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on Agricultural Research (SCAR)

The 3rd SCAR Foresight Exercise

Sustainable food consumption and production in a resource-constrained world

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EXECUTIVE SUMMARY

The 1st SCAR Foresight Exercise (FEG1) identified four scenarios pointing to declines in fossil fuel, land, water, biodiversity, energy availability and ecological services, and increasing world population, demand for food and feed and growing climate change impacts. The 2nd SCAR Foresight Exercise (FEG2) put more emphasis on the socio-economic driving forces and on the different paradigms underpinning our knowledge and innovation system. The purpose of the 3rd Foresight Exercise (FEG3) is to update the state of some critical driving forces and to focus on the transition towards an agricultural and food system in a resource-constrained world, given the likely critical importance of those driving forces. Its aim is to provide building blocks for longer-term perspectives to prepare a smooth transition towards a world with resource constraints and environmental limits and to guide agricultural research in the EU and its Member States. The report is organised as follows:

Chapter 1: Introduction

Between now and 2050, growth in global population and changing diets in emerging countries are projected to bring about a 70% increase in food demand as an average of the different possible scenarios analyzed. Simultaneously, depletion of fossil hydrocarbons will increase the demand for biofuels and industrial materials, which may compete with food for biomass. At the same time, natural resources are being depleted and climate change is pressing the agenda. Sustainable development considerations still remain under-represented in the policy-making process. Thus, the question and practice remain on how to best create a systematic and iterative method within the policy process for ensuring that resource consumption and pressures on the environment do not increase at rates which will eventually result in human and environmental catastrophes. This is the background against which the EU Standing Committee on Agriculture Research (SCAR) decided earlier this year to appoint an Expert Group (FEG3) to undertake a foresight study which would analyse expected environmental and resource issues impacting on long-term food security and the implications for future agricultural research in Europe. The objectives of the study are to:

- Provide long-term assessment and analysis of expected environmental and resource issues and their meaning for future agricultural research
- Prepare the ground for a smooth transition towards a world with resource constraints
- Consider the role the Knowledge-Based Bioeconomy (KBBE) can play in addressing these challenges
- Assemble basic building blocks for a long-term vision of more resilient and sustainable agriculture systems able to feed nine billion people by 2050.

Chapter 2: Methodology

This foresight study involves a meta-review of regional, national and international policy documents, scientific publications and foresight studies published mainly since 2009. It particularly looks at documents with a time horizon to 2050 and with a territorial coverage of the EU. The focus is on new insights — which can be new drivers, new dynamics, etc. — to identify potential risks, opportunities and likely future developments and challenges for agricultural research in the EU and its Member States. The key focus of the study is on those scarcities of natural resources and the resilience of the Earth´s life support system — land, water, energy, nutrients, climate, biodiversity- which will seriously impact on future food security. The analysis is conducted within the framework of two extreme narratives, which, of necessity, are simplistic and do not account for the full complexity of all issues. These frames are important, particularly as these narratives are often used to provide the assumptions and arguments for future technological developments and pathways.

Chapter 3: Main changes since FEG2 in 2008

The main changes since 2008 are that (1) there is a new quality of changes in the form of unquantified feedbacks amplifying changes, uncertainty and risks; (2) a new speed of changes, such that time itself has become the greatest scarcity and (3) the global political and economic crisis. These challenges differ in complexity, duration, scale and speed from any faced before. Due to the interconnectedness of the combined scarcity challenges and the limited understanding of the feedback loops, the future is more uncertain. In addition, we are ill-prepared to deal which such interconnected and highly dynamic issues. Time is running short to organize the necessary transitions and, in that sense, time too is a scarce good. Challenges must begin to be addressed at a time when the world is in the midst of an enduring economic and financial crisis, the depth and scale of which are still taking shape. The current crisis is helping to promote a new emphasis on economic growth that is decoupled from resource use. The need for a global approach to sustainable resource use is at odds with the trend of increasing protectionism and 'resource nationalism'.

Chapter 4: Two narratives

According to the *productivity* narrative, world population will increase to an estimated 9.2 billion people in 2050, while agricultural productivity has been slowing down over the last decades. Rising income levels in emerging countries will shift diets to include more protein rich food and will increase energy demand. At the same time, resource constraints and climate change severely limit the world's capacity to expand food production. Hence, there is a serious threat that food demand will not be met in 2050, leading to more hunger and political instability Scientific advances have the potential to bring forward technologies that boost productivity whilst addressing resource scarcities and environmental problems. To achieve this, massive investments need to be made in R&D, in speeding up technology adoption by farmers and addressing barriers in rural infrastructure, trade barriers and access to markets.

According to the *sufficiency* narrative, world population will increase to an estimated 9.2 billion people in 2050, which will lead to dramatic environmental problems as system Earth does not have the capacity to support expected rates of consumption. In addition, current food systems produce waste and over consumption leading to mass health problems. The destruction of important ecosystems will have dramatic feedback effects that undermine the foundations of our food systems, leading to more poverty and conflict. Scientific advances have the potential to bring forward technological solutions that are productive, reduce resource use and preserve biodiversity. However, to stay within the capacity of system Earth, demand increases need to be mitigated through behavioural change and structural changes in food systems and supply chains. Moreover, environmental externalities need to be internalised in markets through appropriate governance structures that also address the disruptive effect of unregulated trade.

Chapter 5: A picture of a resource-poor world

Rising resource prices in recent years, combined with increasing global demand for resources due to a growing population and increasing wealth, have brought the issue of resource scarcity to the forefront of the political agenda. A changing world order, globalization, the effects of climate change and the risk of irreversible loss of biodiversity in ecosystems critical for food production add to concerns about the future scarcity of resources and strengthen calls for new policies to deal with resource scarcities.

In light of agricultural production in a 30-40 years perspective, the following issues were identified as most critical: (1) "Classical" or "old" scarcities related to natural resource use: fertile land, freshwater, energy, phosphorus, and nitrogen, (2) "New" scarcities related to environmental limits that aggravate the "classical" scarcities: climate change including ocean acidification and biodiversity loss, and (3) Societal contributions that aggravate these scarcities but can also become important pathways for transitions to sustainable and equitable food consumption and production.

Many of today´s food production systems compromise the capacity of Earth to produce food in the future. This makes food security in the future highly uncertain. Globally and in many regions including Europe, food production is exceeding environmental limits or is close to do so. Nitrogen synthesis exceeds the planetary boundary by factor four, phosphorus use reaches the planetary boundary. Land use change and land degradation, and the dependence on fossil energy contribute about one fourth to climate change. Agriculture including fishery is the single largest driver of biodiversity loss. Regionally, irrigation exceeds the replenishment of water resources. Given population growth and increasing prosperity and the accompanying rise in consumption, we can expect ecosystem services and entire ecosystems such as coral reefs to collapse by 2050 if production systems and consumption patterns do not change. The various scarcities and their causes are characterized by many similarities and interlinkages. Therefore, an integrated approach is required to enable a transition to a sustainable world economy and society, which encompasses natural sciences, social sciences and improved governance.

Chapter 6: Transition pathways towards a sustainable food consumption and production system
Trends in *consumption* include the increasing variety of food consumption, changing habits and the divergence in diet between the rich and poor, leading to a health gap. The nutrition transition towards more meat-based consumption that is occurring in low and middle income countries has world-wide consequences for food supply and places major stress on natural resources, as well as on climate change. Evidence is emerging that a second transition occurs from a diet rich in animal proteins to one that is closer to health guidelines and that at the same time puts less pressure on the environment. A better scientific basis is needed for guiding food choices towards more health-promoting eating habits. Moreover, consumers need to be empowered to choose instead of being told what to eat and what to avoid, and food should be safe. Structural elements such as the food industry, the retail sector and the media play a key role in changing consumer habits.

Investment in technological innovation is critical in achieving the transitions required to make the food system more efficient and resilient to surprise. Trends in *technological innovation* are manifold: biotechnology, nanotechnology, ICT, agro-ecology, etc. Advances in these fields may both hold threats and opportunities. An overarching concept channeling these innovations is the Knowledge-Based Bio-Economy (KBBE), a concept that is a fusion between two concepts: knowledge-based economy and bioeconomy. However, in the KBBE concept, the human factor disappears and industry is considered the main player of the bioeconomy.

The transitions required to an economy which sustainably uses scarce natural resources also depends on the successful operation of some system of multilateral *governance* that will promote consultation and cooperation between nations. Innovations in governance, public policies, and organisations also seem also crucial at all scales in order to manage a rapid transition. Changes in the governance of food supply chains are particularly central, as recent trends show interesting transformations whose combined impacts on the sustainability of the food systems is difficult to predict. The increasing concentration of resources and power into a limited number of multinational corporations and the emergence of an agro-industrial model where food products tend to become services more than products might be combined in the future with other emerging trends such as corporate social responsibility and multi-stakeholder policy platforms.

As globalization intensifies, necessary food exchanges between regions of the world will increase, mainly because some regions like Asia or Middle East / North Africa will not be able to produce as much food as they will presumably consume under standard demographic assumptions. The governance and regulation of trade will therefore be at the heart of future food systems and food security, even in a scenario where maximum regional food self-sufficiency is sought for.

Transition pathways also rely centrally on the way *knowledge systems* are going to be managed. It is on this part of the system that the two narratives differ profoundly from one another, showing two different pathways of innovation. Each narrative represents a specific bet on what should be the best innovation policy for future challenges. The debate about innovation policy has to be informed by a thorough explanation of both possible pathways, their advantages and their pitfalls. The two options cannot just be combined with one another. A prudent but at the same time, anticipatory research and innovation strategy should be designed, trying to preserve all options open, but a system of watch should then be put in place in order to detect early warnings in order to choose the most appropriate and timely pathway of innovation.

Chapter 7: Implications for research

In light of the major new challenges and uncertainties, the IAASTD (2009) concluded that our existing farming systems and the knowledge system that supports them are no longer fit-for-purpose and that a new approach is called for. Such an approach must enable the world to raise the productivity of agriculture in a sustainable manner and increase the resilience of systems to deliver food security, feed, fuel, fibre and other ecosystem services under current and future climate and resource availability.

Continued and increased investment in relevant research and innovation at EU and national levels is critical in addressing the transition to new food consumption and production patterns that respect the interlinked global scarcities. In particular, the Expert Group recommends that the EU must prioritise the development of an 8th Framework Programme that will place a primary focus on resource-conservation and a sustainable and knowledge-based economy, which will secure prosperity and social participation for all citizens in the European Union. A better understanding of the complexities surrounding scarcities and how they are linked is essential to ensuring that decisions are made that are conducive to the emergence of a more sustainable world. The EU could aid in the development of this understanding by including specific lines on these issues in the 8th Framework Programme. The Programme should progress the transition towards a mission-orientation for European research aiming to solve, as the Lund Declaration (2009) states, “the Grand Challenges of our time” (global warming, tightening supplies of energy, water and food).

Necessary transformation will not happen in the short term, and in light of this, we propose that two parallel and overlapping approaches are needed to ensure the realisation of the elements of a long-term vision for European agriculture outlined above.

1) Towards sustainable intensification of the elements of food production systems building on existing technologies and knowledge systems: The Expert Group recommends that sufficient publicly funded research be maintained at EU and national levels to ensure the development and adoption of new technologies that will enable farming practices to meet the diverse challenges of sustainability and increased production demands. We would also recommend that increased support be provided for research on the economic and social dimensions of these new technologies and farming practices. Approaches that promise building blocks towards low-input high-output systems, integrate historical knowledge and agroecological principles that use nature´s capacity, should receive the highest priority for funding.
2) Developing radically new farming systems: “Systems are needed that enhance sustainability while maintaining productivity in ways that protect the natural resource base and ecological provisioning of agricultural systems” (IAASTD, 2009, p.5). Accordingly, we recommend that priority funding be allocated to integrated research and extension on farming systems that takes account of the interactions between productivity, environmental, economic and social sustainability goals and how such systems can be made more robust and resilient in the long run. Furthermore, in order to enhance two-way information exchange and strengthen adoption of new technologies, we recommend that new systems research programmes should involve participation by farmers or farmer-managed trials as one element. As these approaches only work if they are embedded in the regional context, they could be developed in pilot regions (cf. LEADER programmes). In general, this type of research does not attract private funding, so will need to be funded by EU and Member States.

In particular, research must pay renewed attention to the exploitation of feed resources in order to develop feed sources that are not competing to the same extent as they currently do with humans for food, in particular by taking advantage of the ability of ruminants to produce high quality products from grassland that is not suitable for other food crops and by maximising the use of by-products and co-products in non-ruminant systems.

Chapter 8: Conclusions
The fundamental building block of a vision for 2050 is that of "a world that is able to guarantee access and control of a growing population to safe, nutritious and culturally acceptable food and to manage the necessary balance between food demand, health and nutrition requirements and natural resources". Global systems for producing and distributing food must also be more resilient, more sustainable, and more equitable.

On the basis of the conclusions emerging from the analysis conducted in the foregoing chapters, we have derived a set of principles upon which our food system in general and research concerning our agriculture and food system in particular should be based:

1. Well-being and high quality of life of all stakeholders involved in food and agricultural systems , from producers to consumers.
2. Resource use efficiency and optimality by avoiding waste, recycling and reducing our footprint and by applying the cascading principle of resource contribution.
3. Resource conservation: to avoid the irreversible loss of natural resources, critical natural resources, including biodiversity, land and water should be maintained, taking into account the interaction between scarcities. Resources conservation does not only imply an increase of productivity in their use, but also a shift towards sufficiency.
4. Diversity and inclusion: food and agricultural systems should reflect the territorial diversity present within the EU and worldwide to ensure resilience and equity.
5. Transdisciplinarity: research and innovation underpinning future food and agricultural systems should fully integrate the various sciences, including the social sciences and humanities, but be also transdisciplinary, that is, fully integrating the end user into research and innovation.
6. Experimentation: research should be diverse, that is, ranging from blue sky research (fundamental research with no immediate applications) to applied research, but also based on different paradigms and narratives.
7. Coordination and impact evaluation: research should be better coordinated across thematic domains as well as Member States. At the same time, research impacts should be better monitored and evaluated.
8. Public involvement: strong public investment into research remains crucial to safeguard all of the previous principles.

A radical change in food consumption and production in Europe is unavoidable to meet the challenges of scarcities and to make the European agro-food system more resilient in times of increasing instability and surprise. Inspired by the fact that Europe is taking up the climate change challenge in industry and is intending to make new energy technologies a win-win-win strategy for market, labour and human welfare, the agro-food sector should now consider that there is an opportunity to positively take the challenge and be the first to win the world market for how to sustainably produce healthy food in a world of scarcities and uncertainty.

1. INTRODUCTION

"The Earth is the only world known so far to harbor life. There is nowhere else, at least in the near future, to which our species could migrate. Visit, yes. Settle, not yet. Like it or not, for the moment the Earth is where we make our stand." [1]

The 1st SCAR Foresight Exercise (FEG1) identified four scenarios pointing to declines in fossil fuel, land, water, biodiversity, energy availability and ecological services, and increasing world population, demand for food and feed and growing climate change impacts. The 2nd SCAR Foresight Exercise (FEG2, Brunori et al., 2008) put more emphasis on the socio-economic driving forces and on the different paradigms underpinning our knowledge and innovation system. It highlighted seven issues:

- The complexity of the new challenges,
- The underestimation of the rate of climate change
- The vulnerability of the food system
- The sustainable development challenge of agriculture and food systems
- The research and innovation needs
- The adequacy of the Agricultural Knowledge System
- The governance design

The purpose of the 3rd Foresight Exercise (FEG3) is to update the state of some critical driving forces and to focus on the transition towards an agricultural and food system in a resource-constrained world, given the likely critical importance of those driving forces. Its aim is to provide building blocks for longer-term perspectives to prepare a smooth transition towards a world with resource constraints and environmental limits and to guide agricultural research in the EU and its Member States.

The report is organised as follows. Chapter 2 introduces the methodology used and defines the key concepts used throughout the report. Chapter 3 lists some of the major changes since the previous report. Chapter 4 offers two narratives as lenses to analyze scarcities and transitions. Chapter 5 gives an update of the main scarcities that the agricultural and food system is facing in the next 50 years. Chapter 6 provides some transition pathways to deal with these issues. Chapter 7 discusses implications for research and chapter 8 provides some building blocks for developing a longer-term vision for agriculture.

[1] Carl Sagan, Pale Blue Dot, 1994

2. METHODOLOGY

This foresight study is a meta-review of regional, national and international policy documents, scientific publications and foresight studies published mainly since the 2nd foresight exercise, that is, in 2009 and 2010. It particularly looks at documents with a time horizon of 2050 and with a territorial coverage of the EU. In addition, documents relating to particular global hot spots and global foresight studies are also included. The focus is on new insights—which can be new drivers, new dynamics, etc.—to identify potential risks, opportunities and likely future developments and challenges for agricultural research in the EU and its Member States. Next, the various ecological drivers were scanned using the perspective of two main narratives that are used explicitly, but mostly implicitly, in many reports and policy processes. Combined with economic and socio-political drivers, transition pathways and implications for research are derived from these new insights.

We chose two extreme narratives, which are necessarily/purposefully simplistic and do not account for the complexity of reality. We show how much they ignore uncertainty and complexity in biophysical feedbacks but also in social systems. However, framing how we look at reality is important for the use of future technologies and practices, particularly as these narratives are often the implicit basis of assumptions about the future that underlie arguments about social and technological developments and pathways.

In this report we use a set of key concepts which we would like to define and explain up front.

Narrative: a narrative is a discourse based on a coherent set of assumptions and principles underpinning and communicating a certain worldview. Levidow (2008) defines narratives as having three elements: "descriptive accounts: claims about objective reality as threats, opportunities and imperatives; normative accounts: claims about necessary or desirable responses to that objective reality; policy instruments for carrying out those responses. Regardless of its stated aims, a dominant narrative succeeds in the normative sense of gaining resources and power, while pre-empting alternative futures."

Scarcity: "Scarcity means not only an observed shortage of natural resources, but also a perceived dependency on natural resources and fear of their global depletion. There are concerns about future availability, accessibility, utility value and distribution of resources" (Passenier and Lak, 2009, p. 17). Following the definition by Passenier and Lak (2009), we differentiate between "old" and "new" scarcities. "Old" scarcities refer to physical and biological resources (e.g., land, water, food, nutrients, energy, metals) that can fall short of supply, security (availability, distribution) or quality. "New" scarcities are "planetary boundaries" (Rockström et al., 2009), environmental limits or conditions that increase resource scarcities. We include here climate change and the loss of biodiversity due to the limited capacity of the system to absorb human induced stress. They increase resource scarcities. In a wider sense, time can be seen as a scarcity, too (Passenier and Lak, 2009). Often scarcities are more an issue of access and distribution than of supply. Scarcities are combined effects of physical boundaries, political, social, organisational, institutional and economic obstacles (Passenier and Lak, 2009). Important resources are in the hands of few and governance for an equitable access and distribution can be hampered by market imperfections, nationalism, conflicts or inadequate knowledge or capacity to act. While short-term scarcities cause disruption or crisis that may be tackled by organisational, political or technological means, long-term trends and structural developments in scarcities require a systemic response. There is a positive feedback mechanism between many scarcities (e.g., food demand – energy demand – fertile land – water – biodiversity – climate change). Scarcity is a societal concept, because scarcity depends on the level of demand. Scarcities include scarcities of natural resources, and scarcity of societal resources including time.

Transition: A transition is a process in which the existing system of structures, institutions, culture and practices are broken down and replaced by new ones. This shift is a non-linear process in which a system moves from one dynamic equilibrium to another one. Transitions thus concern large-scale processes that cover at least one generation with interactions between different scale levels (Loorbach, 2007; Loorbach and Rotmans, 2010). "Transitions are processes instigated to achieve long-term changes in systems so that potential scarcities around the world can be controlled. Transitions typically entail a wide complexity of interrelated developments in economics, culture, technology, institutions and the environment. They imply great uncertainty because the course they take is unpredictable and is influenced by exogenous factors" (Passenier and Lak, 2009, p. 27).

3 MAJOR CHANGES SINCE FEG2 IN 2008

Compared to FEG2 (Brunori et al., 2008), this Report takes a longer-term perspective up until 2050. While FEG2 focused on resilience, vulnerability and crisis, the current Report also focuses on scarcities. It also includes new scenarios that do not take demand for food and biofuels as an exogenous driver but include changes in the demand side in the solutions.

3.1. A new quality of changes: unquantified feedbacks amplify changes, uncertainty and risks

The main change since FEG2 is less the emergence of unforeseen new driving forces, but rather that we are confronted with a new quality of changes. The driving forces behind global warming are interconnected in many ways with environmental, social and institutional changes. Each of these driving forces will feed back and amplify the others leading to a non-linear system behaviour with abrupt and surprising developments. The challenges ahead differ in complexity, duration, scale and velocity from any faced before during human history. Crutzen and Stoermer (2000) introduced the term *Anthropocene*, which marks the beginning of the Earth as a self-organizing system driven by economic, environmental and social changes. New and typical is the interconnection of human and natural systems at planetary scale. Due to the interconnectedness of the combined scarcity challenges and the limited understanding of the feedback loops, in particular between human and natural systems and across spatial and temporal scales, the future is more uncertain. In addition, we are ill-prepared to deal which such interconnected and highly dynamic issues.

3.2. Scarcities: a new understanding of their complexities and interlinkages

A feature of today's concern is the attempt to understand the complexities surrounding scarcities, involving a number of different dimensions of scarcity, of the interactions between these different dimensions and between the different scarcities themselves. A better understanding of the complexities surrounding scarcities and how they are linked is essential to ensuring that decisions are made that are conducive to the emergence of a more sustainable world.

The high degree of interlinkages between various scarcities further compounds attempts at understanding and analysis. Future interaction between scarcities are shaped by complex feedback loops and by human efforts to mitigate them, making it difficult or impossible to predict how these linkages will develop in future (Evans, 2009). Most trends in scarcities tend to speed up or amplify trends in others. The interconnection between climate change, biodiversity and water is particularly complex and non-linear. Surprises and extreme events with catastrophic yield losses in world regions will become the rule rather than the exception.

3.3. A new speed of changes: time has become the greatest scarcity

We are living in the era of the "Great Acceleration" of technological, societal and environmental changes (Svedin, 2009). Many of the human pressures on ecosystems and the resulting perturbations to the earth system are growing exponentially. Climate change occurs faster than expected (Raupach and Canadell, 2010). Ecosystem services are much more severely degraded than expected. The survival of coral reef ecosystems is at risk through the combined effects of climate change and ocean acidification and coastal pollution (TEEB, 2009).

Of course, one might question whether changes are really faster than they were before or only faster than humanity had expected them to be. The important point is that many recent studies insist on the fact that scarcities in natural resources may be more constraining than we had imagined in the last decades.

Recent trends in uncertainty show clearly that risks are becoming higher (Evans, 2009, p. 49; Rockström et al., 2009). It seems clear that the situation for humanity will become much more uncomfortable in the next three to four decades. This acceleration of change, which is expected to increase, is of a new quality compared to FEG2. Yet the necessity to make our food system and societies more resilient to surprises has not yet impacted on political and private decision making.

3.4. Changes in the international situation

Since the last FEG2 some major changes have occurred in the international situation which are affecting the conclusions of the previous exercises.

The first issue is the one of the major economic, social, financial and political crisis that has affected all countries since 2007. Of course, we are still not able to assess clearly what will be the long-term effects of this crisis, but at least we can indicate that this situation has completely changed the visions and even values of policy makers and citizens.

The questioning about the capitalistic model is now more open although there is no alternative model proposed, except the one of "décroissance" (degrowth or ungrowth or nogrowth?). This notion frequently used in French is co-notated with a movement which is contesting the use and expansion of any technology, and the need to reduce drastically our consumption habits and our use of energy. In any event, the model is under discussion and even responsible politicians argue for an integration of social indicators in policy analysis.

The second main issue is the one of "Rising Asia". A recent foresight reporthas shown that this issue may be the most important one for the next 20 to 30 years (European Commission, 2009d). The basic assumptions are:

- In 2025, nearly two thirds of the world population will live in Asia.
- Asia, with increasing inequalities, becomes the leading producer and exporter of the world.
- Asia catches up with (and overtakes?) the United States and Europe in the area of research.
- Asia will be the main destination for the location of business R&D.
- International migrations will develop and, in the absence of a major inflow of immigrants, the European population would start to decrease as from 2012.
- A third of the world population is undernourished; on the other hand obesity increases in developed countries.
- The global health situation is improving but new risks are emerging.

Analysis of what implications these assumptions will have in terms of agricultural and agro-food production and consumption is necessary. It is known for instance that an increase in welfare and wages has a direct impact on meat consumption. This will affect not only meat production but also crop production to feed these animals. Feeding the planet may become one of the most important source of tensions and challenges in the next future.

The third main issue deals with nature and environment, there is an increasing scarcity of natural resources and growing vulnerability of the planet

- The new geopolitics of energy is characterised by a relative balance of the strategic importance of the Middle East, Russia and the Caucasus.
- More than 50 % of the major ore reserves are located in very poor countries.
- Three billion people will be missing water in 2025.

Dadush and Stancil (2010) provide the following summary of the world order in 2050:

The World Order in 2050

- "The world's economic balance of power is shifting rapidly, and the trend has only been accelerated by the global recession. China remains on a path to overtake the United States as the world's largest economic power within a generation, and India will join both as a global leader by mid-century.
- Traditional Western powers will remain the wealthiest nations in terms of per capita income, but will be overtaken as the predominant world economies by much poorer countries. Given the sheer magnitude of the challenge of lower-wage competition, protectionist pressures in advanced economies may escalate.
- The global economic transformation will shift international relations in unpredictable ways. To retain their historic influence, European nations will be pressed to conduct foreign policy jointly, an objective implied by their recently ratified constitution, and will need to reach out to emerging powers. Japan and Russia will seek new frameworks of alliances. The largest emerging nations may come to see each other as rivals.
- Absolute poverty will be confined to small pockets in sub-Saharan Africa and India, though relative poverty will persist, and may even become more acute. Carbon emissions are also on a path toward climate catastrophe, and by mid-century may constitute a serious risk to the global growth forecast.
- International organizations such as the IMF will be compelled to reform their governance structures to become more representative of the new economic landscape. Those that fail to do so will become marginalized."

All reports insist on the danger of choosing strategies with narrow or short-term visions of the economy (protectionism), biodiversity, climate change and poverty. These three domains require global and broader approaches.

3.5. Long-term challenges

Some of the main questions raised cannot be answered just from the point of view of agriculture, such as global financial systems regulations, these questions should be considered as global issues necessitating international decisions at the highest level.

On the geopolitical issues certainly the usual competitive philosophy does not allow to take on board the needs and possibilities of the poorest countries and populations. This means that one of the big challenges we are facing is to progressively change the mindset and the way of thinking and behaving of policy makers and probably most of the producers; it is a <u>long-term challenge</u>.

Global long-term challenges beyond agriculture

- 2050: A New Economic Order
- The New Triad
- New Alliances in a More Balanced World
- Can Africa Break Through?
- Feed the world population
- A healthy nutrition
- Low costs and short circuits meaning based on local productions respecting traditional habits
- Respect of biodiversity which means also a better control on fishing

Global agricultural long-term challenges

- More adapted regulations
- Food as a common good?
- Need for a more international coordination in some specific domains such as fishing
- International coordination (and maybe) regulations on agricultural prices
- How to integrate sustainability as a key objective in all policies?
- How to raise awareness and knowledge at all levels of the agricultural production and consumption chain?
- What basic research in social sciences should support new agriculture policies?

Up to now solutions have been sought in terms of adaptation to changing situations. Now we really need to find new ways and directions out of the scope of smooth and linear transitions. In any case, the answers to be found will have to take on board six types of transitions:

- The transition towards a multi-polar world and world governance.
- The politico-cultural transition towards a new universalism.
- The transition towards a "large integrated Europe" and a "global Europe".
- The transition towards a new "socio-ecological" production model.
- The urban transition and the new "territorial dynamics".
- The demographic transition and "active ageing".

4. TWO NARRATIVES

4.1. Introduction

Foresight studies always use a certain language or discourse that combines into a consistent storyline or narrative that reflects underlying worldviews and paradigms. These are sometimes made explicit, but are mostly implicit particularly when the narrative reflects the dominant paradigm. In the discourse used by foresight studies on the future of the agricultural and food system, two such contrasting narratives can be found. We refer to the dominant narrative as the Productivity Narrative and to the alternative narrative as the Sufficiency Narrative, as we believe that these two concepts best summarise the underlying worldviews. Making these underlying worldviews explicit is a first step towards better understanding our possible futures. Of course, the two narratives represent extremes of a likely future pathway of agriculture and food. In reality it is expected that a mix of both extremes will be pursued and be necessary to deal with the diversity in trends, cultures and lifestyles.

Narratives are simplistic in that they do not capture the full complexity of underlying systems. However, we do observe the discourses used by these narratives in policy documents, and in stakeholder feedback. In this document, the narratives are not guiding paradigms for deriving research implications. Rather, they are two lenses or perspectives that act as an entry point for analyzing scarcities and transitions.

4.2. The Productivity Narrative

The challenge

World population will increase to an estimated 9.2 billion people in 2050, while agricultural productivity has been slowing down over the last decades. Rising income levels in emerging countries will shift diets to more protein rich food and will increase energy demand. Hence, there is a serious threat that food demand will not be met in 2050 leading to more hunger and political instability. In addition, resource constraints and climate change severely limit the world’s capacity to expand food production.

The solution

Scientific advances have the potential to bring forward new varieties, breeds and technologies that boost productivity and that at the same time take into account resource scarcities and environmental problems. To achieve this, massive investments need to be made in R&D, but also in the removal of barriers to adoption by farmers, such as infrastructure, trade barriers and access to markets.

> *By 2050 the world’s population will reach 9.2 billion, 34 percent higher than today. Nearly all of this population increase will occur in developing countries. Urbanisation will continue at an accelerated pace, and about 70 percent of the world’s population will be urban (compared to 49 percent today). Income levels will be many multiples of what they are now. In order to feed this larger, more urban and richer population, food production (net of food used for biofuels) must increase by 70 percent. Annual cereal production will need to rise to about 3 billion tons from 2.1 billion today and annual meat production will need to rise by over 200 million tons to reach 470 million tons.* First paragraph of *How to feed the world in 2050* (FAO High-level Expert Forum, Rome, 12-13 October 2009)

Hidden assumptions and neglected issues

The Productivity Narrative's main assumption is that economic growth is the only way forward for human development. Issues such as social inequality, resource scarcities and pollution are not ignored, but rather considered as constraints thus ignoring the underlying complexity of socio-ecological systems. Demand is considered to be exogenous. The social impacts of new technologies, as reflected in IPR issues and market power, are underestimated.

This narrative also includes the assumption that ecosystems are best preserved if the existing cropland areas are subject to massive intensification, in a way that can stop further extension of cropland into forests and other natural ecosystems. This assumption might seem correct when examining the global level of production, consumption and resources as land, but when looking at the processes at stake, there is no evidence that intensification can lead to halting of the extension of cropland.

Background

According to Thompson et al. (2007) the narratives of technological change and economic growth have come to dominate key food and agriculture policy debates. They find their roots on the one hand in the dramatic increases in output and productivity following the various "Agricultural Revolutions": from land intensification in the 18th century, the invention of synthetic fertilizer, large-scale mechanisation, advanced plant breeding, the Green Revolution to the Gene Revolution of the late 20th century. On the other hand, the 1960s saw development thinking shifting towards seeing agriculture as an engine of growth, thus calling for the modernisation of agriculture. Recently, the discourse has shifted from the modernisation of agriculture by increasing scale towards the growth of small-scale farming by technological change and access to markets (World Bank, 2007).

4.3. The Sufficiency Narrative

The challenge

World population will increase to an estimated 9.2 billion people in 2050, which will lead to dramatic environmental problems as system Earth does not have the capacity to support expected rates of consumption. In addition, current food systems produce waste, and overconsumption leads to mass health problems. The destruction of important ecosystems will have dramatic feedback effects that undermine the foundations of our food systems, leading to more poverty and conflict.

The solution

Scientific advances have the potential to bring forward agro-ecosystems that are both productive, respectful for ecosystems and resource saving. However, to stay within the capacity of system Earth, demand increases need to be mitigated through behavioural change and structural changes in food systems and supply chains (among which food chain efficiency, reducing or re-using waste…), and environmental externalities need to be internalised in markets through appropriate governance structures that also address the disruptive effect of unregulated trade.

Hidden assumptions and neglected issues

The Suffiency Narrative's main assumption is that there are limits to growth imposed by the Earth's finite resources and finite assimilative capacity and by the vulnerability of its ecosystems that provide essential services to mankind. It believes that agro-ecological innovations and behavioural changes and changes in supply chains reducing demand are sufficient conditions to meet the world's food demand in 2050. Demand is considered to be endogenous, but economic, social and cultural barriers to a transition towards sufficiency are underestimated or not explicitly dealt with.

This narrative also contains an assumption that diversity is a better source of resilience, for the variety of systems considered: ecosystems and biodiversity, food patterns, markets, supply chains, agricultural production systems.

Background

Alternative narratives find their origins in the realisation of limits to growth, first advocated by Meadows et al. (1972), and the increasing realisation of the irreversible effects mankind has on the environment and thus on the foundations of our very existence (Rockstrom et al., 2009). The paradigm of maximisation is replaced by the paradigm of sufficiency. This requires action at both the supply and the demand side. Holistic, agro-ecological farming systems rely less on exogenous resources and use resource-conserving technologies such as IPM, integrated nutrient management, conservation tillage, agro-forestry, etc. It calls for a diversification of research questions in agronomic research, reintroducing ecology in agronomic sciences, and changing the organisation patterns of the R&D system from a product focused perspective to a system concerned perspective, and enabling more site- and ecosystem-specific innovation. In the EU, the concept of multi-functionality was introduced to capture farms aiming for the production of agricultural goods and ecosystem services. At the same, this narrative calls for a change in lifestyle to drastically reduce our ecological footprint, particularly by eating less red meat. The narrative also implies increased participation and dialogue among stakeholders at all levels of the agro-food system.

4.4. Comparing the two narratives

The recent Agrimonde study by INRA and CIRAD clearly translates these two narratives into two quantifiable scenarios, which the study calls Agrimonde GO and Agrimonde 1 respectively (Chaumet et al., 2009). Agrimonde GO is rooted in the Global orchestration scenario of the Millennium Assessment (Carpenter et al., 2005) that is based on major technological advances in terms of yields with the objective of economic development. It is referred to as the Business-as-Usual scenario. Agrimonde 1 is freely based on a scenario proposed by Griffon (2006) that has as its objective to fulfill all possible sustainability conditions and feeding the world. It is thus a normative scenario. Table 1.1 summarises some key parameters of both scenarios.

4.5. Underlying dynamics

Demand side dynamics

There does not seem to be much uncertainty but that world population will increase up to 9 billion people in 2050, with an increasing share of older persons (particularly in the North) and with increasing urbanisation. In addition, with increasing income food demand will increase in developing countries following the first phase of the nutrition transition, the expansion stage—in which people will increase their energy intake through calories from vegetable-based foodstuffs— as well as the second phase, the substitution stage—in which carbohydrate-rich staples (cereals, roots, tubers) are replaced by vegetable oils, animal products (meat and dairy foods) and sugar. The substitution effect, coupled with changes in lifestyle, results in considerable health effects. While the expansion stage is universal, the substitution effect is culture-specific (Kearney, 2010). Further, both worldwide and across the EU, consumer behaviour is converging across countries as well as diverging across lifestyles.

Table 1.1: Agrimonde scenarios

	2000	Agrimonde GO 2050	Agrimonde 1 2050
Population		8.8 billion	8.8 billion
Food consumption		3,588 kcal/cap/day	3,000 kcal/cap/day
plant origin		2,698	2,500
animal origin		890	500
Other uses*		30,874 Gkcal/day	5,757 Gkcal/day
plant origin		29,809	5,664
animal origin		1,065	93
Total use		61,959 Gkcal/day	41,920 Gkcal/day
plant origin		53,551	37,646
animal origin		8,408	4,274
Food crop area	1,300 Mha	1,639 Mha	1,880 Mha
Food yields	18,703 kcal/ha/day	32,942 kcal/ha/day	20,027 kcal/ha/day

*Feed, seed, waste and other uses of food biomass
Source: Chaumet et al. (2009)

A first uncertainty relating to demand is how the nutrition transition will evolve. Aggregate food demand is expected to increase from 2,789 kcal/capita/day in 1999/2001 (Alexandratos, 2006) to values that range between 2,970 kcal/capita/day in the CAWMA study and the Adapting Mosaic scenario of the MA to 3,580 kcal/capita/day in the Global Orchestration scenario of the MA in 2050. Particularly noteworthy is that the shift towards eating more meat is much more pronounced in China than in India, due to cultural differences (Kearney, 2010).

> *Stehfest et al. (2009) calculated that a healthy diet worldwide would reduce the required area of arable land globally by 10%, and the area of grassland by 40%, compared to the FAO assumptions. An example of a healthy diet is the Willett diet, which includes 10g beef, 10g pork, 47g chicken and eggs, and 23g fish, per person, per day on average. The associated reduction in costs for mitigation of carbon dioxide emissions could be as large as 50% in 2050, compared to the reference case.* (Getting into the right lane)

A second uncertainty relates to how a next change in consumer diets, that is, a shift to a more healthy and values-based consumption (high quality, organic, fair trade, local, regional, environmentally friendly, seasonal), will evolve. Such a shift is observed among so-called "cultural creatives", but seems to be slow and very volatile and sensitive to the economic situation.

