuous evolution

8 over the last few decades. The great number of elements involved in its definition and their

9 interrelations are partially responsible for this evolution. An extended definition is "the system of

10 production used by a farmer as specified by the technology used, resources available,

11 preferences held and goals pursued within a given agroecological and socioeconomic

12 environment" (Dillon and Hardaker, 1993).

13

14 In the arena of discussion about the agricultural systems in Europe, references to the dichotomy 15 between traditional or mainstream systems, on the one side, and emerging or alternative 16 systems, on the other side, are frequent. However, there is no clear consensus about the scope 17 of these concepts. As a first approach (Grudens-Shuck et al., 1998), alternative agricultural 18 systems could be systems that include non-traditional crops, livestock and other farm products; 19 services, recreation, tourism, food processing, forestry and other enterprises based on farm and 20 natural resources; unconventional production systems such as organic farming; or direct 21 marketing and other entrepreneurial marketing strategies. A European prospective analysis of 22 agricultural systems (Libeau-Dulos and Cerzo, 2004) shows that the principal alternative 23 agrosystems coexisting with mainstream agriculture are organic farming, integrated production, 24 conservation agriculture and agriculture under guaranteed quality. Other, less widely used 25 agrosystems in the EU, include precision agriculture, short-chain agriculture, urban agriculture, 26 agriculture paysanne and permaculture. 27

Farms are becoming specialized, increasing in size and declining in number. In Eastern Europe,

29 farms were first industrialized after WWII, although private small-scale farming continued to exist.

30 Food chain organizations developed towards global, linear and centralized structures with

31 regional specialization (McFetridge, 1994; Royer, 1998; Cook and Chaddad, 2000; Reardon and

32 Barrett, 2000; Hendrickson et al., 2001; Harwood, 2001).

33

34 5.4.3.2 Uncertainties of the future

35 Examples of questions about the future are:

- What is the economic viability of family farm systems? Will the trend toward larger, capital
 intensive farms continue? Will the marketplace support farms that produce specialty
 products for niche markets?
- 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?
- 10 5.4.3.3 Consequences for AKST

11 The adoption of a new agricultural production system involves changes in the way holdings are managed; this makes the presence of a science and technology transfer system capable of 12 13 meeting the new requirements of farmers especially important. The availability of such a system 14 therefore strongly influences the choice of production systems that involve substantial changes, 15 as is the case with organic farming, (which recovers traditional practices) and conservation 16 agriculture (which experiments with new practices). The influence of this factor on the adoption of 17 agriculture of certified quality is dictated by marketing and distribution criteria; in fact, this 18 agrosystem facilitates acquisition of better knowledge, and ergo fulfillment of consumers 19 demands.

20

21 Farmers' willingness to make the transition from mainstream agricultural practices is not enough if 22 they do not have access to the technology required. Hence, this factor strongly affects the 23 selection of agrosystems whose practices require the use of new technologies (e.g., integrated 24 farming and conservation agriculture). The choice of organic farming involves the use of natural 25 resources, thus requires good knowledge about soils, biological pest and disease control, organic 26 fertilizers. If conservation agriculture develops not only in large farms, for specific production 27 types (cereals, wood crops), but also in smaller farms, substantial investments in special 28 machinery will be necessary. Production and distribution of AKST must be carefully examined if 29 alternative agricultural systems are to be developed.

30

31 5.4.4 Agricultural labor and organizations

Migrant labor represents a high proportion of the workers in the agri-food sector, especially in parts of the United-States and the southern countries of Europe. An increasing number of these laborers have come illegally. Enforcement of immigration law would force undocumented workers to leave the countries. The loss of labor force cannot be offset by mechanization and technological advancements alone. Changes in migrant labor could lead to higher wages, and thus higher prices, going out of business or moving production overseas.

- 1
- 2 5.4.4.1 Labor and gender dynamics: on-going trends

In 2003, in the European Union, agriculture provided jobs for 13.3 million people, representing
6.6% of total employment. The national distribution of employment in agriculture was extremely
uneven. There were 5.8 million people employed in agriculture in the 13 'old' Member States,
where employment in agriculture made up only 3.6% of total employment. In the Eastern
European countries of the EU, there was an average of 12.4% of total employment in agriculture
(EIROnline, 2005).

9

The composition of labor in agriculture has changed over time, particularly with the sector being affected by different stages of economic development (Hayami and Ruttan, 1985). Four major trends affect the labor situation: important use of migrant labor in agriculture, growing unemployment in rural areas, aging farmers and enlargement of skills needed to be a farmer.

14 There are no major territorial discrepancies in these trends (Brouwer, 2006).

15

16 In North America and Europe, an important proportion of workers in the three agri-food sectors 17 (farming, fishing and forestry; meat and fish processing; food service) are migrants. They are 18 especially important for crop agriculture. In the United States, a significant majority of 19 farmworkers lack proper work authorization and immigration status (Raggelbrugge, 2007; Kandel 20 and Mishra, 2007; Martin, 2007). Two major proposals for immigration reform could lead to 21 reduction in the farm labor supply. Enforcement would force undocumented workers to leave the 22 countries. Legalization would give workers greater flexibility to seek other jobs and wages would 23 probably rise. Possible responses to wage increases by firms would be to increase prices, to 24 produce other crops/products, to adopt labor-saving technology, or to go out of business or move 25 production overseas. In crop agriculture, fruit, vegetable and horticultural producers have high 26 farm costs and would be most affected by immigration reforms. In the United States, Hispanics 27 were the principal operators of 51% of the farms and ranches in the 1997-2002 period (Dohm, 28 2005). This trend might become even stronger in the future.

29

Unemployment in rural areas is exacerbated by a trend for farms to be abandoned or sold for
other purposes (EC, 2004, 2007). To realize an adequate income, farmers leave their farms or
combine farming with another job. Women have a higher tendency than men to leave rural areas.
Conversely, larger farm have difficulty finding enough qualified personnel. Better-educated and
skilled persons seek other opportunities because the hard and dirty work of agriculture is
unattractive. In the future, without sufficient labor, many farms will be forced out of business.

1 More than half of all farm holdings in EU-15 are owned by farmers above 55 years of age, and 2 one out of three farms, by farmers above the age of 65. Less than one out of twelve farm holdings 3 in EU-15 is owned by farmers under the age of 35 years. The economic transformation in 4 countries of Central/Eastern Europe and Asia caused significant changes in agricultural labor 5 use. Estonia, the Czech Republic and Slovakia all have an ageing agricultural population. For the 6 other countries, the relative importance of the oldest age group fell in the period up to 2000 7 (IAMO, 2003). The average agricultural labor force migration rate varies between approx. 8% in 8 Estonia and 10% in Georgia (Herzfeld and Glauben, 2006).

9

10 Success in agriculture has been based on production skills for at least 10,000 years. Producers 11 learned about crops and animals and understood seasonal cycles and the need to adapt to 12 climate and pest unpredictability. Knowledge was transferred from parent to child and from 13 neighbor to neighbor. Today's farmers need a larger range of skills. They need relationship skills 14 to effectively cooperate with input and information suppliers. Farmers need knowledge and 15 market skills, particularly to reach emerging markets. They frequently enter collaborative 16 agreements with fellow producers in new models of cooperation. In addition to production skills, 17 today's growers need mechanical/technical skills and financial management skills (Butler-Flora, 18 1998). But there are still many poorly educated farmers in North America and Europe. Most of the 19 people living in rural Poland (aged 13 years and more) have no more than a secondary education 20 (Central Statistical Office of Poland, 2007). On the other hand, in Estonia and Hungary, almost 21 10% of those active in agriculture have a university qualification or the equivalent (IAMO, 2003).

22 5.4.4.2 Organizations: on-going trends

<u>Farmer associations</u>. Today in North America and Europe, most farms and ranches are still small
 (Dohm, 2005), but they are getting larger and more concentrated. Many farmers sign contracts
 with large businesses to secure outlets for their products. Others sell their products themselves
 elsewhere, such as on commodity exchanges but they have greater exposure to the risks and
 vagaries of the open market.

There is great variation in the level of influence of farmers' organizations. In North America and most of Western Europe, some groups (e.g., cotton or wheat in the USA) are well organized

- 30 politically and have a platform to directly influence resources that support their commodity.
- 31

32 <u>Inputs enterprises</u>. These companies supply seed, fertilizers, pesticides and other components

33 needed to produce crops. Within the last fifteen years, agricultural inputs have become highly

34 concentrated within a small number of companies. Less than ten multinational companies control

- 35 the lion's share of the global pesticide and the global seed market. These companies also control
- 36 nearly all of the private sector agricultural research.
- 37

Draft—not for citation 23 March, 2008

1 Processing/marketing enterprises. These companies buy agricultural products and process them 2 for the marketplace or make them available to consumers without further processing. The largest 3 of these companies are multinational in scope and wield tremendous influence on agriculture and AKST. For example, Frito-Lay which controls about 40% of the snack food market worldwide and 4 5 is the largest snack food company in more than thirty countries. If the company needs a certain 6 type of agriculture product or refuses a certain type of commodity, agriculture and AKST will be 7 revised to accommodate them. Even though the genetically engineered NewLeaf potato was a 8 valuable tool for pest management, potato farmers in the United States guit growing them largely 9 because MacDonald's corporation told their suppliers not to use NewLeaf potatoes in their french-10 fries.

11

Media. The media has a powerful influence on consumer preferences; consumers reflect their desires in the marketplace and the polling booth. The tremendous growth of the organic market, for example, 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.

<u>Agricultural universities/colleges</u>. 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.

23 Although these actors have been presented individually, their influence is a much more 24 complicated interaction. For example, a processing company may use the media to promote 25 cotton as a clothing material. As consumer demand for cotton increases, cotton producers need 26 to increase productivity. The university recognizes a need for a cotton AKST position to help 27 cotton growers achieve production goals. The companies that provide inputs for cotton production 28 introduce new plant varieties and chemicals that the cotton researcher incorporates into a more 29 efficient production system. The cycle repeats as the media report that cotton production 30 degrades the environment; the processing company demands more environmentally-friendly 31 cotton: the university turns its attention to more sustainable production methods; the input 32 companies produce less dangerous chemicals and so on...

33

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 1 multinational food companies transcend national borders and give rise to greater

2 interdependence of economies and larger trade flows. To manage and harmonize product flows

3 along the food chain, they also are at the basis of vertically cocoordinated marketing systems.

4 The purpose of these systems is to ensure that product and process requirements for food

5 products are met at all stages of the supply chain, thereby reducing transaction costs. Thus,

6 evolving globalized systems of food production and retailing are becoming an element of

7 increasing importance with respect to the integration of developing countries into global food

8 markets (OECD/FAO, 2005).

9 5.4.4.3 Uncertainties of the future

There are generic and specific uncertainties related to labor and organizations. Here are some ofthem.

12 _ Farmers' age and gender. Will measures be taken to formalize women's status in the farm 13 enterprise? Will women manage an increasing number of farms? In the EU, will there be 14 enough young people interested in farming and capable of managing sustainable production 15 methods that meet environmental and societal goals while providing an adequate income? 16 Employment. How can unemployment / under-employment in rural areas be solved? Will 17 farmer education and the creation of non-farm jobs in rural areas be addressed 18 simultaneously? How will the pluriactivity of men and women in rural areas be taken into 19 account? How will pluriactivity influence benefits and resources available to farmers? How

will structural unemployment in agriculture be tackled, especially in the Eastern Europeancountries?

22 - Migration. How will NAE political leaders address the problems associated with illegal

23 migrants coming to rural areas for permanent or seasonal agricultural work?

<u>Education, skills</u>. Will there be training courses to help farmers become entrepreneurs who
 can compete in global agricultural markets while achieving the goals of sustainability and

26 multifunctionality? Will there be administrative and financial measures to facilitate young farmers'

27 training and installation?

28 5.4.4.4 Consequences for AKST

29 Decisions related to labor will have consequences on AKST. For example, if migration is

30 permitted and people from outside NAE move to rural areas for seasonal work, the need for

research on crop harvesting, etc. will not be great. On the other hand, strict migration policies will

32 lead to research on productivity improvement. Another example: the demand for mechanization,

33 computer assistance and automated responses will also not be the same if NAE is able to attract

34 young, well-trained, entrepreneurial farmers, or if the rural population continues to age, is not very

35 well trained, and labor is not available.

36

1 5.4.5 Natural resources availability and management

2 Increasing prices of energy, water, minerals and other natural resources could affect outputs, 3 costs and practices in all sectors of the food system. Decreasing availability of natural resources, 4 for example oil, water and phosphate, and increasing competition for the use of these resources 5 are leading to rising costs which could have very negative impacts on agricultural production, 6 processing, distribution, retail and purchasing. A substantial reduction of the use of these 7 resources in agricultural production through savings, improved management and new 8 technological developments that increase use efficiency, etc., could alleviate the consequences 9 of this trend. 10 11 5.4.5.1 Ongoing trends 12 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 theseresources in order to remain viable.

15

16 Natural resources, including raw materials, comprise minerals, biomass and biological resources 17 such as forest, soil, water, air, energy resources such as fossil fuels, wind, geothermal, tidal and 18 solar energy and land areas. Whether these resources are utilized as materials/inputs for 19 production, or as environmental buffers or sinks, most of them are essential for the functioning of 20 agroecosystems and socioecological systems at large. The way and speed in which renewable 21 and non-renewable natural resources are being used strongly determines the basis for 22 sustainable development (Millennium Ecosystem Assessment, 2006). The climate system is an 23 important issue since it is an important natural resource (see 5.4.6: Climate change and 24 variability); energy and bioenergy issues are also important (see 5.4.7).

