



Future Agriculture
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Future Agriculture

– Livestock, Crops and Land Use

A Strategic Programme for Research

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Preface

The future of agriculture, globally as well as in Europe, faces great challenges due to population growth, climate and environmental changes, and the limited availability of natural resources. The conditions for agricultural production of food, feed and fuel in Sweden are affected to an increasing degree by global and regional changes and events. The climate-change scenarios indicate an increasing production potential at northern latitudes, with great opportunities for Swedish agricultural production, but also indicate increasing risks for, e.g., new plant and animal pests and diseases, and extreme weather events such as heat waves, flooding, and draught. Scientific knowledge and new research approaches are required to meet these challenges.

“Future Agriculture – Livestock, Crops and Land Use”, is a multi- and interdisciplinary research programme initiated by the Swedish University of Agricultural Sciences (SLU). Within the programme, researchers together with the

agricultural sector, governmental agencies, and nongovernmental organisations will develop research on sustainable use of natural resources, with an emphasis on agricultural production and land use.

The research programme is hosted by the Faculty of Natural Resources and Agricultural Sciences but involves important contributions from the other faculties at SLU. As the programme evolves I foresee that alliances will also be built with other research institutions, nationally and internationally. I am confident that the Future Agriculture initiative will stimulate formation of novel research networks and collaborations that will develop innovative knowledge of the highest relevance and impact for the future of sustainable agriculture. ●

Kristina Glimelius

Dean of the Faculty of Natural Resources and Agricultural Sciences

Summary

The strategic programme for research “Future Agriculture - Livestock, Crops and Land Use” was developed within the SLU initiative Future Agriculture. The programme is both multidisciplinary and interdisciplinary. Working to a time horizon of 40 years, it outlines future challenges and research issues connected with sustainable food production and land use.

Six overarching challenges for agricultural research were identified:

- Reduction of the environmental impact of agriculture and mitigation of climate change
- Responses to societal values and contribution to policies
- Adaptation of agriculture to a changing climate
- Management of present and potential risks
- Agriculture and rural development
- Resolution of conflicting goals of agriculture and land use

These challenges must be addressed if food, and other products and services, are to be supplied sustainably to a growing world population. Key research issues are outlined, and examples of possible research questions are given in connection with each challenge.

The six challenges emerge from five future scenarios, each with a global and a regional (European) part. The scenarios have been developed through a structured process of morphological analysis guided by the Swedish Defence Research Agency (FOI). The process of identifying future challenges and research needs involved researchers and repre-

sentatives from the agricultural sector, governmental agencies and non-governmental organisations.

The Future Agriculture programme emphasises the importance of initiating and fostering multi- and interdisciplinary research while at the same time strengthening disciplinary research within the agricultural sciences. It aims primarily to identify research needs connected with the development of sustainable and efficient food production and land use systems, but it also seeks to improve coordination and strengthen cooperation both within SLU and between SLU and other universities, research institutions and stakeholders.

The document outlines arrangements through which the multi- and interdisciplinary research goals of the programme can be furthered. These involve the formation of teams in which researchers from different scientific areas and representatives from different stakeholder groups participate. The task of the teams will be to develop research issues and questions, and to initiate syntheses and analyses of current and new knowledge. In addition to strengthening agriculture research, it is hoped that the programme will inspire scientists to build new collaborations, facilitate joint applications for research projects, and inform educational initiatives. It could also serve as background material in strategic discussions within and between different interest groups, including research funding agencies, the agricultural sector, governmental and non-governmental organisations, and academia. ●

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Introduction



How to feed the world in the future, in a sustainable way, is the largest challenge for mankind. This is reflected in the overarching UN millennium development goal (MDG 1), which is: “to halve extreme poverty and hunger from 1990 to 2015“ (UN, 2000). Obviously agriculture will play a key role in reaching this goal. Equally obvious is the fact that agriculture, as well as trade and the distribution of food, are global businesses. Therefore, local and regional agricultural activities and food markets must be considered in a global context.

The research initiative Future Agriculture is a multi- and interdisciplinary research programme focusing on future food production and land use. The focus is on agricultural research tasks that are central to the Swedish University of Agricultural Sciences (SLU), although it is recognized that some of these would gain a strong leverage from partnership with other universities and research institutes. The programme should deliver new, internationally significant, scientific knowledge and support the synthesis of knowledge. Future Agriculture is also intended to be a key partner in the dialogue both within academia and between academia and other sectors of society, and to provide knowledge on which policies and decisions can be based. Another important task is to train a new generation of agricultural scientists with global as well as local perspectives, thereby contributing to sustainable

development. The programme should also be a source of inspiration to those involved in education, and environmental monitoring and assessment, at SLU, although these aims are not specifically addressed here.

This research programme deals with scientific issues relating to agriculture and food production, including livestock, crops and land use. It takes as a starting point five future scenarios. These scenarios have evolved from a structured process in which researchers and representatives from the agricultural sector, governmental agencies and non-governmental organisations, hereafter called stakeholders, have been involved. First, European agriculture was examined in a global context. Then, the Swedish situation was analysed as an integrated part of European developments. Obviously, the issues are very different depending on whether the system boundaries are set at farm level, vis-à-vis the landscape, within national

borders, regional boundaries, or globally.