> *Research regarding the type of consumers retailers will be dealing with in 2030 has identified the following future trends: increasing numbers of older people; more single-person households; fewer children; a blurring of the boundaries between work and leisure; bonus schemes by health insurance companies providing motivation for adopting a healthy lifestyle; a willingness by consumers to pay more for food as they become increasingly aware of quality and health. The globalisation of the range of food on offer will also probably evoke a reaction. The sheer quantity of available food products will strengthen the desire for regional and*

> *organic products. But there will also be an increase in food consumption outside the home, an increased demand for convenience food, chilled food and functional food.* (Edda Müller)

A third uncertainty relates to demand for crops, and thus the use of land, for non-food uses and particularly bio-energy. Fischer et al. (2009) predict an increase in cereal demand for ethanol production that ranges from 100 million tons to 330 million tons depending on different transport energy scenarios.[2] There are two amplifying factors for this demand for bio-fuels. First, the failure to reach an agreement in Copenhagen is illustrative of the difficulty of human societies to reduce their dependence on fossil fuels: with low mitigation efforts, demand for fuels will keep growing very rapidly, and therefore putting even more pressure on fossil sources and on bio-fuel sources. Second, as underlined by Fischer et al. (2009), the very probable innovation effort in producing more efficiently bio-fuels of 2nd generation might very probably lead to increasing again the demand for bio-fuels rather diminishing their pressure on resources.

> *A difficulty in arresting the effects of the nutrition transition is due in part to the paradox that while the diet associated with the nutrition transition (high fat, sugar and salt) is unhealthy, it is also more diverse and pleasurable (fat and sugar are two of the most pleasurable elements of the diet in terms of taste preferences). This then is part of the challenge: to provide more varied and tasteful diets while ensuring that these diets and a healthy activity level reduce the incidence in obesity, adult-onset diabetes and cancer related to nutrition and exercise.* (Kearney, 2010)

Supply side dynamics

In the framework of the productivity narrative, the challenge ahead is generally phrased the following way:

> *The global community faces an important choice: expand the area of agricultural land to increase gross production, or increase yields on existing agricultural land.* (The Royal Society, 2009)

The first uncertainty therefore relates to the levels of crop and livestock productivity potential that will be reached in 2050 following technical progress. Whereas crop productivity has been the focus of many recent studies trying to understand the range of possible and / or necessary increases in yields per hectare of crops, the future role that animal production systems could play is still very controversial, as it is not only a question of productivity (of animal production per unit of vegetal feed, or per unit of grazing land), but also a question of overall environmental impact of animal production systems.

The second uncertainty relates to the impact of climate change and resource scarcity that could put limits to the ability to reach potential productivity levels. Here again the productivity narrative has to be made more complex by understanding the complex feedback loops that may exist between environmental degradation and the reduction of the resource basis for productivity increases, for instance when looking at soil fertility.

The third uncertainty relates to the greening of industry, that is, the implementation of sustainability standards, particularly for basic commodities such as cereals.

[2] World cereal production in 2000 was assumed to be 2,150 million tons and was forecasted to increase to 3697 million tons in 2050 in the reference scenario with no use of crops for bio-fuels.

4.6. Towards a synthesis?

If the two narratives are perceived as two very opposed visions, reflecting contrasting paradigms, it seems impossible to produce a synthesis of both by only taking a mid-term position, mixing one with the other. Nevertheless, several foresight documents do acknowledge both narratives and contain suggestions that hint towards a synthesis.

Building a vision for the future of agriculture and food at least involves using these two narratives to make more explicit assumptions about what we consider as possible trends and possible levers for action, either on the productivity side, the efficiency side, or the demand side.

In the next sections of this report, the understanding of how the systems considered are functioning is brought a step further by focusing on specific issues or themes that have emerged in recent studies as of particular complexity, or as particularly important for what concern transitions, and that are underestimated in the two main narratives presented here.

5. A PICTURE OF A RESOURCE-POOR WORLD

The outlook for global food security over the coming decades will be characterised by turbulence, uncertainty and risk (Evans, 2009, p. 49).

5.1. Scarcities in agricultural production

Agricultural production relies on natural and human capital. This chapter analyses those environmental and resource issues that may become important in a 30-40 years perspective and that may impede the further use of current technologies for agricultural production. These are biophysical constraints, the strong global environmental limits and their societal contributions, which we summarise in the term "scarcities". This section also takes stock of how much of the necessary research is already under way and identifies priorities and gaps. These research needs are then further specified in Chapter 7.

Scarcity is used here in a comprehensive way to describe the constraints on agricultural production (Definition in Chapter 1.2). These are the biophysical limits like resource supply and availability, economic constraints like prices or limited access as well as environmental limits like pollution and its impacts on ecosystems and the global climate system. However, scarcities are also found from the solution perspective, e.g. technological and social scarcities (access to, or utilizing knowledge, behavioural and institutional barriers to change …). The technological and social aspects are analysed to the extent that they act as barriers to the transitions towards sustainable and equitable food production and consumption.

In economic terms, the Earth´s life support system can be seen as a production function in which the regeneration of a natural resource depends not only on the stock of the resource, but also on external variables such as exploitation rate and magnitude, and pollution (Siebert, 1982). The key question in defining the strong global environmental limits is: To what extent is the regenerative capacity of the Earth´s life support system negatively affected by pollution and human pressure? The answer to this question determines how much of the natural resources, and at what speed and cost, can be used. Optimal resource use is then a function of demand, regenerative capacity, resilience of the natural and social system, and the economic paradigm of whether short-term or long-term benefits are preferred (Siebert, 1982).

Scarcities arise as region-specific imbalances of energy, matter or capacity. We can distinguish between shortage-abundance-excess-pollution or environmental, economic and social disruption.

In light of the productivity narrative, scarcities are related to the regional under-exploitation of the theoretical production potential of land and of input of energy, nutrients and technology, and the over-exploitation of the buffering and regenerative capacity of ecosystems. The aim is to maximise the output per unit of land, and the output/input ratio of the primary agricultural product, often with a short-term economic perspective.

In light of the sufficiency narrative, scarcities are related to the multi-dimensional boundaries and competing ecosystem and societal services of agricultural production that need to be reconciled. The aim is to find a compromise in which the optimal output per unit of land is regionally determined by criteria of maximum allowed input and whole-chain resource use efficiency, often a with long-term economic perspective.

In light of agricultural production in a 30-40 years perspective, the following issues were identified as most critical:

1. "Classical" or "old" scarcities related to natural resource use and pollution: fertile land, freshwater, energy, phosphorus, and nitrogen,

2. "New" scarcities related to environmental limits that aggravate the "classical" scarcities: climate change including ocean acidification and biodiversity loss, and

3. Societal contributions to scarcities: governance, economic development and urbanisation.

5.2. Interactions between scarcities

Whilst many studies have addressed the outlook on individual issues such as energy, food, water, climate change and biodiversity or the environmental limits at national, European or global level, there is a systematic lack of analysis of the multi-dimensional interactions between scarcities. However, such interactions can strongly affect the direction and speed of trends including disruptive scenarios. The lack of understanding, knowledge, and of scientific and political attention to the interactions between scarcities constitutes a major uncertainty in existing foresight studies since projections risk being too smooth and linear. Being aware of the limitations of existing foresight about scarcities, the Expert Group has attempted to analyse the type of interactions and to give a ranking of intensity, which can form the basis for deriving an urgency to act.

As common features among the scarcities is that each of them acts in different ways along a hierarchy of spatial and temporal scales, each of them can be part of the problem or part of the solution and many of them are interlinked in a complex, non-linear manner. In consequence, scarcities are context-specific and therefore require context-dependent solutions. Nevertheless, acknowledging this complexity, we developed a systematic approach for identifying potential risks, opportunities and likely future developments and challenges for agriculture:

1. The major mechanisms of scarcities were identified,

2. The major mechanisms of interactions among scarcities and their likely intensity were qualitatively determined,

3. The importance of each scarcity and the most critical mechanisms were identified for Europe and major world regions.

5.2.1. Systematics of scarcity mechanisms

Adapting and extending the analytical framework from Passenier and Lak (2009, p. 61-62) and Leadley et al. (2010), the major mechanisms of individual scarcities were characterised as supply, access, and distribution (Passenier and Lak, 2009, p. 61-62), as well as trend, variability, threshold, time lag, and tipping point (Leadley et al., 2010).

Supply reflects the ultimate physical availability of a resource, e.g. fertile land, nutrients, and genetic diversity. *Access* describes the ability to use resources in adequate magnitude and timing for agricultural production, e.g fertile land, nutrients, water, energy, and has a strong economic and social dimension. While the abundance of the resource itself is not limiting, the costs of purchase, market distortions, e.g. by oligopolistic structures, or the availability of alternative sources, e.g. of energy, freshwater or nutrients, are short. *Distribution* refers to inadequate timing, e.g. of freshwater or precipitation, and inadequate spatial distribution of resources. For instance, phosphorus and nitrogen excess prevail in regions with high concentration of animal husbandry while these nutrients are lacking elsewhere. *Trends* may impede the further use of current technologies because they change the regional frame conditions of agricultural production, e.g. by increased demand and the need for more production, by changing precipitation and temperature patterns associated with new opportunities or risks, or by continued decline of natural resources. In a similar way, *variability* will increase the production risks and therefore will require new strategies for coping with risks. In addition, individual scarcities can be attributed to particular drivers, e.g. pollution by nutrient excess, degradation of fertile land, water quality, or the declining resilience of ecosystems.

We characterised interactions between scarcities as feedbacks, threshold, tipping point, time lag. *Feedback* means intensification or acceleration of system dynamics so that the trend in one scarcity speeds up the trend in another one. *Threshold* means that if systems gradually move beyond a certain limit they reach a new state, e.g. lose their suitability for agriculture. *Time lag* means that systems react with a long delay time or that the depletion of the supply causes irreversible damage. Typical examples are ocean acidification or sea level rise, which take centuries or millennia to move into a new equilibrium state. The term *tipping point* is defined as a critical threshold at which a tiny perturbation can drastically alter the state or development of a system (e.g., climate: Lenton and Schellnhuber, 2008). A tipping point leads to an irreversible catastrophic change of the system.

It is very difficult to quantify the intensity of interactions in light of consequences for risks and required adaptation in agriculture in the next 30-40 years. Strong interactions imply that the scarcities have to be addressed jointly to avoid negative consequences and be effective. We applied a ranking system, based on literature and our expert judgment, to highlight

1. what scarcities, and what mechanisms are most critical in terms of risk, limitation and urgency for transition for the future of food production

2. what interactions between scarcities are most critical so that research and policy have to address them jointly to find sustainable ways of future agriculture?

Although the ranking is based on the current inadequate knowledge, and may contain some bias it can serve as a tool for setting priorities in research and policy.

5.2.2. Global analysis of scarcities and their interactions

The challenges and scarcities with which the global food system is faced multiply and interact with each other in complex, unpredictable ways (Evans, 2009, p. 49). The interaction and feedbacks across scarcities are not quantitatively understood. Research has focused on a limited set of scarcities interactions such as between various features of climate change (temperature, precipitation, CO_2 increase) and between climate change, water and land use change, but has largely ignored the feedbacks between natural and societal systems.

Figure 5.1 shows conceptual feedbacks of major scarcities which impact on food production and consumption and which create an urgency for transition. From Figure 5.1. we can deduce the following insights:

1. We have identified economic development as the strongest driver of scarcities for food production, assuming that economic development increases the demand for food and for meat, fat and sugar. Urbanisation will further stimulate the trend for convenience food and will impact access to food although its impact on food demand is less clear.

2. The amount, method of food production and the type of food produced, shown as the use of fertile land and the intensity of resource use on the land have strong impacts on water, energy and nutrients, pollution and their consequences, e.g. climate change and biodiversity loss. The provision of water, energy and nutrients themselves requires input of water and energy.

3. Water and energy are no scarcities in the sense of shortage[3] but in the sense of efficiency, finding alternative sources and means of access and distribution. Therefore, the interactions with other drivers depend on the way in which water and energy use develops. They are as much part of current problems as they are part of solutions. Nitrogen acts in a similar way.

4. Phosphorus is least connected with the other drivers.

5. Climate change and biodiversity loss aggravate each other in manifold ways. The link between climate change and ecosystem functions has been the focus of research for more than 20 years so that trends and risks can be roughly assessed. In contrast, the functional role of biodiversity in food production and the interaction between climate change and biodiversity risks are far from being understood. The combined effect of climate change and biodiversity makes the food production systems vulnerable to surprises up to regional collapse and may call for a complete re-thinking of agricultural production systems.

6. Positive feedbacks that speed up change are the most prominent mechanism of interactions between scarcities. Many drivers impact on others, often in causal chains. For instance, economic development will increase the demand for food, which will increase the use of fertile land, water, energy, phosphorus and nitrogen, which will contribute to further climate change and loss of biodiversity. Transitions will seek to reduce the pressure at any step of the causal chain and best act in an integrated manner via supply-side or demand-side measures, increased efficiency and recycling. Scarcities operating as constraint to food production or as local pollution from food production can be addressed by productivity or sufficiency strategies at local to large scales, including incremental progress in line with past and current research and policies.

7. Tipping points represent an unquantifiable risk for food security and as such, strong global environmental limits. Tipping points are mainly related to climate change - biodiversity relations. The die-back of coral reefs and the destruction of coastal ecosystems and over-exploitation of marine resources was identified as the most urgent, maybe even catastrophic risk for a major part of the world´s food resource. Tipping points relate to systemic instability as a result of large-scale, multi-source pressures. In the case of marine resources, warming, pollution, ocean acidification and over-exploitation act together on ecosystems with a long memory and lag time for response. Humanity can only curb the trend or risk in a joint global or large-scale regional effort. This requires a fundamentally new global governance in light of sufficiency strategies and a much stronger link between agronomic and earth system sciences.

8. Scarcities with time lags in response, e.g. the limited availability of phosphate ore reserves, soil degradation or the loss of genetic agro-biodiversity, have been known for long but have never attracted adequate resources for research unless they become strong economic assets. Time lag issues demand for a long-term strategic orientation of research, creativity,

[3] Here we should differentiate between North-European and Mediterranean areas. While in some areas water is not a scarcity, its is becoming one of the most important scarcities in many Mediterranean countries.

niches and openness for new research directions because some of the solutions will need to break with our current way of producing food.

9. If governance is taken as indicator of decision-making mechanisms, functioning of markets and cultural background of consumer choices, it can be seen as the root of any scarcity and as the heart of any solution.

Interactions, in particular feedbacks, can further intensify, accelerate or change directions when several drivers are combined. These complex multiple interactions are critical for projections of global food security but unknown. These unknowns may pose a stronger and faster limit on global food production than any of the individual scarcities.

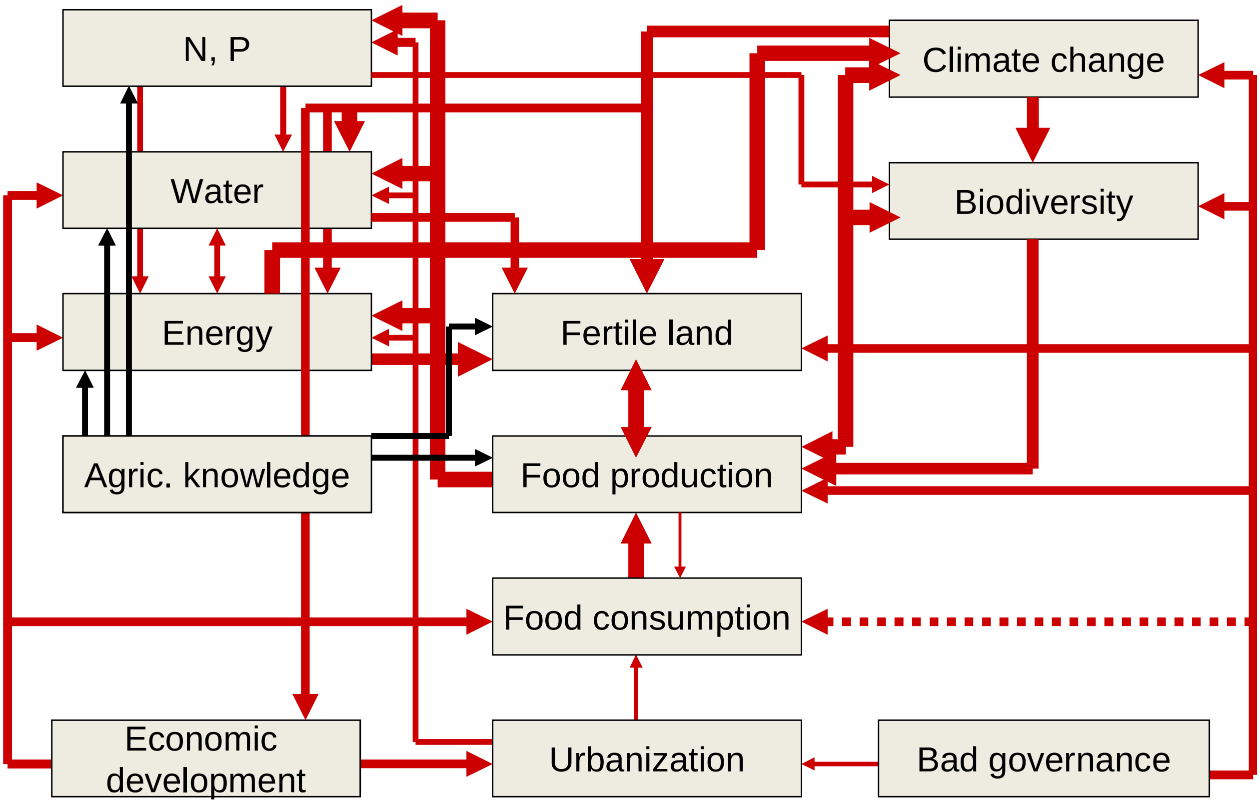

Figure 5.1. Scheme of interactions between scarcities according to our analysis. The size of the arrows indicates the intensity of interactions. Arrows in both directions indicate complex, non-linear feedbacks

A major challenge underestimated so far in foresight is that regional, and eventually the global system of climate, biodiversity and water cycle will move out of their historical ranges towards new equilibrium (?) states so that experience from the past may not suit for solutions tomorrow.

5.2.4. Pathways to solutions

Food consumption, technological drivers, agricultural knowledge systems and all societal drivers offer elements of solutions. Less waste directly addresses the core: food consumption and hence, food production. Agricultural knowledge systems can improve the efficiency and environmental soundness of food production and alleviate classical resource constraints through regionally adapted management (fertile land, energy, water, nutrients). Measures in light of the productivity narrative include resource use efficiency and technological innovation. They can improve food production efficiency, classical resource constraints and agricultural knowledge systems, but may not be best suited to address the new challenges of climate change and biodiversity and the societal drivers of food consumption. In contrast, in light of the sufficiency narrative, solutions addressing food chain efficiency include less meat and healthy consumption. They attack the ultimate drivers food consumption and production with their behavioural basis, reconciled with new challenges by climate change and biodiversity loss. The only comprehensive approach to all interdependencies and their underlying causes in the human and social systems, however, works via changes in governance.

There are no easy solutions to meet the scarcity challenge. A diversity of approaches and a mix of tools will be needed, together with fundamentally stronger governance of resource use and pollution abatement from local to global level, which may lead to a complete turn from the present resource-intensive agriculture to new smart ways of working with nature´s nutrient and water cycling mechanisms or landless food production.

5.2.5. Regional patterns of scarcities

Scarcities have distinct regional patterns globally and in Europe. In consequence, the urgency and potential to act also differs regionally. Annex 1**Error! Reference source not found.** presents an overview of key issues in critical world regions.

African agriculture is strongest hit by climate change, seasonal and interannual variability and shortage of freshwater, and limited access to nutrients. Resource scarcity is exacerbated by bad governance, poverty and ongoing land degradation and land grabbing. Traditional agricultural knowledge systems that could build resilience are strong and diverse but have not been adequately integrated in export oriented agriculture. The competition between traditional smallholder subsistence farmers, export oriented agriculture and migrants due to conflicts, population growth or drought is increasing. Morocco, South Africa and Jordan together have more than 50 % of the world´s phosphate ore reserves (Passenier and Lak, 2009).

China and India are on the path of intensification so that nutrient excess versus shortage has already become an issue. The fertile soils in the uplands are prone to erosion. However, the major scarcity is water, in particular the seasonality in the monsoon climate, and water quality and management in the mega-deltas. Due to the melting of the Himalayan glaciers, the distribution of river water use in the uplands versus lowlands is an emerging scarcity with strong potential for regional conflict. China has 27 % of the world´s phosphate ore reserves (Passenier and Lak, 2009) and already has a policy of resource nationalism for other important minerals. China is actively seeking control over critical knowledge and resources by buying mines, land and companies abroad.

The economies in the mega-delta cities are among the fastest growing so that competition for land, but also vulnerability to sea level rise and storms is increasing. Pollution and expanding infrastructure have damaged the capacity of coastal ecosystems to buffer floods and storm surges. Scarcity mechanisms are similar to China and India but aggravated by the strong development and concentration of people.

Focusing on Europe it is worth mentioning that the diverse cultural background, traditions, history and governance systems (e.g., subsidiarity versus centralism) affect scarcities as much as promising pathways into a sustainable future. Water shortage and soil degradation represent the major scarcity in the South, aggravated by climate change. Excess of nitrogen and phosphorus dominate in the animal production regions of the West and Centre. In contrast, the East often still remains below its production potential – partly due to unresolved land governance questions. The East has preserved much of the original biodiversity in Europe. The North may profit from climate change but its ecosystems are most vulnerable to eutrophication and acidification.

The Europe 2020 Strategy (European Commission, 2010a) identifies pressure on natural resources as one of the three long-term challenges confronting the EU, the others being globalisation and aging. A "Resource efficient Europe" is one of the seven flagship projects aimed at securing the decoupling of economic growth in Europe from the availability of resources.

5.3. Trends in `classical´ scarcities and their impacts on food systems

5.3.1. Fertile land

Current state of the problem

Land is an indispensable natural resource for many essential human activities: it provides the basis for agriculture and forest production, biodiversity and wild life habitat, purification and catchment of water, recreation, and settlement. Agriculture now occupies about 37% of the global land surface, reflecting the historical trend of bringing more land into agricultural production as the solution to growing demand for food. In more recent decades, as the impact of 'Green Revolution' technologies took hold, the necessary increase in food production was primarily met by way of yield increases rather than expansion of harvested area. For example, globally 78% of the increase in crop production between 1961 and 1999 was attributable to yield increases and 22% to expansion of harvested area (Bruinsma, 2003).

Although modern agriculture has been successful in increasing food production, it has done so at a cost. High-energy crop production depends on high inputs of fertiliser, pesticide and water use, and consequently energy, which can lead in turn to increased emissions of nitrates and pesticides into the environment and depletion of groundwater aquifers (Moss, 2008). It is currently estimated that land-use change, primarily deforestation, is responsible for as much as 18% of global GHG emissions (Millennium Ecosystem Assessment, 2005; IPCC, 2007a).

According to the UNEP Global Environmental Outlook (UNEP, 2007), unsustainable land use is causing land degradation, which sits alongside climate change and loss of biodiversity, as a threat to habitat, economy and society. Land degradation in the shape of soil erosion, nutrient depletion (vast tropical and subtropical upland areas) or nutrient excess (industrial and transition countries), water scarcity, salinity and disruption of biological cycles is a basic and pervasive problem. Land degradation lessens productivity and ecosystem services and contributes to climate change. Human activity continues to lead to the release to land, air and water of harmful and persistent pollutants, such as heavy metals and organic chemicals.

Future changes in the nature, scale and intensity of agricultural land use will be influenced by the interaction of factors relating to:

- *Demand*: for food and bio-based products, including biofuels. There is also likely to be greater demand for non-market environmental goods and services such as landscape management at the local scale, and services such as carbon sequestration and biodiversity conservation at the global scale.

- *Supply*: the development and application of agricultural knowledge, science and technology that can improve agricultural productivity and its environmental performance (The Government Office for Science, 2010).

Competition for land

Over the coming decades, land as a global resource will become a source of increased competition from a range of different potential uses. In a recent paper, Harvey and Pilgrim (2011) review the increasing competition for land from in the framework of the 'food, energy and environment trilemma' (Tilman et al., 2009), where all demands to expand the area of cultivated land represent high risks of increasing agriculture's carbon footprint (Figure 5.2). In this model, competition for land use in the coming decades is seen as being driven by the objectives of delivering food and energy/raw materials in a post-fossil carbon economy. The authors conclude that the dual challenge of delivering both food and energy and doing so in a sustainable manner calls for a "combined new green and bioeconomy revolution. The political shaping of this process will require both sustainability regulation and strongly directed innovation, delivering the means to achieve the ends (Harvey and Pilgrim, 2011).

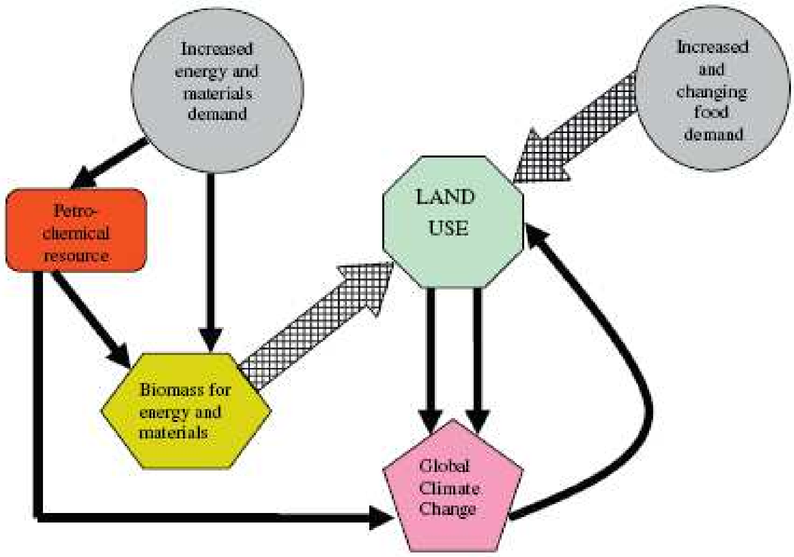

Figure 5.2. The new competition for land use: interactions and feedbacks
Source: Harvey and Pilgrim (2011)

Projections

FAO projections are for a 70% (nearly 100% in developing countries) increase needed in agricultural production by 2050 in order to cope with projected population and to raise average food consumption to 3130 kcal per person per day (FAO, 2006a). The expected growth in global meat consumption will exert a particular pressure on future land needs. With growing affluence, average meat consumption per capita is expected to increase from the existing level of 37 kg, to 52 kg in 2050 (FAO, 2006a). This development will underpin significantly increased demand for agricultural land, because several times more land and water is needed to produce animal products than would be required to produce plant products of similar nutritional value.

Increased food production will either result from increased yields or from expansion of the cropped area. In theory, there is plenty of land that could be converted to agricultural use. Only around 11% of the world's land surface is currently used to grow crops. Gross and net land balances (GLB and NLB) have been estimated using agro-ecological modelling (Fischer et al., 2002). The NLB value (GLB less areas currently allocated to forests, urban areas or protected areas) is estimated at a further 1.6 billion ha that could be added to the existing 1.6 billion ha of cultivated land (OECD/FAO, 2009). There are significant areas of unused agricultural land and production potential in parts of Eastern

Europe and the former Soviet Union. But most of the potential new land is in Sub-Saharan Africa and South America. (Fischer et al., 2002). Much of this land would have lower productivity, most would come from forest and savannah, and its conversion would involve significant negative climatic and biodiversity effects (Bruinsma, 2009).

These estimates of NLB for crop production do not take account of increased competition from pasturelands needed by growing global livestock numbers (FAO, 2010). Furthermore, the boom in bio-fuel demand will also potentially limit the amount of cropland available for food production, as will the emergence of carbon markets. Growing pressure to address climate change has created rapidly growing carbon markets that are expected to reach billions of dollars in annual transactions within the next 10 years. The resulting increased competition for land could increase land prices and shift production towards commodities with smaller carbon footprints (OECD/FAO, 2009).

All projections stay far below these theoretical limits of cropland expansion. According to FAO projections, arable land would expand by some 70 million ha (or less than 5%), based on an expansion of 120 million ha in developing countries offset by a decline of some 50 million ha in developed countries. Almost all of the expansion would take place in sub-Saharan Africa and Latin America. These figures do not take account of additional requirements for bioenergy crops and the potential impacts of climate change.

In a review of studies of future land use, Smith et al. (2010) state that the projections for cropland increase range from as low as 6% to an increase of more than 30%. The average is around 10-20%. For grazing land, the range of 2050 scenario projections ranges between a 5% contraction to a 25% increase. Most studies show an increase of 10% or less. The differing figures to a great extent reflect differing assumptions about the impact of technology on productivity and consequentially, on future investment in R&D designed to develop productivity enhancing technologies.

In their paper on 'planetary boundaries', Rockström et al. (2009) propose that no more than 15% of the global ice-free land surface should be converted to cropland. For humanity to stay within this boundary, cropland would have to be allocated to the most productive areas, and processes that lead to the loss of productive land, such as land degradation, loss of irrigation water, and competition with land uses such as urban development or biofuel production, would have to be controlled.

The WWF (2010) also adopt a less optimistic view than the FAO in assessing future land availability to meet competing human needs. For them, competition for land is likely to be a far greater challenge in the long term and they believe that determining the optimal allocation of land to different uses "is one of the greatest challenges facing policy-makers, businesses and society" (p. 81). New tools and processes will be needed for managing and deciding between the many competing demands on land.

The other option for increasing global food supply is by way of enhancing yields and cropping intensities. The FAO projections are for 90% (80% in developing countries) of the growth in crop production to result from higher yields and increased cropping intensity, with the remainder coming from land expansion. What is the potential for a continuation of yield growth?

With a few exceptions, the growth of yields has been slowing since 1982. Grain yields world-wide grew at an average of 2.1% p.a. from 1950 to 1990, but growth dropped to just under one percent between 1990 and 1997. The reasons are complex. In Northern America and Europe this has mostly been because policies changed in order to reduce the growth in production. In former Soviet Union territories, the reason lies in the collapse of the planned production system. In Asia, it is because of the high level of land intensity and input use already achieved. Soil losses and erosion also contribute significantly (IAASTD, 2009).

In countries and localities where the potential of existing technology is being exploited fully, subject to the agro-ecological constraints specific to each locality, further growth, or even maintenance, of current yield levels will depend crucially on further progress in agricultural research (Bruinsma, 2009). Predictions for future yield growths vary enormously. WBCSD (2010) projects that " a doubling of agricultural output without associated increases in the amount of land or water used" is possible by 2020". However, the FAO (2009a) suggested that crop yield increases could be only half historical rates, and that agricultural research would need to intensify efforts to increase yields in "the often unfavourable agro-ecological and also often unfavourable socio-economic environments of the countries where the additional demand will be". Moreover, Nelson et al. (2009) conclude that climate change will cause yield declines for the most important crops and that South Asia will be particularly badly affected. Accordingly, while crop yields could double, as forecast by some, efforts may be impacted by climate change and socio-economic factors in many areas of the world.

Even at current levels of technology, however, large and economically exploitable yield gaps remain in many places. In sub-Saharan Africa, in particular, there are indications of yield gaps which could be exploited with given varieties and with known practices (FAO, 2010). Cereal yields in Africa have grown little and are still at around 1.2 tonnes per hectare, compared to an average yield of some 3 tonnes per hectare in the developing world as a whole. Fertilizer consumption was only 13 kg per ha in sub-Saharan Africa in 2002, compared to 73 kg in the Middle East and North Africa and 190 kg in East Asia and the Pacific. Bruinsma (2009) concludes that there is a *prima facie* case for believing that there is considerable scope for increasing crop yields in different countries, which could be exploited if market conditions so determine.

In regard to livestock productivity, Nin et al. (2007) provides a global comparison of livestock productivity of 115 regions (92 developing and 23 high income regions) over two periods, 1961-80 and 1981-99. The latter period showed higher total factor productivity (TFP) growth, with Asia showing the fastest expansion followed by Latin America, and Sub-Saharan Africa remaining relatively static over the period (table 5.2). Acceleration of TFP growth in the latter period was mainly the result of an increased rate of expansion of the technical frontier, including genetic improvement of animals, improved disease control and improved management practices (FAO, 2010).

Table 5.2. Livestock total factor productivity growth

	1961–1980			1981–1999		
	Total factor productivity	Technical change	Efficiency	Total factor productivity	Technical change	Efficiency
South Africa	−0.73	0.67	−1.39	1.3	0.74	0.56
Sub-Saharan Africa	0.01	0.01	0	0.02	0.03	0
Africa	0.17	0.31	−0.14	0.63	0.21	0.43
China	0.32	1.04	−0.72	6.27	0.82	5.4
India	−1.05	0.64	−1.67	1.66	1.62	0.05
Asia	−0.75	1.11	−1.85	2.54	2.33	0.21
Mexico	0.39	0.77	−0.38	1.41	0.64	0.76
Brazil	−2.38	1.1	−3.44	1.73	1.07	0.66
Latin America	−0.44	1.01	−1.43	1.15	1.55	−0.39

Source: OECD/FAO (2009)

Hotspot regions

Estimates of the current extent of degradation of the world's croplands vary wildly. A recent assessment (Bai et al., 2008) identified 24% of land as degraded, mainly in Africa (south of the Equator), southeastern Asia and southern China, North and Central Australia, the Pampas and parts of the boreal forest in Siberia and North America. Further losses, which may be exacerbated by climate change, are likely (IPCC, 2007b). The IAASTD (2009) report confirms soil degradation as a key factor underlying a slowing in the growth of yield levels. Nearly 49% of grasslands are lightly to moderately degraded and at least 5% are considered strongly to extremely degraded (White et al., 2000).

Most of the cultivable land in Asia is already in use, and the population increase expected by 2050 will reduce per capita availability of cultivable land to below the critical level of 0.1 ha per person.

The southern and eastern Mediterranean is expected to face a situation of decline in water availability per capita, while currently water is only modestly available or scarce. Problems arising from water scarcity, with consequential erosion risks, are projected to worsen, aggravated by climate change (Netherlands Environmental Assessment Agency and Stockholm Resilience Centre, 2009).

Agricultural yields in many developing countries are threatened by climate change. Simulations show that reduced yield growth due to climate change will probably affect regions that have limited options to expand agricultural land areas, such as Northern Africa, the Middle East, India and China (Nelson et al., 2009).

Type of scarcity

Globally, physical scarcity of land is not an immediate risk to food security, although physical land shortages is an immediate concern in certain parts of the world. Within total agricultural land, arable land per capita is steadily declining, e.g. from 0.35 ha /head in 1970 to 0.24 ha/head in 1994. Exacerbating this trend, by 2025 the population of the countries around the world that are net food importers, as a result of insufficient cropland per capita, will rise to over 1 billion, from the current estimated 420 million.

Land Grabbing
China and other capital-rich countries, particularly in the Middle East and North Africa, are now beginning to look outside their borders for agricultural land in an effort to ensure greater security of food supply. According to von Braun and Meinzen-Dick (2009), 37-49 million acres of farmland were the subject of deals or proposed deals involving foreigners, between 2006 and mid-2009 alone. The investments are spurred by concerns over food security and growing populations, as well as the expanding market for bio-fuels. Governments and private investors alike are brokering deals for large swaths of fertile land, sometimes in exchange for promises of investments in infrastructure or education, and sometimes for very small amounts. There are two predominant schools of thought when it comes to these land deals: one is a “win-win” view, typically encouraged by the World Bank and FAO, where poor countries receive some combination of money, infrastructure and resources, and investing countries increase their food security. The second, usually supported by numerous farmers’ groups and non-profit organisations, believe that these land grabs are exploitative and colonialist, expelling people from their land and decreasing food security for “host” countries.

Land grabbing, as described above, is one response by some countries so affected. A significant and unchecked growth in land grabbing could have serious impacts on land availability and, consequently, food security, in poorer countries affected by land grabs. A similar effect could arise from continuation of existing trade and subsidisation policies in the developed world, which have consequences for land use in third countries. A recent EU report states that the EU has become the world’s largest net importer of agricultural produce, and therefore the largest user of agricultural land that is not its own (von Witzke and Noleppa, 2010). Access to fertile land for local and domestic food supply is an emerging scarcity in developing countries.

Other scarcity arises in terms of the quality of the land resource. Soil degradation, erosion and desertification are all impacting the quality and hence the perceived scarcity of land in many parts of the world. This problem will be added to by climate change impacts, which will have a significant impact on productivity, yields, water and land availability.

Interaction with other scarcities

Resources are interlinked in many different and complex ways. Land, energy (in the form of fertilisers and diesel) and water are needed to produce food while biotic resources are degraded or through nutrient leaching, pesticide emissions and physical destruction (van Schaik et al., 2010). The intensive Western type of highly specialised, high-input agricultural land targeted at production levels close to the physiological maximum has a high demand for nutrients, water, energy and low levels of biodiversity including agro-biodiversity. There are strong feedbacks between a further expansion of this type of agriculture in the future and the other scarcities .

Agriculture has multiple links with climate change: animal farming and fertiliser production and use significantly contribute to global greenhouse gas emissions. Recent estimates of the contribution of cattle breeding to global greenhouse emissions vary from 12% (JRC, 2009c) to 18% (FAO, 2006b). These emissions need to be significantly decreased in order to limit climate change. At the same time, ongoing climate change will compromise agricultural productivity, particularly in the poorest areas. Furthermore, bio-energy has a role in mitigating climate change, although this comes at a price. Biofuels compete with food production and biodiversity. To achieve the EU 10% target for biofuels will require putting additional land into production, in and outside Europe (Eickhout et al. 2008).