25

26 The linkages between natural resource availability and agricultural management practices are

27 considerable. For example, the need for irrigation will not be the same if and where climate

28 becomes drier and water gets more polluted and the frequency of major floods increases, etc.

29

30 Agriculture utilizes natural processes to produce the goods (food and non-food) that we need to 31 support the demand of an ever growing population (Verhagen et al., 2007). While acknowledging 32 that population trends and projections for NAE show stagnation and decline, the region will most 33 likely continue to produce for and export to other regions of the world to help satisfy their needs 34 and requirements. Both, renewable resources like agricultural soils, and non-renewable 35 resources like the world's fossil fuels, have their limits. The most limiting resources to food 36 production and other goods provided by agroecosystems in NAE are land and water. Agricultural 37 systems are typically managed to maximize provisioning services to provide food, but they

1 require several other supporting and regulating services to support production. Agriculture both 2 depends on and generates ecosystem services. Agricultural ecosystem services have been 3 grouped into three categories: services that directly support agricultural production (such as 4 maintaining fertile soils, nutrient cycling, pollination), services that contribute directly to the quality 5 of human life (such as cultural and aesthetic values of the landscape) and services that contribute 6 towards global life-supporting functions (such as carbon sequestering, maintenance of 7 biogeochemical cycles, supply of fresh water, provision of wildlife habitats) (Björklund, 2004). 8 Growing populations and activities put increasing pressure on land, soil and water resources. 9 Current estimates suggest that 10-20% of the global terrestrial area has degraded soils, and that 10 that area is extending. Pressure on land and water will be further exacerbated by climatic change. 11 Lack of access to natural resources is a major reason for many local, regional and (trans-) 12 national conflicts. This applies, currently, to low-income countries, where food, forests, wildlife, 13 fisheries and energy sources, which are bound to land and water, form the basis for the livelihood 14 of a large share of the population. 15 16 Resource use in the NAE region has been and remains very high. At the same time, resource 17 used by growing economies such as China, India and Brazil increases at an accelerated pace. If 18 the world as a whole would follow the patterns of consumption experienced in NAE, global 19 resource use is estimated to double within the next 10-15 years. However, there is still an 20 enormous slack in resource use efficiency, namely water and nutrient use efficiency, leaving 21 much scope for improvement (Smil, 2000). Inefficient use of resources and overexploitation of 22 non-renewable resources are obstacles, whereas sustainable production and consumption are 23 key to sustainable development (within NAE and globally). 24 25 Agriculture generates waste and pollution, yet it also conserves and recycles natural resources, 26 and can significantly contribute to the enrichment of landscapes and creation of habitats for

- 27 wildlife.
- 28

29 Agriculture both causes and is affected by changes in natural resource availability and quality.

30 In the following paragraphs we describe major trends and uncertainties related to changes in and

31 threats to agriculture resulting from changes in natural resources and *vice versa*, agriculture's

- 32 impact on natural resource availability and quality.
- 33

34 Among the major threats affecting agriculture in the NAE region are climatic change, water

- 35 scarcity, soil erosion and biodiversity loss (see
- 36 <u>http://ec.europa.eu/environment/agriculture/index.htm</u>).
- 37

- 1 On the other hand, NAE agriculture affects natural resource availability and quality mainly through
- 2 its demands on land, soil, water and energy for producing biomass (food, feed, fiber and fuel), its
- 3 impacts on the environment from inappropriate management practices such as soil, water and air
- 4 pollution through excessive use of agrochemicals, soil degradation (erosion, organic matter
- 5 decline and compaction) and biodiversity loss (see
- 6 http://ec.europa.eu/environment/soil/pdf/soillight.pdf;). However, there is also a range of
- 7 environmental benefits created by agriculture such as maintenance of semi-natural habitats for
- 8 wildlife and of agricultural landscapes thanks to its important environmental services (see

9 <u>http://ec.europa.eu/agriculture/publi/fact/envir/2003_en.pdf</u>).

10

11 Effects on agriculture

12 Favorable climatic and soil conditions are the basis of fertile, diversified and rich agricultural 13 landscapes in the NAE region. The impacts of natural resources are often concentrated locally 14 and regionally, although some are of national and international significance. Land, water and 15 other natural resources are limited. Resource scarcity and competing claims for scarce natural 16 resources, among different agricultural land use types and with other land uses are increasing. 17 That competition is currently very alarming in the very densely populated agricultural lowlands of 18 Asia where fertile arable land is reduced by its conversion for other than agricultural uses (Van Ittersum et al., 2004). In the NAE region, under current climatic conditions, water is at times 19 20 scarce in parts of NAE such as in the Mediterranean region. That water scarcity will become more 21 severe with anticipated climate change. More extreme weather conditions will lead to more 22 frequent drought and heat stress, more intensive precipitation, frequent flooding, erosion and 23 poor trafficability of agricultural land. Despite many efforts in the NAE region to reduce 24 environmental degradation and improve the guality and availability of the natural resource base, 25 policies and new technologies have not been sufficient to reverse unsustainable trends (Van 26 Camp et al., 2004).

27

28 Agricultural impacts on natural resource availability and quality

Agriculture has a significant effect on the environment in the NAE region. In the European Union, for instance, about 50% of the lands are farmed. Many of the environmental effects of agricultural activities are confined to the sector itself, but off-farm effects are also important. 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, the first global assessment of soil degradation found that 38% of currently used agricultural land has been degraded. Such phenomena are signs of an 'overshoot'¹ or, an imbalance between

¹ To go too far, to grow so large so quickly that limits are exceeded (after Meadows et al., 2004)

1 availability, quality and claims on the earth's natural resources, beyond what can be sustained 2 over time. A core question of the various "limits to growth" scenarios was: How may the 3 expanding global population and economy interact with and adapt to the earth's limited carrying 4 capacity over the next 100 years? The simulation model applied to that end has been criticized 5 for underestimating the power of technology and for not adequately representing the adaptive 6 capacity of the free market. Its "30 years update" (Meadows et al., 2004) concludes that: "We are 7 still drawing on the world's resources faster than they can be restored, and we are releasing 8 wastes and pollutants faster than the Earth can absorb them to render them harmless." This is in 9 line with analyses by European research agencies that led to, among others, the recent EU 10 strategy on soil protection (e.g., Van Camp et al., 2004), and the EU Thematic Strategy on the 11 Sustainable Use of Natural resources. Human demand started to exceed nature's supply as of 12 the early 1980s and has exceeded it by about 20% since 1999 (Wackernagel et al., 2001). This 13 kind of 'footprinting' is a way to translate human activities into appropriate areas. There are 14 different approaches to this exercise (e.g., Johansson, 2005). Although the method of calculating the ecological footprint just using one single measure has its limits and may be criticized,² the 15 16 basic message has been confirmed by the Millennium Assessment (2006) and other recent 17 studies (e.g., www.RedefiningProgress.org).

18

To use a concrete example, in Sweden, thanks to its large forest resources, the total ecological 19 20 footprint per citizen is 20.2 global acres per capita with no deficit (Wackernagel et al., 2001). 21 However, even Sweden is extremely dependent on areas outside its borders for its food 22 consumption (Deutsch 2004; Johansson 2005). There has been a decrease in agricultural land in 23 Sweden after WWII. Between 1951 and 1992 about 20% of Swedish agricultural land has been 24 reallocated; most of it has been afforested or urbanized (Björklund et al., 1999). Furthermore, the 25 direct foodprint has decreased in size due to agricultural intensification with increased use of 26 external inputs.

27

28 The total land area of Sweden is 41.1 million ha, of which a major proportion is mountain and 29 forest area, not suited for cultivation. In 1997-2000 Sweden had an average agricultural area of 30 3.2 million ha, with 2.8 million ha being arable land and more than 0.4 million ha permanent 31 pasture land. This corresponds to 0.31 ha of arable land per capita in Sweden, (compared to the 32 world average of 0.23 ha per capita), and 0.05 ha of pasture land not suited for cultivation, 33 (compared to the world average of 0.58 ha per capita) (FAOSTAT, 2003). During that same 34 period, one-third of the area, which Sweden required for food consumption, was outside Swedish 35 borders (Johansson 2005). In 1999, almost 80% of the agricultural area needed to produce 36 manufactured feed for Swedish animals was outside Swedish borders and 60% of all imports 37 were for animal feed (Deutsch, 2004). The total agricultural area, in Sweden and worldwide,

supporting Sweden's annual food consumption in 1997-2000 was, on average, approximately
 four million ha, or 0.44 ha per capita (Johansson, 2005).

3

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 varies between the
different existing systems and is based on 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.

9

10 In many of the densely populated parts of northwestern Europe and since the late 1980s also in 11 the new member states, fertile land is lost and soil is sealed by urbanization, with increasing 12 demand for built-up area per capita, roads, industrial terrain, etc. In the Netherlands, the land 13 covered by built-up areas is already around 10% (Klijn and Vullings, 2005). In its communication 14 on soil protection the Commission of the European Communities states that there is evidence that 15 soil may be increasingly threatened by a range of human activities, which may degrade it and its 16 functions, so vital for life, thus undermining sustainability (CEC, 2002). In the EU, an estimated 52 17 million hectares, representing more than 16% of the total land area, are affected by some kind of 18 degradation process. In the new member states this figure rises to 35%. Soil degradation in dry 19 areas is also known as desertification. Areas that risk desertification include central and 20 southeast Spain, central and southern Italy, southern France and Portugal and large parts of 21 Greece. The major threats to soil functions in Europe are erosion, a decline in organic matter, 22 local and diffuse contamination, sealing, compaction, a decline in biodiversity and salinization 23 (Van Lynden, 2000; CEC, 2002). These threats are complex and interlinked and although 24 unevenly spread across Europe, their dimension is continental. The biggest threat is soil erosion 25 by water. Within EU-25 it is most serious in central Europe and the Mediterranean region, where 26 50-70% of agricultural land is at moderate to high risk.

27

28 <u>Water</u>

29 In addition to domestic supplies, water is also provided for (Ashley and Cashman, 2006):

- Agriculture: irrigation of crops, livestock, horticulture, very dependent on activities, local
 soils and resources and climate;
- Trade and industry: factories, shops and institutions such as hospitals, also for power
 generation and cooling. Consumption is very specific to the nature of the activity, but in a
 number of developed countries industrial demand has fallen due to a general decline in
 heavy industry in favor of service industries; better use of recycling and reuse/recovery of
 water locally; and better water accounting and auditing, reducing wastage and

1	unnecessary use. Overall, demand in this sector is expected to rise by a small
2	percentage worldwide from current levels of about 20% of global water use.
3	- Public amenities: parks, street washing, fire fighting, flushing mains and sewers. This
4	may be water provided free of charge (and unmeasured) where the water service
5	provider (WSP) is a municipality. Fire fighting is a major reason for ensuring that water
6	main pressures are maintained and for supplying high-rise buildings.
7	- Losses: in distribution systems, domestic leaks and dripping taps, where "unaccounted
8	for" water is due to metering errors, unauthorized use and general unrecorded
9	consumption (Alegre et al., 2000). Unaccounted for water (including all losses) may
10	comprise from 6% up to 55% of the total water supplied in areas with aging mains and
11	service pipes.
12	
13	Agriculture consumes about 70% of all freshwater withdrawn from lakes, waterways and aquifers
14	around the world (FAO, 2007). The same figure holds true for NAE (Shiklomanov, 1999). It takes
15	1,000 to 2,000 liters of water to produce one kilogram of wheat and 13,000 to 15,000 liters to
16	produce the same quantity of grain-fed beef (FAO, 2007).
17	
18	Water use by agriculture is primarily determined by the development of irrigated land use, but
19	also by cattle-rearing and people's domestic needs. The EU has 9% of its agricultural production
20	under irrigation (13 M ha), over 75% of this is in Spain, Italy, France and Greece. More than 22 M
21	ha (18% of total cropland) are irrigated in the US, over 80% of which is in the West (Gollenhon et

al., 2006). In agriculture the efficiency of water use, per unit, would increase substantially through
the ability to target and tailor the application of water coupled with an improvement in crop strains.
The greatest impact could be felt in the area of biotechnology, with the possibility of engineering
more water-efficient cultures, and ICT, which would bring about more effective water use in
agriculture. Improvements could also come from a greater acknowledgement of the need to better
manage the role of "virtual water" (water used to produce products) and changes in crop

28 production (in developing countries) and import patterns (in developed countries).

29

Water use efficiency depends upon agricultural practices and water management techniques. In
 agriculture the amount of fertilizers and animal manure applied often far exceed crop demands

32 (Wolf et al., 2005). Nutrient surpluses cause problems for human beings, plants and animals.

33 Excesses or nutrient emissions to the environment are being reduced very slowly, *inter alia*

34 through the implementation of the EU nitrate directive. In North America, in an increasing number

35 of watersheds, water supply limits have already been exceeded. In the Midwest of the US, the

36 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.