Several drivers influence local, regional and global agriculture: changes in demography (Sharma, 2007), armed or other conflicts (Harroff-Tavel, 2008), the availability and degradation of ecosystem services¹ and biodiversity (MA, 2005; Rockström *et al.*, 2009), changing climate (IPCC, 2007), the availability of energy and other resources (FAO, 2000), policies and politics (EC, 2010), pandemics (Tomley and Shirley, 2009), market volatility (OECD-FAO, 2010), technical development (IAASTD, 2009), and so on. Thus, several competences and scientific disciplines need to act in concert to position research on the future development of agriculture.

Research on the development of agriculture and food production must have a long-term perspective. It needs to embrace various changes in farming systems for crop and livestock production, as well as alterations in land use. The process of change in production systems and land use takes time. A time-horizon of about 40 years (to the year 2050) was chosen for this research programme. This timeframe encouraged the consideration of issues lying well beyond those arising today while remained sufficiently contemporary to engage stakeholders and scientists.

Here important research issues for sustainable food production and land use are outlined. The document can be used as the basis for setting research priorities at SLU and other organisations funding agricultural research. It is hoped that it will inspire scientists to enter into new collaborations and joint applications for research projects. The document

was devised by the steering group of Future Agriculture. Many other people have been involved and contributed to the programme through discussions of future challenges and research issues at workshops, seminars and other meetings.

¹Ecosystem services are the benefits people obtain from ecosystems. Many resources and processes are generated by ecosystems, including provisioning (e.g. production of food crops), supporting (e.g. pollination, pest control, nutrient cycling), regulation (e.g. carbon sequestration) and cultural benefits (e.g. traditional landscapes). (MA, 2005).

Box 1. A definition of multi- and interdisciplinary research

In this strategic programme for research the terms “multi-disciplinary research” and “interdisciplinary research” are used as described below (NAS, 2004).

In *multidisciplinary research*, which involves more than one discipline, with each discipline makes a separate contribution. Researchers work together on a common problem. However they part when the work is done, and the disciplines are not changed by the cooperation.

In *interdisciplinary research* scientists from two or more disciplines integrate their research (e.g. their techniques, perspectives, concepts and theories) to address issues whose solutions are beyond the scope of a single discipline or field of research. The interaction may forge a new research field or discipline.

Box 2. Sustainable development and sustainable production

Sustainable development ties together concern about the carrying capacity of natural systems with the social and economic challenges facing humanity. Conceptually, it can be broken down into three parts: social, economic and environmental sustainability.

The concept of sustainable production was introduced in forestry industry 350 years ago (Gamborg & Sandøe, 2005). At the Conference on the Human Environment (UN, 1972), the management not only of resources that are important for production, but also of biodiversity and ecosystems was included in the concept of sustainability. A further development of the concept was formulated in the report of the Brundtland Commission, *Our Common Future*, in which the needs of future generations are added (UN, 1987): “Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs. It contains two key components; (i) the concept of ‘needs’, in particular the essential

needs of the world’s poor, to which overriding priority should be given; and (ii) the idea of limitations imposed by the state of technology and social organisation on the environment’s ability to meet present and future needs”. In the 1992 Rio Declaration the need for a fair share of global resources between developed and developing countries was further stressed (UN, 1992).

Glavic & Lukman (2007) review sustainability terms and their definitions. The authors suggest the following definition of sustainable production: “Sustainable production is creating goods by using processes and systems that are non-polluting, that conserve energy and natural resources in economically viable, safe and healthy ways for employees, communities, and consumers and which are socially and creatively rewarding for all stakeholders for the short- and long-term future”. In Future Agriculture the goods mentioned by Glavic & Lukman are food and other products and services connected with livestock, crops and land use.

Scenarios for identifying future challenges and research issues

The focus of research is often on present-day and urgently upcoming issues. In this programme the strategy is to identify and engage with potential challenges of the future. To identify these challenges a thorough process was used in which five global and five corresponding European scenarios for 2050 were constructed (Öborn *et al.*, 2010). These scenarios are neither necessarily likely nor desired, but all of them are possible.

“Morphological analysis” was used to develop the scenarios. This method was developed for analyses of multi-dimensional, non-quantified problem complexes (Zwicky, 1969; Ritchey, 2006). With it, very complex problem areas can be disassembled into different factors which are analysed piece by piece and then combined in a structured way into different scenarios. This in turn allows for full traceability of the considerations made and makes it possible to check for internal logics between the different factors analysed. Morphological analysis does not require causal relationships between influencing factors to be understood; it is necessary only that the factors are related to each other in some

way. The scenarios were developed under the guidance of the Swedish Defence Research Agency (FOI), according to Ritchey (2006).

Eight main factors were analysed for the global scenarios (Figure 1). For each factor three to six variables were analysed. The factors “Distribution of power” and “Natural resources” incorporated four and five sub-scenarios, respectively. The factors analysed for these sub-scenarios are also presented in Figure 1.

In each of the global scenarios the situation in Europe was analysed in relation to the global factors and additional regional factors (Figure 2). For each factor between two and five variables was analysed. The factors “Human population” and “Natural resources” incorporated three and five sub-scenarios, respectively. The factors analysed in these sub-scenarios are also presented in Figure 2. In the European scenarios the factors “Climate change”, “Access to energy resources” and “Development and dissemination of new technology” were set as in the global scenarios.

The five scenarios are briefly described in Box 3.