Reflection on narratives

The principal reflection stems from the emphasis in the sufficiency narrative on global governance addressing land and trade and also a different emphasis on future consumption. The sufficiency narrative places an emphasis not just on producing enough food for the world, but also on taking additional policy steps to ensure that all have access to that food. This could mean, for example, a new approach towards access to land and security in land tenure rights in poorer countries which lays greater emphasis on easing access for local people and discourages 'land grabbing' practices.

In policy terms, it could embrace changes in subsidisation policies in developed countries and their trade practices which currently heavily influence land use in third countries, often to the detriment of local food security.

It could involve greater emphasis on promoting diversity in agriculture, which also creates more resilience to climate change, strong emphasis on cutting food losses and waste, currently running at 30-40% of the food produced in affluent countries (Netherlands Environmental Assessment Agency and Stockholm Resilience Centre, 2009) and reducing meat consumption.

Solutions and transitions

There is an emerging consensus from the various assessments produced over the past few years that the world will need to produce substantially higher yields of food for humans and livestock feed in the next half century. However, there is no clear agreement on the exact increases required, as there are substantial uncertainties in many areas. Most agree, however, that the challenge of food security can only be met through a combination of measures across all relevant science and policy arenas. Their shared conclusion is that the complacency about food availability over the last two decades has resulted in a steady erosion of investment in relevant scientific research and that this needs to change.

Public and private agricultural research capital and public agricultural extension are essential for introducing new technologies that can enhance agricultural productivity. Public investment in agricultural research continues to rise in real terms but growth rates in public agricultural research expenditures declined in the 1980s and continued to fall in the 1990s (Beintema and Stads, 2008). The decline is particularly notable in poorer countries (Figure 5.3) and expenditure is increasingly concentrated in a few leading countries in each region, e.g., China, India and Brazil.

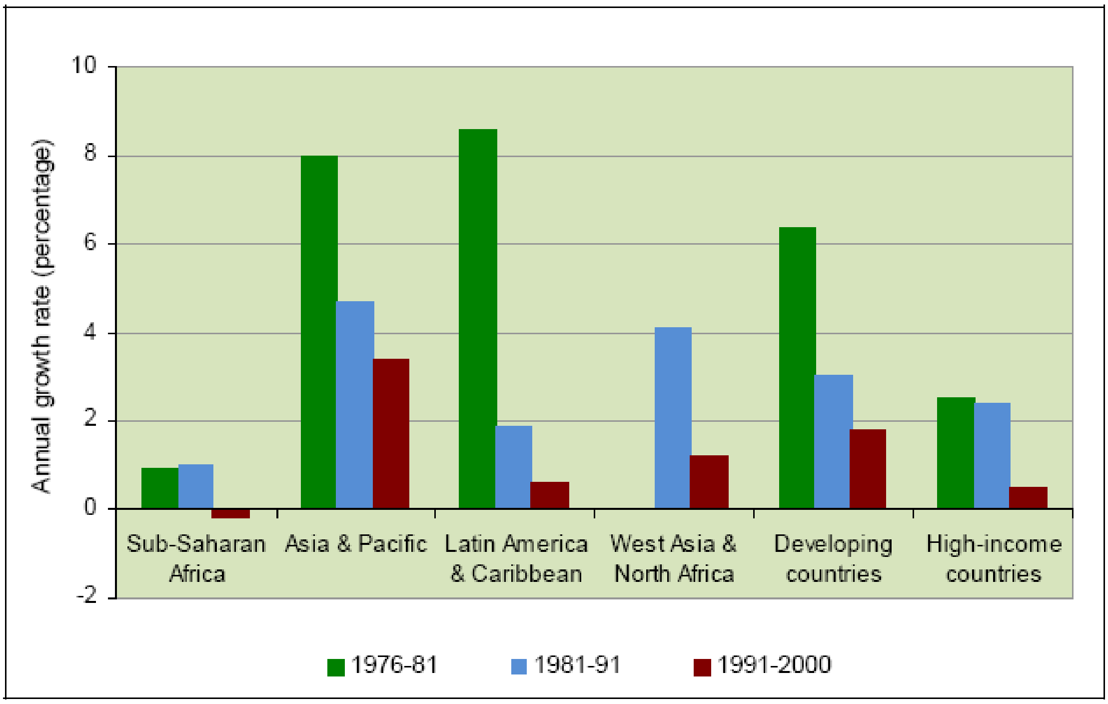

Figure 5.3. Annual growth rates in agricultural R&D by geographic area
(Source: Beintema and Elliott, 2009)

Increasing food demand would be met by closing the yield gap with locally adapted forms of sustainable intensification and organic farming and gardening, in particular in Africa, broadening the genetic basis and spectrum of food and feed species to best match local soil and climate constraints, including vegetable and tree species. In parallel, landless high-intensity agriculture with close nutrient cycling and urban gardening and agriculture would produce high-value fresh food for the cities.

As well as increases in agricultural yields, future land needs can be influenced by dietary changes and reduction in post-harvest losses. The greater share of global agricultural land (80%) is used for meat-especially beef-production. A transition towards less meat-intensive diets would be an effective way of reducing demand for land. Decreasing post-harvest losses-estimated to be around 30%-is another way to ease the pressure on land (van Schaik et al., 2010).

Research needs

Given the need to feed more than 9 billion people towards the middle of the century, and given growing competition for land use for non-food production, it is evident that unit area agricultural productivity needs to be maintained in those areas where it is currently close to its optimal potential, and increased in those extensive areas where it is presently less than optimal. The challenge is to deliver these increased levels of production without further damaging the environment and further undermining other ecosystem services (The Royal Society, 2009).

It will be necessary to discover and implement ways of increasing agricultural productivity and the resilience of agricultural systems. Increasing agricultural productivity and efficiency with regard to water and nutrient use first and foremost requires increased investment in agricultural research. An investment of 1000 billion USD over the next 50 years is needed to increase food availability and to reduce the impact on biodiversity by reducing pressure on land (IAASTD, 2009). Research should partially be aimed at increasing agricultural productivity by enhancing input efficiency and ensuring greater compatibility with sustainable land management practices (Netherlands Environmental Research Agency and Stockholm Resilience Centre, 2009). Investment in the implementation of existing technologies is also critical, especially in developing countries.

Research should also seek novel ways of integrated crop and animal production in which nutrients are effectively recycled and pests controlled by biological means, including novel forms of landless agriculture, aquaculture and urban gardening. Much can be learned from exploring and adapting traditional agricultural knowledge.

Sustainable intensification

Producing more food from the same area of land while reducing the environmental impacts requires what has been called "sustainable intensification". In exactly the same way that yields can be increased with the use of existing technologies, many options currently exist to reduce negative externalities. Net reductions in some greenhouse gas emissions can potentially be achieved by changing agronomic practices, the adoption of integrated pest management methods, the integrated management of waste in livestock production, and the use of agroforestry. …Strategies such as zero or reduced tillage (the reduction in inversion ploughing), contour farming, mulches, and cover crops improve water and soil conservation, but they may not increase stocks of soil carbon or reduce emissions of nitrous oxide. Precision agriculture refers to a series of technologies that allow the application of water, nutrients, and pesticides only to the places and at the times they are required, thereby optimizing the use of inputs.

The suite of technological options should be as broad as possible, ranging from new plant varieties and animal breeds better adapted to changing conditions; to farming systems with improved water- and labour-saving technologies; reduction of losses and waste; and natural resource management. Technological advances are particularly needed in the staple crop sector (FAO, 2010). Public investment in innovative research are necessary to create better management techniques that combine large agricultural production with low inputs, low emissions and high biodiversity value. New methodologies that embrace all elements of the agricultural system are needed, including better soil management and enhancement and exploitation of populations of beneficial soil microbes (The Royal Society, 2009). Work on enhancing the feed conversion efficiency in animal production is needed as is that on animal welfare.

Agricultural extension services should be a key component of any strategy to ensure that scientific knowledge are appropriately developed and targeted.

The future must also involve increased diversity in agriculture, which is key to strengthening resilience in agricultural systems (Netherlands Environmental Research Agency and Stockholm Resilience Centre, 2009). Specifically, in the EU, diversity needs to become a strategic objective of the Common Agricultural Policy and related policies. This is essential in maintaining and increasing current agricultural productivity in the EU, as well as providing a buffer against shocks and in helping to maintain the biodiversity and cultural landscapes of Europe.

5.3.2. Water

Current state of the problem

An average, 42% of total water abstraction in Europe is used for agriculture, 23% for industry, 18 % for urban use and 18% for energy production. Agriculture accounts for 50–70% of total water abstraction in southwestern European countries and countries of Eastern Europe, the Caucasus and Central Asia. Cooling for electricity production is the dominant use in Central European countries.

The breakdown of water consumption between the various economic sectors varies considerably from one region to another, depending on natural conditions and economic and demographic structures. In France (64%), Germany (64%) and the Netherlands (55%), for example, most of the water abstracted is used to produce electricity. In Greece (88%), Spain (72%) and Portugal (59%), water is mostly used for irrigation. In Northern European countries such as Finland and Sweden, little water is used in agriculture. In contrast, cellulose and paper production, both highly intensive water-consuming industries, are significant activities and water is abstracted mainly for industrial purposes (66% and 28% respectively of total abstractions).

In Southern Europe, irrigation is an essential element of agricultural production, whereas in Central and Northern Europe, irrigation is generally used to improve production in dry summers. Southern European countries account for 74 % of the total irrigated area in Europe. This is expected to increase further following new irrigation development in some countries. In the central EU Accession Countries, changes in the economic structure and land ownership, and the consequent collapse of large-scale irrigation and drainage systems and agriculture production have been the main drivers for agriculture changes over the past 10 years (UNEP, 2003).

The Water Framework Directive (EU) (2000/60/EC[4]) seeks a greater responsibility in how water is used and its effects on the environment and also demands more water for environmental uses. At the world level water requirements are summarised in Table 5.2.

Table 5.2. Water consumption by sector and crop in km^3 in the year 2000

	Total Crop water consumption agriculture	Share from Irrigation (%)	Total withdrawals for irrigation	Total withdrawals for domestic and industrial	Water consumption of biomass and energy	Water consumption for biofuels crops
Sub-Saharan Africa	1071	6	68	10	149	
East Asia	1661	22	518	99	139	14
South Asia	1505	41	1095	34	102	8
Central Asia and Eastern Europe	772	20	244	156	27	
Latin America	895	12	175	52	84	4
Middle East and North Africa	225	61	173	24	4	
OECD countries	990	17	233	519	27	32
World	**7130**	**22**	**2630**	**877**	**535**	**104**

Source: De Fraiture et al. (2007)

Projections

In different scenarios and forecast, water as a basic resource of agriculture productivity is an essential strategic objective mainly oriented to improve productive efficiency in the use of water ("more food per drop"; UNESCO, 2003).

[4] Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy, http://europa.eu/legislation_summaries/agriculture/environment/l28002b_en.htm

It seems evident that water for irrigation within the EU will not increase in the future, especially in the most irrigation water demanding countries, or even be reduced due to environmental pressures and urban demand.

Irrigation projections have been simulated with the WaTerSIM model (De Fraiture, 2007) which consist in two fully integrated modules: 1) food production and demand (increase water productivity) and 2) water supply and demand (increase irrigated lands). Business as usual scenarios (Table 5.3) result in world irrigation water requirements (2631 km^3 in 2000) and the 2050 forecasting for two different scenarios are 3460 and 4121 km^3.

Table 5.3. Irrigation scenario results (business as usual)

	Irrigation cereal yield 2000 (tm/ha)	*Irrigated cereal yield 2050 YI-Sc (tm/ha)*	*Irrigated cereal yield 2050 AR-Sc (tm/ha)*	*Irrigation withdrawals 2000 (Km^3)*	*Irrigation withdrawals 2050 YI-Sc (Km^3)*	*Irrigation withdrawals 2050 AR-Sc (Km^3)*
Sub-Saharan Africa	*2.2*	*5.6*	*3.1*	*72*	*110*	*159*
Middle East and North Africa	*3.5*	*6.8*	*4.4*	*181*	*273*	*279*
Central Asia and Eastern Europe	*3.4*	*7.2*	*4.2*	*256*	*374*	*333*
South Asia	*2.7*	*5.4*	*4.1*	*1150*	*1491*	*1817*
East Asia	*4.0*	*6.8*	*5.7*	*544*	*694*	*927*
Latin America	*4.0*	*7.6*	*5.5*	*184*	*268*	*304*
OECD countries	*6.6*	*9.0*	*7.2*	*245*	*274*	*303*
World	***3.7***	***6.5***	***5.0***	***2631***	***3460***	***4121***

Source: De Fraiture and Wichelns (2010).**YI-Sc**: Yield scenario that emphasizes improvement of land and water productivity; **AR-Sc**: Area scenario focused on irrigated areas expansion.

A more recent analysis by the same authors (De Fraiture and Wichelns, 2010) concludes that only if water is managed more effectively in agriculture will sufficient land and water resources be available. In Table 5.4 the first columns show the necessary improvement in productive water use efficiency (in this case in cereals) to fit the objectives. Special attention should be given to the OECD countries where the optimised scenario only allows 2% more water for irrigation to accomplish the general goals.

Table 5.4. Regionally optimised irrigation scenario results

	Irrigated water productivity cereals 2050 (kg/m^3)	**Cumulative change (%)**	**Rainfed water productivity cereals 2050 (kg/m^3)**	**Crop water consumption 2050 (km^3)**	**Cumulative change (%)**	**Irrigation withdrawals 2050 (Km^3)**	**Cumulative Change (%)**
Sub-Saharan Africa	0.50	58	0.28	1379	29	100	46
Middle East and North Africa	0.82	41	0.25	272	7	228	8
Central Asia and Eastern Europe	1.05	43	0.69	773	0	271	11
South Asia	0.79	62	0.46	1700	15	1195	9
East Asia	1.05	45	0.57	1990	19	601	16
Latin America	0.91	52	0.63	1361	52	196	12
OECD countries	1.42	18	1.30	1021	4	238	2
World	**0.93**	**38**	**0.64**	**8515**	**20**	**2975**	**13**

Source: De Fraiture and Wichels (2010).

Water productivity is the ratio of the net benefits from crop, forestry, fishery livestock and mixed agricultural systems to the amount of water used to produce those benefits. Water productivity is an important indicator of efficiency. It can be related to different outputs (physical, economic, social, etc.; Table 5.5). Nowadays water productivity presents a wide range of values depending on the product but also within the same product. The upper ranges can even be higher than those shown in Table 5.5.

Summary of the Comprehensive Assessment of Water Management in Agriculture

The Comprehensive Assessment has identified a clear need for investments in agricultural water management. The best types of investments and optimal implementation plans will vary across water basins and regions. In most situations, efforts to improve water management and increase agricultural productivity will require difficult choices involving tradeoffs that might include:

(1) Providing water storage for agriculture—ensuring water for the environment. The Comprehensive Assessment describes the need for more storage of water including, as locally appropriate, reservoirs behind large and small dams, groundwater recharge and storage, and water harvesting – albeit at a slower rate than in the past. The strategy of increasing water storage will be implemented in many regions, partly as a precaution against changes in rainfall patterns due to climate change. This strategy, while optimal from a water supply perspective, will decrease stream flows in some rivers for some period of time.

(2) Reallocation—over-allocation. Providing access to water and safeguarding water rights have been identified as key poverty concerns. In many ‘‘closed’’ basins, water resources are already over-allocated, making allocation decisions particularly difficult. New allocations of water in closed basins will require renegotiating existing water allocations. Key questions in this process will include who will benefit the most from increases in water allocations, and how will winners compensate the losers.

(3) Upstream–downstream. Economic development in the upstream reaches of river basins often has impacts on freshwater fisheries, environmental flows, and coastal areas in lower portions of the basins. Often economic development projects are implemented without discussing them with those who might be impacted. Discussions regarding upstream developments, downstream impacts, and potential compensation programs often are complicated due to cause and effect relationships that are difficult to identify and property rights that are not clearly defined. Inadequate property rights, unequal social status, and too little political influence often leave poor farmers and poor fishers unable to retain access to water when upstream developments reduce flows to downstream areas.

(4) Equity—productivity. Investments that promote productive and efficient agriculture tend to favour the wealthy, while investments and policies that promote more equitable agriculture are not necessarily productive.

(5) This generation—the next ones. Some choices made now will impose benefits and costs on future generations. For example, with groundwater levels dropping in many areas, mining the groundwater further today will reduce the volume available in future. Hence, investments and policies pertaining to groundwater use must account for the long-term ‘‘scarcity cost’’ that users today impose on future generations. The optimal investments and policies will ensure that the incremental benefits of groundwater use today are sufficient to cover today’s pumping costs, plus the cost of having less groundwater available in future. This perspective is consistent with the notion of developing groundwater resources in a sustainable manner, rather than supporting economic development today, with no plan for maintaining economic activity and supporting livelihoods in future (De Fraiture et al., 2007, 2010).

Where water productivities can be improved (mainly physical and economic water productivities), we have to realise that water productivity gains are slow, and depend not only on the knowledge or science available but also on the degree of uptake by farmers.

Several analysts have suggested that in order to improve productivity it would be appropriate to combine public investments in improving infrastructure with training and awareness programs, as if run only the first a significant increase in the volume of irrigation water used has been observed. In this sense, Gordon et al. (2010) propose three main strategies by which agricultural water management can deal with the proposed objective: (a) improving water management practices on agricultural lands, (b) better linkage with management of downstream aquatic ecosystems, and (c) paying more attention to how water can be managed to create multifunctional agro-ecosystems. This can only be done if ecological landscape processes are better understood, and the values of ecosystem services other than food production are also recognised.

Table 5.5. Range of water productivities in biological, economic and nutritional terms for selected commodities

Product	Value	Water Productivity			
	Dollars per kilogram	Kilograms per cubic meter	Dollars per cubic meter	Protein grams per cubic meter	Calories per cubic meter
Cereal					
Wheat	0.20	0.20 - 1.20	0.04 – 0.30	50 – 150	660 – 4000
Rice	0.31	0.15 - 1.60	0.05 – 0.18	12 – 50	500 – 2000
Maize	0.11	0.30 - 2.00	0.03 – 0.22	30 – 200	1000 – 7000
Legumes					
Lentils	0.30	0.30 - 1.00	0.09 – 0.30	90 – 150	1060 – 3500
Fava beans	0.30	0.30 - 0.80	0.09 – 0.24	100 – 150	1260 – 3360
Groundnut	0.80	0.10 - 0.40	0.08 - 0.32	30 – 120	800 – 3200
Vegetables					
Potato	0.10	3.0 - 7.0	0.30 – 0.70	50 – 120	3000 – 7000
Tomato	0.15	5.0 – 20.0	0.75 – 3.00	50 – 200	1000 – 4000
Onion	0.10	3.0 – 10.0	0.30 – 1.00	20 – 67	1200 – 4000
Fruits					
Apples	0.80	1.0 – 5.0	0.80 – 4.00	Negligible	520 – 2600
Olives	1.00	1.0 – 3.0	1.00 – 3.00	10 – 30	1150 – 3450
Dates	2.00	0.40 – 0.80	0.80 – 1.60	8 – 16	1120 – 2240
Others					
Beef	3.00	0.03 - 0.10	0.09 – 0.30	10 – 30	60 – 210
Fish	1.42	0.05 – 1.00	0.07 – 1.35	17 – 340	85 – 1750

Source: Molden et al. (2010)

Water scarcity

Because climate is probably the main factor (physical factor) in crop water productivity climate change brings a further uncertainty to the scope for increasing water productivity (Molden et al., 2010). However, the key drivers to increase water productivity are scarcity and raising water prices (Berbel and Gómes-Limón, 2000; Hellegers and Perry, 2006; Molle and Berkoff, 2006).

Temporal water scarcity scenarios seem to be one of the general agreements within the climate change discussion. Water scarcity may increase water productivity, sometimes because this scarcity helps to use only the necessary water to produce, but if the scarcity acts on areas with high irrigation water demands (especially southern and central-south EU countries) or in areas with adjusted equilibrium between all water users, the water availability for irrigation can be drastically reduced, on a temporary basis, and as usual these reductions coincide with the higher crop water requirements.

It has been shown that agriculture can coexist with water shortage (Girona et al., 2010), especially if this is temporary, and also that applying different deficit irrigation strategies yield can be increased (Chalmers et al., 1981; Girona, et al., 2003). Studies on how to use less water to increase yield and productivity have only started (Marsal et al., 2008).

Farmers´ water use

Scientific advances in the field of plant water relations have not materialised in improved production efficiency in the water. The causes may be the type of research (more plant-physiological studies and less irrigation water ones) or lack of incentives to make this information as applicable in the irrigation management practice. Efficient implementation of the irrigation water is a complex task that requires time and expertise. A recent exploration of knowledge that farmers apply in irrigation management indicated that agriculture could currently be applying less than 10% of existing knowledge. However if technology is analyzed (irrigation, communication systems, automations, etc.) it could exceed 85% (J. Girona, unpublished data). For more efficient use of water, therefore it is necessary to provide the farmer with practical tools for irrigation management.

To improve this situation and to complement large investments in infrastructure, three things to keep in mind are proposed: (1) train and inform the farmer on water management and irrigation practices, (2) develop practical technologies to help the farmer to apply irrigation, (3) facilitate implementation of the commercial (private) technical irrigation services (especially if it is automated), and to improve technical help from the administration on this matter (extension services).

Interaction with other scarcities

Water scarcity refers to regional shortage or excess. Here we focus on irrigation, where scarcity mechanisms comprise limited access, either technological, legal or through pricing. Water mismanagement immediately feeds back on the fertile land resources. Much formerly fertile land in dry regions has been lost due to salinisation. Rising water demand increases energy costs of water provision and risks of nutrient losses. Climate change strongly affects water resources and the seasonality of water supply. Interactions between irrigation and biodiversity are unclear. Overall, irrigation and water management are critical drivers of productivity increase in agriculture to meet future food demand.

Reflections on narratives

The two narratives used do not supply much information or discussion about water issues. But using the main data from the different scenarios developed (population and human nutritional requirements (Kcal/hab/day), together with the water nutritional productivity (Table 5.6), total water requirements to produce the Kcal necessary for six scenarios covering the narratives has been calculated

The methodology used to calculate the total water requirements was:

Total Water to produce meat (km^3) = Population (billion)* Kcal from meat (Kcal/hab/day)* 365 days/ (297 (Kcal/m^3)*1000)

For vegetables a value of 1460 (Kcal/m^3) was used. The results for the year 2000 are in accordance with those by De Fraiture et al. (2007) in Table 5.3.

If we assume that a possible scenario could be between AGO and AG1, and also that water availability will be the same in future, water productivity in EU countries should increase by 24% (moving from 1460 Kcal/m^3 in vegetables to 1810, and from 297 Kcal/m^3 to 369 in meat). However the likely scenario is that water availability for agriculture will be reduced because of other demands, mainly urban and environment, and consequently water productivity should increase much more, especially in the countries where water allocation in agriculture is high.

Table 5.6. Total calculated water requirements to produce the calories required for 2050

Year	Scenario	World water requirements (Km^3)	World Irrigation withdrawals (Km^3)	World % Differences from Current	OECD water requirements (Km^3)	OECD Irrigation withdrawals (Km^3)	OECD % Differences from Current Scenario
2000	Current	7003	2311	0%	1700	289	0%
2050	Western high	13416	4427	92%	2009	342	18%
2050	Current Trend	11212	3700	60%	1982	337	17%
2050	less meat	9988	3296	43%	1285	218	-24%
2050	fair less meat	7987	2636	14%	914	155	-46%
2050	AG1	10911	3601	56%	1322	225	-22%
2050	AGO	15565	5136	122%	2881	490	69%

Research needs

Based on the different scenarios described, the aspects to be addressed by research in water uses have to provide science and technology to the following main topics:

- To maximise water productivity.
  - The used irrigation systems have to be the most efficient ones.
  - Specific field or orchard water requirements have to be easily evaluated to schedule irrigation.
  - Irrigation management has to take into account spatial field and orchard heterogeneity.

- To reduce energy consumption.
  - Less energy- consuming systems have to be developed in order to preserve energy and to reduce farm costs.

- To use alternative water resources.
  - To use ground water resources.
  - To use reduced water supplies to increase yields in dry land zones.
  - To use waste water resources.

- To preserve the environment from pollution, soil degradation and soil erosion.
  - To reduce water drainage enough to prevent pollution or contamination, but at the same time to apply enough to prevent soil degradation (soil salinity).

- To develop legal and economic incentives to promote the best uses of irrigation water.
  - To develop water markets.
  - To analyze the effect of water prizing on water efficiency, productivity and the possible impacts on global food production.

- To develop technologies to facilitate on farm irrigation efficiency.
  - To increase famers education and knowledge on irrigation management.
  - To develop public or private services to help farmers to manage irrigation.
  - To provide farmers with online information about crop water requirements.

And one of the most important:

- To learn how to manage water scarcity.
  - To apply water to the most efficient crops (food production and economical aspects).
  - To develop irrigation strategies based on plant seasonal sensitivity to water stress.

- To develop systems to facilitate Irrigation districts managers to distribute water based on online irrigation demand.

5.3.3. Energy

Current state of the problem

The Second Foresight Exercise has given a detailed analysis of energy issues and their relation to food production, which is still up to date. We therefore only add aspects that have emerged, changed or gained additional dynamics since FEG2, and focus on bioenergy-food relations. In 2008 the world experienced the complexity and the reality of the interlinkages and the interdependencies between food and energy. So far in-depth analyses and assessments of the likely impacts of biofuels development and biofuels use on international food prices, the security/insecurity of food, the risk of losing biodiversity and the greenhouse gas savings are not available (Fisher et al., 2009).

There are several global energy scenarios, e.g. by IEA (2009) and Greenpeace (2010). They differ in their assumptions on climate policies but generally agree that oil will remain the single largest fuel in the primary fuel mix for the next decades. Oil prices have fallen from the 2008 level of $97 per barrel to around $60 per barrel in 2009 due to the effect of world recession, but then they are expected to rise again with the economic recovery, to reach $100 per barrel by 2020 and $115 per barrel by 2030.

As Hubbert (1957) first pointed out, oil extraction rates follow a logistic distribution trend. The peak is the rate of extraction (per unit of time) that equals the rate of demand growth. Beyond this limit, demand will outpace supply and prices will grow. What is important for the stability of economic systems, then, is not only the time to exhaustion of reserves, but also the time of the peak. There are a large variety of opinions on when fossil fuels will peak, but very few think that oil reserves will peak after 2020.

Agriculture is strongly dependent on fossil fuels, and especially oil and gas. In a very well known article, Pimentel et al. (1973) provided a breakdown of energy inputs for an hectare of maize. From his analysis it was shown that in 1970 31% of energy employed in corn production was fuel, and nitrogen accounted for about 28% of total energy input. More recent evaluations (Pfeiffer, 2006) show the following breakdown for US agriculture:

- 31% for the manufacture of inorganic fertilizer
- 19% for the operation of field machinery
- 16% for transportation
- 13% for irrigation
- 0.8% for raising livestock (not including livestock feed)
- 0.5% for crop drying
- 0.5% for pesticide production
- 0.8% miscellaneous.

Energy-intensive agriculture and food provision depend so much on fossil energy that production prices are linked with energy prices (IFPRI, 2008).

Growing food amounts only to one fifth of the total energy used in the food chain (Murray, 2005). Transport is important because the distance between production and consumption is increasing. In the field of fresh fruit and vegetables this allows the supply to fully overcome the constraints of seasonality. More generally, grocery chains tend to restrict the number of suppliers and therefore prefer big ones who are able to organise large amounts of product. Also processing and packaging account for an important share of total energy consumption and can consume five times as much energy as contained in e.g. packaged fruits or cereals (Murray, 2005). Refrigeration and food preparation account for the remaining part.

Policy actions, bioenergy subsidies and the growing demand for biomass energy have been increasing the prices of land and for important crops such as maize, wheat and oilseeds. Support to biofuels is perceived to be one of the most important causes of the food prices spike in 2008. The development of large-scale biofuel chains could harm vulnerable local food systems (Brunori et al., 2008). With every one percent increase in the cost of food today, 16 million people are made food insecure (IAASTD, 2009). For details about bioenergy, see sections 5.5.3. and 7.2.6.

Projections

Oil scarcity may affect the food system in two ways: (1) shocks, that are a sudden deviation from normality; and (2) stresses, which are a continuous trend of intensification of the problem. Shocks would strike most where the system is most oil dependent: for example, the British system is very efficient, but heavily dependent on long distance sourcing, and a crisis in the energy sector may put food access of the Britons in danger. In countries with less efficient power distribution, the damage and chaos resulting from a black out could be much worse. Stresses could manifest themselves in a trend of rising prices, and if unattended, could bring to forms of adaptation which might be far from efficient.

Among the possible effects of stresses on agriculture related to oil prices there could be:

- Increase of costs of production, bringing a reduction of fertilizer and pesticide use, especially by resource poor farmers, and therefore a reduction of yields and / or impoverishment of soils (Jaggard et al., 2009).
- Increasing profitability of energy production from agricultures, that would generate problems for land use competition and consequently to further rise in food prices
- Reduction of consumption and changing dietary patterns, that may lead to an increase in malnutrition.

Hotspot regions

According to the Greenpeace (2010) energy scenarios, Latin and North America, Europe and the Transition Economies all have the potential to exploit modern technologies either in stationary appliances or the transport sector. In the long term, Europe and the Transition Economies will realise 20-50% of the potential for biomass from energy crops, whilst biomass use in all the other regions will have to rely on forest residues, industrial wood waste and straw. In Latin America, North America and Africa in particular, an increasing residue potential will be available. In other regions, such as the Middle East and all Asian regions, the additional use of biomass is restricted, either due to a generally low availability or already high traditional use.

Type of scarcity

In principle, there is more than enough solar energy to supply the world´s population. The next decades will need to face a rapid shift of energy sources from fossil ones, in particular oil, to renewable ones. During this transition, energy prices are expected to raise further.

Bioenergy itself is not a scarcity, but it is linked to scarce resources of other energy carriers and concerns about energy security at national and global level. The supply of energy itself is not scarce globally but the reliance of the world economy on finite energy carriers, which are concentrated in few world regions and resulting oligopolistic structures of governance make energy access and prices an issue of scarcity. Bioenergy therefore has often been seen as a means to enhance national energy security by domestic sources although e.g. Europe is increasingly depending on biomass imports to meet the renewable energy targets.

Interactions with other scarcities

The energy demand of intensive agriculture and food processing accounts for a significant share of electricity and heat demand, and associated environmental impacts.

Apart from the price effects, existing support to biofuels might have important implications for global land use and all other resource scarcities.

An appropriate choice and management of energy crops can also decrease soil erosion or water pollution risks from agricultural and pastoral practices and provide certain biodiversity benefits. Such benefits will only come about, however, if policy and economic incentives are in place to steer bioenergy production in this direction. Protecting soil and water resources as well as avoiding loss of biodiversity, required particular attention at local and regional level whereas issues such as climate change have a strong global dimension (EEA, 2008).

Reflection on the narratives

Oil scarcity brings to the fore the dilemma between productivity and sufficiency: on one hand, the productivity narrative should be undermined due to the effect of oil scarcity, and then could make less effective some of the solutions proposed, e.g. higher level of fertilisation in poorest countries and mechanisation (World Bank, 2007). On the other hand, a combination of more efficiency in resource use and a path for changing consumption behaviour could help integrate the productivity narrative into the sufficiency one.

The narratives point to choices of biomass substrates for bioenergy. In the productivity narrative, agrofuels can play a major role and the emergence of second generation biofuels is interpreted as means to reduce pressure from food crop production (e.g., UNDP, 2000).

In the sufficiency narrative, environmental safeguards are stronger so that the potential for bioenergy production on fertile land is projected in far lower ranges (e.g., Eating the Planet). Biomass substrates are preferably derived from cascading use of biomass, e.g. as end use. Dietary changes could release fertile land for additional agrofuel production.

Transitions and solutions

Low-input agriculture and enhanced energy efficiency offer great potential for making food production more resilient to oil price spikes.

Development of cheap, sustainable and effective bioenergy chains based on residues and waste from the food and fibre sector via cascade utilisation is an option. This includes the use of biomass in combined heat and power generation where almost no pre-treatment of the biomass is needed.

Strong efforts are needed in a range of policy and research areas to minimise the potential negative environmental impacts of bioenergy production, including the use of harmonised internationally recognised environmental sustainability standards (EEA, 2008). A global consensus and control of sustainability criteria is needed, which should not only be used for bioenergy but be expanded to agricultural production as a whole.

Research needs

Agro-ecological approaches, nutrient management and replacement of energy intensive inputs, in particular of synthetic nitrogen fertilizer by legumes, need to be further developed. They have multiple benefits, not only for energy consumption of food production, but also for reducing eutrophication. Research should also find energy-efficient technologies in the hotspots of the food chain where most of the energy consumption takes place: food processing and retail and energy-intensive production systems, in particular in animal husbandry and greenhouse gardening.

RTD activities are concentrated mainly in the developed countries. Research needs to ensure that second-generation biofuels will provide economic, environmental and social benefits for developing countries (Eisentraut, 2010). This could include a global road map for technology development, an impact assessment of commercial second-generation biofuel production, and improved data on available land, water and required nutrients, and land competition. Additionally, more case studies could analyse local agricultural markets, material flows, and specific social, economic and environmental benefits and risks in developing countries.

Further, additional research is needed to better understand the environmental and social risks related to land use changes resulting from biofuels expansion.

As the Green Revolution had focused its efforts on high yielding, high input seeds to fulfil the goal of increasing food production, it had implicitly counted on cheap oil. With oil scarcity becoming the dominant scenario in the future, a sustainable agriculture will have to look to other resources as the basis for new technological pathways. In this regard, those who work in the field of GMOs claim that there is a huge field of research addressed to plant improvement for saving resources (for example, by increasing photosynthesis efficiency). For the prospects of genetically modified organisms, see section 6.3.2. However, there are also other fields to be explored, such as diversification of the genetic base of cultivated plants (populations, species and varieties), use of renewable energy in agriculture, and improvement of ecological efficiency of the whole system.

In our view, it is also necessary to focus on three main research and innovation pathways:

- Systematic energy accounting of different food chain patterns, including domestic food management;
- Information feedback to consumers about the environmental impact of their consumption styles and diets;
- Community based innovation, aimed at replacing oil and existing oil-based technologies with other–cheaper–resources. In this regard, social and organisational innovation–and the potential of ICT–should be taken into account as well.

5.3.4. Nitrogen

Current state of the problem

Nitrogen is the major macro-nutrient for plant growth. Human activities now convert about 150 Mt N yr^{-1} N_2 from the atmosphere into reactive forms – more than all natural terrestrial processes. Ammonia production amounts to ~80 Mt N yr^{-1}, N_2 fixation by leguminous crops ~40 Mt N yr^{-1}, fossil-fuel combustion ~20 Mt N yr^{-1}, and biomass burning ~10 Mt N yr^{-1} (Rockström et al., 2009). Most of this new reactive N is used as fertilizer for food and feed production, and more recently, for biofuels but much of it leaks out of the agricultural production chain into the environment, eutrophying and acidifying forest and other terrestrial ecosystems, freshwater and coastal zones via leaching, runoff and atmospheric deposition.

Nitrogen is a scarce resource in agriculture in two respects: undersupply of nitrogen and phosphorus poses a critical constraint to yields in developing regions, while in high-intensive agricultural regions, nitrogen excess and loss cause environmental pollution. Closing the existing yield gap, in particular in Africa, will require higher input of reactive nitrogen – either by fertilizers or by legumes. The regional concentration of animal husbandry and the use of imported protein-rich feed leads to high levels of nitrogen excess in some agricultural regions, while nitrogen is lacking in other regions dominated by crop production. The value of animal manure as fertilizer is currently not adequately recognised in Europe apart from niche applications in organic farming.

Synthetic fertilizer is one of the most energy-intensive agricultural inputs, if not the most energy-intensive one. The roughly fivefold increase in fertiliser price between 2005 and 2008 was strongly influenced by the oil price (The Government Office for Science, 2011). Although short-term projections until 2013 see the global N fertilizer supply ahead of demand (FAO, 2009b), in the mid-term, growing global demand for synthetic N fertilizer may lead to high prices and increased price volatility, coupled to fossil fuel prices.

According to local and regional studies and the default assumption by IPCC (2006), 30% of N input to agro-ecosystems is leached to surface waters and groundwater in humid regions. Nitrogen from agricultural sources accounts for between 50 and 80% of the nitrates entering Europe's water (Brunori et al., 2008). Reactive nitrogen emitted from agriculture is a major constituent of air pollution. By 2010 at the latest, EU Member States will be obliged to limit their emissions of SO_2, NO_X, NMVOC and NH3 to the ceilings defined in the NEC Directive 2001/81/EC to reduce the acidification and eutrophication of ecosystems. For 2010, EU-27 NO_X emissions are projected to remain 4 % above the aggregate emission ceiling given in Annex I (calculated on the basis of the individual Member State ceilings defined in the NEC Directive), and 14 % above the stricter Annex II ceiling of the NEC Directive for the EU-27 as a whole (EEA, 2010a). Whilst EU-27 is projected to meet the NH_3 emission ceiling the important emitter countries, Germany, the Netherlands and Spain expect to remain above their emission ceilings (EEA, 2010a). Hence reducing acidification and eutrophication of European ecosystems by reactive nitrogen remains a yet unresolved issue in Europe. Despite great technological progress that minimises NH_3 emissions from manure spreading, the common agricultural practice in Europe still leaves a significant N saving potential unexploited, which could immediately be mobilised. Some EU Member States have attempted to limit the N surplus at farm level or field level with variable success. The implementation of existing national legislation often remains imperfect.

Projections

Current trends in agricultural production would lead to more than a two fold increase in global consumption of N fertilizers (Tilman et al., 2001). This is incompatible with the fact that even today, the planetary boundary for human N fixation is exceeded by a factor of four (Rockström et al., 2009) .