1

2 [Insert Figure 5.1]

3 [Insert Figure 5.2]

4

5 <u>Forestry</u>

6 Forests: the services, goods and products they provide affect the daily lives of most, if not all 7 citizens. Within EU-25, forests cover 140 millions ha, or about 36% of the land area. Europe's 8 forests are extending in area, increasing in growth rate and expanding in standing volume due to 9 under-exploitation. In EU-25, there are over 4 million people directly or indirectly employed in 10 forestry and forest-based industries, mainly in rural areas. Europe produces 28% of the world's 11 paper supply and is a major operator in wood-based panels and engineered wood products; the 12 contribution of the forest sector accounts for 8% of Europe's added value (i.e. 600 billions euros). 13 With five percent only of the world forest area, Europe produces 25-30% of the world production 14 of forest-based products. The forestry sector's main asset is based on the renewable natural 15 resources and the use, to a large extent, of environmentally-friendly processes. Forest-based 16 industries are very efficient in recovering, reusing and recycling their materials and products, for 17 the manufacturing of new products as well as for energy production. Rigorous life cycle 18 assessments of forest products have shown that they have a strong comparative advantage vis-19 à-vis other materials. More utilization of forest biomass as a source for energy will be of high 20 importance for a more environmentally-friendly energy secure, sustainable Europe.

21

22 Fisheries and aquaculture.

23 In a little more than half a century, the situation of the world fisheries has undergone dramatic 24 change. After the Second World War, fishery landings guadrupled from 20 to 80Mt. This 25 progression was due to the successive opening of new resources to exploitation and greater 26 fishing capacities. In the 1970s and 1980s, the pace slowed down, and for the last two decades, 27 world production has stagnated. Fleets are at over-capacity, and the states of many stocks are 28 degraded. Since the 1970s, the proportion of overexploited stocks has been increasing, that of 29 the under or moderately exploited stocks decreasing, and that of fully exploited stocks, largely 30 stable (50%). There is probably no new stock resource, underexploited or unexploited, anymore. 31 Overexploitation has been controlled more quickly in zones exploited by developed countries 32 (Northern Atlantic, Northern Pacific) but now, , in varying degrees, affects all the oceans. The 33 Northwestern Atlantic fisheries have experienced one of the most spectacular collapses because of cod stocks, which had been fished for five centuries. Since the moratorium on cod fishing in 34 35 1993 in Canada, stocks have not been replenished. The commercial fisheries of the Northeast 36 Atlantic are fully exploited, overexploited or depleted. If the total captures are seemingly stable, it 37 is because of the transfer of fishing from the traditional and high trophic species (cod, haddock)

1 towards species of lesser value (blue whiting, sandeel) or temporarily productive stocks

- 2 threatened with depletion in the short term (deep-sea species).
- 3

4 5.4.5.2 Uncertainties of the future

5 While progress has been made in developing new technologies and new institutions and in

- 6 creating awareness of environmental problems, the outlook today on natural resources is no
- 7 better than in the early 1970s. There are a number of uncertainties involved concerning the future

8 availability and quality of natural resources, land use and environment in NAE, some of them

9 arising from or being aggravated by global trends such as trade liberalization and climatic

10 change:

11 Among the major factors influencing natural resource availability and land management in NAE,

12 is the rise in the consumption for food, feed, fiber and fuel in and outside the region. How will

- 13 demand for these goods develop in the next decades, and what can and will the NAE supply in
- 14 order to meet these 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 the 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 contribute to environmental degradation? How polluted will water be and what kind
 of efforts will be made to depollute, desalinize and reuse such water?
- How much suitable agricultural land will be shifted to other land uses? Will less suitable
 lands be cultivated? 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 the expansion of biofuel crops have on the supply of other agricultural
 products and on natural resource quality in the different sub-regions of NAE?
- How will the required goods be produced, and how will that affect the quality of water,
 soil, air and land use?
- What gains in efficiency and increases in water, land, energy and labor for agriculture
 would be needed to avoid jeopardizing future environmental sustainability? What gains
 could be achieved by new, improved production technologies and better water resources
 management? Can such knowledge be generated and be adequately disseminated and
 implemented in a timely manner? Will policy interventions be sufficient to overcome
 expected shortages?
- 37 Will there be crops that require fewer fertilizers and other agrochemicals and that also

1	require less water resources, obtained as a result of a fuller understanding of factors		
2	regulating nitrate and phosphate utilization, water use efficiency and their impact on		
3	natural resources?		
4	- What will happen to natural resource quality if the viability of rural areas in NAE declines?		
5	- Will current trends towards more consumer concern for environment and health, greater		
6	demand for food safety (labeling and traceability), organic products, less meat and more		
7	convenient foods continue? What will be the implications for natural resource use, land		
8	use practices and environmental quality?		
9	- In order to improve the sustainability of coastal capture fisheries and increase their		
10	productivity, will research be carried out on efficient management systems, taking into		
11	account the ecosystem and improved fishing technologies?		
12	- Will NAE develop its aquaculture production? Will there be more research on the aquatic		
13	environment for aquaculture?		
14			
15	Agricultural land use has the potential to damage or destroy the natural resource base and in so		
16	doing undermine future needs and development. It also has the potential to conserve agricultural		
17	landscapes. Most often, it focuses on short-term economic gains, disregarding long-term impacts		
18	and needs and thus contributing to environmental degradation. Clearly part of the solution lies in		
19	a change in demands from society, e.g., via changes in dietary preferences and lifestyle, but it		
20	also devolves to the agricultural sector to assume responsibility and find ways to reduce the		
21	negative environmental impacts by developing appropriate AKST.		
22			
23	5.4.5.3 Consequences for AKST		
24	Agriculture is a major user of land and water resources and is in competition with other users for		
25	these limited resources. The sustainable development challenges for agriculture are strongly		
26	related to this competition and the role agriculture has in rural development. The pleas made 15		
27	years ago and expressed in Agenda 21 are also valid for today: "Major adjustments are needed		
28	in agricultural, environmental and macroeconomic policy, at both national and international levels,		
29	in developed as well as developing countries, to create the conditions for sustainable agriculture		
30	and rural development" (UN, 1993).		
31			
32	The concepts of production ecology are very helpful in structuring the interrelationships between		
33	agriculture, natural resources and environmental quality (Van Ittersum and Rabbinge, 1997).		

34 Cropping activities, for instance, are defined by the mix of inputs to produce given target yields.

35 The level of undesired outputs (i.e. nitrate leaching, pesticide leaching, or unproductive

- 36 evaporation) associated with a given target yield will critically depend on the production
- 37 technology (i.e. the various resource management practices and their use efficiencies) applied.

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1 Nutrients, pesticide and water loss will critically depend on the timing and splits of fertilizer

2 application, type of crop protection and tillage. Policies need to support the diffusion of improved

3 or 'best practices' by environmental regulations that aim at reducing nitrate and pesticide

4 leaching. The rigorist approach of such regulations depends on societal choices , which in turn

5 also co-determine the preferred production orientation and farming systems.

6

7 Striving for food security and responding to the consequences of globalization of markets and 8 global environmental change (including climate change) are some of the major challenges of our 9 time (CGIAR Science Council, 2005; Roetter et al., 2007). In the future, particular attention needs 10 to be given to climate change and possible (mitigative) adaptation options, as it is superimposed 11 on and will influence other major challenges for agriculture such as the production of sufficient, 12 affordable, high-quality, safe food, as well as feed, fiber and biobased fuel. So far, climate-13 induced risks and opportunities for agricultural systems have not been sufficiently addressed by 14 AKST.

15 One of the challenges for AKST is to improve its adaptive capacity. This will be required and

16 beneficial for the sector irrespective of the precise impact of global environmental change.

17 Closely related to this is the development of modern, resource-use efficient and low emission

18 farming systems and agricultural practices. For the design and *ex ante* evaluation of such

19 systems, the development of better tools like crop models, farm household models and regional

20 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

22 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
 designs and the implementation of effective policies.

25

26 Directly related to this, is the challenge for AKST to generate the means that can contribute to 27 conflict resolution regarding competition for scarce natural resources. During the 1990s, some 28 public AKST systems (CGIAR and NARS partners world-wide) have tried to respond to that 29 challenge seriously, e.g., by developing ecoregional research methodologies (Bouma et al., 30 2007). Both, top down and bottom up approaches to Natural Resource Management (NRM) have 31 been developed (Van Ittersum et al., 2004), with the top down approaches directed more towards 32 policy makers and regional resource managers and the bottom up approaches more towards 33 participatory technology development and support for decision making on optimizing resource 34 use at the local level. Both approaches are required and need to be interlinked in the future to 35 effectively support NRM by improving decision making on land/resource use issues. If the future 36 world opts to achieve sustainability goals mainly through technological solutions and refuses to 37 change its attitude towards consumption and dietary issues, AKST will have to be organized

1 differently than in a world that considers solutions only sustainable if they increase equity, are 2 owned and accepted by local resource managers and contribute to environmental sustainability. 3 In the first case, AKST should be organized to seek local solutions by linking local knowledge 4 networks tightly to global networks of excellence. Whereas, in the latter case, a local learning 5 approach should be promoted to better integrate the different local knowledge centers and link 6 them to global centers of excellence for tapping the relevant disciplinary knowledge. Likewise, in 7 a world that favors technological solutions above behavioral change, AKST will have to focus 8 more on technological improvements in precision agriculture and conventional, specialized 9 agriculture to restrict negative environmental effects than on integrated systems of organic 10 agriculture that minimize emissions through recycling and avoid the use of agrochemicals. The 11 focus of AKST will also depend heavily on whether choices clearly support a biobased economy 12 in which biofuels play a big role. Given the threats of global environmental change, a AKST that 13 directs its efforts towards the development of sustainable, (energy, water, nutrient, and labor use 14 efficient), economically viable farming and land use systems that serve the multiple development 15 objectives of rural areas will be beneficial for natural resources quality and the environment under 16 different plausible futures. Finally, if society decides to make a serious effort to overcome 17 environmental degradation and resource depletion, well designed technologies will be effective 18 tools in supporting sustainable development.

19

To enhance the aesthetic value and sustainability of the landscape, research will be needed on ornamental plants, genetic exchanges with wild species and improved management strategies to preserve the 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. (ETP, 2005b)

25

Last, little research has been carried out on the sustainability of coastal fishing production
 systems which are still intensive, while 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 the sustainability of coastal fishing while AKST directed to local food supply
 should favor aquaculture. Market-led AKST will probably put little priority on these themes in their
 present condition.

33

34 5.4.6 Climate change and variability

To counter the increasing effects of climate change on agriculture will require a wider and stronger spectrum of adaptation responses as well as efforts to reduce energy needs and emissions. Increasing temperatures, more erratic precipitation patterns and increased risks of droughts, particularly in the southwestern parts of USA and Europe, coupled with a northern shift
 of cropping zones, will lead to changes in agricultural systems and production regions. Extreme
 events will severely challenge adaptive capacity. AKST could be developed to provide better

4 adaptation and mitigation responses.

5

6 5.4.6.1 On-going trends

7 Agricultural systems, forestry and fisheries are quite sensitive to climate change and variability 8 and can be strongly affected by them. Concurrently, land use and land use change, particularly 9 through agricultural and forestry activities, can strongly influence climate. There is now 10 unequivocal evidence that the Earth's climate has demonstrably warmed since the pre-industrial 11 era and that most of the warming over the last 50 years is very likely to have been due to increases in greenhouse gas² concentrations in the atmosphere. Atmospheric concentrations of 12 13 these gases are at their highest recorded levels and continue to go up, mainly due to combustion 14 of fossil fuels, agriculture and land-use change (Figure 5.3). It is generally not the changes in the 15 means of weather variables that impose the greatest risks, but the increase in frequency or 16 intensity of extreme events that pose challenges to agricultural systems. The full appearance of 17 many of the impacts of these changes is delayed by inertia in the climate system and in the 18 behavior of ecosystems (IPCC, 2007ab).

19

20 Agricultural climate change response options are often taken in the context of other stresses and 21 objectives through a range of technological, behavioral and policy changes. While the impacts of 22 a changing climate are complex, farmers have shown a considerable capacity to reduce 23 emissions from agriculture and adapt to climate change by adopting appropriate agricultural 24 practices and systems. To manage current climatic risks and increase resilience to likely future 25 changes, mitigation measures such as cultivation practices that increase soil carbon 26 sequestration, manure management and reforestation need to be continued. The earlier and 27 stronger the cuts in emissions, the quicker concentrations will approach stabilization (although the 28 effects of such measures on the climate will only emerge several decades after their 29 implementation). Regardless of these mitigation measures, global warming will continue and the 30 associated climate changes during the 21st century are expected to exceed any experienced in 31 the past thousands of years over which agriculture has been practiced in the NAE region. While 32 mitigation measures clearly need to be pursued to reduce emissions from agriculture, some 33 changes are now inevitable and will require adaptation responses.

 $^{^2}$ 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 vapor, carbon dioxide (CO₂), methane (CH₄) nitrous oxide (N₂O) and ozone (O₃), while halocarbons and other chlorine- and bromine-containing substances are entirely anthropogenic.