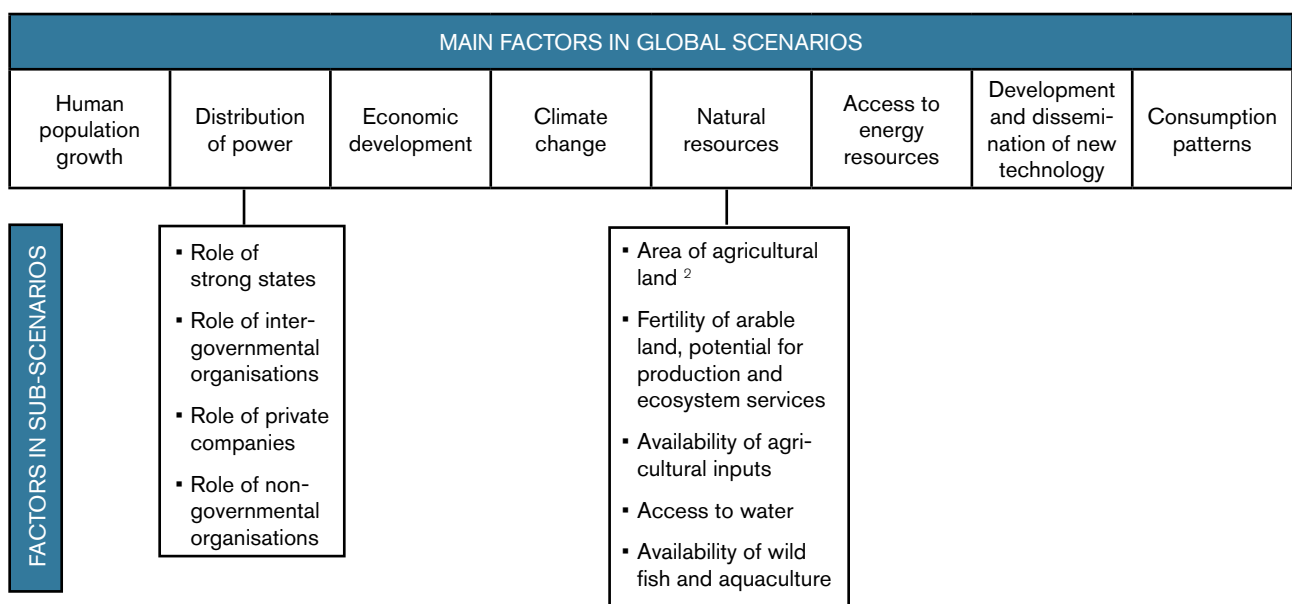


Figure 1. Factors analysed for the global scenarios.

² Agricultural land here is land suitable for agricultural production, both crops and livestock. Arable land is land in crop rotation, mainly under annual crops; it also includes land left temporarily fallow. Agricultural land covers 38% of the world's land area, with arable land representing less than one-third of that (11% of the world's land area). (WDI, 2008).

Extremely dramatic and unpredictable, high-impact events, such as global nuclear war and highly lethal pandemics, were not included in the analysis.

Three workshops were arranged with stakeholders and scientists from different disciplines. The scenarios were used as starting points to identify and discuss future demands,

gaps in knowledge and research issues. On the basis of the outcomes of the workshops it was possible to formulate six challenges for future agricultural research. Some of these were relevant in all scenarios; some were relevant in just one or two scenarios. Within each challenge several research issues were then identified. ●

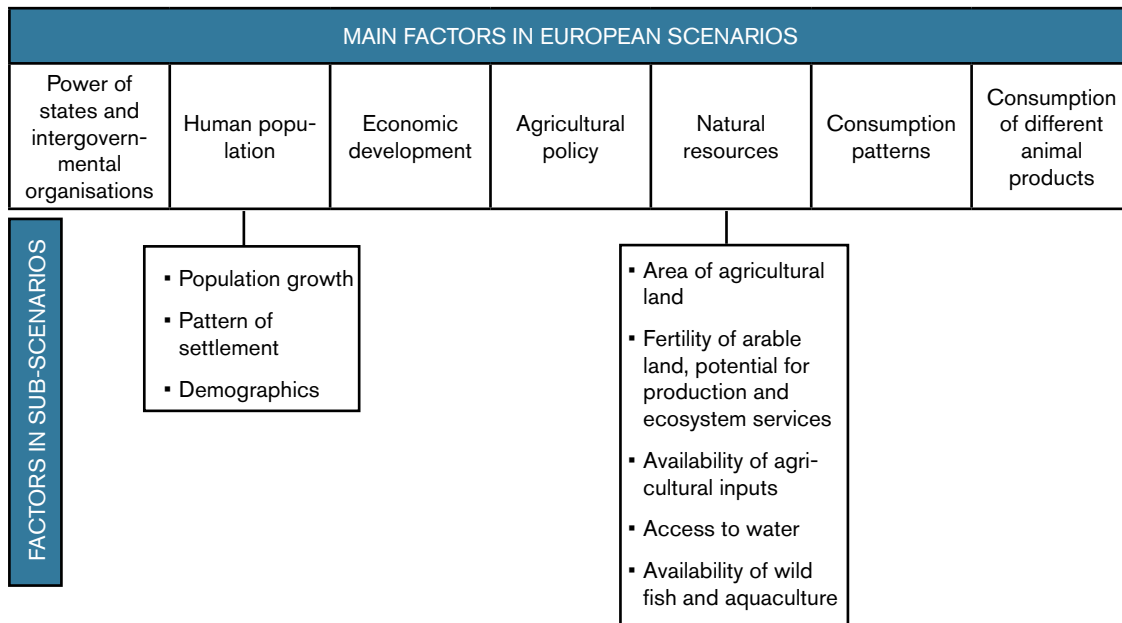


Figure 2. Factors analysed for the European scenarios.