Type of scarcity

The scarcity of N refers to the global constraints on the use of N that are created by the need to move to sustainable food production systems in which reactive N is recycled rather than leaked to other ecosystems. Nitrogen was classified as one of seven planetary boundaries (Rockström et al., 2009). The addition of reactive N to the environment acts primarily as a slow variable with time lag, eroding the resilience of ecosystems via acidification of terrestrial ecosystems and eutrophication of coastal and freshwater systems. Nitrous oxide emissions from agriculture also contribute to the climate change boundary.

Rockström et al. (2009) recommend as a first guess to limit global industrial and agricultural fixation of N_2 to 35 Mt N yr^{-1}, which is 25%-35% of the total amount of N_2 fixed per annum naturally by terrestrial ecosystems, and about 25% of present industrial and agricultural fixation. In light of the required increase in reactive N input to close the yield gap in developing regions, the reduction in newly fixed N input in European agriculture must be proportionally stronger to stay globally within the planetary boundary.

Within European regions, nitrogen imbalances – surplus versus shortage or demand – are unsustainable in light of pollution and inefficient in light of output/input ratios of agricultural products with regard to energy and nitrogen.

Interaction with other scarcities

Inefficient N input to agriculture (too little, too much) leads to land degradation. The energy-intensive production of synthetic N fertilizer links the nitrogen scarcity closely with the energy scarcity.

There is a close interaction between nitrogen and phosphorus as key biological nutrients in driving abrupt shifts in aquatic and marine ecosystems and disruption of biodiversity. Human-induced degradation of ecosystems (e.g., overfishing, land degradation) and increase in N and P flows at regional to global scales may lead to detrimental non-linear change in terrestrial, aquatic, and marine systems, while simultaneously functioning as a slow driver influencing anthropogenic climate change and biodiversity loss (Rockström et al., 2009). The imbalance in the phosphorus cycle needs to be tackled jointly with the nitrogen cycle, in particular in excess regions of animal husbandry.

Reflection on the narratives

Nitrogen management most commonly followed the prevailing productivity narrative, in which high input of synthetic N fertilizer produces high yields, with dramatic consequences for ecosystem health locally to globally.

Tight nitrogen cycling in agricultural production has developed in tropical legume-based and agro-forestry systems and in organic farming systems in which N input entirely relies on biological N fixation and subsequent N recycling on-farm. These systems are in accordance with the sufficiency narrative.

Even though an enhanced N use efficiency can be achieved by breeding and farm management the reduction challenge posed by the planetary boundary is so huge that nitrogen use in agricultural production needs to be fundamentally revised. The challenge will most likely not be met without changing demand-side drivers of meat consumption.

Transitions and solutions

A reduction of meat consumption according to the recommendations of the WHO for healthy diet, and a shift from animal-based to vegetable-based proteins could reduce the carbon and nitrogen footprint of food consumption in the Western world considerably. Red meat and dairy products require much more nitrogen than cereals. The ranking of food nitrogen footprints is not consistent with their carbon footprints. Dairy products and chicken/eggs have relatively higher nitrogen footprints than carbon footprints (Xue and Landis, 2010).

At field, farm, regional, national and higher level, agriculture must move towards N budgeting and recycling in the agro-food and waste system. This is a radically different approach compared with the patch-work of 'end-of-pipe' policies and technologies that try to remove reactive N from the human system by back-converting reactive N to N_2 such as Nitrates Directive, NEC Directive and N removal by sewage treatment. The existing policies and technologies are ineffective in a systemic view because new energy is required to return the N_2 into plant available forms. There is a need for radically improved management and innovation within European farming systems and agro-food systems to improve the efficiency with which N is used and recycled and to reduce losses to the wider environment. Nitrogen in waste must be seen as a resource rather than a problem.

Low external input sustainable farming system (LEISA) and further advancements in the scientifically-informed development of organic farming systems show strong socio-technical possibilities and potential for reducing energy use and new human N fixation. Examples include: N-optimised animal husbandry in mixed animal – cropping systems, the optimal use of legumes in the rotation or as green manure, in integrated intercropping systems and agro-forestry. Nitrogen leaching rates in organic arable fields are reduced by 35% to 65% when compared with conventional fields (various European and US studies quoted in Brunori et al., 2008) .

A meat-reduced diet in the Western world and a shift to meat produced by grazing ruminants not fed by grain or by crop residues, milling wastes and other leftovers was suggested by Holmes (2010). More than half of the present global meat production would not qualify under this ecological approach.

Research needs

Taking the planetary boundary serious involves triggering much more efficient and less polluting ways of enhancing food production, N recycling at local and regional level and in the agri-food system and the return of N in human effluent back onto productive landscapes. Research and innovation need to make a step change in N efficiency, reducing N emissions and increasing value per resource unit, with benefits for saving scarce resources such as energy and water (The Government Office for Science, 2011).

A number of European research projects address this issue and need to be further developed in future thematic collaborative research. Critical research areas include legumes, organic N recycling and enhanced predictability of N availability and efficiency of organic forms of N fertilizers, agro-forestry systems that recover nitrate deeper from the soil profile, breeding and management for enhanced nitrogen use efficiency, including ICT-based monitoring, precision farming, animal feeding and novel concepts of animal-crop integration on-farm.

Comparative footprint studies of diets across the world, of meat and dairy products, should be performed with harmonised, comparable methodologies, for a better quantification and decision basis with regard to the energy, water, nitrogen and phosphorus footprint of human food consumption patterns.

In parallel, efforts to close the yield gap urgently need to be scaled up to develop sustainable, resilient and equitable LEISA systems in the areas where N input is below optimum today.

5.3.5. Phosphorus

Current state of the problem

Phosphorus is an essential, non-substitutable plant nutrient. Phosphorus is the major non-renewable and non-replaceable input to agriculture. Grain yields are highly sensitive to phosphorus deficiency.

Phosphorus is mainly lost from cropland by erosion and washed into rivers and the sea. Phosphate is the major limiting nutrient in aquatic ecosystems. an estimated 10.5 Mt P yr^{-1} is lost from the world's cropland, the primary source of P inflow to the oceans (Rockström et al., 2009). Phosphate eutrophication leads to anoxic zones in coastal areas which are lethal for fish and other marine organisms.

Despite the critical role of phosphorus for global food supply and security, as well as for the eutrophication and biodiversity loss in freshwater, coastal and marine ecosystems, phosphorus scarcity seems to have been underestimated so far (Vaccari, 2009).

Projections

Global phosphate demand is growing. Some researchers believe that phosphorus use will peak by 2030. Geological surveys suggest that the global phosphate reserves that are economically recoverable with current technology could last for another 90 years at present use rates (Vaccari, 2009). The phosphorus price peak in 2008 has demonstrated the potential of phosphorus access and distribution to cause geopolitical tension. The impacts of phosphorus scarcity are likely to be immense – in terms of rising food prices, growing food insecurity and widening inequalities between rich and poor countries. Decreasing quality of phosphate ore will raise fertilizer costs.

Hotspot regions

The highly weathered soils and young volcanic ash soils in tropical regions, in particular of sub-Saharan Africa and South America, have a high capacity to absorb phosphorus in non plant-available forms so that productivity in these regions depends even more on adequate phosphorus availability to crops than in the current high-producing cropping regions of the world.

Nearly 54% of global P fertilizer is being applied by Asian farmers, proportionally more than any other region. In contrast, only 3% of global P fertilizer is being used in Africa, although the soil is often naturally low in phosphorus (Lott et al., 2009). This imbalance between world regions of excess versus shortage is also found at sub-national and local level driven by a concentration of animal husbandry and P-rich manure in specialised farms and regions.

Seventy four percent of the global phosphate reserve is concentrated in the three major producing countries Morocco, China and South Africa (Passenier and Lak, 2009, p. 25 & 37). The EU is fully dependent on imported phosphorus.

Type of scarcity

Phosphorus scarcity in terms of supply will ultimately result from the irreversible consumption of ore reserves and from the loss of phosphorus from fertile soils by runoff, leaching and harvest (Annex 1). Phosphate eutrophication of aquatic ecosystems has demonstrably led to seasonal algae blooms or long-term tipping points when certain thresholds of P availability (together with high N availability) are passed. However, the exact position of these thresholds and of long-term accumulation in ecosystems are poorly known. Currently, the inefficiency of phosphorus use and its transport into sensitive aquatic zones has exceeded the planetary boundary which would limit human extraction of phosphate ore to 10-100 times the natural weathering rates. Current extraction would match the low end of this highly uncertain planetary boundary (Rockström et al., 2009).

Interaction with other scarcities

Phosphorus scarcity can be increased by climate change when extreme events increase phosphorus loss or in combination with freshwater scarcity when drought or flooding reduce the capacity of plants to take up phosphorus. Biodiversity loss can increase phosphorus scarcity if genetic resources with phosphorus-efficient or low-phosphorus traits are affected. Phosphorus scarcity has the lowest degree of interactions with other physical and biological scarcities (Annex 1) but may turn into a very sensitive geopolitical issue.

The phosphorus cycle needs to be tackled in combination with the nitrogen cycle, in particular in P and N excess regions of animal husbandry and because the combined effect of eutrophication is particularly detrimental for aquatic and marine ecosystems.

Reflection on the narratives

Arguments about phosphorus use in agriculture are similar to those about nitrogen: see section 5.3.4.

Transitions and solutions

Phosphorus fertilizer use needs to be optimised and better regionally balanced, i.e., more efficient use in Asia and more P could be applied in Africa in conjunction with more N to close the yield gap (Lott et al., 2009).

Reducing soil erosion and recycling phosphorus from farm and human waste could help make food production sustainable and prevent eutrophication of rivers and coastal waters (Vaccari, 2009).

Passenier and Lak (2009) suggest an integrated phosphate study to determine the risk of phosphate scarcity, its potential impacts on food security, and to enable better political control of the phosphate cycle. P lost today limits the capacity of future generations to feed themselves. Inter-generational equity necessitates a strong research effort to quantitatively understand and project phosphate demand, availability, geopolitical issues, to develop approaches towards a regional and global phosphate governance and to reduce the dependency on phosphate ore. The European Community fully relies on phosphate ore from abroad, so reducing demand, recycling and reusing phosphorus is also wise for phosphorus security in Europe.

Research needs

Relevant research is being coordinated by the Global Phosphorus Research Initiative:

- Phosphate governance
- Reduce the dependency on phosphate ore
    - Recycling of phosporus in the agricultural system from manure, feed supplements, sewage and municipal waste, and manufacture of detergents. The EU could recycle about half of its annual phosphate consumption of 1.34 million tonnes of phosphorus in the form of phosphate fertilizers (Haarr, 2005).
    - Reducing losses in agricultural production chains
    - Increased phosphorus use efficiency including mycorrhiza

- Reduced phosphorus demand by low-phytic varieties of crops developed by breeding and genetic modification can reduce global phosphate fertilizer demand by factor three (Lott et al., 2009).
- P-reduced human diets, i.e., less meat.

5.4. Trends in new or recently acknowledged scarcities and their impacts on food systems

5.4.1. Climate change

Current state of the problem

In 2008 and 2009 anthropogenic CO_2 emissions were the highest ever recorded despite the economic crisis. For 2010 a further rise in emissions at the high end of the past growth rate is projected (Friedlingstein et al., 2010). Net CO_2 emissions from forest cover change have slightly been corrected downwards to 1.1 ± 0.7 Pg C yr^{-1} for the last decade, which is consistent with estimates from remote sensing (Friedlingstein et al., 2010). The global anthropogenic CO_2 budget fails to include the emissions from peatlands in Southeast Asia, which are increasingly being deforested and drained for agriculture. These lands originally had some of the highest carbon stocks per hectare and are now rapidly losing carbon by peat decomposition or fire. In 2006, these 12.9 million hectares of degraded land emitted additional 0.1 to 0.2 Pg C yr^{-1} by peat decomposition (Hooijer et al., 2010) and have turned into the global hotspots of carbon vulnerability.

Many studies confirm that as the glaciers melt, the seven major river systems in Asia will be faced in the short and medium term with a sharp increase in the influx of water and therefore with floods, followed by periods of drought in the long term. A large proportion of the world´s population lives in these areas (Passenier and Lak, 2009, p. 23). Sea-level rise impact on coasts and mega-deltas, monsoon changes and extreme floods can occur in mega-rivers while droughts and high interannual variability can affect the Sub-Saharan Africa and Asian highlands.

It is now generally admitted that for a majority of regions in the world, the impact of climate change on plant productivity in agriculture is going to be negative, even when taking into account the positive effect of an increased CO_2 concentration in the atmosphere (IPCC, 2007b). The potential positive response to CO_2 is further limited by nitrogen and phosphorus, which is not yet adequately considered in the earth system models (Matear et al., 2010).

The general consensus at the climate summits in Copenhagen 2009 and Cancún 2010 that global warming should not exceed 2°C or even 1.5°C above the pre-industrial level has not been backed by political action although global anthropogenic greenhouse emissions would need to peak between 2015 and 2020 to stabilize at 450 ppm CO_2. Leadley et al. (2010) even conclude that a concentration of 350 ppm CO_2 would be needed to guarantee the survival of coral reefs, which is in line with the suggested planetary boundary for the atmospheric CO_2 concentration (Rockström et al., 2009). Stabilizing global warming below 2°C will require cutting anthropogenic CO_2 emissions by 2050 compared with 1990 levels by half globally, or by 80% in industrial countries (IPCC, 2007a).

Agriculture both affects and is affected by climate change. For 2005, agriculture accounted for 10–12% of total global anthropogenic emissions of greenhouse gases, plus, e.g. for the year 2009, ~13% of CO_2 from deforestation (Friedlingstein et al., 2010). Globally, agriculture is the most climate sensitive economic sector. Food production will be adversely affected by climate change, in particular in developing countries that are already climate-vulnerable (drought, flood and cyclone) and that already face hunger and poverty. Climate change will also threaten food safety by increasing the pressure from vector, water and food-borne diseases (FAO, 2009c).

Projections

Business-as-usual scenarios following the high end of IPCC scenarios (as emissions do today) and the slow and uncertain process under the United Nations Framework Convention on Climate Change (UNFCCC) suggest an increase of global temperature of up to 4°C or more, with a high risk of passing several tipping points of the earth system.

Without additional policies, agricultural N_2O and CH_4 emissions are projected to increase by 35–60% and ~60%, respectively, to 2030, thus increasing up to twice as fast as between 1990 and 2005. Emerging technologies may reduce the emission intensity per unit of food produced, but absolute emissions are likely to grow to meet the expected increased food demand (IPCC, 2007c).

Climate change is also a question of mitigation, and agriculture is one of the important sectoral contributors to greenhouse gas emissions at the global scale. In the near future, agriculture will have to find joint solutions for adaptation to and mitigation of climate change, and FAO particularly calls for innovations and policies that will help to work in synergy for adaptation and mitigation.[5]

Hotspot regions

The frequent and severe droughts in the Sahel region since the 1970s and 1980s were mainly caused by recent ocean warming due to climate change (Giannini et al., 2003). In Western Africa, the impact of future climate change is very uncertain, but might be very radical: possible futures range from the complete disappearance of the African monsoon to its amplification. Under such possible prospects, agriculture must seek for a very robust adapative capacity, although for the moment existing farming systems in the area are among the weakest and least robust in the world, particularly because of other possible scarcities. Understanding and projecting rainfall patterns in West Africa and their agronomic consequences has led to a strong international research initiative for African Monsoon Multidisciplinary Analysis (AMMA, 2010).

In Europe, contrasts are going to be amplified between Southern and Northern regions. In Southern Europe, climate change is projected to increase stress by high temperatures and drought so that in a region already vulnerable to climate variability, water availability and crop productivity will further decline. In Central and Eastern Europe, water stress in summer and frequency of peat fires are projected to increase. Forest productivity is expected to decline. In Northern Europe, in the short term, climate change will bring benefits such as increased crop yields, wider range of crop species and increased forest growth. However, in the longer term, negative impacts by more frequent winter floods are likely to outweigh the benefits (IPCC, 2007b).

Hotspot regions with regard to greenhouse gas emissions from agriculture have not been systematically analysed at global level. However, emission per unit of area are high where animal density is high, e.g. in parts of Western Europe and the Po Valley, in paddy rice areas when flooding persists over the whole growing season, where peatlands have been drained for agriculture, and where ecosystems with high carbon stocks, e.g. forests or lands with high-organic soils, are converted to agricultural land. Regional differences in terms of emissions per unit of product cannot be assessed yet.

[5] FAO (2010). Towards a work programme in agriculture for the expertise body of the UN convention on climate change.

Type of scarcity

Climate change is a global anthropogenic phenomenon, which may already have exceeded the planetary boundary (Rockström et al., 2009).

Climate change increases the stress on ecosystems by trend and variability drivers. The need for adaptation to, and mitigation of, climate change poses additional pressures on food production. The challenge is to produce more, and to produce reliably, while not increasing, or even reducing, greenhouse gas emissions. Climate change trends already demonstrably impact marine fish populations and coral reefs. Extreme events and seasonal droughts damage fertile land and regional harvest quality and quantity and global food supply, leading to price volatility on food markets.

Climate change is a prime example of the failure of the global and national governance systems to solve, in a timely and equitable manner, one of humanity's major challenge, when the actors most suffering the consequences differ from the actors having caused the problem.

Food-affecting seasonal weather events in 2010
The extremely cold 2009-10 winter killed nearly 6 million (14%) of Mongolia's heads of livestock, adversely affecting 500,000 people. A severe, long drought throughout 2010 in the Sahel caused acute hunger for 10 million people in west Africa as livestock and crops were lost and food prices surged. In spring 2010, East Asia faced a drastic drought and dust storms, reported the worst drought in a century in southwestern China and Vietnam. The drought affected over 25 million farmers, and 18 million livestock, and 8.13 million hectares of arable land in China. One million farmers have left from the province of Guizhou to find work in other provinces. Later in the year, several Chinese provinces were hit by strong floods. The 2010 Pakistan floods directly affected about 20 million people. Floods have submerged 6.9 million hectares of Pakistan's most fertile crop land used for cotton, sugar cane, rice, wheat and animal fodder, have killed 200,000 herd of livestock and have washed away 500,000 tonnes of stocked wheat. Farmers may be unable to meet the fall deadline for planting new seeds in 2010, which would lead to a further loss of food production in 2011. In summer 2010, Russia and the Ukraine had massive forest and peat fires and yield loss of wheat by drought. The peat fires near Moscow and St. Petersburgh mainly happened on land that had been drained for agricultural use and mining of peat to generate energy. Drought also reduced yields in the CIS countries, which are one of the world´s major bread basket. Russia reacted on the droughts with an export ban for wheat, which immediately led to a price spike on the global cereal markets. China and India have already introduced bans for the export of wheat and rice in 2008 to protect national food prices.
Sources: www.en/wikipedia.org, FAO (2010)

Interactions with other scarcities

Climate change is intimately linked with all other scarcities in a bidirectional manner. Climate change accelerates, or increases changes in other scarcities. E.g. energy use is the main single cause of climate change, but climate change itself restricts e.g. the potential for water power by droughts and floods, higher energy demand for air conditioning in hot regions and by increasing risks of agricultural production of e.g. bioenergy. Climate change adds stress on ecosystems, which are already stressed by eutrophication. Agriculture will increasingly need water for irrigation, but climate change alters water supply and its seasonal distribution.

Climate change drastically increases uncertainty in projections because it makes the future more variable and unpredictable with contemporary knowledge and models. Climate change impacts on all human sectors and life support systems of the Earth so that feedback mechanisms can be strong and are so complex that even the easiest ones to measure and model are far from being understood.

Climate change is a major threat to global biodiversity. The great majority of organisms and ecosystems will have difficulty adapting to climate change (IPCC, 2007b).

Reflection on the narratives

Climate change impacts are therefore one of the main limits to the productivity narrative, because of potential systemic consequences of climate change that would induce a difficulty attaining theoretical potential productivity levels. The scarcity of water and other agricultural inputs is even reinforced when also thinking of the global budget of GHG in the atmosphere as being a limited natural resource.

In some recent reports, particularly concerning climate change, the sufficiency paradigm is understood in the following way: as resources are scarce, activities on the planet have to be distributed geographically in a way that corresponds to resources. This apparently simple vision can lead to very complicated impacts, particularly when one looks at future development pathways and development opportunities for low productivity agricultural systems. As an illustration, when the scarce resource considered is our limited greenhouse gas emission budget, the reflection about global allocation of production potential is particularly interesting but difficult.

Transitions and solutions

The interrelated challenges of food security, adapting to and mitigating climate change, and the growing demand for bioenergy require joint solutions. The impetus seen by FAO for investing in improved agricultural policies, institutions and technologies to meet the food security and energy goals "offers a unique opportunity to mainstream climate change mitigation and adaptation actions into agriculture" (FAO, 2009c).

So far, however, the international debate is fragmented and oriented in a short-sighted manner to profits from emerging carbon markets from carbon sequestration and 1st generation biofuels.

Formerly, a kind of weak consensus prevailed that climate change negotiations were an opportunity for the agricultural sector to gain payments for ecosystem services, when sequestering carbon in agricultural soils. But it is now clear that sequestration is only resulting from a change in agricultural practices and can therefore never be thought of as a permanent source of revenue for agriculture. However, both northern countries (for the CAP reform for instance) and southern countries (development agencies for Africa) think of carbon sequestration as a global public good that can be remunerated. Both assumptions are very fragile and are going to be either very controversial, or just abandoned in the near future. Carbon sequestration and mitigation for agricultural systems must obviously be mainly seen as an incentive for change towards soil-protective and low-emission practices, as the ones presented in IAASTD, rather than a new economic opportunity for farmers or for protection – oriented trade policies.

Agricultural biofuels (1st generation) have also until now seen as a new opportunity for the agricultural sector, mainly because of oil price increases. They are now being considered as a dangerous development for food security (IIASA – FAO report), and having an adverse environmental impact. European agricultural sectors are going be marked by the existing biofuels subsidisation policies, but it seems reasonable to envisage that their development is nevertheless going to stay limited. One possible scenario related to trade issues is that the demand for biofuels stays high, because the individual car use patterns will be very difficult to reverse, and that western developed and emerging countries might import biofuels from countries where it is more profitable to grow them, like Brazil. This scenario and its impacts on trade and food security should be studied further.

A visionary approach would develop a novel global division of land use activities that would significantly improve the geographical pattern of food and fiber production, biodiversity protection, infrastructure and energy generation. Science needs to demonstrate what an "optimal land use pattern" might look like, in a way that would warrant provision of ecosystem services and production. Analyses by WBGU (2009) show that the cropped are could be reduced if best sites were used for most appropriate crops and world food trade operated undistorted by protectionism. A resource scarce world is therefore a world where nations will negotiate and might enter conflict about the allocation of a development potential among countries, corresponding to resources and to their level of productivity in using these resources. The pricing of these resources in a global market would be the solution proposed by economists to avoid these conflicts and to rapidly come to efficient and flexible allocation of scarce resources, but as these global prices of resources (here, a global price for carbon) are difficult to implement, it is important to address more generally what global policies to allocate agricultural development potential in a resources scarce world would mean in social, economic and political terms.

Research needs

Agriculture is entering the process of national mitigation efforts since the Copenhagen agreement. This can lead to new challenges for agriculture and agricultural research concerning international regulations about climate and about trade. Further research is needed to understand, quantify and project the various dimensions and impacts of climate change and bioenergy on food security across regions and over time (FAO, 2009c). A globally consistent, comparative analysis of greenhouse gas emissions per unit of product would substantially help in finding opportunities for low-emission systems, setting priorities for greenhouse gas mitigation, and as a scientific foundation for the debate about "climate-optimal land allocation".

Mitigation in agriculture is being addressed by the Consultative Group on International Agricultural Research (CGIAR) and the Global Agricultural Research Alliance, an international initiative of national agricultural research centres launched by New Zealand. The climate change and general environmental impact of intensive and extensive livestock system can be compared, and the solutions for each type of systems will also be very different (controlling and innovating in the feed given in intensive systems in order to control methane emissions, on one side; arguing of the potentially positive social and biodiversity impact of extensive livestock systems; and discussing the impact of both systems on global balances for vegetal commodities will also be an issue).

The role of northern agricultural countries in this controversy and of the CGIAR centres is going to be of importance, as New Zealand for instance (the only OECD country with more than half of its GHG emissions coming from the agricultural sector) is already putting the stress on integrating carbon efficiency in global agricultural trade regulations in order to avoid a scenario in which existing animal product exports might have to be reduced to enable New Zealand to comply with national GHG reduction targets, although their production might be replaced by that of other countries, that could be much less efficient in terms of GHG emissions. Should agricultural trade ensure that production is distributed throughout the world with respect to its carbon impact? How are pathways of development taken into account in this discussion?

5.4.2. Biodiversity

> *Global warming may dominate headlines today. Ecosystem degradation will do so tomorrow.* (Hanson et al., 2008).

According to the definition by the Convention on Biological Diversity (CBD) biodiversity refers to genes, species, habitats and ecosystems. Agrobiodiversity has two important aspects: (1) the genetic resources for food and agriculture, and (2) ecosystem services. FAO (2004b) defines: "Agrobiodiversity is the result of the interaction between the environment, genetic resources and management systems and practices used by culturally diverse peoples, and therefore land and water resources are used for production in different ways. Thus, agrobiodiversity encompasses the variety and variability of animals, plants and micro-organisms that are necessary for sustaining key functions of the agro-ecosystem, including its structure and processes for, and in support of, food production and food security. Local knowledge and culture can therefore be considered as integral parts of agrobiodiversity, because it is the human activity of agriculture that shapes and conserves this biodiversity."

Current state of the problem

The 2010 Biodiversity Target under the Convention on Biological Diversity (CBD) "to achieve by 2010 a significant reduction of the current rate of biodiversity loss at the global, regional and national level", has not been met at the global level. Only some of the twenty-one sub-targets have partially or locally been achieved (CBD, 2010). Loss of biodiversity in reptiles, fish, birds, and large mammals continues at high rates and growing geographic scales. The 'biodiversity crash' is unprecedented in human history, with unforeseeable consequences for agriculture and food security (FEG2).

The loss of functional biodiversity destabilises ecosystems, and weakens their ability to deal with natural disasters such as floods, droughts, and hurricanes, and with human‑induced stresses, such as pollution and climate change. Already, flood and storm damage exacerbated by deforestation is very costly; such damage is expected to increase due to global warming (CBD, 2010, quoted in EEA, 2010c). Terrestrial and freshwater ecosystems are being degraded. The survival of coral reefs is at risk (TEEB, 2009).

In Europe, biodiversity in agro-ecosystems is under considerable pressure through intensified farming and land abandonment (EEA, 2010b). According to the RUBICODE project (2009), most ecosystem services in the European Union are 'degraded' — no longer able to deliver the optimal quality and quantity of basic services such as crop pollination, clean air and water, or controlling floods and erosion (EEA, 2010c).

Europe is currently consuming twice what its land and seas can produce; the European Ecological Footprint increased by 33 % in the last 40 years (Global Footprint Network 2008, quoted in EEA 2010c). Europe´s livestock production which heavily relies on imported feed is tightly connected to land use change, agricultural intensification and impacts on biodiversity in South America. Almost 80% of feedstuff (mainly soy cake) imported from non-Member countries by the EU-27 in 2007 originated from Argentina and Brazil (Eurostat, 2008).

Genetic diversity has declined globally, particularly among cultivated species (Millennium Ecosystem Assessment, 2005). Global food chains focus on a few species and varieties that are processed and sold globally, marginalizing local species and diverse traits. Loss of agrobiodiversity makes food systems more vulnerable to climate change (´resilience gap`) and to volatility in prices for energy, water and fertilizer, because in general 'global varieties' depend strongly on external inputs (Brunori et al., 2008).

On the other hand, agriculture is a major provider of environmental services, which are not adequately recognised and remunerated. Soil biodiversity is largely unknown although it underpins processes and ecosystems services that are essential for agriculture, such as soil formation, maintaining soil fertility, water cycle regulation and pest control. The consequences of soil biodiversity mismanagement have been estimated to be in excess of 1 trillion dollars per year worldwide (Turbé et al., 2010).

Projections

"Current trends are bringing us closer to a number of potential tipping points that would catastrophically reduce the capacity of ecosystems to provide these essential services. The poor, who tend to be most immediately dependent on them, would suffer first and most severely. At stake are the principal objectives outlined in the Millennium Development Goals: food security, poverty eradication and a healthier population" (CBD, 2010, Foreword by the United Nations Secretary-General).

Leadley et al. (2010) warn that the most recent global land use scenarios, Earth System models and models of climate change impacts on terrestrial and ocean systems show a much greater variability and far greater climate-induced transformations in projections of biodiversity loss than previous assessments. Degradation of the ecosystem provisioning and regulating services are often more closely related to changes in the abundance and distribution of dominant or keystone species than to global extinctions. Even moderate change in some groups of species (for example top predators) globally can have a disproportionately strong influence on ecosystem services (CBD, 2010).

Globally, the combined pressure from overfishing and destructive fishing practices, overexploitation of marine and coastal resources, pollution, climate change and ocean acidification make it likely that the basis for coastal marine food production is severely declining, and in parts irreversibly damaged in the next decades. Coral reefs are much more seriously and acutely endangered than projected in previous assessments of climate change and biodiversity (TEEB ,2009). 60% of coral reefs could be lost – even by 2030 – through fishing, pollution, diseases, invasive alien species and coral bleaching due to climate change. At present, 500 million to over one billion people rely on coral reefs for their food resources, including about 30 million of the world´s poorest and most vulnerable people in island communities (TEEB, 2009). More than a billion people rely on fisheries as their sole source of animal protein, especially in developing countries, but "fishing down the foodweb" is destabilizing the wild fish resources far beyond the traditional species (TEEB, 2008). **Without an immediate, drastic shift to halt and reverse climate change, manage marine resources in a coordinated, sustainable way and reduce pollution, the coastal and marine food production and protective ecosystem services are at serious risk of collapse, including some of the currently most productive regions of the globe.**

By 2050 (TEEB, 2008), agricultural land use intensification will be the direct cause of 4% of biodiversity loss from 2000 to 2050 – more than that caused by climate change and similar to infrastructure extension. Almost 40% of the land currently under low-impact forms of agriculture could be converted to intensive agricultural use, with further biodiversity losses. The cumulative welfare loss by losing ecosystem services from land-based ecosystems alone could conservatively reach up to 7% of annual consumption by 2050.

Hotspot regions

CBD (2010) has identified world regions and mechanisms where tipping points might be reached in the 21st century with potentially catastrophic global repercussions (Figure 5.3). Tipping points will have exceptionally large impacts on human well-being if they occur. Terrestrial tipping points will hit regions with developing economies the hardest (Leadley et al., 2010).

Global hotspot regions with risks of tipping points are shown in Figure 5.3. All of the regions are affected by climate change. The coastal and marine ecosystems and coral reefs and the fisheries based on marine resources are also endangered by long-term physical reactions of the earth system to climate change – sea level rise and ocean acidification. The vulnerability of these ecosystems is a much stronger global environmental boundary than the 2°C limit agreed on in the climate negotiations under the United Nations Framework Convention in Cancún, December 2010. With current trends in global greenhouse gas emission, even the 2°C limit is out of reach.

Human demand for food, fiber and energy plays a key role in driving many of the tipping points, especially through conversion of natural and semi-natural ecosystems to farming and the overexploitation of marine resources. Except for polar ice sheets and tundra ecosystems, the pressure from human food and fibre demand on biodiversity resources is intimately interwoven with climate change. Demographic change, land use change, in particular deforestation in the Amazonian forest and in the Miombo woodlands, water management and water pollution in dry regions and coastal zones, lead to land degradation, loss of biodiversity and ultimately, the production function of ecosystems. Due to lags in the socio-economic, biological and physical systems of the Earth, the transformations occurring now and in the coming decades will be essentially irreversible over the next several centuries (Leadley et al., 2010).

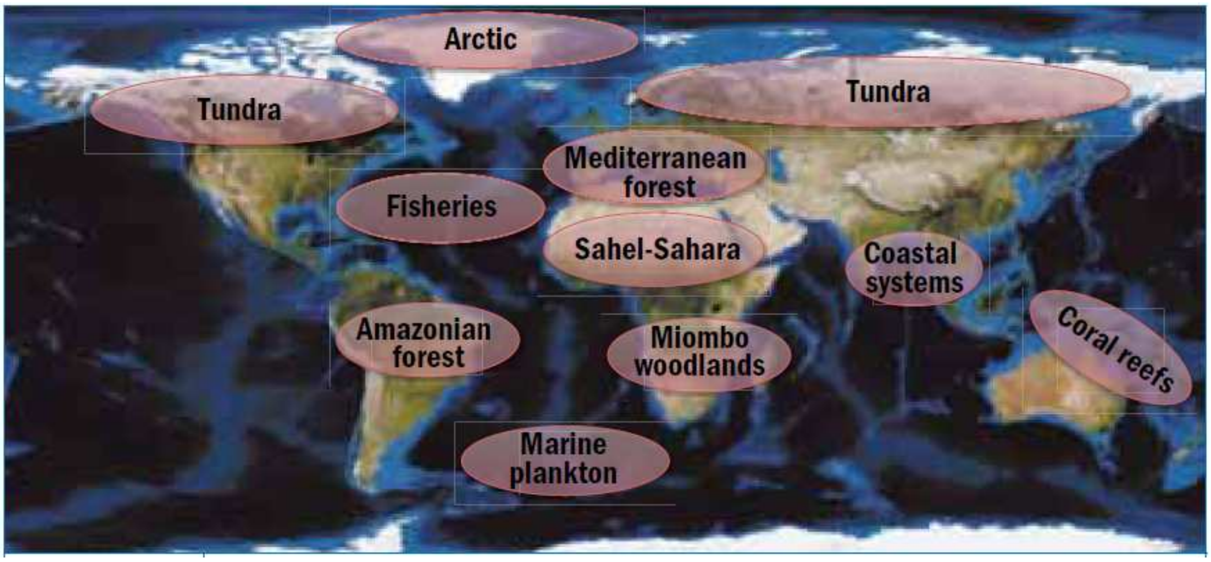

Figure 5.4. Global hotspot regions with risks of tipping points
Source: Leadley et al. (2010), p. 11

In Europe, the Atlantic biogeographical region has the highest pressure on agricultural land and includes some of the most intensively farmed areas on the continent (EEA, 2010b). Maintaining high-nature-value (HNV) farmland in the Mediterranean area and the Iberian Peninsula, central and eastern Europe, together with Scotland and Western Ireland, is clearly a priority (Cooper et al., 2009).

Type of scarcity

The concept of biodiversity is challenging for society, policy and research, because diversity is inherently multi-facetted, complex and unsuitable for simple, one-dimensional answers. And it is free of charge. We do not really know the value of genes, traits, species or ecosystems until we miss them.

Biodiversity, consequently, can be described as a multi-dimensional scarcity that combines aspects of supply (genetic resources) and time lag (consequences of extinction), loss resilience (related to keystone species and unknown unknowns), strong feedback from climate change and all other scarcities (Annex 1), and maybe the first global tipping point (collapse of coral reefs). The societal, economic and political context aggravates the scarcity. There are a fundamental barriers at the level of governance, institutions and societal awareness to adequately remunerate genetic diversity, local traits in food and ecosystem services provided by sustainable agriculture. Consistent concepts and knowledge how to conserve biodiversity at local, national to global scale are missing. At local level, conservation approaches compete with process approaches. At global level, the CBD still lacks potent implementation mechanisms. A very critical scarcity is knowledge, in particular related to the multiple, non-linear interactions of biodiversity with the productivity of land, other scarcities and in particular of soil biodiversity.

Interaction with other scarcities

According to our assessment (Annex 1), biodiversity is most intensely linked to all other scarcities, but the intensity of feedback mechanisms are hardly understood. Land use change, abstractions from river flow, freshwater pollution, and exploitation of marine resources are currently the most important drivers of biodiversity change and are projected to remain so over the coming century. Climate change and consequently, ocean acidification, will become important drivers during the 21st century. Overall, thresholds, amplifying feedbacks and time-lag effects leading to “tipping points” are widespread and make the impacts of global change on biodiversity hard to predict, difficult to control once they begin, and slow and expensive to reverse once they have occurred. The potential importance of thresholds, amplifying feedbacks and time-lag effects leading to tipping-points has been underestimated in past global biodiversity assessments (Leadley et al. 2010).

The rate of climate change may make it impossible for many (plant, insect, bird, animal, tree, fish) species to adapt, decreasing agrobiodiversity, with presently unknowable effects (IPCC, 2007b; Brunori et al., 2008). The largest climate change impacts are projected to be habitat and species losses in tropical forests, biome shifts in boreal and Arctic tundra, and dramatic changes in species abundance in many freshwater and marine systems (Leadley et al., 2010).

The deposition of reactive nitrogen impacts ecosystems negatively, especially those that have been developed under low-nutrient conditions such as flower-rich meadows, but also forests and moor land. In many areas in Europe N-depositions are still significantly above these critical loads. The emission ceilings for reactive nitrogen compounds are the ones most missed by EU member states under the NEC directive (EEA, 2010a).

Reflection on the narratives

Concerns about agro-biodiversity are integrated in the productivity narrative with regard to the loss of genetic resources for agricultural production. This concern is shared in the sufficiency narrative, which also addresses the importance of wider ecosystem services for e.g. pest control, water retention, soil fertility and resilience of agriculture. Population-based breeding, local traits and niche markets and the integration of traditional agricultural knowledge are embedded in the sufficiency narrative.

Transitions and solutions

"The action taken over the next two decades will determine whether the relatively stable environmental conditions on which human civilisations has depended for the past 10,000 years will continue beyond this century. If we fail to use this opportunity, many ecosystems on the planet will move into new, unprecedented states in which the capacity to provide for the needs of present and future generations is highly uncertain" (CBD, 2010).