1

2 [Insert Figure 5.3]

3

4 Large parts of North America and Europe are located in the temperate climatic zone 5 characterized by favorable agroclimatic conditions, i.e., neither too dry nor too hot - with ample, 6 well-distributed rainfall and relatively mild winters. The NAE region also includes areas in which 7 current climatic risks such as drought, frost and flood play a considerable role, but the risk-prone 8 areas are proportionately smaller than in other regions. Drought-prone regions include large parts 9 of southwestern US, the Canadian Prairies and the Mediterranean, while frost risk and low 10 temperatures limit agricultural activities in large parts of Canada, the Nordic countries and Russia. 11 The highest emissions of greenhouse gases from agriculture are generally associated with the 12 most intensive farming systems whereas some of the low input farming systems currently located 13 in marginal areas may be the ones that are the most severely affected by climate change (IPCC, 14 2007b). 15

16 Agriculture contributes significantly to methane and nitrous oxide emissions. Land-use change 17 can also provide a significant contribution to carbon dioxide emissions, but emissions connected 18 to the use of fossil fuel for machinery and heating are considerably worse (Figure 5.4) 19 (Rosenzweig and Hillel, 2000; Stern et al., 2006; UNESCO, 2006a). In the NAE region, 20 greenhouse gas (GHG) emissions from agriculture are in the range of 7-20% of total country 21 emission inventories (in terms of radiative forcing). Latest estimates suggest that agriculture 22 accounts for 48% of CH₄ emissions and 52% of N₂O emissions in the EU. The role of agriculture 23 both as a source of and as a sink for GHGs varies significantly across the NAE region because of 24 the different agricultural policies and practices. Emissions also come from changes in forests and 25 other woody biomass stocks, forest and grassland conversions and from the soil (IPCC, 2000b; 26 UNESCO, 2006a). There is a clear trend across the whole NAE region to boost efforts to 27 decrease emissions by replacing fossil fuels with liquid biofuels (IEA, 2006).

28

29 [Figure 5.4]

30

31 The effects of climate change on agriculture (including forestry and fisheries) are already visible 32 in different parts of NAE (IPCC, 2007b). During the 20th century, for instance, as a result of 33 spring and summer warming and a shorter period of snow, the thermal growing season (with daily 34 mean temperatures above 5°C) was lengthened by about ten days in southern Finland (Carter, 2007). 35

- 36 5.4.6.2 Uncertainties for the future
- 37 How might GHG emissions develop in the future?

1 There are a number of uncertainties involved in predicting the future development of GHG 2 emissions (IPCC, 2000a). Some of the uncertainties relate to economic development, energy 3 supply and use as well as consumer behavior around the world (Sachs, 2006; EC, 2007). Other 4 uncertainties relate to the operation of the carbon cycle which is crucial in translating emissions 5 into concentrations as well as the magnitude and behavior of vulnerable carbon pools (UNESCO, 6 2006a; IPCC, 2007a): Natural carbon pools could well turn into sources as global warming and 7 deforestation continue. Some of the most vulnerable pools are (i) carbon in frozen soils, (ii) 8 carbon in cold and tropical peatlands, and (iii) biomass-carbon in forests vulnerable to fire and 9 insect infestations. Within the time span of our assessment (up to 2050) most of the IPCC 10 emission scenarios are indistinguishable because of the inertia in our economic and technological 11 systems. Furthermore, and as a result of this and the inertia also in the climate system, climate 12 projections in the NAE region until 2050 are quite similar. 13

14 Possible evolution of NAE climate and possible consequences for agriculture

15 Climate projections indicate that annual temperatures over Europe will continue to warm at a rate 16 of between 0.1 and 0.4°C per decade. The greatest increases are expected over southern Europe and north-east Europe (Parry, 2000). Higher temperatures will increase evaporation from 17 18 plants and soil, worsening the water problems that already afflict the hotter (southern) regions of NAE. Annual precipitation is expected to increase by 1-2% per decade⁻¹ in northern Europe. 19 There will be little decrease (at maximum -1% decade⁻¹) in southern Europe, and hardly any 20 21 change over central Europe. In North America trends towards increased temperatures and 22 changes in the frequency of heavy precipitation over most land areas are expected to continue. 23 Furthermore, extreme events are likely to increase in frequency and severity (IPCC, 2007a).

24

25 Warming in NAE will generally lead to a northward expansion of suitable cropping areas, and an 26 increase in the length of the growing season for indeterminate crops (whose growth is determined 27 primarily by environmental conditions e.g., root crops) but a reduction for determinate crops (that 28 develop through a pre-determined set of stages, from germination to ripening e.g., cereals). It is 29 assumed that about 10-20% of the increased crop productivity, which has doubled over the last 30 100 years, may be due to the growth-enhancing effect of CO₂. It is unclear whether this will 31 continue and to what extent this fertilization effect will be reduced by combinations of multiple 32 biotic (pests, diseases) and abiotic (drought, heat) stresses. The increase of atmospheric CO₂ 33 concentrations may increase water use efficiencies (Roetter and van de Geijn, 1999; IPCC, 34 2007a). However, the expected frequency of extreme weather (flooding and droughts) will

- 35 possibly offset the potential benefits to Europe (Olesen and Bindi, 2002) as well as to Canada
- and the United States (Reilly et al., 2003; Easterling et al., 2004; Lemmen and Warren, 2004).
- 37 Northern Hemisphere snow cover, permafrost and sea-ice extent are projected to decrease
1 further. In some areas, the timing of water availability is expected to change – more precipitation

2 falling as rain in winter, earlier snow-melt and more frequent dry spells in summer (IPCC, 2007a).

3 In regions where crop production is affected by water shortages, such as in southern Europe,

4 increases in the year-to-year variability of yields in addition to lower mean yields are predicted.

- 5 Extreme high or low temperatures during crucial stages of plant growth can lead to considerable
- 6 yield loss. Sea level rise could lead to larger areas being susceptible to flooding and saltwater
- 7 intrusions with potentially disastrous effects on harvests.
- 8

9 In NW Europe, climate change may lead to positive effects for agriculture by triggering the 10 introduction of new crop varieties and species, higher crop production and expansion of suitable 11 agricultural land area. However, climate change may have negative effects on infectious diseases 12 of plants (Chancellor and Kubiriba, 2006) and may motivate a demand for different pest 13 management practices and for measures to reduce nitrate leaching and the turnover of soil 14 organic matter (Olesen and Bindi, 2002). Estimated increases in water shortages and extreme 15 weather events may result in lower yields (and harvest indices), greater yield variability and a 16 reduction of suitable areas for traditional and region-specific crops. Such effects will most likely 17 aggravate the current trends of agriculture intensification in NW Europe and extensification in the 18 Mediterranean and SE parts of Europe.

19

20 In the US and Canada, future climate change is likely to result in agricultural shifts toward higher 21 latitudes and elevations. Moderate increases in temperature $(1-3^{\circ} C)$ along with elevated CO₂ and 22 changes in precipitation will have small beneficial impacts on crops such as wheat, maize and 23 cotton. Further warming, however, will probably have increasingly negative effects (Lemmen and 24 Warren, 2004; Easterling et al., 2004; Stern et al., 2006). Some authors have reported positive 25 crop yield responses to temperature increases of about 2°C, but negative yield responses at 26 increases over 4°C. Higher temperatures and warmer winters could reduce winterkill of insects 27 and broaden the range of other temperature-sensitive pathogens (Rosenzweig et al., 2000). It is 28 still not clear whether North American agriculture as a whole will be affected negatively or 29 positively by climate change. Part of the reason for this is the difference in assumptions regarding 30 agriculture's adaptation potential. The growth enhancing effects of increasing CO₂ concentrations 31 (currently around 380 ppm and increasing at an annual growth rate of 2 ppm) on crops may mask 32 much of the negative effects of changed temperature and precipitation patterns. Agriculture will 33 likely be vulnerable to higher frequency and severity of extreme events – as was demonstrated 34 during the summer 2003 European heat wave that was accompanied by drought and maize yield 35 reductions of 20%, representing the largest yield decline since the 1960s.

36

1 How could technological innovations influence the ability of agriculture to mitigate and adapt to

2 climate change?

3 Although unable to erase uncertainties, technological innovations may greatly influence the ability 4 of agriculture to mitigate and adapt to climate change. For Europe, mitigation and adaptation are 5 necessary and complementary for a comprehensive and coordinated strategy (Olesen and Bindi, 6 2002; Metzger et al., 2006). Adaptation is an important complement to greenhouse gas mitigation 7 measures and policies. Adaptation to climate variability and change is not a new concept. 8 Managed systems are likely to be more amenable than natural systems, and some regions will 9 face greater obstacles than others. Throughout human history, societies have shown a capacity 10 for adapting – though not always successfully (Lamb, 1995; Diamond, 2005). However, adapting 11 to climate change will not be an easy, cost-free task, and adaptation decisions in one sector (e.g., 12 water resources) might have implications for other sectors. Many of the existing adaptation 13 strategies may be strained by the expected changes in climate, particularly extreme events. 14 Adaptation technologies include: changing varieties/species to fit in better with changed thermal 15 and/or hydrological conditions, changing irrigation schedules and adjusting nutrient management, 16 applying water-conservation technologies (such as conservation tillage), altering timing or 17 location of cropping activities, etc. Some of those adaptation measures also have mitigative 18 effects – such as applying "zero tillage" practices or using cover /catch crops in spring to reduce 19 leaching and erosion. The provision of appropriate enabling environments and policies such as 20 technology and knowledge generation and dissemination mechanisms will also be important 21 considerations (Easterling et al., 2004; Kabat et al., 2005; Carter, 2007).

22

23 Adaptive capacity and sustainability

24

25 The essence of sustainable development as defined by the Brundtland Commission (WCED, 26 1987) is meeting fundamental human needs while preserving the life support systems of the earth 27 (Kates et al., 2000). Actions directed at coping with the impacts of climate change and efforts to 28 promote sustainable development share some important common goals and determinants such 29 as access to resources, equity in the distribution of resources, and abilities of decision-support 30 mechanisms to cope with risks. Sustainable development can result in improved adaptation to 31 climate change and enhance adaptive capacity (IPCC, 2007b; Verhagen et al., 2007). Climate 32 change adds an extra challenge or constraint to existing obstacles to achieving the various social. 33 ecological and economic objectives defining sustainable development. For agrosystems, any 34 changes in technologies and institutional arrangements that increase flexibility and resilience 35 regarding the different sustainability dimensions, will, in turn, increase their adaptive 36 capacity/capability to cope with climate change.

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1 Impact of climatic change (a function of exposure and sensitivity of a system) and adaptive

2 capacity determine the vulnerability of socioecological systems to climate change (Yohe and Tol,

- 3 2001).
- 4

5 For Europe, the ATEAM (Advanced Terrestrial Ecosystem Analysis and Modeling) project 6 constructed scenarios for a range of possible changes in socioeconomic conditions, land use 7 patterns and climate to assess the vulnerability of the human-environment system to global 8 change (Ewert et al., 2005; Schröter et al., 2005). Results from that assessment show that global 9 change will have a large influence on ecosystem service provision in Europe. There is, however, 10 a large heterogeneity in the projected vulnerability between regions. The Mediterranean region is 11 projected to be most vulnerable, while northwestern European countries face the lowest impacts 12 and show the greatest adaptive capacity (Metzger et al., 2006).

13

14 For the United States, US agriculture on the whole can adapt (with either some net gains or some 15 costs) if warming occurs at the lower end of the projected scale of magnitude (i.e. 2 to 3°C by the 16 end of the century) and the variability level stays constant (Easterling et al., 2004). These authors 17 have shown that the. However, with a much larger magnitude of warming, even under optimistic 18 assumptions about adaptation capabilities, many sectors would experience higher losses and 19 costs (Easterling et al., 2004). Canada will likely experience similar effects (Lemmen and Warren, 20 2004). In this context, another feature that clearly distinguishes NAE agriculture from other 21 regions is the significant high level of its current adaptive capacity. This is mainly due to the 22 region's access to important economic, technological and other resources which is better than 23 that of other regions (Adger et al., 2005). It is also co-determined by the fact that relatively large 24 areas have a relatively low exposure to climate change, compared to other regions.

25 5.4.6.3 Consequences for AKST

26 Options for dealing with the threats of climate change require examination at regional and local

27 scales. Questions include: how can emissions from agriculture and forestry be effectively

- reduced, how can agriculture and forestry best adapt under given local conditions, what role can
- 29 biofuels play and, finally, what are the implications for AKST?
- 30

31 There will be different requirements for AKST, depending on future policy and societal choices,

32 such as the degree of emission reduction, energy price increases, reduced consumption,

- 33 proactive adaptation and enhanced adaptive capacity.
- 34

35 Some of the obvious consequences for AKST are given below. Furthermore, some suggestions

36 are given on the efficacy of different measures in reducing the vulnerability of agriculture and rural

37 areas to climate change:

1	(1)	AKST needs to generate the information required to improve climate modeling and
2		scenario development. This includes developing improved methods for determining GHG
3		emissions from agricultural activities and improving our understanding of the carbon
4		cycle.
5	(2)	Another area that requires attention is the effectiveness of adaptation to today's climate
6		variability (Adger et al., 2005); such lessons are important for better understanding of
7		vulnerabilities and measures needed for different climatic risks.
8	(3)	Improvement is also required in the area of climate change impact assessment
9		methodologies - this refers to the modeling of multiple stresses as well as to the
10		quantification of climate change scenarios on the whole range of ecosystems goods and
11		services (Carter, 2007) and the effects of climate change on the quality of crop and
12		animal production.
13	(4)	More effort is required to develop knowledge and tools needed to support the design and
14		evaluation of mitigation and adaptation options for agriculture; this also includes more
15		comprehensive cost-benefit analysis than now available (Stern et al., 2006; Carter,
16		2007). Comprehensive energy-efficient agricultural systems need to receive particular
17		attention.
18	(5)	Likewise, more consideration needs to be given to the establishment of AKST multi-
19		stakeholder approaches for designing and implementing feasible strategies at the farm
20		and sub-national scale. All actors need to be involved in a participatory planning process.
21	(6)	There needs to be more focus on regional studies of impacts and mitigation/adaptation of
22		climate change in agriculture, including assessments of the consequences on current
23		efforts in agricultural policies for sustainable agriculture that also preserve environmental
24		and social values in rural communities.
25	(7)	The development of strategies to enhance the adaptive capacity of agroecosystems is a
26		related issue that dwells on the generation of interdisciplinary knowledge and a
27		willingness to better integrate different AKST activities across sectors and among
28		stakeholders so that they become less vulnerable and risks are better managed.
29	(8)	Finally, research should focus on creating productive and multifunctional land use
30		systems in rural areas that aim to provide sustainable ecosystem services and
31		employment. This should include, where necessary, restoration of degraded lands and
32		the integrated management of natural resources.
33		
34	Where	governments and citizens assume more responsibility for the environment and are
35	proactive in terms of alleviating the threats of climate change, AKST activities will be more far	
36	reaching and will require the provision of better information, appropriate technologies and	
37	multifunctional agricultural landscapes. However, where decisions on natural resources and the	

environment (including climate system) are not integrated with economic decisions, AKST will be
 reduced to contributing to the fulfillment of consumers' requirements regarding food and non-food
 products.