Box 3. Future scenarios for identifying future challenges

This is a short version of the scenarios. The time-horizon is about 40 years (to 2050). See Öborn *et al.* (2010) for full description.

Scenario 1. An overexploited world

- *World population 11 billion*
- *Temperature increase 3–4°C*
- *Shortage of fertile land*

Population growth has exceeded the UN forecasts. Poverty is prevalent. There is a unipolar world order in which the USA dominates and the Western world is achieving strong economic development. Europe has a protected market and a well developed supranational institution. There are no political restrictions on energy consumption. The demand for land resources is high owing to the increased use of biofuels. This leads to the expansion of land areas used for agricultural production and livestock grazing. Soil fertility, water resources and ecosystem services are in decline as the result of overexploitation. The proportions of animal- and plant-based food are the same as they are today, both globally and in Europe. Urbanization is high in Europe and mainly occurs in major cities.

Scenario 2. A world in balance

- *World population 8 billion*
- *Temperature increase 1–2°C*
- *Global agreements and strong environmental policies*

Population growth has been slower than UN forecasts. Climate change is modest due to reinforced and efficient political activities. Economic development is strengthened in many regions of the world. Strong intergovernmental actors are reaching global agreements. Rapid technological development within the energy and agricultural sectors, together with an even distribution of new techniques, are a prerequisite of this scenario. Thus, pressure on land resources is relatively low. Soil fertility, productivity and the availability of ecosystem services are increasing, both in Europe and globally. Urbanization is high, but rural areas are also flourishing as a result of the development of businesses not based on proximity to cities. The proportion of animal-based food in the human diet is lower in Europe than today, and fish constitutes a higher proportion than at present.

Scenario 3. Changed balance of power

- *World population 8 billion*
- *Temperature increase 3–4°C*
- *Rapid technological development*

The global balance of power has been displaced towards India and China, where the economic development is very strong. The economy in Europe is stagnating, except in Eastern Europe where it has grown. The global economy is characterized by deregulation and free trade. Global population growth has dipped below UN forecasts, mainly because

of rapid economic development in Asia. Political ambitions regarding climate and the environment are low. There is good availability of fossil fuels (mainly coal), and the prices for these fuels are relatively low. The agricultural land area is about the same as it is at present, but it is being displaced towards the poles and the equator in response to climate change. The consumption of animal products has increased globally. Population growth in Europe is very high (20% increase to 2050) owing to migration. Urbanization is high, with both large cities and small towns are expanding.

Scenario 4. The world awakes

- *World population 9 billion*
- *Temperature increase 2–3°C*
- *Developed rural areas*

After a number of years of low environmental and climate ambitions the global community finally agrees on efficient policies. Several centres of power are balancing each other: North America, Europe, Brazil, Russia, China and India. The role of environmental and equal rights organisations is stronger than it is at present. Fossil fuels and other energy sources that do not require land resources dominate, but strong climate policies limit emissions. Environmental ambitions are high, so the rainforests are protected from deforestation. The availability of external inputs for agriculture is low, and prices are high. Agricultural land use in Europe has been redirected towards the East and the North following severe drought in the Mediterranean region. Both urban and rural areas are being developed.

Scenario 5. A fragmented world

- *World population 11 billion*
- *Temperature increase 3–4°C*
- *Weak intergovernmental actors and nations*

Population growth is high and has exceeded the UN forecasts. The absence of dominant nations or intergovernmental actors ensures that power relations are unsettled and that failures in international negotiations occur. Private companies dominate, and Europe is mainly self-sufficient in food. Technical evolution is slow and the distribution of new technologies is uneven. Fossil fuels (coal) dominate the energy market. The high food demand increases the need for agricultural land. Water resources are scarce, soil fertility and ecosystem services are decreasing. Population growth in Europe is extremely high (50% increase to 2050) following uncontrolled migration. This leads to high urbanization, with insufficiently controlled urban growth, both within city bodies and in form of "urban sprawl". The consumption of animal products is low as the result of poverty, both in Europe and globally, and the proportion of pork, poultry and eggs in the consumption of animal products is higher than it is at present.

Future challenges and research issues

Feeding a growing world population in a changing climate requires research that focuses on whole food production systems and stretches across disciplines within the agricultural, natural and social sciences, and the humanities. The Future Agriculture programme places a firm emphasis on initiating and fostering multi- and interdisciplinary research to facilitate sustainable food production and land use. The programme will also strengthen disciplinary research within the agricultural sciences.

Land, crops and livestock are the basis of food production in all agricultural systems. Agriculture is a part both of society and of an ecosystem that may be more or less extensively influenced by this society. To develop sustainable food production we need to address a set of challenges scientifically, as illustrated in Figure 3.