At global level, CBD (2010) sees greater potential than was recognised in earlier assessments to address both climate change and rising food demand without further widespread loss of habitats. Biodiversity degradation could be prevented, significantly reduced or even reversed and the diversity of ecosystem be restored if strong action is applied urgently, comprehensively and appropriately, at international, national and local levels. This action must focus on addressing the direct and indirect factors driving biodiversity loss, and must adapt to changing knowledge and conditions (GBO-3, 2010).

Maintaining and restoring biodiversity provides the basis for all agro-ecosystem-related services (EEA, 2010b). A number of farming systems and the practices employed within them are particularly important for the provision of public goods. These include more extensive livestock and mixed animal-cropping systems, the more traditional permanent crop systems, and organic systems (see section on Agroecology; Cooper et al., 2009). There is also a large potential for highly productive farming systems to adopt environmentally beneficial production methods.

Measures to mitigate drivers of biodiversity change and to develop adaptive management strategies in agricultural systems include (extended from Brunori et al., 2008; TEEB, 2009; Leadley et al., 2010):

- Genetic resources: farmer based participatory breeding and seed production concepts, increasing trend in support of organic and local markets, heritage seed systems,

- Terrestrial ecosystems: improved agricultural efficiency and less meat consumption in the Western world (less pressure on biodiverse land), promotion and development of locally adapted low-input farming systems, enhanced role of legumes in agricultural systems

- Marine ecosystems: International regulation of fishing in non-territorial waters and improved governance of fishing at local to global scales, regulations for aquaculture and development of low-impact aquaculture

- Rapid and far more ambitious climate change mitigation to stabilise atmospheric CO_2 concentrations at 350 ppm

- Limited and appropriate deployment of bioenergy production.

Public investment in ecological infrastructure (especially restoring and conserving forests, mangroves, river basins, wetlands, etc.) has demonstrable value for adaptation to climate change with high cost-effectiveness. Ecosystems represent an attractive area for high-return investment, in particular for public money in times of economic crisis. 'Natural capital' can be a much-needed source of growth in a time of recession, a provider of new and decent jobs in a time of increasing unemployment, and a solution to persistent poverty (TEEB, 2009).

Economic and social incentives and appropriate policy instruments need to be developed that measure the costs and benefits of ecosystem services, promote and reward current non-marketable ecosystem services, and equitably share the benefits of conservation. Opportunities include payments for ecosystem services, extending the polluter pays principle, and new markets which support and reward biodiversity and ecosystem services, e.g. habitat banking, endangered species credits and biobanking. Some of them are emerging and have the potential to scale up. But to be successful, markets need appropriate institutional infrastructure, incentives, financing and governance (TEEB, 2008).

Research needs

To promote biodiversity protection, research and political action should focus on the main drivers of biodiversity loss, namely land use and climate change, in order to provide long-term sustainable solutions. Research has to develop an enhanced systems understanding of agroecosystems, identify and quantify synergies with other goals of agriculture and their successful monitoring and integration in policies. Successful biodiversity concepts, tools and policies need to be developed. Among others, they should address how to integrate agricultural activities in local biodiversity programmes (Brunori et al., 2008). The precise ecological and economic values of soil biodiversity services are still largely unknown (EEA, 2010b). Biodiversity based business may offer new avenues for private investment. This will require a much deeper dialogue than we have seen so far between economists, climate scientists and ecologists (TEEB, 2008).

Early warning indicators to anticipate proximity to tipping points in threatened ecosystems and ecosystem services need to be developed (TEEB, 2009). In particular, the development of inventories, indicators and monitoring schemes to track soil biodiversity (Gardi et al., 2009; EEA, 2010b) is a prerequisite for a better understanding the functional role of soil biodiversity, to improve awareness on the central role of soil biodiversity and for developing capacity-building among farmers to promote biological management (Turbé et al., 2010).

In the shorter term biodiversity can be addressed by both more targeted measures for specific endangered organisms (genetic diversity) and by more rapid adoption of production methods that contribute to conservation of a high level of general biodiversity (agronomic and biological diversity), e.g. such as organic or LEISA approaches to production (Brunori et al., 2008) and that maintain the diversity in agricultural production systems.

5.5. Trends in other land uses and fisheries impacting on land-based food systems

5.5.1. Forestry

Foresight studies

Pelli (2008) has undertaken a review of a wide range of future-oriented studies of the forestry sector in Europe, and recommends that a European-scale forest sector foresight study be undertaken which would identify trends and prospects for the forest sector and its value chains and the driving forces. COST (2010) has recently put in place a foresight exercise designed to examine both supply and demand for forest- based products and services, taking account of changes in global population, consumer markets and consumption patterns, public opinion and related social demands, as well as the potential effects of climate change and developments in related policy deliberations.

Current status

The world's total forest area is just over 4 billion hectares, or 31% of total global land area. There are signs that deforestation – principally arising from the conversion of tropical forest to agricultural land use – is decreasing in many countries, but remains at a high rate in others. Around 13 million hectares of forest were converted to other uses or otherwise lost each year in the last decade compared with 16 million hectares annually in the 1990s (FAO, 2010c).

In Europe, the forest area is expanding, growing by 3% (or about 36 million hectares) between 1980 and 2005 (UNECE/FAO, 2005). Europe's forests are growing faster than the annual level of fellings and this gap has increased since 1960 (UNECE/FAO, 2005; Ciais et al., 2008). Forest resources in Europe are predicted to continue growing in light of decreasing land dependence, increasing standards of living, a strong focus on environmental protection and strong policy and institutional frameworks. Total forested area is expected to increase by around 5% between 2000 and 2020, due to a combination of afforestation and natural processes. However, it is possible that the actual area available for wood supply could decrease due to increasing demands for forests to meet other functions (UNECE/FAO, 2005).

The focus of forest management in Europe has shifted from productive functions towards conservation of biological diversity, protection and multiple uses (FAO, 2009d). This prioritisation of environmental services is expected to continue, especially in Western Europe. As a result of this emphasis and increased regulations, wood production in Europe will be less competitive, although it is likely to retain its competitive advantage in the production of technologically advanced products (FAO, 2009d).

Demand for Wood Products: Demographic changes, economic growth, regional economic changes and environmental and energy policies will be the principal factors influencing long-term global demand for wood products. It is expected that the production and consumption of key wood products and wood energy will continue to grow to 2030 (FAO, 2009d).

Forests and Energy: The most notable change will be the sharp increase in the use of wood as a source of energy, especially in Europe, as a result of policies supporting more use of renewable energy. Demand for wood for energy production in the EU is expected to be about 260 million cubic metres in 2010, up from about 160 million cubic metres in 2003 (The Government Office for Science 2010). In particular, if Member States are to meet the targets for renewable energy based the EU Biomass Action Plan, then an increase in harvesting intensity is required, or an increase in the area of wood production, or both. The higher wood prices seen in recent years is already mobilizing more wood resources from European forests. This reduces the carbon sink in forests or may even turn European forests into a source in the future (Ciais et al., 2008).

Future developments in biorefining and bioprocessing technology are projected to create large scale opportunities for bioenergy from forests. In particular, the potential for large-scale commercial production of cellulosic biofuel is expected to impact in a major way on the forest sector (FAO, 2009d). However, as of now, the increasing demand for first generation biofuels is already bringing about major changes in land use that directly or indirectly threatens forests, for example, the conversion of natural forest into plantations for soybean, oil-palm or other rapidly growing biomass crops (Savenije and van Dijk 2010). The longer term impacts of bioenergy on forestry will largely depend on the rules, standards and incentives introduced for the production of biomass and the effectiveness of their implementation.

Demand for Environmental Services: Due to projected changes in socio-economic driving forces, demand for forest environmental services such as clean air and water, mitigation of climate change and biodiversity conservation will increase (UNEP, 2007). Both regulatory and market approaches are used in order to help forestry respond to the demands for environmental services. Regulatory mechanisms include the delineation of protected areas, creation of instruments for sustainable forest management and the operation of green public procurement policies. Market mechanisms in include certification, carbon markets and payments for environmental services (FAO, 2009d).

Climate Change Mitigation: It is now generally recognised that sustainably managed forests, by adopting planting and harvesting strategies that maximise carbon sequestration and preserve soil carbon, have considerable long-term potential to contribute to the mitigation of climate change. (McKinsey 2009). Estimates show that the world's forests store 289 gigatonnes (Gt) of carbon in their biomass alone (FAO 2009d). While sustainable management, planting and rehabilitation of forests can conserve or increase forest carbon stocks, deforestation, degradation and poor forest management reduce them.

All global regions have experienced phases of deforestation associated with large carbon losses, either in the past or today. The historical trajectory of forest cover change is an important background information for decisions how to develop forests regionally in the future (Figure 5.5; IPCC, 2007a).

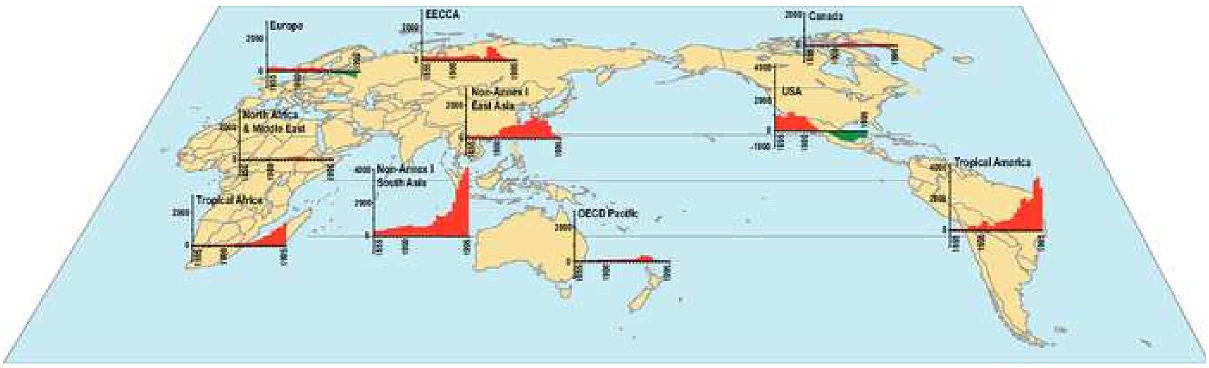

Figure 5.5: Historical forest carbon balance (Mt CO_2) per region, 1855-2000

Notes: green = sink. EECCA=Countries of Eastern Europe, the Caucasus and Central Asia. Data averaged per 5-year period, year marks starting year of period. Source: Houghton, 2003b, cited in IPCC (2007a)

Globally, forest biomass carbon stocks decreased by an estimated 0.5 Gt annually between 2005-2010, mainly due to deforestation (FAO 2010c). Land use, land-use change, and forestry are the fourth largest source of global greenhouse gas emissions, accounting for 16% of the total in 2005 (McKinsey & Company, 2009). There is a clear tipping point in the Amazonian basin where deforestation beyond a certain threshold will drastically affect monsoon patterns by shifting them in a permanent El Niño state. Leadley et al. (2010) recommend that deforestation should not exceed 20% of original Amazonian forest area.

Reducing emissions from deforestation and forest degradation (REDD) in developing countries, in particular, is presented as an opportunity to channel more money into forest protection and other aspects of sustainable forest management. However, it is difficult to implement the abatement measures identified due to major problems in technology, methodology and implementation, for example, regarding definitions, and the monitoring and verification of change (Savenije and van Dijk, 2010). New research is required to enable forests play a full role in climate change mitigation and adaptation.

Forest use has to balance its various roles in climate change mitigation. The large carbon stocks in long-lived pools need to be preserved. On the other hand, wood is a renewable resource with a lower environmental footprint than many other raw materials and has an important role in substituting oil-derived products and fossil energy.

Forest Science and Technology: Innovation has enabled forestry to keep up with the changing demands of society in the developed world and further innovation will be require to maintain this capacity. Research continues to impact on all areas of forestry, from production, harvesting and processing of wood energy to the provision of environmental services. New technologies such as biotechnology, nanotechnology and information and communications technologies contribute to these developments. A significant trend in Europe is that saw mills are specializing on smaller diameter trees, partly because the demand for paneer wood rises more than the demand for round wood. Consequently, harvest age of trees is expected to be reduced and large-diameter timber is difficult to sell. Whilst harvesting younger trees is also seen as adaptation to climate change because of lower risk of storm and partly pest damage, ecologists argue that the value of old-growth forests for biodiversity and as long-term carbon stock to mitigate climate change is compromised (Schulze and Schulze, 2010).

Present and future products of tree breeding could have a major impact on productivity. Within 40 years, yields of timber per hectare could increase by 25% compared with areas planted 15 years ago before the benefits of tree breeding became generally available (The Government Office for Science, 2010). Laboratory screening using DNA-marker technology means that improved material can be released to the industry much more quickly in the future (The Government Office for Science, 2010). Further potential gains may be made through clonal forestry. This involves reducing diversity so that nearly all the trees are fit foe end use at rotation stage. GM technology may also be part of forest production in the future.

Challenges include reducing barriers to the transfer of technologies within and between countries, ensuring that social and environmental issues are mainstreamed, and transcending national sectoral boundaries to take advantage of scientific and technological developments from outside the forest sector.

Reflection on the narratives

There is a considerable scope for improved forest management and the development of environmentally friendly and socially just tropical forestry which will serve multiple purposes. The prospect of carbon markets to reduce deforestation and forest degradation in developing countries holds promises and risks depending on the level of participation of local people and whether the livelihood of the forest dwellers is improved.

Turning forests and pastures into fast-growing plantations to enhance timber production is a strategy widespread in the tropics, Oceania and increasingly in the Mediterranean. In light of the productivity narrative, meeting the growing demand for timber and pulp wood is best achieved by fast-growing short rotations, often with clones. However, their sustainability is often questionable due to risk of soil degradation, over-use of scarce water and increased fire risk and lower biodiversity.

In the sufficiency narrative, adaptation of forests to climate change is discussed in view of keeping diversity in tree species, structures and maintaining pockets of "wild forest" or unmanaged forests as reserve for biodiversity, local traits and genetic diversity. The role of forests as buffer in the regional climate, the protection against avalanches, floods and for a clean water supply are a priority that determines what kind of production functions the forest can achieve. Sustainable forestry is promoted by labels such as the Forest Stewardship Council. Such initiatives could be further developed to set general standards for forestry.

5.5.2. Fishery and aquaculture

Current status

TEEB (2008) and The Government Office for Science (2011) give a grim analysis of the status of global coastal and marine ecosystems and food resources. "More than a billion people rely on fisheries as their main or sole source of animal protein, especially in developing countries" (Millennium Ecosystem Assessment, 2005). But half of wild marine fisheries are fully exploited, with a further quarter already overexploited (FAO, 2007). We have been "fishing down the food web". As stocks of high-trophic, often larger species are depleted, fishermen have targeted lower-trophic, often smaller species. The smaller fish are increasingly used as fishmeal and fish oil for aquaculture and to feed poultry and pigs. Aquaculture, which includes mobile open sea cages (e.g., for red tuna) is growing quickly, particularly in China and the Mediterranean, and contributed 27% of world fish production in 2000 (Millennium Ecosystem Assessment, 2005). Aquaculture is, however, extremely dependent on marine fisheries for its inputs and, looked at from a global perspective, it may not be reducing our overall dependency on wild marine fisheries" (TEEB, 2008, p. 16).

Already now, some 30% of coral reefs have been seriously damaged through fishing, pollution, disease and coral bleaching (Wilkinson 2004, cited in TEEB 2008). In the past two decades, 35% of mangroves have been lost through conversion for aquaculture, overexploitation and storms, reaching up to 80% in some regions (Millennium Ecosystem Assessment, 2005).

Projections

Prospects that marine resources could help reduce the pressure from food demand on fertile land appear optimistic. In contrast, it seems more likely that without a drastic change in the governance of fisheries, drastically reduced pollution and a stabilization of the atmospheric CO_2 concentration at or below current level (Rockström et al., 2009), the marine food resource risks to collapse in important world regions, in particular in the tropical Pacific – exactly where the largest share of the global population depends on fish and where the largest increase in fish protein demand is projected (The Government Office for Science, 2011).

The governance of capture fisheries faces particular problems because fishery resources are commonly held as public goods, regulation is complex and hardly controlled. Little sanctions for overfishing or resource-depleting fishing (e.g., by-catch) lead to a situation in which the actor have insufficient incentives to resist overexploitation (The Government Office for Science, 2011).

The Government Office for Science (2011) mentions several pathways for transition to sustainable and efficient fish production. Clearly, governance has to be improved at all levels. The technology for implementing control is mature but expensive and would best work in cooperation with the fishing fleet. The civil society can play an important proactive role towards sustainable fishery, e.g. via labels such as the Marine Stewardship Council. However, given the state of fish stocks, marine and coastal ecosystems, a real step change in adaptive management based on efficient ecosystem-based concepts is neededs, and temporarily or permanently protected areas may be required.

5.5.3. Bioenergy

Current status

At present, global bioenergy use amounts to approximately 50 EJ/yr, about 10% of humanity's primary energy supply (Haberl et al., 2010). The growth in bioenergy production has been stimulated mostly by biofuel subsidies, fuel blending mandates, national interest in energy security, climate change mitigation and rural development programmes (IAASTD, 2009). Most current production chains for biofuels show costs per unit of fuel energy significantly above those for the fossil fuels they aim to substitute (Brunori et al., 2008).

However, one of the most used arguments – the mitigation of climate change – has turned out to be of little value in the area of liquid biofuels (Advisory Council on Agricultural Policy, 2008), or even wrong if biofuels are produced on deforested land areas.

According to the EU Bioenergy Directive (European Commission 2009e, 2009f), where biofuels and other bioliquids are made from raw material produced in the EU, they should also comply with EU environmental requirements for agriculture. Fuel-type and biomass-type specific environmental sustainability criteria were set, mainly to meet minimum requirements for CO_2 abatement. In practice, biofuel production on drained organic soils in Europe fails to meet these criteria. The tables in the Annex of the EU Bioenergy Directive with typical and default values for biofuels indicate that biofuels from waste are much more effective in mitigating climate change than fuels produced from dedicated crops. Applying sustainability criteria to imports from third countries was deemed administratively and technically unfeasible in the EU Bioenergy Directive.

European energy policies and subsidies have promoted expensive bioenergy lines in terms of CO_2 abatement per hectare, per unit biomass and in costs per kg CO_2 saved. Liquid agrofuels and biogas based on maize bear much higher costs than other mitigation measures in the agriculture sector per kg CO_2 saved (Advisory Council on Agricultural Policy, 2008) but have been promoted in West and South Europe. Solid biomass options, which have been promoted more in North and East Europe, are much more favourable in all climate related indicators.

The 1st generation of biofuels produced today is from food crops – sugarcane and corn ethanol, oilseed biodiesel. Today the limited ability of this first generation to mitigate climate change is largely discussed and further concerns are raised in regard to the competition for land and water for the production of food and feed, as well as in terms of their sustainability. Although this generation is characterised by mature markets and technologies, its potential to serve as a substitute for conventional fuels is limited. Many of the concerns related to the first generation can be addressed by the second generation of biofuels, which are produced from agricultural and forest residues, as well as from non-food crops and thus have the potential to achieve sustainability in their production (Sims et al., 2008) and may partly reduce the competition for fertile land.

Second-generation biofuels are not yet produced commercially, but a considerable number of pilot and demonstration plants have been announced or set up in recent years, with research activities taking place mainly in North America, Europe and a few emerging countries (e.g., Brazil, China, India and Thailand). Eisentraut (2010) projects a rapid increase in biofuel demand, in particular for second-generation biofuels if atmospheric CO_2 concentration is to stabilise at 450 ppm. The wider use of second generation biofuels may hold potential to enhance the overall economic development of rural areas.

Projections

Projections of sustainable bioenergy potentials have to be carefully analysed to understand the assumptions about biomass types, yield potentials, intensity of biomass production (e.g. in terms of energy input/output ratios), other constraints on available fertile land for bioenergy and in particular, conversion pathways and substituted fossil fuels.

Global projections of the "technical potential" of bioenergy in 2050 widely diverge but have been corrected downwards in recent studies. The World Energy Assessment (UNDP, 2000) reported a global technical bioenergy potential in the year 2050 of between 276 and 446 EJ/yr.

Haberl et al. (2010) reviewed recent literature to derive a "technical potential" of bioenergy in 2050, given current expectations on food demand and environmental targets. They estimate a sustainable primary bio-energy potential in 2050 in the range of 160–270 EJ/yr, which is at the low end of previously published ranges. Residues from food production and forestry could provide a significant amount of energy via cascade utilisation of biomass flows.

In Eating the Planet, Erb et al. (2009) demonstrate that diets have a strong effect on the total global bioenergy potential. The range of gross bioenergy potentials from cropland and grazing land would be 58-161 EJ/yr in 2050. Most of the plant material included in the gross bioenergy potentials cannot be used to produce first generation biofuels.

The global projections of biomass use in the energy scenarios of Greenpeace (2010) show a broad spectrum of energy generation costs for biomass, reflecting the different feedstocks used. Costs range from a negative cost (or credit) for some waste woods to low cost for residual materials and then to more expensive energy crops. Using waste wood in steam turbine/combined heat and power (CHP) plants is one of the cheapest options. Gasification of solid biomass has a wide range of applications but is still relatively expensive. Other likely developments include wider applications of solid biomass for heat generation and a further expansion of ethanol and 'bio diesel', for example in Brazil, the USA and Europe. Processes for obtaining synthetic fuels from biogenic synthesis gases will also play a larger role.

Second generation biofuels hold a significant technical potential to replace fossil fuels in the future. However, the technical constraints to commercialising these technologies are still serious, associated with high production costs (Cheng and Timilsina, 2010).

Biomass power could be supporting 2.1 million jobs in 2030 under both Energy [R]evolution scenarios, compared to less than 1 million in the Reference scenario of Greenpeace (2010).

In Europe, in contrast to current cost estimates, EEA (2008) projected that with the optimal use of the EU bioenergy potential of 1,700 to 2,700 TWh substitutable fossil energy in 2030 around 11% reductions in GHG emissions could accrue in EU-25 in 2030, and the additional generating costs associated with the use of bioenergy would be smaller than the value of the fossil fuels replaced.

5.6. The socio-economic and political context

The analysis of scarcities above has made evident that globally, shortage of supply of fertile land, water, nutrients and energy is no immediate concern. Resource scarcities are much more related to distribution of and access to resources, which is intimately linked to issues of governance, knowledge and economic viability. Climate change and the loss of biodiversity result from the inadequacy of markets, political governance and framing in society that follows the paradigm of economic growth. All scarcities are reinforced by the lack of decision making mechanisms that take the complexities of interactions between scarcities into account.

The socio-economic and political context of food consumption and production is undergoing dramatic changes as well (see chapters 3 and 6). These trends can further reinforce scarcities when they lead to instability, conflict or blockage in decision making. Trends in the socio-economic and political systems also bear the potential for transitions into a society that respects the needs of nature and of future generations equally to the own needs. This section aims to raise some critical issues about governance, agricultural knowledge systems and socio-economic trends which impact future food consumption pathways. A detailed analysis of the issues and their role in transitions is given in chapter 6.

5.6.1. Governance

Governance, the decision making from local to global scale, is the underlying reason for all described scarcities if scarcities are seen as misallocation of global resources in terms of efficiency and equity. Some examples: Mismanagement of irrigation water or soil is often triggered by unregulated access, unclear land ownership, or local conflict. It results in land degradation, which is often almost irreversible. Acts of resource nationalism, e.g the export ban for wheat in Russia in 2010, immediately feedback on food prices.

Important commodity markets are organized as oligopolies. The dominance of the richer nations and companies in the international arena has had a tremendous impact on agriculture during the 2008 food crisis. A combination of unfair trade agreements, concentrated ownership of major food production, dominance (through control and influence in institutions such as the World Bank, IMF and the World Trade Organisation) has meant that poor countries have seen their ability to determine their own food security policies severely undermined (Holt-Giménez and Peabody, 2008).
There is no global institution that could decide and enforce transitions to stay within the planetary boundaries, to distribute scarce resources equitably. International organisations partly try to organise the discourse (e.g., FAO) but lack the mandate for decisions. The UN bodies have the mandate but lack the power to decide and implement transitions in the speed and magnitude needed. There is no single body to reconcile the consequences of the strong feedbacks between the scarcities, which make transitions much more urgent than analysed by sectoral policies, e.g. for climate change or biodiversity.

If the combined scarcity challenges are to be met and a timely transition into a more resilient food system be assured, radically new ways of governance need to be developed at all scales of decision making, that allow

- governance for food security in line with the planetary boundaries and the local to regional natural and socio-cultural context,
- strengthened coordination and integration of policies for agriculture, energy, climate, biodiversity and rural areas,
- strengthened coordination and integration of policies for food consumption and health,

- a better awareness and knowledge of the scarcities and their link to food consumption and production in the whole society, which means a more adequate information and dissemination system by all means of communication.

5.6.2. Agricultural knowledge systems

Agricultural knowledge systems lie at the heart of the day-to-day practices at farm level. Humans tend to have a resistance to adopting new knowledge when there is no immediate advantage or urgency to change. The example of mismanagement of irrigation water or soil above may also result from inadequate knowledge, or inadequate communication or adoption of knowledge.

Agricultural knowledge systems are the key for speeding up transitions. Society has to learn about how to get across barriers. Agriculture has a long tradition of sustainable land management, which needs to be revisited and eventually adjusted to new challenges. The challenge is to conseve local traditional knowledge, utilize new knowledge, and amalgamate the different types of knowledge in a systemic way that makes food production systems resilient and sustainable.

The scarcity of educated labour in developing countries, but also in Europe where the traditional subjects in agricultural teaching are disappearing from curricula, is a serious constraint on the upcoming transitions.

The way in which agricultural knowledge is generated, communicated and finally implemented has to be radically changed to deliver the necessary resilience in a time of drastically increased uncertainty. Challenges ahead include

- organisation of the learning process to allow endogenous development,
- include social sciences in technology research,
- include stakeholders in innovation and research as full partners from the very beginning of project planning. In particular, farmers should actively participate in knowledge generation rather than only be the “receivers” of news by extension services,
- diversity in approaches, transdisciplinary research by themes, blue sky research and on-farm experimentation.

5.6.3. Economic development

Agricultural commodities have become an object of speculation. Global markets for major agricultural commodities seem to have contributed a trend of higher price volatility. For some agricultural commodities, the price spike in 2008 was followed by falling prices in 2009, but prices are again higher than in 2008 again. Price spikes seem to become the rule because global markets react quickly, and partly irrationally, on regional decisions (e.g., Russia´s export ban for wheat) and regional harvest losses.

Similar trends can be observed for phosphorus and energy prices, which result in a growing uncertainty for farmers about the economic viability of their undertakings. Many small-scale farmers, in particular in developing countries, are highly indebted, so that extended phases of high input prices versus high volatility in the tradable commodities can ruin them completely.

Rising food prices and the credit crunch are now spreading to all corners of the world. At the same time, since many more of the poor now depend on wages and are more closely connected to the rest of the economy, they suffer more from economic shocks (CGIAR). Tunisia has already experienced a riot by desperate young people, catalysed by unaffordable food, which is spreading across North Africa.

5.6.4. Urbanization

The first and massive migration in 21st century will be the one to cities. Globally, urban population passed 50% in 2008 and is projected to reach 60% of total population by 2030 (out of 8.2 billion). 1.8 billion urban citizens will be added in 2005-2030 out of which 1.1 billion will be added in Asia. Urban sprawl and new infrastructure for mobility is in strong conflict with the use of fertile land for agriculture because most of the urban and suburban areas are located on the best agricultural soils (Netherlands Environmental Assessment Agency and Stockholm Resilience Centre, 2009).

In developed countries, the retirement of the baby boom generation may curb the urbanization trend, following the preference of recently retired people (between 60 and 80) to live in the countryside. This preference declines when these ageing people go over 80, according to their need for urban health services and assistance. But this temporary movement back to the countryside of experienced people may give the opportunity to build new type of rural settlements that may be transferred to younger generations.

The urban population makes consumer decisions for food in an socio-cultural environment which is largely decoupled from the world of the producers. Widespread ignorance or unrealistic perceptions about food production, in particular about modern meat and milk production, form the platform on which regional food scandals and fears can lead to sudden changes in food markets. The retailers have a critical responsibility in making the food chain transparent and trustworthy. Niche markets with direct interactions between farmers and urban population constitute interesting fields of experimentation how the consumers can be better informed and be realistic about how their food is produced.

Urban zones also hold great potential towards new forms of sustainable, viable food production. Innovative local networks could bring together small-scale producers and the urban poor and supporting urban/suburban agriculture (IIASTD, 2009). At the high intensity end of production, a modernisation of urban gardening, for the production of fresh fruit and vegetables, as well as small bird, animal or fish enterprises, combined with waste/heat re-cycling would remove some primary production off farm land and into the cities, close to consumers, and could reduce the footprint of agriculture and food systems (Brunori et al., 2008).

Urbanisation is going to have a major impact on food systems in general, and on every one of the stages of food systems:

- on farming systems, that might be impacted by the fact that local workforce might exit the agricultural system and rural areas and migrate to cities, and also by the fact that some farming or biomass production systems already develop and could even develop further within cities, with the diversity of systems ranging from industrial livestock farms from western Europe to the inclusion of animal production systems within the realm of suburban areas of African or Asian megacities (Chaumet et al., 2009).

- on food consumers, that are going to become mainly urban, and whose lifestyles will be different from those in rural areas, although a general convergence of food diets around the world cannot be considered a general trend; cities might also be a place where innovations concerning food consumption patterns can occur.

- on the retailer and transformation industry, whose logistics platforms and overall design of the supply chain might be altered depending on the shape of cities and their possible interaction with an agricultural hinterland.

5.6.5. Time

When looking at the challenges of the classical and new scarcities, time seems an even more scarce resource, as changes have to occur at a rapid pace, whereas the ability of our societies to change is limited.

In the productivity narrative, classical and new scarcities are of a different nature, and every scarcity can be dealt with by specific innovations, which can substitute a resource by another, or even could create new resources : in this perspective, time is short because innovations in various fields have to occur rapidly, but scarcity itself will trigger innovations.

On the contrary, in the sufficiency narrative, the system of scarcities that has been described here makes it necessary for a change in paradigms to occur, as no substitution from on resource to another would be sufficient to avoid the systemic problems we might face: innovations in systems and not only in technologies, innovations in organisations and policies, in order to foster changes, are very central and have to be given support and incentives.

These two different visions of time scarcity and of its consequences for research and innovation policies are at the heart of the debate about research and innovations priority setting.

6. TRANSITION PATHWAYS TOWARDS A SUSTAINABLE FOOD CONSUMPTION AND PRODUCTION SYSTEM

6.1. Introduction

We have identified three main pathways to facilitate the transformation of the current European food consumption and production system towards greater resilience and sustainability: (1) consumption, (2) technological innovation and (3) organisational innovation. Each of these domains contains important levers for change. In this chapter, we discuss these domains in a systematic manner. *First*, we briefly discuss the state-of-the-art as well as the major new trends, and we make the link to the resource scarcities that have been discussed in chapter 5. *Second*, we give an overview of the main drivers in each domain. For this we particularly focus on new trends and on changes in trends. *Third*, we discuss how these pathways relate to the two narratives we developed in chapter 4. *Fourth*, we analyse the structural barriers that hamper the evolution of these pathways. *Fifth*, we highlight the main implications for research. Next, we focus on the enabling conditions that provide the context for these pathways. These conditions are formed by the policy context, the rural and regional context and the knowledge systems context. We conclude this chapter with reflections about the Knowledge Bio-Based Economy (KBBE) as an integrating concept for the upcoming system transformation and transition pathways the European agricultural and food system is facing.

6.2. Consumer-driven transition pathways

Trends and developments

In an overview of lessons learnt from FP projects in the field of food consumer science, the European Commission (2007b) has identified three trends in European food consumption:

- A first trend is the *increasing variety of food consumption*. This is due to the rapid expansion in global agri-food trade and social and technological developments over the past two decades. In addition, how food is purchased and prepared has also changed. Regional differences in diet are decreasing and Europe is increasingly consuming the same kind of food in similar ways. In parallel, an increasing number of consumers tend to purchase foods when on holiday, creating a type of "food tourism", particularly for typical products that are not widely commercialised out of their region of origin.

- A second trend is that *habits are changing*. Consumers spend less time eating at home, are confronted with an increasing range of convenience foods and appliances for storing and cooking and increasingly make informed decisions that are based on sound knowledge. Driving forces include changes in lifestyle, the changing role of the housewife and changes in household composition, an Increase in disposable income and revolutions in food processing.

- A third trend is the *divergence in diet between the rich and poo*r. As diet-related diseases (obesity, type 2 diabetes, hypertension, osteoarthritis, and cancer) increase, rich consumers adapt their diets as shown by an increase in novel foods (vegetarian, organic, special nutritional requirements). However, poor people do not adapt, for example the cost of fruit and vegetables is increasing.

Earlier, we reported on the nutrition transition towards more meat-based consumption that is occurring in low and middle income countries and that has world-wide consequences for supply, thus putting enormous stress on ecosystems.

An important lever could be that a second transition occurs from a diet rich in animal proteins to a diet that is closer to health guidelines and that at the same time puts less pressure on the environment. Evidence for such a transition is emerging.

In addition, the shift towards more healthy and environmentally friendly consumption patterns seems to correlate with a rise in consumption of food products that also meets social standards, such as fair trade. As an example, Figure 6.1 shows the steep increase in Fairtrade sales in the UK in the period over the last decade.

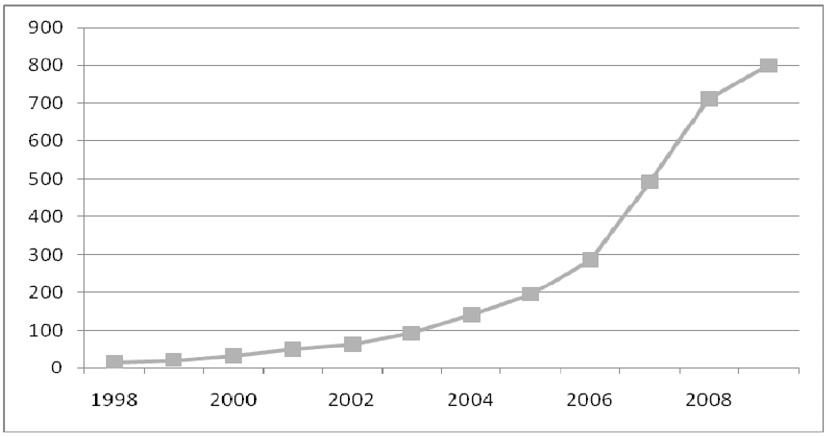

Figure 6.1. UK Fairtrade sales in million GBP
(http://www.fairtrade.org.uk/what_is_fairtrade/facts_and_figures.aspx)

Drivers

Factors influencing food choice include (European Commission, 2007b):
- Biological determinants (hunger, satiety, palatability of food, taste, sensory aspects)
- Economic determinants (cost, income, availability of foods)
- Physical determinants (ease of access to food, education, specific skills, time constraints)
- Social determinants (culture, family, peer-group pressures, meal patterns)
- Psychological determinants (mood, stress, guilt)
- Attitudes, beliefs and knowledge about food.

Understanding these factors is important, as diet is important for health: a scientific basis is needed for guiding food choices towards more health-promoting eating habits (incl. for new product development). Moreover, consumers need to be empowered to choose instead of being told what to or not to eat, and food should be safe. However, our understanding of consumers' attitudes is far from complete.

As food consumption is a daily routine, consumer choices are also daily routines. Habitual behaviour is in fact an evolutionary advantage, as we do not need to invest mental effort in routine decisions that have served us well in the past. As a result, we can use our mental capacity for more important choices (Warlop, 2006). A comprehensive effort to model food consumption by Jager (2000) also shows that our cognitive processing is also a consumer-specific process that is very context dependent. Some researchers therefore suggest a significant influence of the food processing companies, retailers and mass media on consumer choices (Barling et al., 2009; Popkin, 2009). However, it is difficult to substantiate these claims with hard evidence (Barling et al., 2009).

Link to scarcities and narratives

A transition towards more healthy, environmentally friendly and socially just food consumption is generally not part of the Productivity Narrative that considers the demand to be rather exogenous. Ideally, consumers become more and more conscious of the impact they have on the environment and on their own health through their food choices. In this way, sustainable demand shifts are translated into sustainable supply shifts. The Agrimonde 1 scenario, that fits the Sufficiency Narrative, is largely based on the assumption that this will happen (Chaumet et al., 2009). Erb et al. (2009) have simulated various scenarios of supply and demand dynamics and have shown that organic farming even has the potential to feed the world given an increase in cropland of 20% and a diet nutritionally sufficient in terms of nutritional energy (2,800 kcal/person/day), protein and fat supply.

Barriers and policies

All factors affecting food consumption also present important barriers to such a transition. Broadly, there are two perspectives on changing consumption patterns. On the one hand, the individualistic/agentic approach taken by economics and social psychology focuses on the consumer as a pure consumer. On the other hand, the structuralist/systemic approach taken by sociology focuses on the consumer as a citizen who is strongly influenced by the systems and structures in which (s)he is embedded and that the systems can only be changed by political (thus citizen) action (Spaargaren and Oosterveer, 2010).

The agentic perspective is limited by the slowness of the increase in consumer consciousness and is confronted with a gap between attitude and behavior. The reason for this gap is that as food consumption is a daily routine, consumer choices are also daily routines. For this, the consumers use mental shortcuts, or frames, to make food choices. These mental models are derived from a dominant discourse or dominant frame in society that is reinforced by commercial and non-commercial communication messages (Aubrun et al., 2005; Stoefs and Mathijs, 2009). A change in attitude is thus not sufficient to change behaviour, but needs to be reinforced by other factors, including the discourse or narrative on food, price, etc.