4

5 5.4.7 Energy and bioenergy

Increased demands are being levied on agriculture to provide energy and biomaterials. Bioenergy
that includes the production of liquid fuels from biomass could meet some of the world's growing
energy needs. It is unclear to what extent agriculture in NAE will become an energy producer,
and how much can be achieved from other renewable energy sources and conservation. The
development of bioenergy will increase competition for land and water resources and push up
food prices. Social, technological and economic studies are badly needed.

12 5.4.7.1 On-going trends

13 Since World War II, global energy consumption has increased more than six fold. In the same 14 period, per capita energy demand has more than doubled. The energy demand growth rate is not 15 slowing down in spite of record oil prices and global primary energy demand is expected to grow 16 by more than 50% by 2030 (Fresco, 2006; IEA, 2006). According to the World Energy Outlook 17 (IEA, 2006), in the reference scenario, the average annual percent change is expected to be 1.8 18 for the world, 3.0 for non OECD Asia, 1.0 for the USA, 1.2 for Canada, 0.4 for OECD Europe and 19 1.3 for Russia. In the case of a low growth rate, the average annual percent change is expected 20 to be 1.4 for the world, 0.6 for the USA, 0.8 for Canada, 0.1 for OECD Europe and 0.8 for Russia.

21

22 Energy is a key driver in agriculture through the consumption of fossil fuels and fertilizer 23 production. Agriculture also can be a source of energy. Energy consumption in agriculture 24 depends on the type of crop, the production system and agroclimatic conditions and the farm 25 size. Irrigation accounts for the largest share and is thus especially vulnerable to changes in 26 energy prices. It has also been observed that the application of farmyard manure, another source 27 of energy, has been decreasing over time. Application of mineral fertilizers, for improving yield 28 and productivity has been on the increase but a stringent EU policy framework and related 29 national policies have led to a decline in recent years (Wolf et al., 2005; EC, 2007). At present in 30 the USA (Konyar, 2001), average direct and indirect energy account for 19% of the total variable 31 costs, ranging from ten percent for soybeans and up to 27% for cotton. For irrigated crops, 32 energy constitutes an average of 33% of the total variable cost, and ranges from 26% for hay to 33 51% for sorghum. These proportions could change with the use of biobased fuels. The availability 34 and price of energy also influences the transport of agricultural products and hence global trade. 35

Biofuels that can be used for transport include bioethanol, biomethanol, biodiesel, biogas,
biohydrogen and pure vegetable oil as well as solids such as agriculture and forestry wastes

1 (Schröder and Weiske, 2006). The two primary biofuels in use today are ethanol and biodiesel,

- 2 both of which can be used in existing vehicles. Ethanol is currently blended with gasoline, and
- 3 biodiesel with petroleum-based diesel for use in conventional vehicles. Globally, ethanol accounts
- 4 for about 90% of total biofuel production, with biodiesel making up the rest (Marris, 2006;
- 5 Sanderson, 2006). Global fuel ethanol production more than doubled between 2000 and 2005,
- 6 while production of biodiesel, starting from a much smaller base, expanded nearly fourfold. By
- 7 contrast, world oil production increased by only seven percent during the same period.
- 8

9 Petroleum refining is being developed on a very large scale; biofuels are produced in lower 10 volumes and, currently, much more decentralized. According to the World Energy Outlook (IEA, 11 2006), significant technological challenges still need to be overcome for the second-generation 12 technologies to become commercially viable. In the case of biodiesel in particular, where a wide 13 range of plant and animal feedstock can be used, production facilities tend to be rather dispersed. 14 Ethanol fuel production has tended to be more geographically concentrated than biodiesel e.g., in 15 the United States, predominantly in the Midwestern states that have abundant corn supplies 16 (Worldwatch Institute, 2006).

17

18 The various biomass feedstock used for producing biofuels can be grouped into two basic 19 categories. The first is the currently available "first-generation" feedstock, composed of various 20 grain and vegetable crops that are harvested for their sugar, starch, or oil content and can be 21 converted into liquid fuels using conventional technology. The yields from the feedstock vary 22 considerably, with sugar cane and palm oil currently producing the largest volumes per hectare 23 (Marris, 2006). By contrast, the "next-generation" biofuel feedstock comprising cellulose-rich 24 organic material will be harvested for its total biomass (Fresco, 2006). To convert these fibers into 25 liquid biofuels requires advanced technical processes, many of which are still under development. 26 Advanced biofuel technologies could allow biofuels to replace 37% of US gasoline within the next 27 25 years, with the figure rising to 75% if vehicle fuel efficiency were doubled during that same 28 period. The biofuel potential of EU countries is in the range of 20-25% (EEA, 2006) if strong 29 sustainability criteria for land use and crop choice are applied and bioenergy use in non-transport 30 sectors grows in parallel. 31

32 5.4.7.2 Uncertainties of the future

- 33 As far as energy and bioenergy are concerned, there are three major uncertainties for the future:
- 34 To what extent will bioenergy supply develop globally?
- 35 Which considerations will determine future bioenergy use in NAE?
- 36 Will agriculture be able to substantially reduce energy required for production?
- 37 What will be the consequences of bioenergy production on food prices and water usage?

1 Among the major considerations in NAE that will influence the energy market will be the energy 2 security aspect. Second, there will be the increasing awareness of the need to protect the Earth's 3 climate system through the reduction of greenhouse gas emissions (GHG). The recent (March 4 2007) agreement of EU leaders on greenhouse reduction targets and renewable energy use is a 5 milestone that may well trigger changes in energy policy elsewhere (i.e. the US, Russia, China). 6 There continues to be a lively debate regarding the trade-offs between economic growth and 7 energy. Some experts claim that energy costs will rise sharply if we increase the share of biofuels 8 in the energy supply mix. This does not consider the many opportunities for reducing the use of 9 fossil fuel e.g., by applying energy-saving technologies and choosing low-emission activities (as 10 has already been demonstrated by many NAE multinational companies such as BP. Shell, Bayer, 11 General Electric) (Fresco, 2006).

12 The "next-generation" biofuels are based on cellulose biomass such as tall grasses as well as 13 wood and crop residues that are generally abundant and can be harvested with less interference 14 with the food system and potentially will put less strain on land, air and water resources. Another 15 potential "next-generation" feedstock is the organic portion of municipal solid waste. The use of 16 "next-generation" cellulose biomass feedstock has the potential to dramatically expand the 17 resource base for producing biofuels in the future (Fresco, 2006; Marris, 2006). Over the next 10-18 15 years, lower-cost sources of cellulose biomass, such as the organic fraction of municipal 19 waste and the residues from the processing of crops and forestry products, are expected to 20 provide the initial feedstock. Many questions arise in this context. One is, to what extent can 21 these technological developments be accelerated by further supporting policy interventions, 22 better public-private research cooperation and increased investment?

23 Research and development efforts to date have demonstrated the feasibility of producing a 24 variety of liquid fuels from cellulose biomass for use in existing vehicles. As of mid-2006, 25 however, the costs of producing such liquid fuels were not competitive with either petroleum-26 derived fuels or more conventional biofuels. The diffusion of "Flex Fuel Cars" (currently about 27 50% of the cars in Brazil) introduces flexibility to respond to fuel price fluctuations. Various 28 government and industry-sponsored efforts are under way to lower the costs of making liquid fuel 29 from cellulose biomass by improving the conversion technologies. (Worldwatch Institute, 2006). 30 How fast these developments will proceed is still unclear. Unambiguous cost signals as well as 31 information regarding the availability of new technologies will influence consumer preferences 32 and behavior. These developments will depend on economic growth and sustainable 33 development outside the NAE region. According to recent projections China and India are 34 expected to account for 30 to 40% of energy demand by 2030 (IEA, 2006).

35

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1	The dual challenge is to secure adequate energy at affordable prices and, at the same time, limit		
2	consumption such that it does less environmental harm. It is unclear to what extent agriculture in		
3	NAE will become an energy producer, and how much its energy-efficiency can be increased. This		
4	depends on AKST as well as on other KST efforts. More centralized and technology-intensive		
5	renewable forms of energy may well outweigh agriculture as an energy-producer.		
6			
7	5.4.7.3 Consequences for AKST		
8	Actors in AKST need to pay more attention to the following energy-related issues:		
9	- Research into new farming systems that are able to satisfy their own energy needs and		
10	defray their own costs by producing biofuels, as well as installing other renewable		
11	sources of energy such as wind and solar power.		
12	- Generation of knowledge that allows sustainable production of biofuels, i.e. in an		
13	economically-viable, environmentally-friendly and socially-acceptable manner.		
14	- Proper accounting for the full energy demand of the agricultural sector in environmental		
15	impact assessments.		
16	- Biochemistry and ecosystem studies to eliminate agricultural and forestry residues or use		
17	it to produce bioenergy.		
18	Furthermore, the following general issues need to be considered:		
19	- Evaluation of investment options in the short, medium and long term for energy		
20	exploration and production infrastructure.		
21	 Increasing energy efficiency, identifying measures to reduce the demand from the 		
22	transport sector, promoting the development and deployment of technology.		
23	- Assessing options for next 50-100 years, e.g., potential for biofuels and other renewable		
24	sources like wind, solar, tidal, etc.		
25	 Making use of new technologies to combine energy sources in an efficient way 		
26	(photovoltaic with fuel cells or new large accumulators), especially in decentralized		
27	systems.		
28			
29	5.5 Key Drivers for Agricultural Knowledge, Science and Technology (AKST) and		
30	Agricultural Research and Innovation Systems and Their Uncertainties		
31	Agricultural R&D is not conducted in isolation; it is strongly influenced by the rest of science. In		
32	2000, the world invested 725 billion dollars in all the sciences carried out by both public agencies		
33	and private firms – that is about one third more than in 1995 – with the biggest increases in the		
34	Asia and Pacific region. However, there is evidence of a huge, and partly growing, divide between		
35	the "scientific haves and have nots." The total amount spent on sciences is approximately 1.7% of		
36	the world's GDP worldwide. Public agricultural R&D funds amounted to 23 billion dollars in 2000,		
37	about 3% of the total science spending (CGIAR Science Council, 2005).		

1

- 2 Today's agricultural research systems are increasingly being asked to tackle problems that are,
- 3 strictly speaking, external to agriculture. The emphasis is shifting away from the development of
- 4 productivity and increasing technologies towards that of new approaches to social and
- 5 environmental issues, such as the protection of natural resources, food safety and animal
- 6 welfare. The challenge is to promote development that balances equity and environmental
- 7 interests with those of economic growth, while limiting the negative external effects of agriculture
- 8 (ISNAR, 2003).
- 9

10 5.5.1 Organizations and funding of 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. Funding will also be considered.

16

17 AKST organizations in North America and Europe include all the formal and informal 18 organizations controlling, generating, distributing and utilizing agricultural knowledge, science, 19 technology, inputs, markets, credits, capital and assets. This implies primarily research, education 20 and extension organizations, but also government agencies, administrative and political decision-21 making bodies, NGOs and associations, and private enterprises, acting within the food chain and 22 interacting with it e.g., in regulation, input production, waste management, markets and financing. 23 The North American and European agricultural innovation systems have had a major impact on 24 shaping a broad range of AKST organizations outside the region, for example, transnational 25 private companies and NAE-based and -dominated international organizations, and the 26 Consultative Group for International Agricultural Research (CGIAR), as well as many national 27 organizations of Africa, Asia and Latin America.

28 5.5.1.1 On-going trends

29 Formal AKST structures started to take shape in the late 1800s. In the USA, contrary to most of

30 Europe, education, research and extension were integrated among each others (Huffman and

31 Evenson, 1993), while in Russia they were separate with no public extension service (Miller et al.,

32 2000). In USA, decisions on AKST were taken at state level which fostered innovation and

33 diversity, while in Eastern Europe there was a strictly centralized top-down model (Miller et al.,

34 2000). The governmental responsibility for AKST in NAE rested traditionally with an agricultural

35 ministry, but now is increasingly been brought into closer connection with the general public KST

36 and innovation policy (OECD, 1999, 2005abc). To counteract consequent disintegration of

37 components of AKST, cooperation between them and across institutes (especially between

research institutes and universities), disciplines and territories, is increasingly being encouraged,
also by specific funds. This has been more successful for research and extension entities that for
universities. 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).