Six major challenges that need to be overcome if food, other products and services are to be provided in a sustainable way for a growing world population were identified:

- Reduction of the environmental impact of agriculture and mitigation of climate change

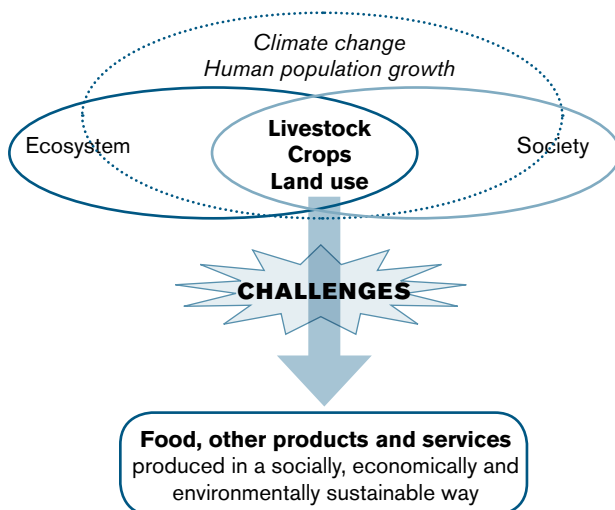


Figure 3. The context of the Future Agriculture research programme.

- Responses to societal values and contribution to policies
- Adaptation of agriculture to a changing climate
- Management of present and potential risks
- Agriculture and rural development
- Resolution of conflicting goals of agriculture and land use

Based on these challenges, gaps in knowledge were identified, and these gaps were used to generate research issues. A research issue may relate to one or several of the challenges. In the following paragraphs the research issues and examples of research questions are described for each challenge.

Reduction of the environmental impact of agriculture and mitigation of climate change

In several of the scenarios there will be considerable pressure on the resources needed for food production and on surrounding ecosystems. The scenarios differ in the strength of the policies for reduced green house gas emissions and the environmental impact of agriculture. The development of technology within the agricultural and energy sectors – e.g. resource efficient production systems and energy sources not requiring agricultural land – differs from one scenario to another. In some scenarios new technical solutions are available on a global scale. In others they are restricted to certain regions.

Improved efficiency is a key tool in reducing the environmental impact of agriculture. There is a need for research on high-productivity systems involving minimal waste of energy and materials. The recycling of nutrients and other materials within the farm, as well as between urban and rural areas, is also a central issue. An important question concerns the degree to which efficiency can be improved and impacts mitigated by integrated production systems (e.g. crops and livestock, or crops and trees) at farm, landscape or regional level, taking transport needs into account. The potentials and limitations of using new technology should be explored and evaluated for whole production systems. This requires an advanced understanding of agriculture as an ecological system, and an appreciation of the way technology can be used to reinforce ecological processes. It is closely linked to the question how agro-ecosystems can be managed sustainably,



and to the further question how biodiversity and ecosystem services can be used and valued in the short- and long-term. Research is also needed on how to decrease land degradation and greenhouse gas emissions from cropping and livestock systems, and this research must consider the transport of inputs and products. The triple linkage of usages of energy in production, transportation and for consumption should also be investigated. All of this must be combined with measures to ensure animal welfare and health, crop protection and product quality.

If global warming is to be mitigated effectively it will be necessary to develop a better understanding of how human consumption patterns affect the climate. It is also important to develop assessment tools for evaluating new production systems. This requires new methods designed to address the synergies and conflicts of multiple goals on different scales. In addition, the environmental and climate impacts of structural changes in food production systems, resulting from changes in agricultural sector, and from market and consumer demands, need to be better understood.

Examples of possible research questions within the

challenge are listed below. Note that other research questions also may be relevant.

- Exploration of sustainability and efficiency indicators.
- How can sustainable production systems with minimal use of non-renewable resources be designed? Analyses of historical, current and future production systems.
- Potentials and limitations of the recycling of nutrients, e.g. nitrogen and phosphorus, between agricultural and urban areas.
- Prospects for improved animal health, reproduction and longevity as means to reduce environmental impacts.
- Methods for decreasing greenhouse gas emissions and land degradation from crop and livestock production systems.
- Evaluation of the environmental impact of small-scale versus large-scale production of various agricultural products and aquaculture.
- Economic and ecological valuation of biodiversity and different ecosystem services.



Responses to societal values and contribution to policies

While the scenarios all involve population growth and rising temperatures, they differ greatly with regard to the extent of these changes. However, all scenarios involve changes in power relationships between global institutions, governments, private companies, non-governmental organisations, religious and political movements, and so on. All scenarios allow for the possibility of global or local scarcity of agricultural products or resources. These changes can both influence and be influenced by various societal values – e.g. ethical and political values, such as equality and human rights, ideological or religious values, or different views about animals, nature and the environment.

Sustainable development of the agricultural sector requires research that helps us to understand different under-

lying sets of values, their origin, justification and implications. Such understanding requires a number of approaches – e.g. empirical studies of attitudes to different types of agricultural production system and prospective studies of consumers', producers' and politicians' valuations of, and fears about, new technologies in food production. Which factors influence consumers' food preferences? How important are consumer choices in the sustainable development of agriculture? The research should include analyses of the way societal values affect the choice and development of new food production systems, and also of how past and current systems influence societal values.

An important area of bioethical research considers the normative status of different forms of food and energy production, examining the issues from a local and a global perspective. Research on the political process leading to international, regional (e.g. EU) and national agreements and policy instruments is also needed, as is research into the effect of these policy instruments at different levels.