> *Overcoming problems of consumer lock-in, unfreezing old habits and forming new ones, understanding the complexity of the social logic in which individual behaviours are embedded: all these are pre-requisites for successful behaviour change initiatives* Jackson (2005, p. 119).

The structural perspective is limited by the slowness of social and structural change using democratic practices. If demand shifts are too slow, the greening of food can also occur through the imposition of standards. Standards can be imposed by government or are voluntary. Of course the voluntary development of sustainability standards by industry is generally a reaction to a shift of demand: industry will not impose costly measures when there is no market for the goods thus produced. Science has a pretty good understanding about consumer behaviour and about changing consumer behaviour, but it is very difficult, and often ethically problematic, to convert that knowledge into policy actions. How far can government go? How far can government act itself via campaigns, standards, regulations, payments? How far can government empower civil society actors such as NGOs, or market actors such as health insurances?

Recently, a third way emerged that focuses on social practices as a synthesis of the agency approach and the structural approach. This approach joins the individual-focused and the structuralist approach (Spaargaren and Oosterveer, 2010).

With respect to the role of policies, DEFRA (2005) proposes that government should enable, encourage and engage consumers to consume sustainably, and that government should lead by example. An important barrier, however, is that a sustainable diet requires a radical shift in consumption practices. An example of how this may work has recently been provided by WWF (2011) in its Livewell Report. WWF proposes the Livewell diet, a diet that meets dietary recommendations, while reducing 70% GHG by 2050. The Livewell diet requires more than 50% reduction in the categories “Meat, fish, eggs, beans and other non-dairy sources of protein” and “Food & drinks high in fat and/or sugar”, while the consumption of milk and dairy products can be maintained at current levels. Finally, both business and government could engage in choice editing by setting minimum sustainability standards, thus avoiding the production and consumption of unsustainable products (Sustainable Consumption Roundtable, 2006).

6.3. Technology-driven transition pathways

According to the third edition of the Oslo Manual (OECD/Eurostat, 2005) ‘an innovation is the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organisational method in business practices, workplace organisation or external relations.’ The common feature of any innovation is that it must have been implemented. ‘A new or improved product is implemented when it is introduced on the market. New processes, marketing methods or organisational methods are implemented when they are brought into actual use in the firm’s operations’.

For transition pathways related to organisational innovation we refer to section 6.4. This section discusses the following innovation fields:

- Biotechnology
- GMOs
- Nanotechnology
- Information and Communication Technologies (ICTs)
- Agro-ecology

6.3.1. Biotechnology

Trends and developments

The United Nations Convention on Biological Diversity defines biotechnology as "Any technological application that uses biological systems, living organisms, or derivatives thereof, to make or modify products or processes for specific use." Biotechnology makes use of a plurality of “platform technologies” such as genomics, proteomics, metabolomics, bioinformatics, genetic modification, marker assisted selection, synthetic biology. Its fields of application are in the primary sector (green biotechnologies), in the health sector (red biotechnologies) and in the industry (white biotechnologies). The connection among these sectors is shown in Figure 6.2 below (OECD, 2009).

The primary sector is involved in biotechnologies as source of feedstock for the industry and of active principles for the health sector, as a producer of functional food, and as user of biotechnological applications such as seeds, bio pesticides, animal therapeutics and diagnostics. There is a large agreement that these new technologies are introducing ‘revolutionary’ changes both in the amount of knowledge, processes and products (The Royal Society, 2009). The applications of biotechnology in business activities belong to the so-called bioeconomy. A recent evaluation of the total turnover of the bioeconomy in Europe states that it amounts to about 60 millions euro (50 chemical and plastics, 1 enzyme and 6 biofuels) (CleverConsult, 2010). Given the common scientific and technological platform, the integration between the three sectors is bound to develop further, as in the case of nutraceuticals, which cross the boundaries between food and drugs.

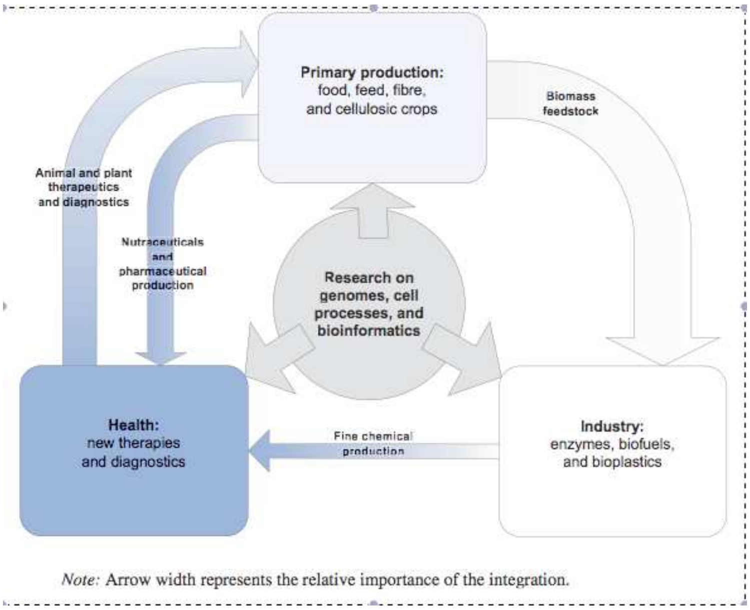

Figure 6.2. Connections within the bioeconomy
Source: OECD (2009)

The main biotech applications in agriculture encompass marker assisted selection (MAS), genetic modification, propagation, therapeutics and diagnostics. Biotech applications important in regard to livestock are breeding, propagation and animal health. In the short run, the "most important application of biotechnology to animal health is likely to be for diagnostics for genetic conditions and for recombinant vaccines. Genetic diagnosis for diseases hold great promise, but the technology is not as advanced as other biotechnology applications" (OECD, 2009). The largest commercial application of biotech in animal breeding is the application of MAS to conventional breeding programmes for pigs, cattle, dairy cows and sheep. This trend is expected to continue until 2015. With regard to propagation techniques the expectations are that the cloning of GM animals to produce pharmaceuticals will reach the market, and the application of the same technology for meat production is likely to occur in non-OECD countries, in which public opinion and consumer acceptance seem to be of less importance.

Drivers

OECD (2009) takes into consideration the following drivers for the development of the bioeconomy (see table 6.1). Biotechnology development and industrial application will be strongly linked in the future. In fact, the industry will be driven by a 'technology push' coming from expected advancements in fields of research such as systems biology, metabolic engineering, enzyme evolution (Kircher, 2010). At the same time, biotechnological research will be subject to 'demand pull' created by the development of the bioeconomy.

Ethical concerns will also play a major role when analyzing future trends (European Commission, 2010c). As far as ethical aspects are concerned, there are some issues still debated, such as cloning in animal production and synthetic biology. These aspects, in fact, raise critical answers to questions concerning the difference between life and non-life or between the natural and the artificial

(European Group on Ethics, 2009). OECD (2009) analyses GMOs, biomass energy, welfare of animal cloning, bioprospecting[6] as critical points in the ethical debate about biotechnologies (Table 6.1).

Table 6.1. Drivers, effects and uncertainties in the bioeconomy

Driver	Effect	Effect on bioeconomy	Uncertainties
Population growth	Increase of food demand	Pressure on food productivity	Sustainable consumption patterns
Ageing	Increase of the prevalence of neurodegenerative and other diseases of old age	Increasing demand of long term therapeutics	
Globalisation of trade in services	Investments in R&D	Investments in biotech technologies	IP regulation
Higher incomes	demand for healthcare, meat, fish and specialty foods, consumer durables, automobiles, higher education, and travel	Biotech therapeutics, added value food, biofuels	Inequalities will limit access to therapeutics Limited availability of feedstock for biofuels
Climate change	Spread of new diseases Reducing yields, stress on crops	Sensors and diagnostic Tolerant varieties	
Supporting technologies	Computing and nanotechnologies	Computing power and storage space, nanoscale devices, biocompatible replacements for body parts and fluids, material for bone and tissue regeneration, environmental remediation.	Ethical and environmental impact
Competing technologies	Integrated pest management, agroecology, Solar energy, disease prevention	Alternative industrial application and different policy approach may alter the development of biotech as solutions	Possibilities for integration

Source: OECD (2009)

Link to scarcities and narratives

As stated already, biotechnologies have a key role in enabling agriculture to produce adequate feedstock for the industry or to turn feedstock into end products. Biotechnological applications may have a relevant impact on the efficiency of the use of biomasses. On the other hand, availability of biotechnological solutions may put available biomass resources under stress, so adding to the conflict over land use.

Barriers and policies

The OECD study *The Bioeconomy to 2030: Designing a Policy Agenda* discusses the potential role of biotechnology in addressing global challenges on scarcities. These challenges encompass ensuring food security, water, energy, healthcare and other resources and services to a world that will be

[6] Together with stem cells and use of genetic information, which are not relevant to the agricultural sector.

home to a population increased by one third over the next 20 years. The study outlines the impact of the bioeconomy in achieving long-term sustainability.

Some biotechnological applications may raise concerns about their social impact. For example, so-called functional foods, defined as “any modified food or food ingredient that may provide a health benefit beyond the traditional nutrients it contains”, raise very complex issues. For example, they may weaken the efforts of public authorities to improve healthy eating styles. In fact “…by emphasizing a narrow range of dietary components and their potential impact on disease and often relying on specific ingredients”, and sustained by the power of advertisement, functional foods may be perceived by people as ‘magic bullets’ and solutions, and therefore considered as a substitute for the more rigorous discipline implied by healthy eating habits (Heasman and Mellentin, 2001; Scrinis 2008). As in many other cases, it would not regard biotechnology per se as a cause of negative social impacts, but its combination with existing social structures, regulations and business strategies.

As all new technologies, biotechnologies are sources of opportunities and threats. Many reports show that their application may have a revolutionary impact on business. A more prudential approach would state that in order to contribute to sustainable development, biotech research should a) incorporate ethical, social and environmental implications from the design of the research; b) proceed along with research that identifies institutional arrangements appropriate to avoid negative consequence of biotechnological application; c) be open to public debate.

6.3.2. Genetic modification (GM)

Trends and developments

Currently, GM plant breeding programmes are focused on four main traits: herbicide tolerance, pest resistance, stress tolerance, and product quality, among which two dominate the approved products – herbicide tolerance and pest resistance. These are very likely to be as well in the focus of non-GM breeding programmes in the foreseeable future (Arundel and Sawaya, 2009). According to most recent statistics (ISAAA, 2009), 134 million ha GMO crops are cultivated in the world (about 10% of total arable land in the world). At the moment, more than 90% of ha cultivated land involve four crops (soy, canola, maize, cotton) and two traits (pest resistance, herbicide tolerance). Most of the growth in recent years is due to ‘stacked products’, that is varieties endowed with combinations of traits (example herbicide tolerance + resistance to pests). Herbicide tolerance tends to be the common trait of any new commercialised variety.

According to the report *Biotechnologies in Agriculture and Related Resources to 2015* field trials of GM traits have been conducted for 130 plant species so far. The fastest uptake of GM technology has been registered for soybeans, where GM varieties account for 65.8% of global cultivation in 2008. The forecasts for 2015 are that this share will reach 88.2% of the total area planted; the figures for GM cotton are respectively 47.1% in 2008 with forecasted increase to 72.7% in 2015. Concerning vegetables, nuts, fruits, olives and wine grapes the report contends that the GM varieties on the market are very few, and that future adoption of GM varieties in this group will largely depend on consumer acceptance.

The expectations are that in the years to come the developing countries will be much more involved in the commercialisation of biotechnologies, mainly for new crop varieties suitable to the local conditions, as well as for other crops that adapt to these local conditions.

Drivers

Costs of GM technologies and time to market. Costs of bio-molecular techniques are decreasing in an impressive way. In 2006, sequencing a DNA basis cost $0.001, while in 1991 it cost about $30. A whole genome sequence may cost one tenth of the cost of ten years ago. This means that the use of these technologies may spread to small and medium enterprises. However, there are many other costs to be sustained to produce a GMO. An analysis of the only regulatory costs (risk analysis, test into fields) for a new variety is about 425 million dollars. It is said that developing one variety costs about $1 billion. Up to now, the development of a new variety takes 10 years.

Competing technologies. The advancements in molecular biology do not benefit only GMO technologies. There is a large variety of "omics" (genomics, metabolomics, ...) studying the genetic basis of the phenotype, and with the assistance of ICT huge amount of data to understand plant physiology can be analyzed. These applications can be used by many other technologies. MAS (marker assisted selection), for example, is an upgrade of conventional breeding practices; markers help breeders to identify more clearly which varieties to cross-breed in order to create new varieties: the time to market of products using these techniques is half of GMOs. There are other 'radical' alternatives, based on the principles of applied ecology, that start with the study of relation among species and their environment and propose 'ecological engineering', based on functional biodiversity, to solve most relevant agronomic problems (The Royal Society, 2009).

Evolution of scientific debate. GMO R&D is based on the Gene → DNA →protein paradigm, which now is largely dismissed by theories showing a much bigger complexity of relations among genotype (genetic endowment) and phenotype (characteristics of the organism in a specific context). GMO development based on the idea that a gene can directly express a function (e.g., tolerance to drought) does not take into account the complexity of feedbacks and unintended consequences that may arise from genome modification (Thompson et al., 2007; Mattick, 2009).

On the analysis and evaluation of the impact of GMOs there is a large variety of opinions and of data, most of which are lacking clear independence and neutrality. More often than not, controversies on the impact of GMO are particularly rude. High reputation scientific journals, such as Scientific American and Nature Biotechnology among others, have referred to violent concerted attacks, from established academic groups within the scientific community, to researchers that have presented results that put into evidence negative impact of GMOs (Scientific American, 2009; Waltz, 2009). They have also shown that a great deal of research on GMOs is not feasible if not authorised by seed producers. The point is that any allegation of negative impacts is amplified by the media into public opinion, and there may be a direct effect on sales and of public administrations' attitudes towards GMO. As quite a big share of GMO research done in public institutions is funded by seed corporations, it is understandable that claims that are not positive give rise to great concerns. On the other hand, people who would look for critical analysis is often forced to source information from non-academic organisations, which have a clear political aversion to GMOs.

Link to scarcities and narratives

According to the Productivity Narrative, biotechnology developments[7] and their applications in agriculture have an enormous potential to fight against scarcities as well as to address social challenges. Agricultural biotechnology is expected to have a major role in the years to come. Some areas where biotechnology will have a prominent role include increasing yields based on improved and new crop varieties (for instance draught-tolerant; reducing the use of natural resources on one the one hand and increase the efficiency of resource usage on the other; reducing the level of CO_2;

[7] Europe 2020 and Biotechnology, EuropaBio

contributing to meet the Millennium Development Goals on reducing poverty; increasing food safety; biofuels and recycling of food waste.

GMOs are considered by supporters as the technology that can revitalise the concept of the Green Revolution while taking into account the undesired effects that it had generated. The slogan of one of the biggest seed corporations, 'producing more with less', shows the attempt to combine productivity, which is the main objective of Green Revolution, with ecological efficiency. However, so far the traits in commerce respond to the principle of efficiency only if compared with conventional (industrial) agriculture.

At the moment, GMOs do not seem to correspond well to the sufficiency paradigm. In fact, GMO traits so far being developed refer to a model of conventional agriculture, needing fertilizers and machinery to be fully exploited. However, supporters of GMOs have reacted to the criticism by developing arguments more in line with the sufficiency paradigm. Some of the areas where GMOs are expected to have a leading role in achieving sufficiency are (Nath, 2008):

- Improved and new crop varieties, adapted to local conditions
- Protection against insect damage and thus decrease pesticide usage
- Protect soils from erosion and compaction
- Increase food safety
- Improving nutritional content of crops

Many development specialists respond to this 'pro-poor narrative' by arguing that it "…downplays the complex and difficult socio-economic, political, institutional and even technical causes of hunger and poverty" (Jasanoff, 2005 in Glover, 2009). According to Glover (2009) promises of future benefits have driven investments in biotechnology for long, but technical risks and social concerns have not been factored in adequately. Others underline that competing technologies (first of all agroecology) would be much more effective in addressing sufficiency problems.

Barriers and policies

GMO adoption primarily meets with the following barriers:

- *Regulation*. Even in most GMO friendly countries, regulatory costs are rather high. In order to make GMO develop even faster, some suggest a certain degree of deregulation. China is increasingly criticised for lack of regulation or controls (Arundel and Sawaya, 2009), while in the US recent court rules (alfalfa, sugar beet) show that regulation may be tighter.[8] In Europe, the rules on coexistence will raise consistently appliance costs for farmers (Menrad and Gabriel, 2009).

- *IPRs*. This is probably one of the major drivers for future GMO scenarios. There is an increasing agreement that the present regulatory frame creates natural monopolies and prevents innovation in fields different from those already taken by big corporations[9]. In a different regulatory context, for example in one where open access was largely spread, public research and small farmers may play a very different role, so to insert GMO in a very different socio-technical configuration.

[8] Gina Keating, U.S. court cuts off appeals in Monsanto alfalfa case, Jun 24, 2009 http://www.reuters.com/article/idUSTRE55N5QH20090624

[9] "Gene Giants typically claim any plant that has been engineered to express what the companies claim as a proprietary gene or genes – that's the standard approach that biotech companies have been using for the past two decades. With the patent grab on climate genes we're seeing far more expansive claims – which are likely to result in conflicting/overlapping claims" ETC group (2008).

- *Public opinion***.** In Europe, GMOs are largely disapproved by public opinion (Brook Lyndhurst, 2009). GMO labelled foodstuffs are interpreted as low-quality products, and many retailers and processors tend to position themselves as GMO-free.[10]

6.3.3. Nanotechnology

Trends and developments

According to the analyses and forecasts of the *Lux Research Company*, by the year of 2015 'nano' at the global level will be incorporated in $ 3.1 trillion of manufactured goods, accounting for 11% of manufacturing jobs. Although the degree of awareness of the public of them is not high, nanotechnologies have entered into markets and are growing at a fast rate. Also in the food sector, where applications are fewer than in other fields, evolution is fact. The Woodrow Wilson Center, a Washington research institute, has compiled a list of 1,000 nanotech commercial products, of which about 50 are food. Annex 3 shows the main fields of application. Nanotechnologies in the food industry have multiple functions: their first application is in food packaging, where it improves functionality. Other applications aim at improving taste, enhancing the bioavailability of certain ingredients, reducing the content of some elements such as sugar and salt, and slowing down microbial activity.

According to the report *Nanotechnology Developments for the Agrifood Sector – Report of the ObservatoryNANO* (Robinson and Morrison, 2009) the direct application of nanotechnologies in agricultural production is still limited in the EU. The expectations are that nanotechnologies developed and applied in other sectors are very likely to recognise in the future potential applications in agriculture. The report discusses the application of nanotechnology in three sub-sectors:

- In terms of *agricultural production*, five application areas have been analysed: sensors and diagnostic devices for monitoring environmental conditions, as well as for monitoring plant and animal health; disease and pest control (including the use of novel delivery systems for pesticides, and limiting the environmental impact of agrochemicals); water and nutrient controls; genetic engineering of plants and livestock to improve productivity, and agriculture as a means to produce nanomaterials. The report recognises as well the potential of agriculture as a producer of *nanomaterials*, which in its turn is an area which needs future research activities in (i) waste products from agriculture and forestry as raw materials for new nanocomposites (where research activities are quite advanced and at the applied stage), and (ii) biogenesis of nanomaterials, which is still at the basic stage, and hence will need further work and investments 'to scale up to industrial process level'.

- *Food processing and functional food*. Three areas are in the focus of the report: quality control, processing technology and functional foods. The report recognises that within the EU a large number of various research teams work in these domains, namely in sensors, coatings and delivery systems, but the *'uptake in foodstuffs' is still limited.* The focus is to be placed on ensuring that 'all food contact materials like coatings and filters, as well as ingredients, are safe for human health'.

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[10] Tom Pirovano (Nielsen) GMO-Free is Fastest Growing Retail Brand. Mar 07, 2010 http://shatterlimits.com/gmo-free-is-fastest-growing-retail-brand

- *Food packaging and distribution*. In regard to food packaging and distribution the drivers being spelled out are 'reducing costs' in parallel with 'increasing sustainability and functionality'.

Drivers

Nanotechnology is developing very fast under the thrust of public and private research. It also has been favoured by the regulation void in which it has operated. There are clear signals that regulation will enter into force, and the scenario for the future may change. For example, the EU parliament food commission has approved in April 2010 a report from a Swedish MEP urging the Commission to revise the legislation concerning the release of nanotechnologies into food[11]. MEPs said all nanomaterials should be considered as new substances, and that existing legislation does not take into account the risks associated with nanotechnology. This implies that food containing nanoparticles will be labeled and a regulation on introduction and risk assessment will be introduced.

In recent years the debate on nanotechnologies has grown. Issues such as health and environment have been raised, together with 'new' ethical concerns regarding privacy, terrorism, and broader socio-economic issues[12]. Many reports and articles have concentrated on regulation and on a need for more research on the impact of nanoparticles on the human body[13].

Robinson and Morrison (2009) discuss the following future developments of nanotechnologies:

- Nanotechnology is likely to exert a strong impact on active packaging in the future.
- The report reads that self-healing composites are unlikely to appear in food packaging materials in the foreseeable future due to the large costs, and the fact that such materials would need to be approved for food contact use or GRAS (generally accepted as safe).
- Biosensor technologies still need a lot of research before being included in the food packaging material.
- The drive towards greener and sustainable manufacturing means that biopolymers will be increasingly used since the associated advantage is that – in theory - recycling is no longer necessary.

Link to scarcities and narratives

Up to now, nanotechnologies have been emphasised as a revolutionary technology and as a key to competitiveness. It may be said, however, that in the light of sustainability nanofood raises more concerns (related to human safety and environment) than hopes.

With regard to vulnerability of food systems, nanotechnologies have raised some very deep concerns, as they may imply strong structural change in society and in the economy[14]. As far as sufficiency is concerned, it does not seem that nanofood could contribute to a global reduction of consumption footprint: on the contrary, some applications (such as those aimed at improving the taste of food) may bring to a trend of growth of consumption and incorrect nutrition.

Barriers and policies

As stated before, nanotechnologies have developed in a regulatory void. Only recently has there been an acknowledgement of the implications of nanotechnologies on sustainability, and regulatory

[11] EurActive 2010
[12] http://www.nanoethics.org/bad.html
[13] see among others House of Lords (2009)
[14] http://www.nanoethics.org/bad.html

frameworks are being debated and introduced. Also a clear framework for information disclosure by companies is urged by NGOs (ETC Group, 2009). Mainly two themes warrant attention: (1) ethical/moral and participatory issues and (2) risk assessment and governance (Davies, 2009).

Similar to GMOs, the application of nanotechnologies in the agriculture and food industry raises questions of ethical nature: if 'nano' is incorporated in foodstuffs, should these foodstuffs have labeling to indicate what 'nano' has been used and for what purposes. Since the application of nano – like GM – leads to this kind of concerns then the general public – the consumers – must be involved since the stage of development of the technologies, and not only when the technology is marketed. The major concern here is that society is still lacking the mechanisms to express its common voice at the stage of development of technologies, the report points out that 'The public in its role as taxpayer should, at a minimum, have a voice in which technologies the government funds and supports … **The technology of public-participation mechanisms lags behind the science-based technologies of the 21st century**.'

Another policy challenge is the lack of risk assessment data, as well as appropriate risk assessment methods, since the toxicity of nanomaterials is due to a high number of characteristics: mass, number and shape of the particles, electrical charge at the surface of the particles, coating of the particle with another material, etc. Science will have to address these problems and identify which of the characteristics of nanomaterials are of highest importance.

6.3.4. Information and Communication Technologies (ICT)

Trends and developments

ICT is a new technology that is increasing in importance for agriculture. The term Information and Communication Technologies (ICTs) is used to refer to hardware, software, networks and media for collection, storage, processing, transmission and presentation of information in the formats of voice, data, text and images (World Bank ICT Glossary Guide). As such, the nature of ICTs is diverse, ranging from telephones, radios and TVs to more complex technologies such as Internet technologies, mobile telephony, computers and databases. This diversity means that they can be used by people with varying degrees of skills.

A primary purpose of ICTs is to provide an enabling environment for the generation of ideas, their dissemination and use. The most prevalent use of ICTs in agriculture, particularly in the developing world, is providing farmers with information and advisory services through SMS, voice, web portals and call centres (McNamara, 2008). The basic information needs addressed include market information prices, weather forecasts, crop and livestock diseases and general advice related to agriculture (FARA, 2009). In the developed world, ICTs are also important in this regard, but they also serve as a basis for other technologies such as GIS and GPS that are enhancing progress in the application of precision and site-specific agriculture (IAASTD, 2009).

The benefits of ICTs accrue not only from the technologies but also from their potential to facilitate technological recombination and change leading to innovation (UNCTAD, 2008). It is widely acknowledged that transformations in the global economy are being fuelled by ICT-powered innovation. As such, it is imperative for poorer countries, we well as developed nations, to continue to prioritise ICTs in agriculture.

Nearly every aspect of agricultural production and trade includes substantial intangible elements of information exchange, communication, transactions, knowledge and skill transfer. Increasingly, successful agricultural innovation is about accessing, adapting and applying locally-relevant information and techniques, available ‘just-in-time’ to respond to rapidly changing opportunities and threats (The Royal Society, 2009). Therefore, a critical element in enhancing agricultural productivity is to strengthen and diversify the agricultural information economy-increasing the variety, speed, accessibility, local adaptation and affordability of information, communication and knowledge transaction in the rural space (McNamara, 2008).

Increasingly, ICTs empower farmers as innovators by providing:

- ‘smarter’ and more locally appropriate and productive inputs;
- more effective cultivation and production techniques;
- risk mitigation strategies and skills;
- support to farmers as active participants in the innovation process.

ICTs are invaluable as increasingly sophisticated farm management tools. For example, farming enterprises will make much greater use of decision-support systems in a drive to maximise production efficiency and minimise costs. These systems are growing in sophistication providing farmers with decision supports over a wide range of activities. The use of satellite information and imagery for agricultural use will also increase. Combined with GPS, this will enable a greater degree of precision in the application and timing of inputs and assist in enhancing sustainable production.

Drivers

ICT is being driven globally by: major reductions in cost associated with the technology; national and international regulation; global investment in enabling infrastructure; growing dependence on information exchange, communication, transactions, knowledge and skill transfer; the potential to facilitate technological recombination and change leading to innovation; and the fact that ICT is instrumental in a range of other innovations that contribute to greater productivity in productivity and business management.

Link to scarcities and narratives

The solution to the problem of future scarcities of natural resources will primarily be found in technological innovation and changes in consumer and producer behaviour, production systems and the market. New technologies, underpinned by ICT, will help deliver greater efficiency in resource use and greater resource substitution. ICT will also be critical in helping bring about the behavioural changes needed for future sustainable lifestyles.

ICT is relevant to both narratives. Under the productivity narrative, ICT can be considered as a critical element of the technological solution to boosting productivity, whilst its importance as a tool in behavioural change and changes in food systems and supply chains ensures that it is also a component of the sufficiency narrative.

Barriers and policies

In order to fully realise the benefits of ICTs, there are three broad prerequisites that must be provided: access, capacity (skills) and applications (services). Access refers to both the hardware and the underlying infrastructure. Both must be reliable and affordable; additionally, infrastructure must be ubiquitous. The capacity or skills to use ICTs are the second requirement. These skills are required to varying degrees at several levels along a continuum ranging from basic end-users (e-literacy) to ICT specialists with highly developed technical skills. Lastly, there must be applications and services that are relevant, localised and affordable. This requires developing countries, in particular, to undertake a complex set of policy, investment, innovation and capacity-building measures, in close coordination with international donors, the private sector and other partners, to encourage the growth of locally appropriate, affordable and sustainable ICT infrastructure, tools, applications and services for the agriculture sector and the rural economy.

6.3.4. Agroecology

Trends and developments

Agroecology is defined as “the application of ecological science to the study, design and management of sustainable agroecosystems” (Altieri, 1995). “Implicit in agroecological research is the idea that, by understanding these ecological relationships and processes, agroecosystems can be manipulated to improve” (Altieri, 1995). In other words, agroecology is the knowledge basis for Agroecological Engineering, “an umbrella concept for different agricultural practices and innovations such as biological control, cultivar mixtures, agroforestry systems, habitat management techniques (for instance, strip management or beetle banks around wheat fields), or natural systems agriculture aiming at perennial food-grain-producing systems” (Vanloqueren and Baret, 2009). Organic farming is thus considered one amongst the possible applications of agroecology: in fact, on one hand not all agroecology applications are finalised to organic farming, and on the other hand some patterns of organic farming may be quite far from agroecology.

Globally, hundreds of agricultural systems are based on agroecological principles—from rice paddies in China to mechanised wheat systems in the USA, although data are not as accurate as for transgenic crops acreage (Vanloqueren and Baret, 2009). Comprehensive statistics about diffusion of agroecological techniques do not exist. Pretty (2006) gives some figures about adoption on 286 projects in 57 countries. On all projects, involving about 12 millions farmers and 36 million hectares, an average 79,2 % increase in crop yields results. FIBL has released, together with IFOAM, statistics on organic agricultural land. In total, about 35 million of ha of land are dedicated to organic farming, with an increase of 11% since 2005 (Table 6.2).

Table 6.2. Organic agricultural land, share of total agricultural land, 2005-2008

2008		2007		2006		2005	
Org. Ha	%	Org. ha	%	Org. ha	%	Org. ha	%
35.225.259	0,81%	32.351.096	0,77%	30.144.686	0,73%	29.046.688	0,70%

Source: http://www.organic-world.net/statistics-2008.html

According to several authors (Altieri, 1995; Uphoff, 2007; Schmid et al., 2009), agroecology helps to fulfill the following goals:

- Higher productivity per unit of land and water, based on intensified agricultural operations, carefully managing all inputs and the plants and animals within these farming systems.
- Lower dependency on fossil-fuel energy and on agrochemical use, made possible by mobilising and utilising existing biological potentials.
- Environmental benignness, by making fewer demands on scarce freshwater supplies and by reducing the build-up of harmful chemicals in the soil and water.
- Resilience to adverse climate effects as well as to pest and disease damage, by having better root systems and by buffering with poly-cropping strategies.
- Able to operate without subsidisation, although the systems produce enough demonstrable positive externalities for people and the environment that some payments could be justified.
- Accessible to the poor, with minimal capital costs and few barriers to adoption. Skill and motivation are needed, but not as much investment is necessary as with modern agriculture.

Drivers

According to Uphoff (2007), agroecological approaches will spread in the future. The main reason for this is the fact that the general context has radically changed. As far as the dominant model of agriculture is concerned, two of the most important conditions for development are falling: oil availability and diminishing returns. There are also other drivers for the development of new paradigms (Thompson et al., 2007; Brown, 2009; Schmid et al., 2009; The Royal Society, 2009):

- declining land and water available per capita
- increasing costs of energy
- environmental quality and conservation as issues for citizens and for their governments and NGOs
- climate change
- existence of a large number of farmers untouched by modern agricultural technology

In response to these drivers, several concepts of environmentally benign agriculture emerged such as integrated farming, conservation agriculture, organic farming and silvopastoralism. They are partly framed as “low-input farming systems”. Some are ancient methods which have acquired renewed attention (EEA, 2010b).

Constraints to the spread of agro-ecology are related to the bias of current AKS, backed by powerful economic and institutional interests and by lock-in conditions (Vanloqueren and Baret, 2009). As there is a need to develop the agro-ecological paradigm, public intervention is necessary.

Link to scarcities and narratives

As Thompson et al. (2007) state, agroecology is seen as an alternative narrative to conventional agriculture. Vanloqueren and Baret (2009) introducing the concept of agroecological engineering, provide a comparison about the two paradigms (see table 6.3).

Table 6.3. Comparison of genetic and agroecological engineering

Technological paradigms	Genetic engineering	Agroecological engineering
Basic definition	Deliberate modification of the characteristics of an organism by the manipulation of its genetic material	Application of ecological science to the study, design and management of sustainable agroecosystems
Implicit objective	Engineering plants: modify plants to our best advantage by making them productive in adverse conditions or by designing them to fit new objective	Engineering systems: improve the structure of anagricultural system to make every part work well;rely on ecological interactions and synergisms for soil fertility, productivity and crop protection
Scientific paradigm underlying the technological paradigm	Reductionism	Ecology and holism
Examples of subtrajectories progressing along the technological paradigm	Bt insect resistant plants, herbicide-tolerant plants virus-resistant plants etc.	Biological control, cultivar mixtures, agroforestry, habitat management techniques etc.

Source: Vanloqueren and Baret (2009)

Agroecological engineering is considered more in tune with emerging needs because it aims at creating more resilient and ecologically efficient systems and at replacing financial capital with human and social capital. In principle, there is a higher coherence with the sufficiency paradigm, as it embodies the limits to growth as one of the basic assumption.

Barriers and policies

The potentials of agroecology are also its limits. In fact, agroecological techniques are knowledge-intensive, as they are strongly embedded in farmers' local knowledge. As it makes external inputs less necessary, it is not interesting for agribusiness, and therefore does not stimulate external investments. Local knowledge may also be a scarce resource if not maintained and developed through appropriate knowledge systems. Another limit of agroecology is its local specificity, which limits the capacity of diffusion of the innovation. A further limit is related to market pressures, that may make a maximisation rationale prevail over a stability one.

The conditions of development of agroecology will then depend on supportive policy environments, especially in the fields of knowledge brokering, and on steady market conditions for farmers. Given its knowledge intensity, agroecology may show increasing returns of scale: as agroecological learning occurs within social networks, learning rates may accelerate as far as the size of the networks would grow.

Regulation may foster the development of agroecological approaches. Directive 2009/128/EC, establishing a framework for Community action to achieve the sustainable use of pesticides, recommends the member states to incentivate Integrated Pest Management and Organic Farming as alternatives to conventional use of pesticides. The anticipated reform of Common Agricultural Policy, with its emphasis on provision of public goods, will improve the profitability of sustainable agricultural practices vis a vis conventional practices.

6.4. Organisational innovation-driven transition pathways

6.4.1. Organisational innovations in food supply chains

Trends and developments

Governance refers to the act of governing, the way decisions are made in the agri-food system. The governance of food supply chains has been characterised by increasing concentration of resources and power in a limited number of multinational corporations and retailers. To produce conclusive evidence on the abuse of market power, however, remains a problematic issue, due to data accessibility. Despite that we see no turnaround of these trends, and several new trends can be observed in the way food supply chains are governed.

First, some recent foresight studies (Chaumet et al., 2009; Rastoin, 2010) insist on a specific trend in the private sector linked to agriculture and food, and particularly in the processing and retailer industries, from an agro-industrial model to a "tertiarised agro-industrial model", where food products tend to become services more than industrial or primary products. Recent trends are shaping such a future model: always more productive and intensive systems at every level of the supply chain, always more specialised on some specific crops or on some specific stage of the food process, always more concentrated in terms of firm concentration, with a growing importance of financial markets and of global exchanges. In such a model, the multinational companies of the food processing and retail industry play and will play a crucial role in enabling changes in the consumption patterns or the production paradigm.

Second, a number of companies are advancing from a phase in which some green projects are set up in the framework of their corporate social responsibility (CSR) programme towards a phase where the greening of their supply chains has been an integral part of their strategy and thus their core business. At the same time, these companies are joining forces (e.g., SAI Platform) and entering into new governance initiatives together with NGOs. Examples include the Marine Stewardship Council, the Rainforest Alliance, the Round Table on Sustainable Palm-oil, the Round Table on Sustainable Soy and the Sustainable Food Lab. This leads to an increasing adoption of social and environmental standards and an increasing share of certified products (e.g., Chiquita, Lipton), as well as increasing interest of multilateral and development agencies, such as the UN Global Compact and the Global Reporting Initiative (Genier et al., 2008).

The latter trend is in line with a trend that started in the beginning of the 1990s when some governmental agencies began to experiment with new ways of policy making in which they share responsibility with societal actors. A noteable example is the transition management approach, adopted first in Dutch environmental policy in 1990, and applied in areas such as energy, building, health care, mobility, agriculture and water management. Initiatives also emerged in Belgium and the UK (Loorbach and Rotmans, 2010).

Drivers

The 'tertiarisation' of the agro-food sector is a trend that results from the continuous competitive pressure that agro-food companies and retailers face in the international market place. This pressure drives them towards adding more and more value to the products they offer in order to be able to differentiate from the competition. The concept of value itself is also changing: instead of being embedded in products, value is increasingly determined by the use of products and related services by consumers. In fact, this trend is part of a wider shift in western societies from an industrial economy towards an economy based on services (Vargo and Lusch, 2004).

Three sets of drivers influence the adoption of CSR strategies. First, governments, NGOs and the media including internet-based social networks are putting large firms in the spotlight to account for the social consequences of their activities (Genier et al., 2008). Second, firms are more likely to make more use of strategic social positioning in markets where product differentiation is difficult and price competition is intense (Husted and Allen, 2007). Third, the share of ethical or responsible food consumption is increasing, as documented in section 6.2.

Link to scarcities and narratives

The trends of 'tertiarisation' and CSR have the potential to contribute greatly to tackling scarcities and to the realisation of the sufficiency narrative. The main development in both trends is that the focus shifts from the product to the bundle of characteristics and services provided by that product. This opens the avenue for resource saving (decoupling of resource use and consumption) and health promoting innovations. For instance, sensitivity to consumer concerns has urged some food companies to reduce the sugar and salt content in the food items they produce.