6

7 AKST grew during the first half of the 1900s, and the pace accelerated after World War II. The 8 share of public AKST funds to universities increased from the 1970s onwards. Since the 1980s 9 the number of facilities has declined, and they have been privatized and rationalized (Alston et 10 al., 1998). Although the share of agriculture in total R&D funding has declined, the agricultural 11 research intensity ratio (agricultural public R&D relative to agricultural GDP) has risen more than 12 the average science and technology research intensity ratio (Alston et al., 1998). In general, the 13 level of support reflects the size of the country's agricultural sector. The largest budgets for 14 agricultural research are found in the USA, Japan, France, Canada, the UK, Italy, Germany and 15 the Netherlands (Pardey et al., 1999). Spending on private-sector agricultural research is greatest 16 in the USA, Japan, the UK, France and Germany, mainly thanks to the various multinational 17 conglomerates that have their headquarters in these countries. The figures suggest that private-18 and public-sector research complement rather than substitute each other. Countries that have 19 traditionally provided substantial support for public-sector research have created an enabling 20 environment for research and technology development, which motivates the private sector to 21 advance its own research. Between 1981 and 1993 private-sector research expenditure grew by 22 5.1% per year while public-sector research expenditure grew by only 1.8% (Alston et al., 1998). 23 By 2000, private sector investments accounted for around 55% of all agricultural R&D in 24 developed countries, but in low-income countries, it was negligible (CGIAR Science Council, 25 2005). The growth in aggregate agricultural research (public and private sector) continues at a 26 rate of approximately 3.4% per year, slightly lower than the 4% growth rate in total research 27 (ISNAR, 2003).

28

NAE governments are funding 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).

33

The involvement of the private companies in agricultural extension has also gone up (Umali and Schwartz, 1994), while public extension services have become increasingly chargeable and have been down-sized (Read et al., 1988; OSI, 2006) except in some European countries with small farm-dominated agriculture or a conscious choice for independence of commercial interests

82

(OECD, 1999). However, this proportion of private funding is about the same as the general
 repartition of private funding of R&D.

3

The model for international research centers was introduced after World War II, and in the 1970s they were united to form CGIAR, whose centers grew in size and numbers but whose budget in the 1990s stagnated and then took a downturn, until the year 2000 when it started recovering. In 2000, CGIAR represented 1.5% of the global public sector investments in agricultural R&D and 0.9% of all public and private agricultural R&D spending (CGIAR Science Council, 2005).
In NAE agricultural research organizations, there appears to be a decrease in the importance of traditional productivity-oriented agricultural research and an increase in research on socially

12 relevant themes such as environment and food safety. A similar (although less pronounced)

13 change is also apparently occurring in many developing countries (ISNAR, 2003).

14

15 Agricultural research policy is now less frequently coordinated and formulated in agricultural 16 research institutions and is increasingly becoming the responsibility of government ministries or 17 science and technology councils. In addition, agricultural research policy is increasingly being 18 integrated into general science policy. When agricultural research institutions operate as 19 commercial suppliers of research, for example under contract, they are likely to develop a strong 20 client focus, moving close to the goals defined by their clients. Indeed, some institutions are 21 implementing active commercial strategies in order to attain these goals. If the institutions' legal 22 frameworks permit, their client base may very varied and include government ministries, regional 23 and local government entities, industries and farmers' associations. This development is not 24 welcomed in all circles (ISNAR, 2003). In the USA, for instance, researchers' commercial 25 activities tend to reduce their creativity and their willingness to undertake basic research 26 (Huffman and Just, 1999).

27

28 Over the past decade, the structure and organization of agricultural research have been subject 29 to accelerated change. This reflects new ideas about interactions between the public and private 30 sectors, such as the client focus (Persley, 1998). Some of the most rapid changes have occurred 31 in the UK, where the government has sharply reduced its support for agricultural research. In 32 other countries, such as the Netherlands, the government is abandoning institutional financing but 33 still finances a substantial research program through contracts with long-standing research 34 organizations that now function almost as private sector entities. Privatization is not the only 35 means of improving control over agricultural research and client responsiveness. Innovative 36 research methods are being established that combine public and private sector research. And

scientific capacity is well maintained in the majority of EU-15 and North America thanks to the
 important role played by their universities.

3

4 Drivers

5 Major drivers for expansion of formal AKST organizations were industrialization, advances in 6 technology and knowledge, and an optimistic view of societal benefits, affected by demand and 7 mediated through policy (Alston et al., 1998; Van Keulen, 2007). Privatization was fostered by the 8 introduction of Intellectual Property Rights, advances in genetics and new research policies 9 (Alston et al., 1998). Public funding has taken a downturn since the mid 1970s mainly for the 10 following two reasons: first, a general paradigm shift in the society towards a smaller role for 11 public policy and a larger role for the marketplace and second, lesser societal benefits, 12 eradication of food insufficiency, and a smaller share of GNP in NAE. This is true, although there 13 is evidence of continued high returns to investments in public AKST (Alston et al., 2000). Many 14 governments are giving AKST another opportunity to show its comparative advantage in 15 contributing to emerging wider societal interests through innovative, interactive AKST, even if 16 rewarding mechanisms still need further development (OECD, 1999). The limited contribution of 17 AKST to public debate and policies during the recent decade is seen as a major challenge 18 (OECD, 1999).

19

20 Growth in size, specialization, consolidation of food chain organizations and increasing 21 domination by multinational corporations was driven first by industrialization and later by 22 liberalization of international trade, mobility of capital and people, new technologies (Galizzi and 23 Pieri, 1998) and by regulatory barriers discriminating small enterprises. Public AKST had at least 24 as much importance as private R&D and market forces in bringing about changes in livestock 25 specialization (but not in crop specialization), farm size and farmers' off-farm activities (Busch et 26 al., 1984; Huffman and Evenson, 2001), supported by well-targeted agricultural policies. (Van 27 Keulen, 2007). Differences among NAE regions have been mainly due to differences in political-28 economic history.

29

30 5.5.1.2 Uncertainties of the future

31 Public funding to develop AKST organizations

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. Questions
 about the future concern the following: Will research questions be shared and will public sector

35 research be increasingly oriented toward the generation of knowledge? Will the view of the

- 36 societal potential for AKST widen to emphasize the notion of multifunctionality and ethical
- 37 consumption in order to attract public acceptance for funding AKST? Will the share of agriculture

- 1 in the GDP decline? Will food insecurity and the central role of NAE AKST beyond its boarders
- 2 turn the view of the societal potential of NAE AKST positive? Will AKST adjust its paradigms and
- 3 image by adopting a wider, more diverse and flexible agenda to realize its comparative
- 4 advantages in meeting the changing societal demand?
- 5 Will organization structures become flexible enough to promote changes in scopes and targets?6

7 Role of private AKST organizations

- 8 Technological developments (such as functional foods, gene-tailored diets, photosynthesizing
- 9 microbes for energy, GMOs, nanotechnologies, information technologies) tend to increase the
- 10 role of private companies in science and technology, thus compensating the decline in public
- 11 funding. However, the demand for public goods, including food security, will continue to grow.
- 12 Policies determine whether the internalization of externalities make public goods economically
- 13 rewarding to provide through private AKST.
- 14 If not, will the companies cream off or manage to segment supply for different markets, thus
- 15 better contributing to meeting the development and sustainability goals of this assessment?
- 16 Will public and private AKST organizations manage to increase synergy and intermediate
- 17 spaces?
- Or will public AKST develop the public goods and set regulations that constrain the privatesector?
- 20

21 Dis/integration of organizations at global and national level and within AKST

22 On the one hand, the integration of KST and AKST is increasingly being sought (OECD, 1999).

23 On the other hand, we have learned from the US success story of integrating of research,

- 24 education and extension. These two targets may, in some cases, be contradictory. There is
- 25 overall agreement on the need for integration within AKST to increase the multifunctionality of
- food systems and agriculture. This has to proceed on and among different levels, starting from
- 27 policy coherence at the level of ministries and administrative bodies, to increased communication
- among food system actors and among disciplines within the formal knowledge systems.
- 29 Interdisciplinarity is getting wide acceptance as the preferential strategy in the latter. This avoids
- 30 the endless emergence of new sciences and boarders through the unification of existing ones.
- 31 However, there are multiple barriers to this kind of development, such as risks related to
- 32 integration, especially for the necessary advancement of the disciplinary bases. Views opposing
- integration are also being considered (Sumberg et al., 2003; OSI, 2006). Will the barriers and
- risks be avoided, and will integrative approaches in structural development of AKST organizations
- 35 take over as predicted for universities (Väyrynen, 2006), possibly based on flexible models of
- 36 interacting scientific communities (Lele and Norgaard, 2005)? Will incentives and tools be created

- 1 for public NAE science and technology organizations to intensify links with CGIAR and NARS
- 2 organizations, to ensure appropriateness and adoption of technologies?
- 3

4 De/centralization and consolidation

- 5 Physical distancing in food chain and regional specialization has economic benefits but has often
- 6 had negative environmental and social impacts. Food and product chains and marketing
- 7 channels seem to be diversifying, due to more varied product combinations and demand
- 8 segments. Will these developments and the notion of multifunctionality cause a paradigm shift
- 9 towards the development of diversification and integration within regions, or will farm and regional
- 10 specialization continue, using new tools to meet the environmental and social challenges?
- 11 And do policies, demand and formal AKST lead to diversification of on-farm supply, or only
- 12 operate at the regional or even national or international level, through comparative economic
- 13 advantages? Where in this scenario is the lower limit of the economic scale set?
- 14 Will paradigms and their operationalization in policies and demand lead to centralized
- 15 transnational organizations, possibly to the existence of a small number of discipline-based
- 16 international centers of excellence for the whole world, generating knowledge, technologies and
- 17 products and segmenting their activity for diverse markets? Or does contextually and local
- 18 adaptation proceed through decentralization and regionalization of AKST?
- 19

20 Contextualization of AKST organizations

21 There are means to adjust the societal and organizational situation to the requirements of capital-

- 22 intensive agricultural technology, a technology which is less appropriate for resource-poor
- 23 farming communities as such. One example is the Grameen Bank, founded by Muhammad
- 24 Yunus, 2006 Nobel Prize winner. The Grameen Bank provides micro-loans for the poor, with an
- adjusted guarantee system. Will such models for more diverse and contextualized organizational
 structures, e.g., banking systems, be developed and popularized?
- 27 5.5.1.3 Consequences for AKST
- 28 To achieve the development and sustainability (D&S) goals requires reconsideration of
- 29 appropriate organizational structures for AKST. Societal support for the development of AKST
- 30 and relevance for the crucial challenges demand broad dialogue and a broad range of
- 31 perspectives implied in flexible, diverse, integrative organizational structures. The share of public
- 32 and private sectors in AKST is decisive for the kind of public regulatory arrangements that best
- 33 meets the public goals. Regulatory regimes can be limited to covering cover transparency and
- 34 communication, or can set economic incentives for the mainly private organizations to promote
- 35 the goals, or directly regulate their activity through rules and legislation or through a public
- 36 organizational structure. Public economic incentives may increase feasibility and result in higher

1 equity than full reliance on price premia paid by consumers. In any case, proactive policies are

- 2 required to shape AKST organizations and their activity.
- 3

4 The integration of organizations of knowledge generation and dissemination can promote goals. 5 However, if focus is on globally coherent and centralized policies and AKST organizations, the 6 strengths and weaknesses of society will be very different than if focus is on locally coherent and 7 decentralized policies and AKST organizations. Global models with few centers of excellence and 8 top-down approaches in science might be better in meeting global environmental problems, while 9 local horizontally-integrated models and bottom-up approaches might have greater social and 10 cultural benefits. Integration among organizations representing AKST components may produce 11 more traditional solutions that are still highly relevant for present actors, while linkages to KST 12 components foster more substantial changes and innovations with higher risks and opportunities 13 for meeting the D&S goals. Relevance and contextuality of the latter might depend on importance

- 14 given to the social sciences.
- 15

16 5.5.2 Proprietary regimes

The private sector invests in agricultural research purely to make a profit. A legal framework that adequately protects intellectual property rights is therefore very important. Interacting factors determine the effectiveness of patents awarded in any country: (1) the scientific fields in which a patent can be obtained; (2) international treaties that guarantee the respect for patents awarded in other countries and vice versa; (3) the ability to maintain an obsolete patent; (4) the ability to sanction patent violations; and (5) the duration of patent protection (Ginarte and Park, 1997; ISNAR, 2003).

24 5.5.2.1 On-going trends

25 The assignment of intellectual property rights to living things is of relatively recent origin in 26 developed countries. Vegetative propagated plants were first made patentable in the US in 1930. 27 And the protection of plant varieties (or plant breeder's rights - PBRs), a new form of intellectual 28 property, only became widespread in the second half of the 20th Century. Intellectual property 29 laws vary from jurisdiction to jurisdiction, such that the acquisition, registration or enforcement of 30 IP rights must be pursued or obtained separately in each territory of interest. However, these laws 31 are becoming increasingly harmonized through the effects of international treaties such as the 32 1994 World Trade Organization (WTO) Agreement on Trade-Related Aspects of Intellectual 33 Property Rights (TRIPs), while other treaties may facilitate registration in more than one 34 jurisdiction at a time.