Examples of possible research questions within the challenge are listed below. Note that other research questions also may be relevant.

- Ethical issues regarding food production and environmental impact – e.g. imports of cheap food and exports of pollution.
- Perceptions of risks and benefits of various agricultural technologies and practices, and predictors of the acceptance of new methods.
- Consequences of increased food prices on the consumption patterns of various population groups.
- Local and global consequences of policies designed to increase self-sufficiency and local food production versus free trade policies.
- Connection between perceived added values – e.g. high animal welfare – and consumers' food choices.
- Ethical questions arising when society invests in new food production techniques: What if the techniques do not deliver what they promise?

Adaptation of agriculture to a changing climate

All scenarios assume at least moderate global warming of the kind that will alter the conditions for agriculture and food production both globally and regionally. Droughts in areas where water is already limiting production will become more prevalent and severe. In other areas floods and extreme weather events will become more frequent. Pests

and diseases for humans, livestock and crops may be more common and spread to new areas and regions of the world. There is a high risk of new pests and diseases emerging due to climate change. At the same time demand for agricultural products will increase in all scenarios because of the growing global population. Furthermore, food preferences will shift toward more products of animal origin. In several scenarios aquaculture is expected to increase.

The adaptation of agricultural production systems to more variable and changing climatic conditions, in combination with increasing global population and food demand, calls for new knowledge of the vulnerability and adaptability of production systems. Emerging research issues are related to the need for crop species and varieties and livestock breeds that are adapted to new climatic conditions such as higher temperature, longer periods of drought and extreme weather events. This requires new methods that combine classical breeding and modern biotechnology, as well as reliable information on the function of whole organisms and populations in real production systems. In addition, new species may be domesticated, for example, to utilize marginal areas efficiently or to use organic waste as animal feed.

New climatic conditions also require research into resilient production systems that increase resource use efficiency and production on existing agricultural land while maintaining biodiversity and ecosystem services. Research into the management of emerging pests and diseases in crop and livestock production will be a priority area. Innovative production systems and technologies are needed to maintain and improve animal welfare and plant health under new climatic conditions. Novel and adapted production systems are needed – at different scales – where the research includes highly specialized as well as diverse and integrated systems for crop, livestock and energy production. It is especially important to develop systems that combine efficient water use and the recycling of nutrients with low susceptibility to known and future pests and diseases.

Climate change may open up new opportunities, and the prospect of utilizing longer growing seasons at northern latitudes efficiently should be explored. Research on new land-use options, and its consequences, is needed in these areas to explore the potential advantages and disadvantages of more land being taken into different types of agricultural production.

Examples of possible research questions within the challenge are listed below. Note that other research questions also may be relevant.

- Novel production systems (e.g. crop- or integrated crop-livestock systems) which are efficient with regard to nutrient, water and energy use and safe recycling.
- Genetic screening and breeding of crops with higher water-use efficiency and animals with increased heat tolerance.
- Understanding the dynamics and management of emerging pests and diseases in different climate scenarios.
- Assessments of adaptation potential and resilience of different production and land-use systems using novel and existing assessment tools.
- What is the potential to expand the land area for agriculture, including management of land for crops or pasture, under different climate scenarios?
- How can planned and non-planned biodiversity be used to adapt agro-ecosystems to changing climate?

Management of present and potential risks

Since all scenarios assume increased human population globally, greater demands will be made on food production – although in different ways. The power of an intergovernmental organisation such as the UN varies in the scenarios, and this affects the possibility of handling risks at global and regional level. In addition, global warming is expected to increase the frequency of extreme weather events, with both droughts and floods becoming more common; and it is predicted that global warming will increase the risk of diseases and pests emerging in humans, livestock and crops. Urbanization along with increasing animal production may, in several scenarios, further increase the risk of pandemics spreading from animals to humans. In some scenarios the free movement of food products across the globe is restricted by regional policies, regional conflicts, or efforts to restrict the environmental impact of, for example, transport and energy use. Poor food security and hunger increase the risk of social unrest and local conflicts.

The research issues in this area range from risk assessment, via risk management to risk perception and communication. Several types of risks can be identified. First, risks threatening food security as such are emphasized. Secondly, there are the risks connected with current as well as future food production for public, animal and ecosystem health, and for ecosystem resilience. Agricultural research on the ways in which food production can increase globally essentially relies on leaps into the unknown. One cannot safely assume that technologies yet to be developed will bring about increases in food production. Thus there may be risks both in



refraining from using, and in using, advanced forms of novel technology. Similarly, the application of, or failure to apply, new farming systems may generate risks. The same is true for the reliance on ecosystem services in agriculture: what are the risks of increasing or decreasing such reliance in the future? The research issues are therefore designed to feed these aspects of agriculture into risk assessment; to analyse how the subsequent risk management should be performed in a way that is optimal for sustainable development; and to improve our understanding of the constraints and possibilities governing efficient risk communication.

Examples of possible research questions within the challenge are listed below. Note that other research questions also may be relevant.

- Methods for analysing resilience and the adaptability of production systems in order to decrease risks of production failure or ecosystem collapse.
- Assessment of the risks associated with use, or refusal to use, new production techniques such as GMO or high-technology animal production.