Barriers and policies

An important barrier is the consumer's willingness to pay for added characteristics and services, as discussed before in section 6.2. In its communication COM(2006) 136 final on Implementing the Partnership for Growth and Jobs: Making Europe a Pole of Excellence on Corporate Social Responsibility, the European Commission acknowledges the strategic importance of CSR in tackling a number of public policy objectives related to labour markets, skills development, public health, innovation, resource use, entrepreneurship, human rights and poverty reduction. The Commission promotes CSR by raising awareness and stimulating the exchange of best practice, by supporting multi-stakeholder initiatives, by stimulating Member States to encourage CSR and by stimulating consumer transparency, education and research. The Commission also emphasizes the SME dimension and the international dimension.

6.4.2. Social conditions of food production and transformation of farming systems

Trends and developments

At the global scale, both World Development (2008) and the Agrimonde study (Chaumet et al., 2009) outline very different pathways of evolution in farming systems in the world. In the western World, the main features are that intensification has relied on a decrease in the agricultural workforce and an increase in capital intensity; it can also be noted that farming systems have been growing in size, and thus concentrating into a smaller number of larger farming businesses.

In other countries, and particularly in Asia, intensification in agriculture occurred mainly in a labor-intensive way, rather than in a capital intensive way : agricultural productivity per hectare still relies on an important workforce in many Asian countries.

In the EU, the Common Agricultural Policy aimed at preserving a model of family agriculture and thus accompanying the concentration trend by helping to preserve a diversity of sizes and types of farming systems. This diversity is also reinforced by the differentiated pathways of agricultural development between Northern, Mediterranean and Eastern European countries, where a significant agricultural workforce remains.

Drivers

The main drivers of the downward trends in agricultural workforce in western countries are linked to economic competition, economies of scale and technological progress. The decrease in the agricultural workforce is also due to the fact that other sectors of the economy or other contexts, like cities, are more attractive than farming in rural areas.

Policies can have a strong impact on these trends; for instance in the regulation of agricultural land markets, in helping installation of new farmers, and also in rural development policies. These policies tend to be more and more decentralised to local authorities, which can lack means and competences to exert the responsibility of these policies.

Link to scarcities and narratives

The availability of a qualified agricultural workforce can be considered as one of the future scarcities: in both narratives, capacities of farmers have to be improved to face the challenges ahead, but the sufficiency narrative can even suggest that a larger workforce will be necessary for diversified systems and diversified functions of farming systems (multifunctionality); this workforce would also need to have diversified competencies, particularly in ecology, but also in other types of knowledge. In the sufficiency narrative, the social conditions of food production are also one of the concerns for a change in the systems and one of the criteria for innovations in the organisation of farming systems: how to design farming systems that could propose better income and better conditions of living for smallholders (in the South as well as in the North of the planet)?

On the other hand, in the productivity narrative, trends in the concentration of farming systems are very compatible with the objective of making these systems more productive through technological innovation: the demand for the workforce in agriculture will simply be less important, which seems quite compatible with the attraction of cities in some countries, but seems also very problematic in very labour intensive agricultural sectors, whose agricultural workforce will not be able rapidly to find jobs and incomes in other sectors.

Barriers and policies

Many of the reports considered in this report tend to have an implicit idea of what the best form of the future farming system would be, in order to have a both competitive and resilient farming sector (for some it might be agribusiness, probably particularly in the productivity narrative, for some and probably in the sufficiency narrative it is family size farming, and none is probably really sustainable nor what will take shape in the near future...).

Observing trends in the social characteristics of agricultural production systems is therefore a necessity to better understand both the reality of changes in production systems and the capacity of various social forms of production to be more or less resilient and more or less competitive.

Such observation systems are beginning to be put into place (like the Observatory of World Agricultures, http://www.cirad.bf/fr/oam.php), and in some regions like Latin America, a regional observatory enabled light to be shed on interesting alternative emerging forms of agricultural production, where local farmers joined all their capital and land into very large cooperatives (PROCISUR, 2010).

Maintaining a diversity of farming systems throughout the world, throughout Europe and also at regional scales, and a sufficient and qualified workforce seems necessary to ensure the possibilities for a transition towards more sustainable food systems, particularly as this network of diverse farming systems is also at the root of innovating and alternative systems and techniques for agriculture.

Policies are necessary to maintain such a diversity (land market regulation or public intervention, rural development, social or care farming). But it is also important that these public policies that support diverse farming systems, and also the innovation policy that relies on this diversity of farming systems, are designed in a subsidiary way: they must ensure enough diversity and enable the emergence of local initiative and alternative innovations, but at the same time ensure that enough regulation (for instance in land markets) is there to maintain diversity, and that enough coordination and incentives are there for innovation: decentralised policies might be very conservative of the status quo, depending on the local coalition of interests.

Therefore, organisational innovations also concern the capacity of the governance system to ensure both subsidiarity in rural development and innovation policies, and at the same time strong incentives for innovation and change towards sustainability.

6.4.3. Global governance

Trends and developments

Starting from the multilateral institutions, global governance regimes are emerging on various themes: World trade with the WTO, food security with the FAO and the Committee for Food Security, multilateral environmental agreements launched in Rio in 1992 (biodiversity, climate change, desertification).

The Rio Agenda for global governance was based on the assumption that world trade liberalisation and environmental agreements would be mutually supportive, bringing about a change in models of development both in the North and in the pathways of development chosen or experienced by the South, and at the same time ensuring a regulated and organised competition for resources by opening and regulating world markets.

Twenty years after the Rio conference, this central assumption appears to have been too optimistic, as models of development remain mainly on the same track, making competition for resources a source of greater conflict (van Schaik et al., 2010). The resistance to change in the models of development are at the heart of the difficulties that the Climate and Biodiversity negotiations are facing, where sovereign governments from the Northern or Emerging countries resist any global agreement that would force them to change their model, although they actually in many cases already are trying to innovate and find by themselves new pathways of development, in order to be more competitive.

Drivers

The drivers of global governance are manifold. The interrelatedness of all countries is now regarded as a fact in all regions of the world, which makes that even the apparent failure of the Copenhagen conference on climate in 2009 can at least in this regard be considered a success, as all countries considered that global environmental issues are a concern for them. This awareness of the interconnections between all countries constitutes a strong incentive for cooperation. And the efforts of many institutions and stakeholders like NGOs or think tanks for a multilateral treatment of these global issues is for the moment successful in maintaining UN institutions and conventions at the heart of the construction of global governance, although the Copenhagen agreement can be regarded as an agreement between the USA and emerging economies, and although the G20 might also be considered as an alternative forum for negotiation of world regulation.

On the other hand, many bilateral trade agreements or bilateral strategic convergences, relying on the asymmetries in powers between countries in the world, are also a symptom that power relationships and the competition for the appropriation of resources and wealth is also a strong driver explaining the difficulties in establishing global governance institutions.

Link to scarcities and narratives

In this general context, scarcities are very central, particularly concerning classical scarcities of mineral resources where competition for their appropriation seems a major concern because it might lead to conflicts. The Conference held in The Hague in April 2010 (Enriching the planet, Empowering Europe) called for the institution of a global resource management regime (van Schaik et al., 2010).

The issue of the international division of labour among countries in food production has recently been placed at the heart of many studies, as an issue for global governance (Richardson et al., 2009). In the Agrimonde study, one quite robust finding is that in every scenario, even with strong sufficiency assumptions, necessary food exchanges between regions of the world will increase, mainly because some regions like Asia or Middle East North Africa, will not be able to produce as much food as they will presumably consume under standard demographic assumptions (Chaumet et al., 2009).

The governance and regulation of trade, the resilience of food exchange patterns, will therefore be at the heart of future food systems and food security, even in a scenario where maximum regional food self sufficiency is sought. Innovation in regulation systems of global agricultural trade is therefore crucial, but at the same time is at the heart of very important controversies in the field of economics. Food exchanges regulations will also notably be very important because there is a consensus that instruments or policies should be designed to fight price volatility, without a clear convergent solution being proposed. Whereas some experts (Position on the CAP reform by French development and environment NGOs, Groupe PAC 2013, 2010) argue that adaptation and mitigation of southern agricultural systems make it necessary to protect their regional markets from competition with other much more competitive agricultural sectors in the North, some other experts (e.g., Franz Fischler in IFPRIs position paper on agriculture and climate change for Copenhagen, Fischler, 2009) argue that only a liberalised global system of exchanges will be able to fight price volatility (which is controversial in the community of global economics) and reduce overall farmers' vulnerability.

Another series of questions is raised by the role of global trade regulation concerning resources scarcities. As stated earlier in the chapter on climate change, one can also add that some reports propose to think of a global division of land use activities corresponding to resources scarcities, trying to allocate food production with respect to existing resources and resources use efficiency. Is such an objective desirable? Could that be attained through global markets? How could global food exchange policies be designed in order to take into account resource scarcities?

Concerning technology transfers, that seem to be one of the main drivers discussed for the future of agriculture and food systems, there is still a controversy about the importance of trade for innovation in agriculture in order to deal with future challenges like climate change. In southern countries, adaptation of the agricultural systems is seen as being of the greatest importance for the overall socio-economic development of the countries. FAO insists on the necessity of identifying synergies between mitigation and adaptation transformations of these agricultural systems. These opportunities for transformations are generally seen as being based on technological innovations, coming from northern countries' research systems. In this perspective, how should we organise intellectual property right systems enabling these technology transfers? Should we think of systems already imagined in other occasions where some companies accepted to limit their IPR for some specific markets (humanitarian use licenses) because there was no competition issues in the corresponding country?

Other experts (Lybbert and Sumner, 2010; Synthesis from the research programme Global Environmental Change and Food Systems, Ericksen, et al, 2009; CGIAR Challenge programme on Climate Change Agriculture and Food Security, CCAFS, 2009) argue that adaptation and mitigation in southern countries will mainly not have to focus on technological innovations but rather on the whole food system : infrastructures, access to market, agroindustry, but also the development of research capacities in the South, the elaboration of relevant public policies and institutions (extension, cooperatives, insurance, credit…), but also the functioning of markets and notably the anticipation of the effects of climate related commitments and norms on international exchanges and their regulation, and macro-level policies.

Barriers and policies

The role of the EU in these global governance innovations is central, although it has not been always successful. It is in the interest of the EU, because of its dependence on external mineral resources, its position as a major player in the global food markets (both as importer and exporter), to act in favor of a global equitable governance of resources and of food exchanges, preserving both global availability of food and local access to food. For these purposes, the EU has to act both at the international and at the European level:

- identify coalitions for a better multilateral governance with all countries, and particularly with emerging countries

- propose institutional innovations for a better multilateral governance, as the EU has been doing for instance on the role of expertise bodies like the IPBES (international science policy platform on biodiversity and ecosystem services) on biodiversity or the High Level Panel of Experts on Food Security and Nutrition; these scientific expert bodies can build the forum where complex notions of global food security, local access to food, and the competition of food exporters on world markets could be debated with the most objective rules, in order to find equitable and sustainable solutions

- analyze the coherence of European policies (trade, CAP, environment) with global food security objectives and with the Sustainable Development Strategy and global environmental agreements; this is already the role of PCD (policy coherence for development) and sustainability impact assessments, but further research has to be done in order to better analyze the consequences of domestic European policies on food security and the environment in the rest of the world.

Two major issues for research seem to remain:

- To what extent will it be possible to rely on global food markets to ensure a good allocation of food production in the world, ensuring both access to food of net importing regions and a fair competition among net exporters ? How can climate change impacts, climate change mitigation, and other environmental standards be taken into account in this global division of labour in food production?

- How to make innovation policy in Europe an asset in this global competition among food exporters, , while at the same time preserving the sustainability objectives. Investing in research and innovation is a key issue in this competition, and the recent position of China as a leader on photovoltaics is a clear example that innovations oriented towards sustainable development can be key assets for the future. For what concerns agricultural innovations, EU public research and innovation is key both for the European agrifood sector, but also for agricultural sectors in developing countries. A shift in the innovation system in Europe towards more diversified, system oriented research seems to be key for both Southern and European countries, ensuring in both cases an improvement in competitiveness and a more sustainable development model. EU's agriculture has proven quite competitive recently when compared to other regions of the world like the USA or China (Anania, 2009), while other countries, like India or Brazil, have apparently greatly increased their competitiveness, as their share in global markets as net exporters has been growing fast. The role of the EU in this competition would be to both ensure its capacity to remain a major player while also influencing global governance in order that sustainability criteria and sustainable models of agricultural development are also adopted in other countries.

6.5. Enabling conditions for transition pathways

6.5.1. The policy context

The EU Common Agricultural Policy (CAP) has a unique window of opportunity to incorporate the new challenges. The new CAP funding period 2014 to 2020 is being negotiated and the EU Regulation on support for rural development by the European Agricultural Fund for Rural Development (EAFRD) expires at the end of 2013.

In the Communication COM(2010) 672 final, EC, the EU has published a view on how to prepare for a strategic re-orientation for the long-term future of its agriculture and rural areas. According to COM(2010) 672 final, “the objective should be to build more sustainable, smarter and more inclusive growth for rural Europe”. Sustainable management of natural resources and climate action have become a key argument for future payments. The details of the future CAP policy being negotiated in the coming months will be critical for the timeliness of Europe-wide transitions in the agricultural sector towards farmers’ provision of public goods and meeting the scarcity constraints.

The Declarations 2009 and 2010 of a group of leading agricultural economists from across Europe (Reform the CAP 2009, 2010), the Advisory Council for Agricultural Policy of the Federal Ministry of Food, Agriculture and Consumer Protection in Germany (Advisory Council for Agricultural Policy 2010), the German Advisory Council on the Environment (SRU 2009a) and the Social and Economic Council in the Netherlands have called for far-reaching changes in the CAP, including a fundamentally different architecture of agricultural and rural policy, which are in line with the conclusions of this report:

- Targeting on public goods: All subsidies should be closely linked to the provision of public goods (Reform the CAP, 2010).

- Environmental focus: Sustainable land use should become the key objective of the CAP. This includes biodiversity protection, climate change mitigation and responsible water management (Reform the CAP, 2010). A sector-wide concept for “agriculture and forestry in climate change” has to be developed to address the goals of adaptation to, and mitigation of, climate change. Targeted payments and measures supported by monitoring (e.g. the rewetting of drained peatlands and measures for reducing nitrogen surplus; Advisory Council for Agricultural Policy 2010) may be more effective than a minimum share of farmland with environmental measures as proposed by the German Advisory Council on the Environment (SRU, 2009a). Biodiversity protection requires a flexible approach at several spatial scales closely linked to scaled-up research and monitoring of agrobiodiversity. Regional approaches beyond the agricultural sector, linked with education and information, should be linked with targeted payments and measures, which could be supported by payments for general ecosystem services provided by farmers (Advisory Council for Biodiversity, 2008).

- Global food security: The EU should promote global food security through an open trading system, support for agricultural productivity in developing countries, climate change mitigation and the preservation of its own sustainable production capacity. To enhance productivity, more public investment in research and development should be undertaken (Reform the CAP, 2009, 2010; Advisory Council for Agricultural Policy, 2010).

The CAP reform should be accompanied by new policies empowering farmers to use risk management tools, and possibly by providing income safety nets to cope with exceptionally depressed world market prices or extreme weather events (Reform the CAP, 2010).

Modern agricultural policy should no longer operate as protective or distributive policy for the European agricultural sector, but rather be seen as enabling policy for a competitive agricultural and food economy integrated in policy areas of nature protection, climate, energy, technology, animal health, consumer, global nutrition and a new approach to deal with rural areas (Advisory Council for Agricultural Policy, 2010).

Although they might be different, an important part of the positions in the debate converge on the necessity to refocus the CAP on sustainability and public goods objectives : whereas some proposals call for a very reduced public intervention where only environmental externalities would be subject to either taxation (if negative) or subsidies (if positive) (Reform the CAP, 2009), some other appeal to a strong (but transitory) public intervention policy in order to help the reconversion of the sector towards a sustainable agricultural sector (Nallet, 2010).

Regarding EU fishery policies, the German Advisory Council on the Environment concludes (SRU, 2009b) that the main impacts of fisheries are overexploitation of fish stocks, discards and mortality of non-target species, and physical destruction of marine habitats by fishing activities, with benthic communities particularly hard hit by trawling.
Environmentally sound, sustainable fishing can only be achieved if measures are taken to:

- Manage fish stocks well above safe biological limits or to restore that level where required.
- Significantly reduce by-catches and discards.
- Better protect the marine ecosystems from harmful fishing practices.
- Significantly more funding must be invested into researching the impact of fishing and into developing environmentally sound technologies and practices, best jointly with the fish-catching companies to foster innovation and implement monitoring.

In implementing these targets, the EU carries a key responsibility given its exclusive competence to regulate fisheries management (SRU, 2009b).

The Expert Group supports these calls for a strong environmental focus and payments linked to public goods. As there are many unknowns in how and where best to prioritise measures and how to monitor their effectiveness, research and appropriate funding has to become an important element of the future EU CAP.

The Expert Group supports these calls for a strong environmental focus and payments linked to public goods. As there are many unknowns in how and where best to prioritize measures and how to monitor their effectiveness, research and appropriate funding has to become an important element of the future EU CAP.

6.5.2. The rural and regional context

Transition pathways must acknowledge the complexity of agricultural production systems within diverse social, ecological and regional contexts, and the fact that major regional variations exist in levels of rural and agricultural productivity, in access to and capability to use technology, and in availability and access to natural resources.

A critical aspect to recognise is that the availability, quality and access to resources varies considerably on a global basis and some parts of the world are more vulnerable to scarcities than others. The unequal distribution of resources is a critical constraint shaping development and sustainability goals, and coupled with the lack of access to fair markets, results in extreme inequality and increasing poverty. This includes the low market power and education of farmers, particularly of small-scale farmers.

Across all the scarcity issues discussed above, a common theme is that the poorest countries stand to be affected most seriously – not only because of their more limited capacity to adapt to the effects of scarcity issues, but also because of geographical variations inherent in the problems themselves.

Population growth is heavily concentrated in developing countries. Land degradation is most extensive in Africa and Latin America. South and West Asia are most exposed to groundwater depletion and Africa as a whole to changes in water availability driven by climate change. High energy costs impact most heavily on poor, import dependent countries. Above all, negative impacts driven by climate change are expected to disproportionately affect the same fragile states and regions that are most vulnerable to scarcities. The worsening scarcities are a serious regional threat multiplier as they aggravate poverty, disturb international trade, finance and investment and destabilise governments (van Schaik et al., 2010). The foundation of food production from marine resources and in coastal areas is at fundamental risk due to the combined pressures from over-exploitation, pollution, global change and potentially irreversible loss of biodiversity. Globally, this risk is most pronounced in some of the world´s most dynamic urbanisation zones and megacities in the Pacific region.

EU regional agricultural diversity

The rural areas of Europe vary greatly in terms of quantity and quality of natural resource availability and in terms of the potential impact of the new scarcities. This is reflected in the great variety of farming systems within diverse social and ecological contexts that characterise EU agriculture.

Whilst an increasing number of regions within the EU are more and more driven by forces outside of agriculture, nevertheless, agriculture remains as a critical driver of the rural economies of many EU regions. The vitality and future potential of many rural areas are linked inextricably with the existence of a competitive and dynamic farming sector. This is especially true in predominantly rural areas where the primary sector accounts for in the order of 5% of value added and 16% of employment, and in the new Member States where it is vital to build on recent gains in productivity in order to ensure the full potential of agriculture in those countries. Moreover, agriculture is an important element of rural regions through generating additional economic activities, particularly in terms of food processing, tourism and trade. In many regions agriculture is the basis of local traditions and of social identity.

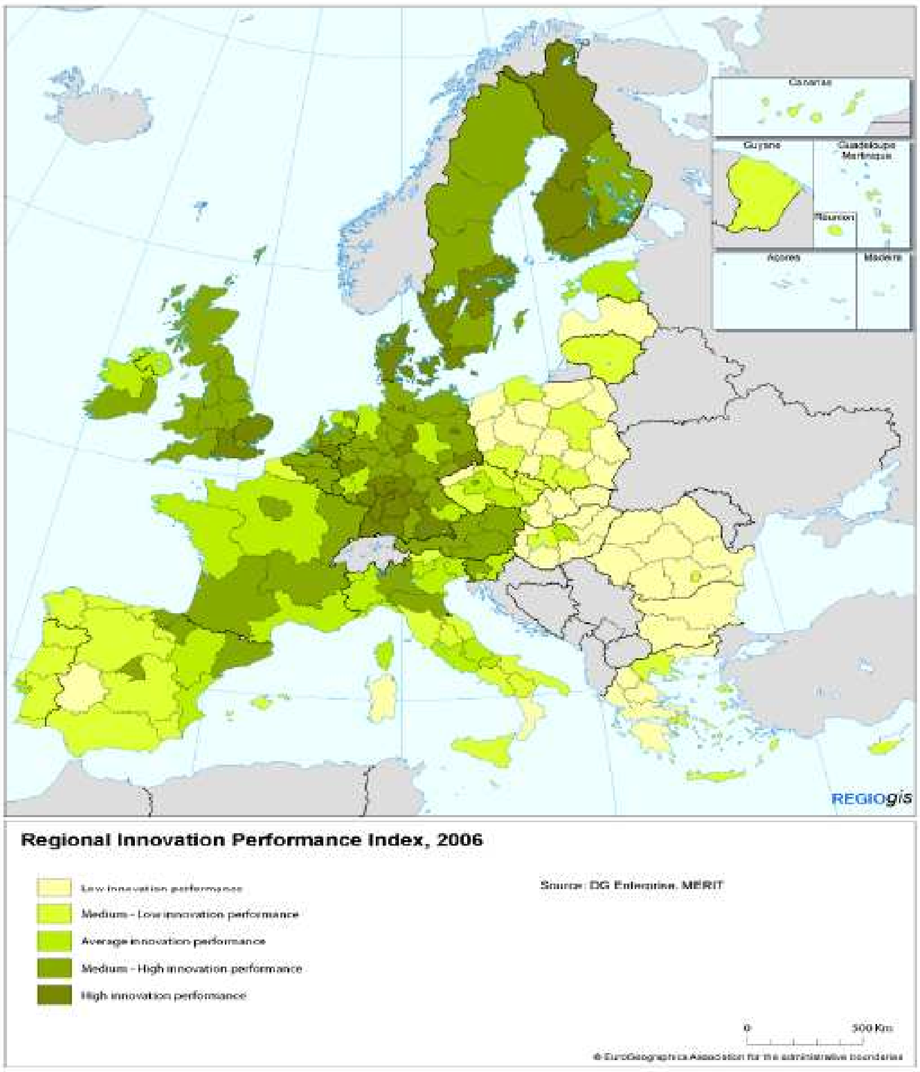
In the context of developing a 'sustainably-competitive' model of European agriculture that would provide Europe with a technical and marketing advantage, Purvis et al. (2011) stress the significance of local and regional food production as a critical element. They state that "in any system that is fundamentally reliant on natural processes, sustainability is strongly dependent on the local environment, and a strong emphasis on 'place and culture' is needed. Thus, in designing new systems of food production, particular attention needs to be given to the central importance of, and the advantages provided by the local environment. For Europe to capitalise fully on its rich heritage of natural and cultural resources, the agricultural sector must also address the daunting challenge of protecting and maintaining environmental quality, which is intimately linked to regional economic viability".

EU Cohesion Policy

Economic, social and territorial cohesion lie at the heart of the Europe 2020 Strategy of smart, sustainable and inclusive growth to ensure that energies and capacities in all regions of the Union are mobilised and focused on the pursuit of the Strategy's priorities. In this regard, Regional Policy is viewed as the key to unlocking the EU's growth potential by promoting innovation in all regions. Indeed, Regional Policy is a key means of turning the priorities of the Innovation Union into practical action on the ground.

To reach the Europe 2020 objective of smart growth, the full innovation potential of EU regions needs to be mobilised. Innovation is important for all regions; for advanced ones to remain ahead and lagging ones to catch up. Performance in R&D and innovation varies markedly across the EU as shown by the Regional Innovation Performance Index (see map 6.1), a composite indicator of many of these factors. Equally, the gap to the target of R&D expenditure of 3% of GDP varies greatly across regions: only 27 regions in the EU, around one in ten has reached that target.

Map 1: Regional Innovation Performance Index



Regional stakeholders increasingly realise that research and innovation are key drivers for their sustainable economic and social development and their competitiveness, in line with the Lisbon strategy to promote the knowledge economy. A strong signal of this is evidenced by the fact that they have earmarked approximately 25% of the budget of their agreed operational programmes in the framework of the current Structural Funds (SF) exercise (2007-13) – totaling €86 billion for research and innovation, including entrepreneurship. Performance indicators, monitoring and learning concepts inherent in these programmes will help in making the programmes effective and in transferring successful examples to other regions.

The FP7 'Regions of Knowledge' (RoK) programme aims to strengthen the research potential of European regions by encouraging and supporting the development of R & D joint action plans, elaborated by mature 'regional research-driven clusters' (RRDCs). This connects the research entities, enterprises and regional/local authorities ('triple helix') and aims to increase regional economic competitiveness through research and technological development (RTD) activities in traditional or emerging business sectors. The RoK programme could take up the challenges described in section 7. Regionally adequate ideas best emerge from approaches bridging from basic research to innovation and implementation.

Strategic intelligence is needed to identify the high value-added activities which offer the best chance of strengthening a region's competitiveness. To have most impact, R&D and innovation resources need to reach a critical mass and to be accompanied by measures to increase skills, education levels and knowledge infrastructure. In this regard, regions are being directed to redirect funding based on a **smart specialisation** approach and focus on relative strengths where they can become excellent. Smart specialisation strategies can ensure a more effective use of public funds and can stimulate private investment. They can help regions to concentrate resources on few key priorities rather than spreading investment thinly across areas and business sector. They can also be a key element in developing multi-level governance for integrated innovation policies. Smart specialisation involves businesses, research centres and universities working together to identify a region's most promising areas of specialisation, but also the weaknesses that hamper innovation. It takes account of the differing capacities of regional economies to innovate. While leading regions can invest in advancing a generic technology or service innovation, for others, investing in its application to a particular sector or related sectors is often more fruitful.

Implications for research priorities

The foregoing discussion holds a number of implications for future research policy at EU and Member State level. Firstly, there is a clear need in the context of building the regional base of the European knowledge economy to accord full recognition to the role of the agri-food sector. In particular, in the context of building the European KBBE, there is a clear need to ensure that agriculture is part of an integrated policy framework covering the entire value chain from basic R&D, through innovation, to the consumer economy (European Commission, 2005).

Secondly, in the context of a growing policy interest in regional specialisation of RTD expertise, particularly in light of the high investment needed in building basic research capabilities, it is important that all regions, particularly those regions with a large agri-based economy, can build capabilities to apply the findings of basic research programmes to the sector.

Thirdly, in light of the recommendation in the following chapter, there is a need to ensure that capability is maintained at local level to develop farmer-centred production systems that are in harmony with local social and ecological contexts. This must also recognise the importance of encouraging and coordinating multiple local actors who can ensure that necessary information is transmitted to farmers.

In light of this, the Expert Group supports the call by Netherlands Environmental Assessment Agency and Stockholm Resilience Centre (2009) for the EU to specifically make diversity a strategic aim for the Common Agricultural Policy. This is essential for maintaining and increasing agricultural productivity in the EU, in strengthening resilience, in providing a buffer against shocks of various types, and in helping to preserve the biodiversity and cultural landscapes that define Europe (Netherlands Environmental Assessment Agency and Stockholm Resilience Centre, 2009).

Research is important in achieving this desirable diversification of the European farming and rural landscape. Resilience will also be enhanced by genetic variability of crops and within crop species. Diversification can also be achieved by, for example, encouraging various types of farm business models within different regions, where some regions and farms are directed more towards agricultural production while others concentrate more on high-value products, delivery of public goods and recreation. In this way, farmers are enabled to generate viable incomes through engaging in a variety of activities, including a combination of primary production, provision of other (commercial) services and from payments for the provision of public goods (Netherlands Environmental Assessment Agency and Stockholm Resilience Centre, 2009).

6.5.3. The knowledge and innovation systems context

Trends and developments

The first SCAR Foresight Report noted a serious imbalance in the allocation of European research funding between academic research and knowledge exchange, the latter being considered merely an add-on dissemination activity after the research is completed (European Commission, 2007). The report recommended that far greater investment is needed in knowledge transfer and exchanges to ensure: firstly, that knowledge exchange forms an integral part of research activity and is considered in the design and implementation phases; and secondly, that research results are translated into useful, easy-to-understand and easy-to-apply knowledge for the end-users, namely farmers and rural communities.

The second SCAR Foresight Report argued that agricultural knowledge systems in Europe should be redefined (and eventually reorganised) in order to respond to problems of complexity and urgency and deliver more resilient and sustainable food and farming systems. The report concludes that the current agricultural knowledge and innovation system (AKIS) in Europe remains highly fragmented, and that "…the remaining publicly funded AKIS appear to be locked into old paradigms based on linear approaches and conventional assumptions." One of the central messages of the Report is that 'renewed' AKIS would respond to these challenges by new types of knowledge mobilised through new forms of cooperation between the knowledge generating institutions such as universities, research institutes, laboratories and by greater involvement of farmers and other resource users as well as consumers in both research efforts and innovation.

> *Since the 1980s farmers' knowledge has been undermined by member states dismantling the institutional basis for disinterested science, public good training and extension services. This structural problem is recognised by SCAR's Foresight expert group. As a remedy, its 2008 report advocates new, broader kinds of Agricultural Knowledge Systems (AKS). Here societal networks experimentally create or apply new knowledge for sustainable agriculture, as the basis for innovation.* ***The AKS concept articulates a co-research relation among all relevant knowledge-producers, including farmers.*** *AKS may also provide a common space for interchanges between divergent paradigms and their research priorities.*[15]

In its December 2009 meeting SCAR decided to set up a working group with the task to study the various agricultural knowledge systems across the Member States and their link to innovation. In

[15] CREPE Project, Grant agreement no. 217647, FP7 Science in Society Programme, WP7 Innovation narratives in European agricultural research, Final report, Nov 2010

June 2010 a Collaborative Working Group was set up under the coordination of the Dutch and French Ministries of Agriculture. The focus of their study is the existing AKIS, including advisory services, education, training and research dealing with agriculture and innovation.[16]

The concept of AKIS emerged in the 1960s, promoting a strong coordination of knowledge transfer and innovation as a driver for speeding up modernisation of agriculture. The draft Reflection Paper on AKIS of the SCAR Collaborative Working Group provides a glossary of terms to present the evolution of thinking about agricultural knowledge system and "the gradual contestation of linear approaches to knowledge transfer in favor of more complex and network-like vision of knowledge, learning and innovation"[17].

The In-Sight[18] project presented the high diversity of actors in the AKIS as follows:

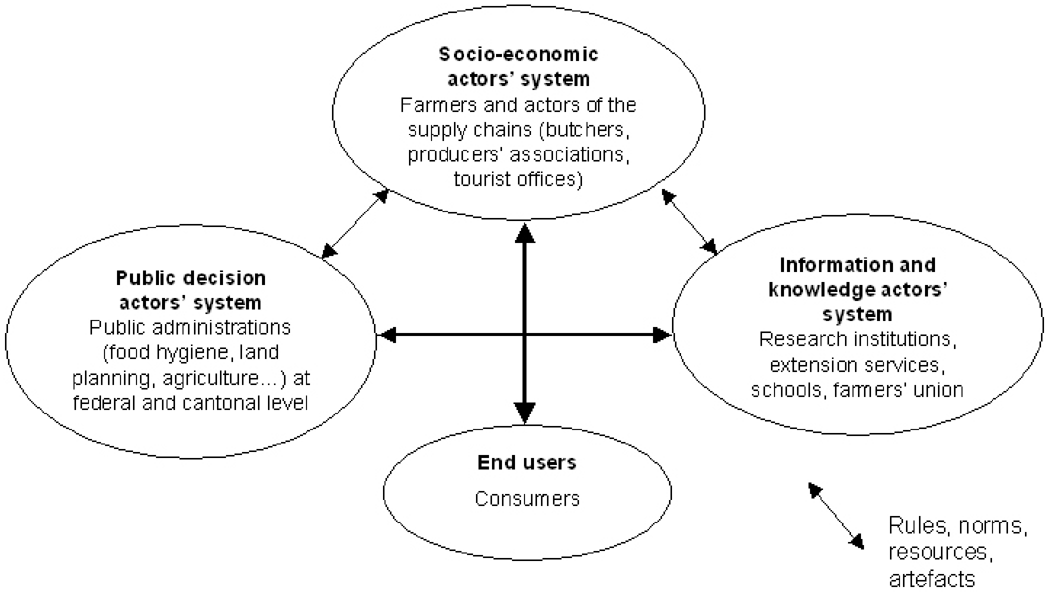


Figure 6.3. Typology of innovation actors

The In-Sight final report further articulates that traditionally AKIS encompasses research, extension and educational organisations, which are structured and governed by governments through the sectoral agricultural policies, with the aim to increase the productivity of the sector, where farms are exploited by professional farmers. The AKIS (in the countries under scrutiny in the In-Sight project) are thus characterised by high fragmentation, which in turn creates coordination problems.

Some of the persistent and continuing problems in regard to AKIS that have been discussed in various analyses and studies on both global and European levels are the role of small farmers in knowledge creation and sharing, their involvement in AKIS, the role of consumers and the civil society sector, the extension services, and education and life-long learning.

Research

Agricultural research, development and innovation activities are nowadays truly global activities, since facilitated and speeded up by decreased barriers of trade and the advances in ICT, internationalisation is a major driver of change in agriculture, respectively in agricultural R&D and

[16] SCAR-CWG Draft Reflection Paper on AKIS, August 2010
[17] SCAR-CWG Draft Reflection Paper on AKIS, August 2010
[18] The In-Sight project, SSP 44510, Final report – Comparative analysis and synthesis, January 2009

innovation (Gijsberg, 2009). On the global level ~80% of agricultural R&D is concentrated in the developed countries, dominated by key private players (the 'big six': BASF, Bayer, Syngenta, Dupont, Dow and Monsanto, in 2006 spending together 3.62 billion USD on research and development, out of 9.02 billion USD spent by all big 446 companies, incl. the 'big six') (Piesse and Thirtle, 2010). The top five countries in terms of agricultural R&D spending are the US, Japan, China, India and Brazil (Beintema and Eliot, 2009). Considering the less developed countries, 90% of agricultural R&D is public, while in most industrialised countries private expenditures on agricultural R&D are much larger than public, complemented by the increasing concentration of R&D in a small number of multinational companies; the effects of which are not yet studied and thus remain unclear (Gijsberg, 2009).

Extension services

Agricultural extension plays a pivotal role in promoting productivity, increasing food security, strengthening rural communities, and underpinning agriculture as the engine of pro-poor economic growth. Though it did not feature on the development agenda for a number of years, recent emerging issues—such as rising food prices, renewed government and donor interest in agriculture, and a broad commitment to restructure global agricultural development organisations—has led to a renewal of interest (IFPRI, 2010). Extension also continues to play a role in supporting agriculture in the developed world and there has also been a reawakening of interest in the topic here (The Royal Society, 2009).

Extension has proven itself to be a cost-effective means of achieving higher economic returns for farmers with significant and positive effects on knowledge adoption and productivity. Studies of extension productivity report rates of return ranging from 13 to 500 percent. Extension is thus a cost-effective tool that can play an important role in dealing with a range of agricultural and rural issues while at the same time helping to increase productivity and reduce poverty (IFPRI, 2009).

Despite the proven economic benefits of extension services, in many countries services have been cut in line with the reform of public institutions; in others, the knowledge base and extension services have been hit hard by HIV-AIDS (FAO, 2009). In the developed world, extension services have been restructured and the emphasis on economic liberalisation has resulted in the radical reorganisation of systems, leading to privatisation of delivery, multiplication of extension organisations and direct payment by farmers (AKIS, 2010).

Small farmers

"In 2007, in 17 Member States half of the holdings had less than 10 ha and there were still 6.4 mio farms in the EU with a (potential) gross value added of less than €1,200 per year, employing 23% of the total labour force but covering only 7% of the utilised agricultural area."[19] These small-scale farms remain largely overlooked by research and innovation policies, and in reality can neither benefit from advances in science and technology, nor participate in the knowledge creation as co-producers. Since they cannot reach a certain level of output and thus do not qualify for government-supported programmes, they also remain excluded from the public support measures for agriculture.

Reality is much different in regard to demand for knowledge and new technologies - small farmers and businesses in rural areas have quite diversified interests and are keen in having access to new knowledge, on one side, and in its application, on the other.

[19] European Commission, Directorate-General for Agriculture and Rural Development. Situation and Prospects for EU agriculture and rural areas, December 2010

Experience from Bulgaria
The municipalities of Maglij and Harmanli receveid support under the LEADER approach for the elaboration of local development strategies. What farmers and businesses on the territory of municipality of Maglij (~12,000 inhabitants) and municipality of Harmanli (~28,000 inhabitants) consider important to know:

- Organic farming – legal basis, certification, distribution channels, new technologies, good practices
- EU standards for the production of high-quality agricultural products
- New technologies in plant growing and animal breeding
- Bulgarian scientific advances in agriculture – dissemination of national ready-for-exploitation research results for agriculture and forestry, in collaboration with the Agricultural Academy and the universities
- Marketing of agricultural products
- Quality management systems: ISO 9001, ISO 14000, HACCP
- Rural tourism – legal basis and requirements, marketing and advertising

Thematic trainings have been budgeted on the above topics in the Local Development Strategies of the two municipalities (2011-2015), with two trainings per topic. The topics have been identified based on interviews and focus group discussions (carried out in the summer of 2010) during the development of the strategies. In-depth trainings are also budgeted for each measure of the LDS on how to prepare a good proposal. Further, the following studies have been identified as important for the development of the local economies and are envisaged in the strategies:

- Potential for organic farming – analysis of local conditions (soil and climate), readiness of the local farmers and businesses, mapping of the territories suitable for organic farming, identification and transfer of good practices in organic farming.
- Outsourcing of services, focused on transferring some of the public services, currently provided by the municipal administrations, to local NGOs and entrepreneurs.
- Potential of the territory for the development of tourism and touristic services as an opportunity for reviving the local economy.