35

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

1 resources should be recognized and preserved. Building on the principles embodied in the 2 Convention on Biological Diversity (CBD), the International Treaty on Plant Genetic Resources for 3 Food and Agriculture (ITPGRFA) seeks to establish principles for facilitating access to plant 4 genetic resources and establishing fair and equitable mechanisms of benefit sharing. The 5 International Union for the Protection of New Varieties of Plants (UPOV) aims to encourage the 6 development of new varieties of plants for the benefit of society by codifying intellectual property 7 for plant breeders. In 2005, 58 countries had joined UPOV. For plant breeders' rights to be 8 granted, the new variety must meet four criteria under the rules established by UPOV. The new 9 plant must be novel, which means that it must not have been previously marketed in the country 10 where rights are applied for. The new plant must be distinct from other available varieties. The 11 plants must display homogeneity. The trait or traits unique to the new variety must be stable so 12 that the plant remains true to type after repeated cycles of propagation. Protection can be 13 obtained for a new plant variety how ever it has been obtained, e.g., through conventional 14 breeding techniques or genetic engineering. (UPOV, 1991) 15

16 In 2001, the FAO Conference adopted the International Treaty on Plant Genetic Resources for 17 Food and Agriculture. This legally binding Treaty covers all plant genetic resources relevant to 18 food and agriculture and is harmony with the Convention on Biological Diversity. The Treaty is 19 vital in ensuring the continued availability of the plant genetic resources that countries will need to 20 feed their people. Through the Treaty, countries agree to establish an efficient, effective and 21 transparent Multilateral System to facilitate access to plant genetic resources for food and 22 agriculture and to share the benefits in a fair and equitable way. The Multilateral System applies 23 to over 64 major crops and forages. The Governing Body of the Treaty, which will be composed 24 of the countries that have ratified it, will set out the conditions for access and benefit-sharing in a 25 "Material Transfer Agreement" (MTA).

26

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 coordinates (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 coordinates 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).

33 5.5.2.2 Uncertainties of the future

34 Bits of information or research tools are contributions to product development, but economically,

35 there is little or no independent value in these piecemeal inventions or discoveries. The economic

36 value derives from the final product. Why can't firms or public research rely completely on

37 biotechnology firms to improve their products? What kinds of incentives must be offered to

1 develop new research tools in public research? What will be the impact on industry of products

2 coming off patent? Will industry continue to be interested in high-risk low-payoff products or will it

3 concentrate on blockbusters? Will the public procurement model be developed, especially for

4 products such as vaccines?

5

How far will the World Intellectual Property Organization (WIPO) go to harmonize international
patent law? Will patent law ever be harmonized? Will world patents be created? How far will the
collective networks in the field of agricultural biotechnologies manage to achieve co-development
and patents for novel technologies?

10

115.5.3Access, control and distribution of Agricultural Knowledge, Science and12Technology

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

17

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, 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 and models of knowledge production (5.3).

24 5.5.3.1 On-going trends

25 Access of farmers was arranged in USA through decentralized, integrated AKST and in Russia 26 and part of CEE through top-down "chain-of-command" with no public extension service (Miller et 27 al., 2000). Decline in public funding has been linked with even higher decline in public control of 28 AKST since the 1980s. The role of the private sector has increased in the management of public 29 funds and publicly funded and performed R&D, with a decreasing net flow of public funds to 30 private research (Alston et al., 1998). Due to privatization, there is less focus on farm-level 31 technologies and on equity and distributional issues and on public goods (Alston et al., 1998; 32 BANR, 2002) and less AKST is available in the public domain. Again on public support, only £219 33 million of the annual UK government subsidy of £3102 millions to agriculture (not including the 34 additional subsidies for foot and mouth disease) was used to create positive externalities (Pretty 35 et al., 2005). Farmers' influence and participation since WWII declined but has recently been 36 increasing (Romig et al., 1995; Walter et al., 1997; Wander and Drinkwater, 2000; Dik, 2004;

37 Groot et al., 2004; Morris, 2006; Ingram and Morris, 2007). However, technologies have sought to

1 increase the scale of food chain actors and the industrialization of the farm sector, and are less

2 appropriate for poor farming communities (Alston et al., 1998; BANR, 2002). The power of the

3 retail end of the food chain has increased, but whether consumers now have more influence is

4 open to debate (Buhler et al., 2002).

5 Since the 1970s, competition and short-termism have been penetrating in public AKST to 6 broaden its scope and make it more transparent and efficient (Alston et al., 1998; Buhler et al., 7 2002). We might ask whether economic efficiency has failed to reach its goal. (Buttel, 1986; 8 Huffman and Just, 1999, 2000) According to creativity research, extreme competition and lack of 9 safety are a serious threat to creativity and true innovation. Recently, governments have been 10 shifting towards funding multi-annual programs and long-term thematic areas with a considerable 11 stakeholder involvement in the process and stronger links among AKST components, to increase 12 efficiency and reduce fragmentation of solutions (OECD, 1999). The target is seen in innovative, 13 interactive AKST, and the role of AKST in becoming a partner by contributing to the decision-14 making processes rather than prescribing optimal solutions (OECD, 1999).

15 Drivers

16 A major driver for privatization (see also 3.4.1) was the shift in paradigms towards the recognition of markets as better regulators than policies. The consequent "laissez-faire" role of the 17 18 government in the management of the national economy (Alston et al., 1998) led to budget cuts 19 and to the protection of space for large private companies to act through regulations, e.g., 20 pesticide regulations and IPR (Bauer and Gaskell, 2000). Trade liberalization contributed to giving 21 more voice to transnational companies. Advances in genetics and intentional research policy 22 (Alston et al., 1998) enhanced control by the private sector. The failure of public AKST to serve all 23 the target groups might have left empty niches for private companies too. These developments 24 and the imposition of more targets for low-income countries as a precondition for support (e.g., 25 the increase of restricted funding for CGIAR; World Bank, 2003) left more room for NAE policies 26 after WWII also beyond NAE. The growing position of NGOs in AKST since the 1970s was a 27 reaction to negative externalities, which over and above the increased role of agri-business, again 28 contributed to short-termism and competitive grants. The re-emergence of longer term and bigger 29 programs was fostered by strife for governmental efficiency. A paradigm of "new public 30 management" increased stakeholder participation in the 1990s: no more, or less, government, but 31 better government, implying more enlightened regulation, improved service delivery, devolution of 32 responsibility, openness, transparency, accountability and partnership (OECD, 1999).

1 5.5.3.2 Uncertainties of the future

2 There are a number of uncertainties for the future of AKST access, control and distribution in

3 North America and Europe and thus for the impacts on development and sustainability goals at4 global level.

5

Privatization: Public goods, the poor and hungry, and rural livelihoods are target groups with the
least voice on the market at present, and the private sector is led by markets. Markets can be
directed to work for the social optimum through internalization of externalities, i.e., 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.

12

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 by helping the market forces to work for social optimum in terms of sustainability and food security? How will incentives to supply public goods through multifunctional farming be created: regulations, internalizing externalities by reallocating subsidies and taxes, creating new markets, e.g., for GHG emission quotas, or consumer certificates and price premia?

19

20 Integration of perspectives: Access, control and distribution of AKST does not only depend on 21 who pays, they also depend on the perspectives and competences represented in AKST 22 processes. There is evidence of reduced efficiency due to excessive introduction of competition 23 and short-term thinking in management of formal public science and development structures 24 (Huffman and Just, 2000). The risks of short-term thinking are especially serious with regard to 25 learning-intensive integrated approaches and sustainability objectives which have an inherent 26 long-term perspective. Will time-consuming and learning-intensive integration win the fight for 27 paradigm shift or become impossible in a context of potentially declining resources and growing 28 competition based on expert values, disciplinary quality and merit criteria? 29

30 Control by beneficiaries: The perspectives of solvent, large-scale industry might steadily be given 31 more emphasis in the knowledge networks if public funding declines and if there are no new 32 creative solutions to diversify perspectives. Multifunctionality of agricultural production and 33 diversification of marketing channels and actor networks could decrease dependence on one 34 market and thus give farmers and the supply chain a better position to negotiate with other actors 35 on the market. Locally-oriented AKST might require less public support to achieve influence and 36 outcomes equal to that of globally-oriented AKST.

37

1 Do policies, demand and formal AKST lead to diversification of supply and distribution channels

- 2 and thus increased independence from retail, mainly at the farm, regional or national level?
- 3 Will the responsibility be put on consumers and other actors, or will more emphasis be placed on
- 4 public control as a means to enhance sustainable consumption? Will the competence and
- 5 viewpoint of beneficiaries with the least voice in low-income countries, the poor and hungry, be
- 6 integrated in knowledge and technology generation in the world-wide influential NAE AKST, to
- 7 prevent past failures and to shape future food systems to meet D&S goals?
- 8

9 Dissemination of information: In a situation of increasing transfer of control from political decision-10 makers to the market, adequate, accessible market information is essential. Well-informed 11 choices by consumers and other food system actors through education of "food competent 12 citizens" is a precondition for promoting D&S goals through consumer choices. Appropriate 13 standards and price premiums create incentives. The option of different consumer segments to 14 influence on the market is not equal, but depends on their purchase power. In addition to 15 economic barriers there are social and psychological barriers for consumption (Jackson, 2005). 16 Will the dominant trend for down-sized, client-charged information to farmers continue with the 17 increasing niche being filled in by agri-business companies, or will there be a demand for 18 independent extension services? Or will the increasingly integrative approaches and structures 19 extensively incorporate clients in interactive communication networks to generate and utilize 20 knowledge and technologies and thus decrease the significance of separate extension services? 21 Will the opportunities offered by modern communication and information technologies be 22 successfully utilized to increase communication and enhance access to knowledge, technologies 23 and markets, avoiding further growth of the "digital barrier"?

24 5.5.3.3 Consequences for AKST

25 More and more agri-business companies are transnational, thus creating a risk of 26 homogenization of practices and less competitiveness for resource-poor farmers. Yet access to 27 knowledge, technology and resources requires participation in AKST processes through equal 28 dialogue, among the various beneficiaries, with their specific value systems, perspectives and 29 skills. This requires a shift from technology transfer approaches to interactive social learning 30 networks. Such a shift is easier to introduce in the more local than global agricultural innovation 31 systems. A word of caution: equity in the daily environment can hide the consequences of global 32 disparities. Global equity requires effective global communication networks based on modern 33 technologies and inter-regional global regulatory frameworks. Meeting D&S goals more broadly 34 will require the integration of varied perspectives of ecological, social and economic sustainability, 35 different parts of the food and non-food chains, and various stakeholders. More emphasis on 36 policies allows for effective internalization of externalities also in terms of D&S goals, while less 37 regulation requires more emphasis on education, information and standards and tends to lead to

1 lower market equity. Regionally and locally oriented AKST systems enhance transparency and

2 direct feedback from consumers, (citizens and communities), as well as from local ecosystems to

3 the production entities and thus complement regulatory and information systems.

4 5

5.6 Future AKST Systems and Their Potential Contributions to Sustainable Development

6 Goals

7 5.6.1 Four normative agricultural innovation systems

Despite on-going trends, there are many uncertainties about the futures of indirect and direct
drivers of AKST systems in North America and Europe. Sketching four normative futures shows
that there is no one best future because the future is a realm of freedom, power and will (de
Jouvenel, 2004) and depends on the strength of the actor(s). Not all options are compatible and
coherent. Choices will have to be made. Reality will probably be a mix of options.

13 5.6.1.1 Market-led AKST

14 The S&T policies of North America, the European Union and Russia and the non-EU Eastern

15 European countries converge and favor the private sector. Market-led AKST decreases hunger

16 and poverty and improves nutrition and human health in NAE and at international levels.

17 However, it contributes little to equity and sustainable economic development.

18

19 Multi-National Corporations (MNCs) in association with a few universities and small innovative 20 firms develop and fund most AKST. Elite research groups throughout North America and Europe 21 form technology clusters with firms. Research is not location specific. It is done where human 22 resources are the best. MNCs and a few universities control and sell most AKST. Important 23 research investments are made to support two markets: functional food for the high revenue 24 consumers and inexpensive safe food for the low revenue customers. International agricultural 25 knowledge centers conduct most public research. The European Research Space is a great 26 success. Centers of excellence at international level associate R&D public institutes and major 27 firms with the objective of developing new activities or markets through innovation. 28

29 Private companies benefit from strong intellectual property rights and the privatization of living

30 organisms. Legislation makes it possible for universities, non-profit organizations and small

31 businesses to keep ownership of intellectual property developed with the support of public funds.

32 Common regulations and standards are designed to facilitate generation and distribution of

33 knowledge. Tax incentives encourage companies to invest and to collaborate with each other and

34 with universities. Large vertically integrated firms own farm enterprises and control access and

35 distribution of inputs and capital.

36

1 As far as the generation of knowledge is concerned, production and problem-oriented

2 multidisciplinary work is encouraged. Despite managerial discourses on sustainable

3 development, AKST generated by MNCs does not prevent certain areas, such as marine

4 ecosystems and biofuels, from being left out of research agendas. Therapeutic successes and

5 widespread application of nanotechnologies lead progressively to a global conception of nature

6 and life. The frontiers between the different worlds of human beings, animals and plants are

7 fading.