- Is there a risk of path dependency in production systems, so that choosing one system on a large scale will make it difficult to choose another in future?
- Analysis of risks arising in production systems under extreme climatic situations.
- Risks of emerging pandemics in humans and animals under different farming systems.
- Risks associated with patents and concentrated ownership within the food production chain.

Agriculture and rural development

In all scenarios the global trend of urbanization continues. This trend brings with it increasing urban and peri-urban farming, with their inbuilt opportunities and risks. However, the scenarios differ in the degree of urbanization they assume, and in the political willingness to provide conditions supportive of development in rural areas. In some scenarios deregulation and free trade further lower the need for employment within agriculture and food production in Europe. In others increased agricultural production in Europe is an outcome of stronger climate and environmental policies at

the global and regional level. In the scenarios this is connected with a willingness to support rural development.

The research in this challenge will look at ways in which changes in agricultural and food production systems may affect rural communities and the rural economy. One research issue is how new forms of land tenure and natural resources management may contribute to social transformations. Research is also needed on the way increased competition for land-based resources affects producer prices and the economy in the agricultural sector. This could lead to more large-scale and specialized production, or to the integration of production in new kinds of constellation of ownership and collaboration.

Further, research is needed on the interaction of urban and rural areas through flows of natural resources, goods, energy, emissions, ideas, capital, and people. How are rural areas affected by the development of new technologies and changes in commuting, migration, and other transport patterns? Another issue is how to combine economically desirable and socially sustainable development in rural areas with food security in cities. The challenge may also incorporate studies looking at ways in which future developments in agriculture and food production are likely to contribute to people's livelihood and quality of life in rural areas – studies that would focus on, among other things, employment opportunities, the availability of services, transportation and communication infrastructures, and cultural and leisure opportunities.

The research addressing the effects of different policies on rural livelihoods will look especially at agriculture production and natural resource management. This raises questions about how best to support rural entrepreneurship. It also points toward questions about the kinds of policy, incentives and regulations that would protect the environment and enhance ecosystem services. There is growing political emphasis on managing whole landscapes and watersheds to obtain public goods while minimizing environmental impact. How to support collective action among landowners and other users of the agricultural landscape needs to be better understood. More research on the communicative aspects of handling multiple claims relating to land use is needed, as is research on communication and collaboration leading to the development of knowledge that can be applied in practical production, and natural resource management, settings.

Examples of research questions within the challenge are listed below. Note that other research questions also may be relevant.

- How is rural entrepreneurship affected by changes in

agricultural production systems and changes in land use? What opportunities and problems arise, and how do actors handle these?

- How do changes in the agricultural sector offer opportunities to men and women, minorities and immigrants, and what is the impact of inter-generational succession?
- Will future transport systems and patterns strengthen, or be a burden on, rural development?
- How will rural-urban relations and flows be affected by changes in such factors as production and transport patterns and by environmental considerations?
- How do land ownership and property rights affect the sustainable use of resources and rural economy?
- How can communication and collaboration leading to the development of knowledge applied in practical production and for natural resource management be improved?

Resolution of conflicting goals of agriculture and land use

The sustainable production of food for between 8 and 11 billion humans will inevitably involve severe conflicts among the goals of individuals, groups in society, and regions with different interests and resources. Water and land-use conflicts will be more or less severe in all scenarios and involve different sectors, such as agriculture, forestry, mining, energy production, infrastructure and urban development. High levels of food production, low environmental impact, and biodiversity conservation, come into conflict in some scenarios. Good animal welfare and low emissions to air and water might also be in competition.

Central research issues involve the trade-offs between different kinds of land use, the utilization of resources and environmental goals. The conflicts also encompass productivity, climate impact, and biodiversity, as well as animal and human welfare and health. For example, crop production for consumption may be traded against the use of land for animal feed crops or bioenergy production. Water scarcity may increase, which emphasizes the need for research on how to resolve conflicts over water use locally, and regionally, by developing technology or through deliberation. When the environment is concerned, conflicts between goals when using different production techniques or land management systems need to be analysed. There is a need for new methods of analysing the trade-offs between goals with different currencies – e.g. biodiversity versus greenhouse gas emissions versus human health. While many trade-offs need to be analysed quantitatively, and in a multi-dimensional context,

good choices for society will require interdisciplinary understanding and analysis.

The predicted global scarcity of arable land is likely to exacerbate the conflict between urbanization and agriculture, as cities often are situated in the vicinity of good arable land. Can targeted investments in efficient urban farming alleviate this kind of conflict, and how can urban planning incorporate the need for small-scale production? A central issue is whether multiple-use or multifunctional systems can be used to resolve land-use conflicts and increase total output – e.g. agroforestry, combinations of forest and livestock production, or simultaneous production of energy and food. To what extent are such integrated systems better, in terms of producing food with less environmental impact, and how can novel integrated systems be developed on different scales – e.g. on individual farms, in connection with landscapes and across whole regions?

Examples of research questions within the challenge are listed below. Note that other research questions also may be relevant.

- Evaluation of conflicting goals regarding the environmental and social impacts of local or global food production.
- Resource conflicts among different users of land and water. How does one user affect other's opportunity to use the same resource?
- Conflicts in peri-urban areas; the needs of agricultural production versus those of urban areas in growing cities.
- How to deal with land-use planning and regulation in multifunctional (multiple-use) landscapes effectively and with participation.
- Conflicts between the interests of landowners or land managers and society, and possible solutions.
- Sustainability, predictability and the management of multiple ecosystem services – analyses of trade-offs and conflicting goals. ●



Development of the programme

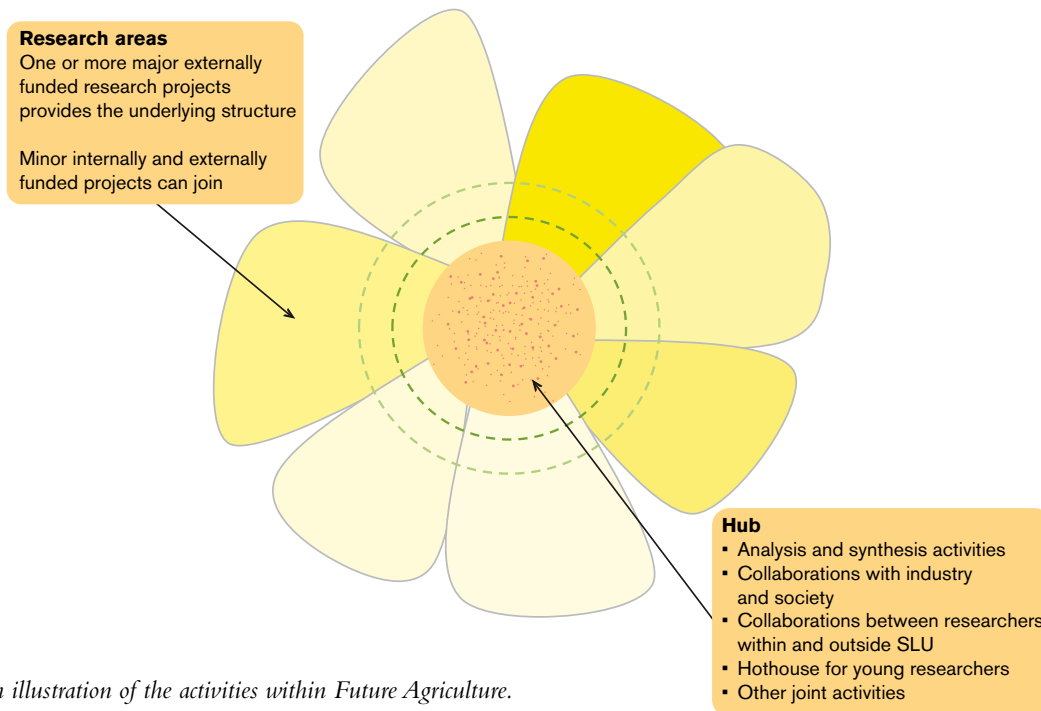


Figure 4. An illustration of the activities within Future Agriculture.

This strategic programme broadly outlines future challenges and research issues connected with sustainable food production and land use. Examples of possible research questions are also listed. The aim of these questions is merely to stimulate further thinking. The next step is to develop the research issues into research projects within which the relevant research questions and hypotheses can be formulated and tested.

To facilitate the multi- and interdisciplinary research environment that the programme is orientated towards, teams with researchers from different scientific areas and representatives from different stakeholder groups are formed. The task of the teams is to further develop research issues and questions that are highly relevant to the future, and to initiate syntheses and analyses of current and new knowledge. The work of these teams will improve coordination and strengthen cooperation both within SLU and with other universities, research institutions and stakeholders. Ideally it will result in scientific, peer-reviewed and popular publications, and in research applications and projects.

The research in Future Agriculture will be organised in thematic research teams and projects addressing research

issues relating to one or more of the identified challenges. The teams will meet in the “hub” where the work is coordinated and reviewed, and where new initiatives can be formulated and discussed (Figure 4). In the hub synthesis of cross-cutting issues, and workshops and seminars of general interest for future agriculture, will also be initiated. It is also possible for projects evolved in parallel with Future Agriculture to participate in the programme and integrate their research within the framework of Future Agriculture.

One important task for the programme is to develop interaction between the university and stakeholders. This has started already. Interaction began when stakeholder representatives participated in workshops discussing challenges and research issues for future agriculture and land use based on the future scenarios. The outcomes of these workshops form the basis of the programme. The participation of stakeholders in the evolution of the research programme will continue through the external reference group and in the teams described above. Seminars and workshops are also vital meeting points between scientists and stakeholder representatives. Information about Future Agriculture is also available on the web.

Another priority of the programme is to develop a “hothouse“ for young researchers (PhD students and post docs). Multidisciplinary seminars and workshops are examples of the kinds of activity that will take place in the hothouse. These activities should complement the work taking place in the Research Schools initiated by the faculties.

An organisational and management structure, and a communication plan, have been established for the programme. These will be revisited annually and further developed as the Future Agriculture research programme evolves.

This document was written to facilitate research priorities at SLU and other organisations funding agriculture research. Ideally, it will inspire scientists to build new collaborations and write joint applications for research projects. The five scenarios and the six scientific challenges and emerging research issues can also be used as background material in strategic discussions within departments and research groups. The scenarios could also be used in education, and in environmental monitoring and assessment, when future knowledge needs are being discussed. ●

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Future Agriculture
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This document outlines research issues for sustainable food production and land use in the future. It can be used as a basis for assessing research priorities at the Swedish University of Agricultural Sciences (SLU) and by other organisations funding agriculture research. It is hoped that it will also inspire scientists to enter into new collaborations.

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