8 5.6.1.2 Ecosystem-oriented AKST

9 In ecosystem-oriented AKST, there is no clear demarcation between university science and

10 industrial science, between basic research, applied research and product development, or even

between careers in the academic world and in industry. Ecosystem-oriented AKST can make a

12 major contribution to at least three development and sustainability goals:

- (1) environmental sustainability by the development of novel, knowledge-intensive and
 resource use-efficient technologies,
- (2) sustainable economic development, by investing human and financial capital in the
 development of "green technologies", and
- (3) enhanced 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.
- 20

Many subsidies and most trade barriers have been eliminated. Support payments reward farmers for the provision of services other than food. In the EU and North America, agricultural policies promote the multifunctional nature of agriculture and the improvement of natural resource quality through strict adherence to stricter environmental regulations. In Eastern European countries and Russia, governments and farmers' associations are conscious of the disasters created by excessive usage of agrochemicals combined with poor infrastructures. Drastic reforms are being implemented to improve environmental policies.

28

29 Laws facilitate the ownership of knowledge by all those who have contributed to this ecosystem-30 oriented AKST. Policies support increased scientific cooperation among NAE countries. Special 31 emphasis is on strengthening cooperation within NAE, especially EU and North America with 32 Eastern European countries and Russia. Innovation, public/private interactions and collaboration 33 with the less developed countries is also being encouraged. Researchers collaborate with a 34 broader range of organizations and disciplines. Problem-oriented, demand-driven approaches 35 prevail, and there is a great deal of research integration (multidisciplinary and interdisciplinary 36 work, systems approach). Incentives are being used to attract young students to science and 37 technology, especially the environmental and agricultural sciences. Efforts are being made to

1 promote new scientific fields in universities and to renew interest in important fields that have

- 2 been ignored.
- 3

4 AKST increasingly serves homogeneous consumer preferences and diets. Lifestyles and social 5 awareness are boosting the demand for convenience and functional foods. Although the demand 6 for organic products is going up, the new technical, convenience-led food solutions (e.g., ready-7 meals) clearly predominate. Efforts are being made to increase national and international budgets 8 for more research and cooperation world-wide concerning access, control and distribution of 9 inputs. Research investments are concentrated on global and regional centers of excellence 10 conducting both basic and applied research. Emphasis is on investments that support a 11 knowledge- and bio-based economy.

12

13 In the field of climate change mitigation and adaptation, policies related to spatial planning 14 stimulate the reduction of greenhouse gas emissions and protect NAE against climate change. 15 Spatial planning has led, for instance, to the diffusion of new technologies such as floating 16 greenhouses (e.g., in the Netherlands in response to the rising sea level), non-animal meats, or 17 low-emission animal farms (to avoid pollution) and roof farming (natural cooling in urban areas). 18 At the same time, conventional agricultural techniques are being further improved with 19 considerable effort to heighten resource use efficiency, especially for water, nutrients and energy 20 (precise provision in time and space). In many regions, farms specialize in either specific 21 livestock or arable farming, depending on their local soil and climatic conditions.

22

23 Relatively inefficient cultivation of biofuel crops e.g., rapeseed oil, barley, sunflower, has been 24 replaced by second generation biofuel production. Agriculture is both an energy producer and an 25 efficient energy consumer. However, the energy-producing capacity of agriculture is outweighed 26 by other more centralized and technology-intensive renewable forms of energy such as artificial 27 photosynthesis (combining sub-processes of photosynthesis), a favored source in large-scale 28 energy labs. Many farms are able to cover their energy needs and costs by producing biofuels 29 and installing eolian and solar parks on their fields. New knowledge allows for the sustainable 30 production of biofuels and innovative, environmentally-friendly farming systems.

31

32 Results from research into knowledge-intensive technologies supported by information

33 technologies (such as GIS, remote sensing, GPS-controlled robots, detailed soil databases, etc)

34 allow wide implementation of precision farming. Food processing is taking place in new energy-

and /or labor-saving forms, such as intelligent greenhouses (with virtually no labor) and multi-

36 story food factories - as developed in the Netherlands (agrometropoles). GMOs are widely

1 accepted (but less in EU-15 than in America and Eastern Europe) and play a significant role in

- 2 reducing pesticide use and emissions from agriculture to the environment.
- 3

4 Research is also done to better understand the concerns and circumstances that influence

- 5 consumer attitudes and choices. This information leads to better models of consumer
- 6 preferences. Advances in research improve the nutritional balance of foods and optimize
- 7 nutritional and genotype interactions in crops and livestock. Better understanding of the system
- 8 leads to improvements in regulatory frameworks.

9 5.6.1.3 Local food-supply led AKST

- 10 Local food-supply AKST is a multi-actor system with little coordination between organizations: the
- 11 AKST systems in North America, the European Union and the non-EU Eastern European
- 12 countries are very different from one another. The AKST systems manage to contribute to
- 13 improved nutrition and human health at national level, but most rural areas are driven by urban
- economies. The importance of agriculture in rural activity differs between regions. At the
- international level, AKST systems have little impact on hunger, poverty and environmentalsustainability.
- 17

18 No coherent research, innovation and IPR policies are designed in NAE, and the policies there 19 are, are not always consistent at the national level. Each country has its own distinctive

- 20 educational and cultural features. Efforts are being made to improve secondary education and to
- 21 put students through the first years of universities, but but not many students become science
- 22 majors. The quality and quantity of research personnel is deteriorating.
- 23

24 In most countries, the access, control and distribution of knowledge, science and technology 25 remains linear. Fundamental research, applied research, extension and education are done in 26 separate organizations. There is little synergy among the many different types of organizations 27 involved. A few large private companies have their own research capacities and are highly 28 integrated. However, as their investments are relatively small, they cannot influence the global 29 research agenda. In the USA and Canada, land grand universities are fading away because of 30 the competition for scarce funding. In the countries of the European Union, governments continue 31 to provide some funding for public research to avoid conflicts with farmers and researchers, but 32 funds given to KST in real terms are below what they were at the beginning of the century. Local 33 universities and public research organizations continue to provide public goods; however they are 34 often in conflict with private companies and accuse them of privatizing knowledge. In Russia and 35 non-EU Eastern European countries, AKST is not a priority; the little research that is done 36 focuses on the large-scale cereal-vegetable farming systems. 37

1 The size of holdings varies greatly which explains the great inequalities in access, control and

2 distribution of inputs and capital. Family farms are still the most prevalent, but they have limited

- 3 access to inputs and capital.
- 4

5 Knowledge generation mainly concerns conventional food production and protection. Except in

6 North America, little is done to investigate or use genetically modified crops and animals.

7 Research tends to ignore growing problems such as water scarcity, soil depletion and

8 socioeconomic viability of agricultural systems.

9 5.6.1.4 Local-learning AKST

10 Local learning AKST is regionally focused and proactive in meeting local development and 11 sustainability goals. It is a well coordinated multi-actor system that successfully integrates the 12 different goals at regional and local levels. It successfully contributes to the goals of enhancing 13 livelihoods, equity and social capital and environmental sustainability. Nutrition and human health 14 are improved through knowledge-based sustainable, fresh and safe local diets and a reduction in 15 meat consumption. Balanced regional economic development and stewardship of natural 16 resources are promoted by keeping the added value and employment of input production, 17 processing, transportation and marketing in the region and through investments in quality growth 18 and welfare services. Due to the local orientation, there is little exportation of products or 19 knowledge outside of NAE, but more resources of low-income countries are left untouched by 20 NAE so they can serve other purposes including the provision of food, fiber and fuel for their own 21 consumption. Nevertheless, many technologies developed for NAE could be appropriate for 22 resource-poor rural communities also in low-income countries. 23

24 Policies and governance are based on cooperation among different sectors, utilizing trans-25 ministry and public-private platforms, i.e., regional food, agriculture, health, environment, rural, 26 trade, and KST policies are fully integrated. Development is knowledge-intensive, and the 27 importance of science policies is widely recognized. Environmental policies are increasingly 28 focused on local and regional issues rather than on global change issues. Agricultural policies 29 allocate subsidies to internalize positive ecological, socio-cultural and economic (widening of 30 spatial and temporal scales) externalities. Diverse and flexible financing and credit systems 31 flourish, and rural capital is primarily addressed to serve local/regional rural needs. Systems to 32 balance regional imparities in capital supply are being created. Global issues are being 33 addressed thereby enhancing understanding through world-wide regional networks and, 34 consequently, learning from and developing local solutions. Intellectual protection is not strict, and 35 therefore many research results are available for less developed countries, and gene resources 36 are owned by local communities. National and international trade is open, but the effects of

37 internalized factors pertaining to climate and energy resources push up transportation prices.

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1 Intensive use of modern communication technologies and rural and nature tourism can replace

2 long-distance traveling and, furthermore, broaden the mindset and provide entertainment.

3 Regarding development collaboration, each sub-region of NAE has close links to its neighboring

4 countries to the south. Universities and the private sector are encouraged to pool patents through

5 licensing, moreover licensing is free for the developing world.

6

7 The agrifood system actors (producers, traders, processors, waste managers, input producers, 8 financers, institutional kitchens and private consumers), together with citizens, NGOs 9 (representing public goods), municipalities, county agencies and scholars form an interactive, 10 open learning network with different platforms designed for different needs. These networks are 11 connected with the networks of other regions of the world on the basis of interests/needs/goals or 12 to connect actor groups/professions/competences. The regional networks work closely with 13 regional, decentralized university systems to develop local and regional agrifood systems. They 14 utilize the international knowledge networks and carry out disciplinary and interdisciplinary 15 research. The networks are linked with the boards of universities; they provide funds and 16 participate in formulating the agendas, planning and performing knowledge and technology 17 generation, and interpreting and evaluating results. The interactive networks ensure that the 18 generated knowledge and technology are highly relevant, locally adapted and socially contextual. 19 They also ensure that agrifood system actors have full access to the results and get the 20 necessary underlying understanding and technical knowledge from the universities. 21

22 Within the universities, disciplinary science communities and cross-cutting interdisciplinary 23 science communities utilizing the developments of disciplinary work, systematically interact with 24 trans-disciplinary stakeholder platforms. Research leads to collaborative, reflexive, democratic 25 processes to develop sustainable, local food systems. Progress provides the capacity to 26 internalize externalities such as food, fiber and fuel that enable consumers to make 27 knowledgeable choices. Purportedly open to all citizens, education emphasizes increased 28 understanding of different values and goals, the multiple impacts of food choices and 29 communicational and team working abilities. In scholarly education, attention is given to systems, 30 interdisciplinary and participatory approaches, a robust scientific-philosophical base and 31 conceptual tools to promote understanding of and communication across different disciplinary 32 paradigms. Advanced communication technologies are used at that level. Universities also 33 interact with actors from low-income countries to integrate their views in knowledge generation 34 and to strengthen their capacities. 35

AKST serves diverse, locally- and regionally-adapted, sustainable dietary and food, fiber and
 energy systems. Health and nutrition draw on a knowledge-based understanding of farming

1 systems and of local diets, composed of fresh, seasonal foods rather than gene-tailored,

- 2 functional food ingredients. Consumers appreciate the cultural heritage. They rely on and ensure
- 3 protection for the local and regional ecosystems, with their goods and services. Local bioenergy
- 4 and renewable energy-based, energy-efficient and integrated agrifood systems are being
- 5 developed and continuously improved. Predominant farming systems are based on biologically
- 6 fixed nitrogen, recycling materials (nutrient cycling) and energy flows within local agriculture and
- 7 as returns from the local demand-chain that includes processing, and from watercourses. Thus,
- 8 bioenergy, food and also wood production are integrated, and their waste is used for energy and
- 9 fertilizers. Small-scale solar and eolian energy sources are connected in the regional electricity
- 10 network. New plant and animal varieties are developed; those fit in with the integrated systems
- 11 and often carry the significant amount of diversity needed to adapt to different locations. Urban
- 12 agriculture is an inherent part of spatial and city planning. Regional and local food processing and
- 13 retailing outfits utilize farm- and waste-based energy and have local contract networks to
- 14 purchase inputs. Life-cycle and sustainability assessments are carried out on the impact of land-
- 15 use changes and features of production and food systems, but the emphasis is on direct
- 16 communication and feedback from local communities and ecosystems.
- 17

18 Local and regional markets that are being developed give special attention to energy-efficient 19 logistical arrangements. Different forms of community-supported agriculture, with shared risk and 20 labor between producers and consumers, food circles, farmers' markets and direct sales flourish 21 besides the horizontally integrated production-trade-consumption chains. The use of fossil energy 22 for transportation is reduced accordingly and the added value of the food chain is kept in the 23 region. Externalities are internalized, but that does not only depend on public regulation, taxation 24 and economic incentives with regional variation. An important part of internalization depends on 25 the proximity of different actors, mutual trust and social capital, and thus on direct communication 26 and feedback from the local socioecological context. Local labels embracing the whole chain are 27 being successfully introduced, and regional marketing ensures an adequate sales level.

28

29 5.6.2 Towards options for action

30 Choices about agricultural knowledge, science and technology (AKST) relate to paradigms,

- 31 investment, governance, policy and other ways to influence the behavior of producers,
- 32 consumers and the rest of the food chain actors. They will have powerful impacts on which
- 33 development and sustainability goals are achieved and where, both globally and within NAE. It is
- 34 unlikely that all development and sustainability goals can be achieved in any of these futures.
- 35
- Outlining these four normative agricultural innovation systems before proposing options for
 actions should help decision markers to make coherent choices. As Seneca wrote "There is no

- 1 favorable wind for the person who does not know where he wants to go." Knowledge about on-
- 2 going trends, uncertainties and possible AKST systems should help decision makers to choose
- 3 among options for actions presented in chapter 6. Appropriate AKST investments and policies will
- 4 require an appropriate mix of strategies that are in line with the potentials and constraints of
- 5 different NAE regions and countries, but they must also address the broader changes taking
- 6 place.