Consumers and civil society organizations

Nowadays consumers are increasingly interested in every aspect of food being consumed daily. As consumers we all expect to have abundant food at affordable prices, yet safe and healthy. We want a great variety of food products, but we also want to have the opportunity to make informed choices of what to consume. More and more we are interested in food produced in a way which cares about the environment, which is natural/organic, and produced and delivered locally. We also demand from agriculture non-food products – natural fibers for clothing, in recent years bio-energy, and plants for the pharmaceutical industry. We have a diversified range of demands, sometimes conflicting, placed to agriculture. Thus, in the years ahead, another challenge agriculture will have to address is how to balance the potentially conflicting demands of consumers. On the other hand, especially with regard to green technologies and sustainable lifestyles, consumers are more and more recognised as active players in innovation.

A recent experience in engaging citizens in research agenda setting is presented in the box below.

CIVISTI – Citizen Visions on Science, Technology and Innovation
CIVISTI is a research project, supported by DG Research of the European Commission under the call **Blue Sky Research on Emerging Issues Affecting European S&T,** Socio-economic Sciences and Humanities programme of FP7, ending up in Feb 2011.
CIVISTI is based upon the idea that the process of defining relevant and proactive research agendas could in many respects gain from consultation of citizens. Our societies are changing rapidly as a consequence of globalisation, new technologies, multi-cultural societies, media developments, environmental and climate challenges, new energy futures, increasing welfare and consumption, etc. Developments, which all involve an interface between science, technology and society. Linked to these developments, issues arise about societal management of the involved needs and uncertainties – for society as well as for the individual. The citizens are

the carriers of the concerns and expectations to the future and with the right facilitating methods, such concerns and expectations can be collected and transformed into relevant research agendas.

For Europe to become the most advanced knowledge society in the world, it is imperative that legitimate societal concerns and needs concerning science and technology development are taken on board, entailing an enhanced democratic debate with a more engaged and informed public and better conditions for collective choices on science issues. The expectation is that knowledge and innovation will become the main sources of wealth creation globally, and that societal relevance of science and technology will enhance the European economy in the global competition. This is why the Seventh Framework programme aims to increase the societal relevance of research, and thus encourages greater public engagement and promotes the participation of society in research and science policy-making. The change in perspective recognises that research activities are a special type of social activity that are embedded in a wider societal context.

CIVISTI was centered on identifying emerging and potential issues in European Science and Technology by developing, combining and using a future oriented participatory process that combines the citizens' knowledge and experience with the knowledge on research policy of experts and stakeholders. Panels of citizens (from 7 EU Member States - Austria, Belgium, Bulgaria, Denmark, Finland, Hungary and Malta) with varied educational and professional background; males and females at different age produced 69 visions of the future (time horizon 2050). Professional facilitators helped to organise the discussions. Thus, the data resulting from brainstorming and future deliberations by the seven national citizen panels provides an authentic sample of European citizens' visions of future. The CIVISTI methodology builds on the interplay of foresight and participatory technology assessment, where citizens describe their visions of the future following the normative approach, while stakeholders and experts have the challenging task to "translate" these visions in S&T issues and policy options, thus supporting the programming process of FP8.

The citizens have extensively discussed seven broad topics in their visions: **healthcare and medical services; education and learning; ICT, automation and artificial intelligence; legislation; quality of life and life style; employment and new modes of work, and energy**. It is worth noting that five of the least prominent topics addressed in the citizens' visions are "big issues" for humanity, including *natural and technological disasters, genetics, religion, space technology, and developing countries*. During a workshop in June 2010 experts and stakeholders 'extracted' from the citizens' visions30 policy recommendations for research and innovation, targeting different levels of governance.

Source: www.civisti.org

According to the draft Reflection Paper of SCAR-CWG on AKIS, "NGOs have an increasingly important role in innovation. In most of the cases they provide ideas and motivation to innovate. They are particularly fit to perform activity of brokerage, as it happens in the cases of Latvia (in the organic and in the rural tourism sector) in Italy (mainly in the local food sector but recently also in the energy sector)."

Education

More and more we can consider agriculture today as "scientific agriculture."

> *Genomics, ecology, chemistry, engineering, and other science disciplines play essential roles in 21st-century food and agriculture. As these disciplines become increasingly intertwined with food, fiber, and fuel production, agriculture has lost a little of its distinct identity. Agriculture now so thoroughly combines basic and applied aspects of the traditional STEM disciplines of science, technology, engineering, and mathematics that the acronym might rightly expand to become STEAM, joining agriculture with the other fundamental disciplines. Agriculture can also connect with social science disciplines in areas such as ethnobotany and rural development, with medicine in areas such as pharmacognosy and nutrition, and with a large range of emerging and traditional fields from throughout the university*. (NRC, 2009)

IAASTD (2009) concludes that the "Organised AKST in the form of public sector R&D, extension and agricultural education across world regions, are based upon a **linear top-down flow of technologies**

and information from scientific research to adopters". Further, the report alarms that the actors and organisations in the AKS are not able to deal with the current pressing challenges due to the very 'narrow' output goals, thus in return the advances of ecological, environmental, social sciences and acquired knowledge remain largely excluded.

Drivers

Never before it has been so important for the world to generate and use agricultural knowledge, science and technologies, given the complexity of challenges to be addressed by the AKS today: to increase environmental sustainability, to improve social sustainability and increase equity, to decrease hunger and improve health and human nutrition, to decrease poverty and improve rural livelihoods, and to propose governance mechanisms for improved institutional and organisational arrangements (IAASTD, 2009).

The major shortcomings of AKIS, as identified in the final report of the In-Sight project, are the following:

- The institutional knowledge system is disconnected from the innovation processes and knowledge flows
- In regard to innovation, AKIS remains fragmented and weak, esp. when the emergence phase and needs, and 'cutting-edge' innovations towards regime change are taken into consideration
- Remoteness of the institutional domain from the actual innovation processes
- AKIS action is insufficiently oriented towards territory

The report further discusses that

> *On the one hand, certain parts of the knowledge system are quite advanced (such as universities, laboratories, research institutes), but they have difficulties in responding to the demands of rural innovators and respectively the innovation process is interrupted. Other knowledge and educational institutes like agricultural schools/colleges have a strong sector orientation and are standing apart from the innovation agenda and needs. On the other hand, farmers, producers, processors and other actors across the agro-food chain, who create innovations, have established their own quite efficient knowledge networks with peers and private consultants and bypass the 'official' AKIS as primary source of information and advice. The IN-SIGHT study confirmed the gap identified by previous discussions between advisory services/training and farmers/rural actors' needs and willingness to diversify business. As part of the recommendations, a plea is made to bridge this knowledge gap.*[20]

The conclusions of the In-Sight project continue to be valid today, although some actions have been launched (i.e. projects under FP7), their effects are yet to be seen, and concerted efforts in the direction of addressing the deficiencies of European AKIS are still missing.

In regard to innovation, we can consider the following major changes that drive the agricultural development:

1. Agricultural development is increasingly influenced by the internationalisation and globalisation processes.
2. Growing dynamics of production, trade, and consumption of agricultural products.
3. Markets.
4. Agricultural knowledge and technologies are predominantly generated, diffused, and applied through the private sector.

[20] The In-Sight project, SSP 44510, Final report – Comparative analysis and synthesis, January 2009

5. Changing knowledge structure of the agricultural sector.
6. The ICT growth and penetration have tremendously increased the ability to benefit from knowledge developed elsewhere and for other purposes.

SCAR-CWG on AKIS advocates in their Reflection paper that in order to understand AKIS, one needs to apply both the system and the network approaches. While systems are based on tradition; networks today are more related to specific targets, and focus on more pressing issues. The paper further articulates that knowledge systems are institutionally embedded, but they are not static. In order to transform existing AKS towards future AKIS, we should not neglect parts of old system (research, extension etc), but let them interact and be more open.

Link to scarcities and narratives

The greatest challenge faced by agriculture is to meet simultaneously both the development and sustainability goals while increasing agricultural production, and these have to happen in the context of a rapidly changing world characterised by strong urbanisation processes, deepening inequalities, internationalisation and globalisation, changing dietary preferences and increasing global population, negative effects of climate change and degradation of environment, depletion of natural resource for agriculture (like phosphorous) growing share of biofuels in the energy mix, and their competition with agriculture for land. (IAASTD, 2009).

Policy and research implications

Although we are aware that no agriculture is fully sustainable, we still want to have agriculture which produces sufficient quantities of safe food at affordable prices in a way, which is as sustainable as possible. This in turn demands from the AKIS to account for both technological and non-technological issues, incorporating as well challenges like overall rural development and employment, management of natural resources, diversification of local economy (incl. non-agricultural activities), etc. This kind of AKIS will have to attract the small farmers as co-producers of knowledge and innovation, and promote and facilitate networking in the rural areas, attracting all stakeholders. It will further require more participatory approaches involving much more actors than now.

The essential "AKIS" processes and products have remained essentially unchanged. Changes have occurred though in the complexity and the urgency of the issues to be addressed, requiring an increased process and product range. Intensive farms producing produce for sale on world markets and more extensive farmers producing environmental goods and services are coexisting while we have a European vision of a profitable and sustainable multifunctional agriculture. The apparent conflict between the need for a competitive farming and sustainability require clarification (SCAR-AKIS CWG Draft Reflection Paper on AKIS, 2010).

In the EU, the growing emphasis on promoting and rewarding the multiple roles of agriculture, not only as a producer of food but also as a provider of a wide range of ecosystem services of benefit to society, highlights the need for effective *extension services* capable of transferring the knowledge and technologies needed by European farmers to respond to these developments.

A comprehensive definition of AKIS at the European level is still missing. The multi-functionality of agriculture and the concept of broadened AKIS suggest that it includes also research / science (e.g including fundamental and applied research in plant breeding or animal science) and the drivers in that area, however science drivers influence AKIS in controversial way: research agendas, priorities and evaluation criteria are set within academic domain whereas diverse users of knowledge and innovation actors need more ‘gray knowledge’ translated and communicated in more customer tailored way (SCAR-AKIS CWG Draft Reflection Paper on AKIS, 2010).

6.6. The KBBE as overall concept?

Trends and developments

The KBBE concept is a fusion between two concepts: knowledge-based economy and bioeconomy. The ‘knowledge-based economy’ was launched in a 1993 white paper, and extended at the 2000 Lisbon summit of the EU Council, which launched the Lisbon Agenda to turn the EU into “the world's most competitive knowledge-based economy” by the year 2010. The key elements of the agenda are: research and development (R&D), lifelong education, information and communication technologies (ICT). Hence, research and scientific innovation are the driving force behind wealth creation.

The emphasis is on an incumbent threat, global competition and aging of population, to which Europe has to respond with a far sighted strategy. The Aho report (European Commission, 2006) concludes that “Europe and its citizens should realise that their way of life is under threat but also that the path to prosperity through research and innovation is open if large scale action is taken now by their leaders before it is too late”.

Bioeconomy has a more uncertain origin. According to OECD, “Over the past two decades, the biological sciences have provided a motor for innovation and sustainability in our economies, by developing new processes and products. We have called this development a bioeconomy” (OECD, 2009). In other words, according to OECD, a bioeconomy emerges when biotechnologies are turned into business.

For the EU, however, it is a different story. “The bio-economy is one of the oldest economic sectors known to humanity, and the life sciences and biotechnology are transforming it into one of the newest” (European Commission, 2005). From this quotation one can argue that bioeconomy, an old activity, becomes KBBE when new knowledge is provided by life science and biotechnologies. In the context of the Commission’s Framework Programme 7, ‘The term ‘bio-economy’ includes all industries and economic sectors that produce, manage and otherwise exploit biological resources and related services, supply or consumer industries, such as agriculture, food, fisheries, forestry, etc.’ And “Life Sciences and Biotechnology in convergence with other technologies provides the knowledge-base for the sustainable management, production and use of biological resources, provides new, safe, affordable and eco-efficient products, supports competitiveness and sustainability of major European industries”.

KBBE covers three spheres—primary production, health and industrial applications—and implies “transforming life sciences knowledge into new, sustainable, eco-efficient and competitive products” (OECD, 2009). As for primary production, KBBE “can lead to applications and products in a wide range of fields, such as new agricultural products and practices, novel foods, biodegradable plastics, as well as sustainable, environmentally friendly biofuels” (European Commission, 2005). This developments could bring, according to the OECD, to a contribution of 5,6 to EU-25 Gross Added Value in the 2030. The European Technology Platform ‘Plants for the Future’ (2007) uses the concept of “plant raw materials”, that is, output to be further processed and transformed. “To address this challenge, European plant scientists should focus on the development of diversified and affordable high-quality plant raw materials for food products”.

This emphasis is even more evident in the recent document of CleverConsult (2010), under the auspices of EU commission, that defines KBBE as: “… the sustainable production of biomass, for a range of food, health, fibre and industrial products and energy, where renewable biomass encompasses any biological material to be used as raw material”. Apparently, the authors of this document set the boundaries of KBBE to the whole agro-food sector, as it states that "..it is estimated that the European bioeconomy has an approximate market size of over 2 trillion Euro, employing around 21.5 people".

Levidow (2008) underlines that under the umbrella of KBBE the output of agriculture is downgraded to mere "biomass". "KBBE encourages the idea that biomass is a cornucopian renewable resource which can substitute for oil and minimise pollution, hence sustainable. Plant characteristics as resources whose economic value must be extracted, or as barriers which must be overcome, esp. through genetic changes. Metaphors of industrial, mechanical, information technology are invested in nature: flywheels, cell factories, cells as micro-computers, etc."

Seen in this way, does KBBE really cover the whole range of issues related to agriculture? In the KBBE concept, the human factor disappears, industry is considered the main player of the bioeconomy and rural territories are only mentioned only as beneficiaries. In other words, the framework built around KBBE covers only a part of what agriculture is and should be. On this regard one can detect several contradictions with recent EU elaboration around agriculture and rural development. How does KBBE respond to the challenge of agriculture producing public goods? How does it respond to the need for "maintaining diversified farming systems across Europe, particularly in remote areas, and to ensure delivery of multiple public goods"? How can it take into account farmers' knowledge and motivations, not just to align them to the industry requirements but taking into account the need of creating a resilient business?

Drivers

Exploiting the full potential of KBBE does not require only investments in research. "How biotechnology is used and the rate and direction of technological developments will be affected by scientific serendipity, regulation, intellectual property rights, private investment decisions, the supply of highly skilled scientists, technicians and managers, public attitudes towards biotechnology and the cost of capital" (OECD, 2009). From the OECD reports it emerges clearly that technologies are only a part of broader socio-technical systems. In order to evaluate societal benefits, it is crucial to understand the characteristics of the socio-technical systems into which technologies are inserted[21].

Link to narratives and scarcities

According to the OECD, governments will have to remove barriers that constraint the full development of a KBBE society, first of all regulation costs and societal concerns. As for societal concerns, they are largely considered 'prejudices', which may be overcome with good communication and education. Such a vision implies a) a clear hierarchy among knowledge and scientific fields; b) a clear definition of the set of applications of the new technologies. In fact, life science and biotechnologies are clearly given a higher status than 'old' science, for example crop management, soil science, etc.

In this regard, it is important to highlight that the current interpretation of KBBE has not generated an unanimous consensus, also within the scientific community. From what said above, the most common interpretation of KBBE implies a scheme by which market opportunities leads research strategies, which in turn produce outputs that can be protected under IPRs and sold to the market. For example, it envisages separation of nutrition from food with a growing industry of supplements, novel food engineering (by disaggregation and recombination of nutrients), isolation of functional traits existing in nature from their original environment and reincorporation into commercial seeds, fertilizers or pesticides. A group of scientists that follows the idea of 'biotechnologies for

[21] See also Stone (2004)

development' (Louwaars et al., 2008; Kloppenburg, 2010), for example, highlight that present IPRs are a barrier to employment of science into genuine development goals, and suggest a different IPR model based on open-source protection.

Barriers and policies

The European Commission intends to launch a Communication "European strategy and action plan towards a sustainable bio-based economy by 2020" (STRAP) during 2011. A draft report commissioned by SCAR formulates the following recommendations among others:

- Apply an integrated approach, addressing not only biotechnological processing into products and considering both material and immaterial values, e.g. ecosystem services and socio-cultural values.

- Focus inter-sector (e.g. chemical industry and agri-sector) and crosscutting issues with respect to synthesis between productivity and sufficiency perspectives.

- Fully acknowledge all the three principal ways to meet the increasing global need for food, i.e. increased environmentally-friendly production per unit area, reduction of the present significant losses in the food chain, and changes in consumption patterns in favour of a larger share of vegetables.

- Address a number of important thematic aspects presently lacking in many "key documents" from EU and OECD, i.e., (1) means to strengthen sustainability of the agri-sector, (2) potential of the agri-sector to contribute to sustainability of the society as a whole through substitution of fossil-based energy and products with renewable alternatives, (3) scarcities challenging the agri-sector, and (4) ongoing serious negative environmental impacts of the agri-sector itself.

- Highlight that the development of Bio-economy strongly needs a significant contribution by human-related research (social sciences and humanities) and find means to effectively increase its contribution (e.g. on consumers´ participation and attitudes, and on food-chain management).

- Encourage a continuous dialogue between scientists and stakeholders throughout the whole research and innovation process, from initiation of research ideas to communication and implementation of final results of relevance for societal development.

- Acknowledge that stakeholders and end-users within the Bio-economy are highly diverse groups and find ways to both positively use this diversity and to adapt the research and innovation dialogue with respect to it.

- Consider a European Innovation Partnership or a JPI for the Bio-based economy as a tentative long-term output of the STRAP .

- Acknowledge the need for a strengthened integration of education, research and extension for promotion of efficient innovation and consider especially the establishment of small-business innovation research (SBIR) aimed at involvement of SMEs

7. IMPLICATIONS FOR RESEARCH

Smarter and more targeted application of existing technologies will help resolve many of the challenges facing agriculture over the next 50 years, but new science and innovation will be required to address the more deep-seated and changing challenges. These challenges cover climate change, land degradation, water and energy availability, biodiversity loss, as well as changing patterns of pests and diseases. Advances in science and technology in areas such as biotechnology, nanotechnology, remote sensing, ICTs, and better understanding and use of agroecological processes hold the potential to greatly change our approach to sustainable use of resources and production of a secure supply of food. Breakthroughs in science and technology must complement and underpin new approaches for farming systems. In this chapter, we will review the issues of scarcities and the need for transitions in light of needs for new approaches in science and technology.

7.1. Scarcities and transitions in the productivity and sufficiency narratives

Between now and 2050, growth in global population and changing diets in emerging countries are projected to bring about a 70% increase in food demand (FAO, 2009a). Simultaneously, depletion of fossil hydrocarbons will increase the demand for biofuels and industrial materials, which may compete with food for biomass. At the same time, the sources of the rapid food supply growth in the 20th century are being depleted. Global land and water reserves are dwindling. In addition, 'new scarcities' are emerging in the form of depletion of ecological assets and pollution as a consequence of resource use in agriculture. Meanwhile, climate change and biodiversity have arrived as a new challenges on the resources agenda. In a business as usual scenario, the adverse resource impacts related to agricultural production are unlikely to be reduced, instead they are more likely to be amplified (UNEP, 2010).

Continued and increased investment in relevant research and innovation at EU and national levels is critical in addressing these challenges. In particular, **the Expert Group recommends that the EU must prioritise the development of an 8th Framework Programme that will place a primary focus on resource-conservation and a sustainable and knowledge-based economy, which will secure prosperity and social participation for all citizens in the European Union. The Programme should progress the transition towards a mission-orientation for European research aiming to solve, as the Lund Declaration (2009) states, "the Grand Challenges of our time" (global warming, tightening supplies of energy, water and food)**.

The increasing natural resource scarcities represent a real threat not only to future food supplies, but also to global stability and prosperity, as they can aggravate poverty, disturb patterns of international trade, finance and investment and destabilise governments. They may cause greater mutual mistrust between states and carry the risk of protectionism and resource nationalism (van Schaik et al., 2010). Such developments do not accord with the need for greater mutual trust, enhanced cooperation and global agreements to ensure that the world uses natural resources in a sustainable manner in the future.

The Ecological Footprint Indicator, which compares humanity's impact with the amount of productive land and sea area available to supply key ecosystem services, shows that humanity now uses the resources and services of 1.3 Earths. In other words, mankind is using about 30% more of the available capacity of the Earth, thus undermining the resilience of the very ecosystems on which humanity depends (WWF, 2010). This Report goes on to state that under a "business as usual" scenario, the prospects for the future is serious: even adopting the UN's modest growth projections for population, consumption and climate change, by 2030 mankind will require the capacity of two Earths to absorb CO_2 waste and maintain pace with natural resource consumption.

Global demand for resources is placing increasing stress on the environment and has resulted in significant environmental degradation, which so far has largely been confined to a local or regional scale. If current patterns of resource use do not change, these impacts will be greater and more widespread and, particularly in the case of climate change, are likely to be global in scale, and partly irreversible in the case of biodiversity.

Higher demand globally is likely to be accompanied by higher and/or more volatile prices for raw materials. In the case of food, such price trends will add to the level of food insecurity suffered by the world's poor. In the case of critical raw materials that are highly insecure, the lack of access may impede the development of new and existing commercial applications. In other cases, the imbalance between supply and demand may be relieved by exploiting new, less abundant reserves, but this is likely to have a higher environmental impact than exploiting current reserves.

To ensure a sustainable future, radically different patterns of resource use will be needed. This presents both a major challenge, and a major opportunity for the EU Member States to generate wealth.

7.1.1. How to speed up transitions

It is vital to start using resources much more efficiently, to reduce unnecessary and wasteful resource consumption and to identify the actions which will be taken at EU level to speed up the necessary transition towards a more sustainable economy. The drivers of the necessary transitions will primarily reside in social innovation and changes in consumer and producer behaviour, production systems and the market, flanked by technological innovation (van Schaik et al., 2010). This approach is more consistent with the assumptions and approaches underlying the sufficiency narrative rather than those of the productivity narrative.

Ensuring the availability of, and access to, necessary resources into the long-term future requires far-reaching changes based on social and technological innovation and behavioural changes. Time itself is becoming one of the greatest scarcities and highlights the need to bring forward solutions that will help speed up the necessary transitions. Time is particularly urgent in the case of the productivity narrative. Here the urgency is such that the scope for new policy interventions is limited and rather the emphasis must be on creating the necessary conditions to enable the necessary demand-driven technological innovations to emerge. On the other hand, the depth and extent of change required is such that solutions must emerge much more slowly and result from a greater variety of approaches which are constantly tested through pilot projects.

However, there are many obstacles in the way of these necessary changes and speeding up transitions will not be easy. In this regard, it is important to determine what enabling conditions can be improved and what developments need to be restrained. Progress is dependent on acquiring a thorough understanding of links between scarcities, but also of the underlying mechanisms that may hamper transitions. This requires development of long- term scenarios and foresight, and also learning embedded in the programmes and policies based on effect-based indicators, monitoring and social research.

So far the focus of research, foresight and policy has been on the supply-side aspects of the challenge to improve resource efficiency, as technological innovation was deemed to have the greatest potential to reduce the impacts of production on resources. Social innovations in the domain of production are as important as technological ones, for instance changing the chains and circuits of supply may have huge impacts on costs and also on creating closer links and confidence between producers and consumers. We recognise that it is equally important, however, to address demand-side issues, and to understand how technology can contribute to reducing levels of consumption; for example, through extending product lifetimes through more durable and/or serviceable products.

In the longer term, substantial improvements in resource efficiency will require a transition to (more) closed-loop models of consumption, taking full account of the resource lifecycle. Ultimately this implies adoption of a zero-waste model whereby all 'wastes' are eliminated or become raw materials for other processes (Technology Strategy Board, 2010). In the case of biomass, resource use efficiency calls for a prioritisation of uses of agricultural products for food, feed and high-value fibre compounds before the products, residues or wastes are used for lower-value, mass services, including bioenergy. As cascading or recycling pathways often multiply resource use efficiency per unit of agricultural product, the current dominant concept of producing bioenergy from agricultural primary products is incompatible with a future, sustainable, resource-efficient agriculture.

The EU can take a leading role in bringing about the necessary global transition towards a more sustainable future in 2050 and influence global processes in securing more sustainable uses of land and other resources. For a start, the EU is well positioned to initiate a global policy debate on the use of land and water for agriculture and ecosystem services as a global resource issue. Once underway, this debate could result in agreement on the idea of a single global food system, just as the reality of one global climate system has assisted in progressing the political debate on climate change in recent years (Netherlands Environmental Assessment Agency and Stockholm Resilience Centre, 2009).

Within the EU itself, the drive towards resource efficiency and sustainable consumption needs to take on a new dimension of urgency, involving closer cooperation between a number of Commissioners and between the Member States. Enhanced EU coordination will increase the possibility of the Union exerting greater influence in moulding a sustainable world economy. If Member States fail to create greater internal cohesion, Europe will grow ever more dependent on the world market for resources and will be faced with higher and more volatile prices and have less influence in bringing about a more sustainable planet (van Schaik et al., 2010).

Addressing scarcity, however, is not solely a technological problem. Institutional and behavioural changes are also important. Technological innovation can help speed up transitions, but not without some kind of interventions to alter our collective behaviour and the manner in which we manage our natural resources. Policy in the context of scarcity and transition should therefore also focus on influencing lifestyles, taking on board new trends and developments in the social sciences. An important contribution from these sciences is in identifying the economic, political and social conditions needed for the socio-ecological transition of our existing model of production and consumption (EU, 2009c).

7.1.2. A better understanding of scarcities and how they are interrelated

Due to the success of technological advances and substitution, the issue of resource scarcity has not featured on either political or research agendas in recent decades. However, concerns about the availability of essential natural resources is now firmly back on worldwide agendas. This concern has been further heightened by the emergence of 'new scarcities' of climate and biodiversity. A feature of today's concern is the attempt to understand the complexities surrounding scarcities, involving a number of different dimensions of scarcity, of the interactions between these different dimensions and between the different scarcities themselves. A better understanding of the complexities surrounding scarcities and how they are linked is essential to ensuring that decisions are made that are conducive to the emergence of a more sustainable world. The EU could aid in the development of this understanding by including specific lines on these issues in the 8th Framework Programme.

Uncertainty is a basic characteristic of all of the scarcities discussed here. There is a range of possible outcomes on population projections to 2050. Estimates of the amount of available arable land vary enormously; no one can be certain as to how water availability will be affected by climate change; methodologies for assessing energy use in agriculture and the food chain vary considerably; the effects of climate change are uncertain at the global level and even more so at a local level; the depletion of agrobiodiversity and of marine biodiversity can lead to a non-linear or even irreversible breakdown of the basis of food production in critical world regions.

The high degree of interlinkages between various scarcities further compounds attempts at understanding and analysis. The production of food requires fertile land, ample water supplies, mineral inputs in the form of fertilisers and diesel, while biotic resources are being degraded through nutrient leaching, pesticide emissions and physical destruction, including the initial land-use transition from nature to agriculture. Future interaction between scarcities are shaped by complex feedback loops and by human efforts to mitigate them, making it difficult or impossible to predict how these linkages will develop in future (Evans, 2009). Most trends in scarcities tend to speed up or amplify trends in others. The interconnection between climate change, biodiversity and water is particularly complex and non-linear. Surprises and extreme events with catastrophic yield losses in world regions will become the rule rather than the exception.

Despite these caveats arising from our current levels of understanding, it is clear from the foregoing analysis that resource scarcity issues are set to impact in a significant way on world agriculture and food production over the coming decades and poorest countries stand to be affected most severely, both because of their weaker capacity to adapt to the impact of scarcities and because of the fact that problems of population growth, land degradation, water shortages and climate change impacts are heavily concentrated in poorer countries. Migration and potential for armed conflicts driven by scarcity issues including concentration of resources in the hands of oligopolies will increase and negatively impact on European security.

Accordingly, there is an increasing and urgent realisation that in order to make better use of limited resources, the world needs a transition to an economy in which energy, food, water and mineral resources are used in a sustainable way so as to protect ecosystems and combat climate change and the loss of biodiversity. The precautionary principle to avoid disruptions and "tipping points" calls for an immediate change in policy.

7.1.3. Geopolitical and global governance

The transitions required to an economy which sustainably uses scarce natural resources is dependent for success not alone on technological breakthroughs, changing consumer behaviour and market reforms, but also on the successful operation of some system of multilateral governance that will promote consultation and cooperation between nations.

The questions arise as to who will lead these transitions and who will take the decisions? Despite long-standing acceptance of the need to conserve biodiversity and achieve sustainable development, both of these goals still remain as aspirations, representing failure both on the part of governments and of the market (WWF, 2010). While some individual governments are responding to the opportunities presented by investment in the "green economy", national-level efforts will not be enough. International collective action will also be needed to tackle the global level challenges described in the preceding chapters.

However, the prospects for such global collective action are not propitious. The WTO still has much to do to harmonise international trade. The 2009 Copenhagen climate summit did not succeed in concluding a global agreement. Similarly, little progress has been made in recent times regarding the international protection of endangered species. Meanwhile, the issue of 'land grabbing' in Africa and the presumed power politics of Russia in the 2006 and 2009 gas crises gain international attention. These developments point to the priority of the political dimension in international resource policies, and seem to suggest that the protection of national interests rather than that of the global community as a whole in the area of resources is the prime concern.

This apparent focus on defending national security of resource supply is occurring at a time when globalisation has made the world a smaller place and increased mutual dependency between nations. For example, growing transport and storage capacities have boosted trade from 21% of GDP in 1970 to 52% in 2008 (World Bank, 2010). Examples of resource nationalism such as China´s blockage of rare earth exports or Russia´s gas policy have recently highlighted the vulnerability of Europe´s import-dependent industry. Europe´s agriculture is similarly vulnerable with regard to phosphorus and feed imports. Such developments should add weight to the desirability of reaching global agreements to tackle issues of resource scarcity and seek to ensure security for all.

Various attempts have been made over the years within the context of the existing system of multilateral governance to set up consultation and cooperation fora in the areas of water, energy, food, minerals and other natural resources. (Passenier and Lak, 2009). However, these efforts have, for the most part, not been successful. It is only in the areas of food and climate change policies that there are global frameworks in place for consultation and cooperation. In particular, the FAO has sought to develop an integrated approach in the area of food scarcity by linking sustainable agricultural development to issues of water, food security, climate change, biodiversity and bio-energy.

Prominent status is accorded the issue of resource scarcity In the *Europe 2020 Strategy.* Pressure on natural resources is identified as one of three long-term challenges confronting the EU and one of the seven flagship projects is 'resource-Efficient Europe', which aims at decoupling economic growth from the availability of resources. EU policies and the EU's external actions have implications for, and can influence, the international debate on resource scarcity and the move towards a more sustainable global economy. The current reform of the system of EU external relations may open up the opportunity to highlight the issue of resource scarcity in the EU's geopolitical positioning and strengthen its efforts to promote sustainable management of natural resources at international level.

7.1.4. Challenges to existing agriculture and food systems

Traditionally agricultural science has focused on delivering component technologies to increase productivity on farms, with market and institutional mechanisms being the main drivers of the adoption of such new technologies. Over time, this model has been sustained by ongoing innovation designed to reduce costs and externalise some of the major costs involved in agricultural production. The model underpinned the growth in agricultural productivity in industrial countries following World War II and the remarkable success of the Green Revolution from the 1960s. But in light of new challenges, risks and uncertainties, there is a growing consensus around the need to look at new models and systems (World Bank, 2007; IAASTD, 2009; The Royal Society, 2009; NRC, 2010; The Government Office for Science, 2011).

Some of the risks, challenges and uncertainties that lead to the questioning of existing systems include:

- Uncertainty about the capacity to produce sufficient food sustainably for a growing and more wealthy population allied to new demands for non-food and ecosystem services
- Uncertainty about the future of world food prices in light of climate change impacts, changing trade patterns, new dietary trends and growing demand for biofuels
- Dependence of existing systems on cheap oil, expensive machinery, synthetic fertilizer, pumped water and transport
- The concentration of critical resources such as phosphorus in the hands of few companies and governments including China
- The weakening of the market power of farmers and growing dependence of farmers on companies and retailers
- The emergence of new competitors such as China, India and Brazil for scarce resources
- The increase in human health problems, including obesity, that increase morbidity and mortality rates and are partially related to poor nutrition and dietary quality
- Projected changes in the frequency and severity of extreme weather events in addition to fire hazards, pests and diseases, all of which will have negative consequences for agricultural production and food security
- Major risks of maybe irreversible damage to coastal and marine biodiversity, which forms the nutritional basis of 20 % of the world population
- Increasing awareness of human responsibility for the maintenance of global ecosystem services and sustainable growth
- Existing agricultural science and technology is mainly geared towards meeting the needs of mainstream, input-intensive, irrigated monocropping systems – principally cereals, livestock and other trade –oriented commodities, to the relative neglect of arid/dry land agriculture, mountain ecosystems, and other non-mainstream production systems
- Need for systems that are focused on ‘green’ processes, reducing waste and enhancing consumer protection
- Deal with the increasing pressure on agricultural production conditions caused by ongoing climatic changes, as well as the need for farmers to reduce their contribution to GHG emissions, play an active role in mitigation and provide renewable energy and raw materials for other industrial sectors
- Growing demand for food, fibre and fuel has contributed to the conversion of approximately 2.2 million hectares/year of new agricultural land. A significant share of this comes from converting natural forests and grasslands. Agriculture is responsible for at least 55% of habitat loss in the last few decades.

In light of these major new challenges and uncertainties, the IAASTD (2009) concluded that our existing farming systems and the knowledge system that supports them are no longer fit-for-purpose and that a new approach is called for. Such an approach must enable the world to raise the productivity of agriculture in a sustainable manner and increase the resilience of systems to deliver food security, feed, fuel, fibre and other ecosystem services under current and future climate and resource availability. The IAASTD Report summed up the existing challenge by stating that “the food security challenge is likely to worsen if markets and market-driven agricultural production systems continue to grow in a “business-as –usual” mode” (IAASTD, 2009, p.22).

According to Godfray et al. (2010), the new challenges “require changes in the way food is produced, stored, processed, distributed, and accessed that are as radical as those that occurred during the 18th- and 19th-century Industrial and Agricultural Revolutions and the 20th-century Green Revolution. Increases in production will have an important part to play, but they will be constrained as never before by the finite resources provided by Earth’s lands, oceans, and atmosphere” (p. 812).

Even allowing for the capacity of existing systems to supply adequate food, feed, fibre and energy crops to meet the burgeoning needs of a growing and richer world population, further questions arise about the trade-offs and risks involved. Simultaneously, new constraints are emerging in the form of scarcity of water, fertile land and the depletion of the agrobiodiversity resources. Along with climate change, these factors are presenting enormous challenges to agricultural production and productivity.

With rapidly rising global population, EU agriculture must address the challenge of producing enough food, feed and fibre to meet increasing demand in conditions of changing climate and scarce natural resources. Innovative policies and new farming practices built on a sound scientific foundation are required to deal with these new challenges. The EU also has a strong responsibility to support the development in vulnerable regions (e.g. Africa) and in the "bread baskets" of the world such as in Former Soviet Union states.

While past research has resulted in the development and adoption of many technologies designed to enhance aspects of sustainability, progress has not been adequate to simultaneously meet all of the many challenges. In part this is due to the fact that not all farmers have taken up the best practices developed by research and also because research, in the main, has concentrated on relatively narrow aspects, placing far less priority on understanding how all of the components of farming systems interact and how specific technologies could be integrated to tackle multiple challenges simultaneously. Technologies developed under these circumstances have engendered high productivity and low costs, but many have also led to negative social and environmental outcomes (or externalised production costs) that could limit progress towards more sustainable agriculture (NRC, 2010). A redirection of such technologies towards the goals of sufficiency requires the definition of new targets and benchmarks and thorough monitoring. The future CAP will be instrumental in managing this transition.

7.2. Research needs and priorities

Science-including the social sciences-is critical in addressing the sustainability challenge. Science permits us to broaden the range of options that can be implemented at all stages of the food chain and also produces the knowledge needed to predict the likely impacts of these different options. Transformation of the EU agricultural sector in line with the transition described above will require a long-term investment in research, education, extension and innovation by the public and private sectors in partnership with farmers.

There is already widespread consensus on the need to reverse the trend of declining investment in agricultural R&D. The IAASTD (2009) calculate that an investment of a 1000 billion USD over the next 50 years is needed to deliver the step change needed in global productivity and to underpin the transition to sustainable production. Success will depend on both the development of new technology and the transfer of existing technologies and best practices

Future technology and innovation designed to meet the needs of a rapidly changing agricultural sector must go well beyond the objective of raising yields and adjust to meeting the challenges of increasing resource scarcity and the structural transformation of the economic and social role of agriculture. Notwithstanding the importance of generating and transferring new and improved technologies for achieving sustained productivity gains, science today must also address the many new challenges already referred to. Such a transformation will grant new significance to the multifunctional role of agriculture and acknowledge the complexity of agricultural systems within specific contexts (Purvis et al., 2011).

The EU and Member States have a particular role to play in increasing public investment in the innovative research needed to create better management techniques that combine high agricultural production with low inputs, low emissions and high biodiversity value (Netherlands Environmental Assessment Agency and Stockholm Resilience Centre, 2009). This will require a focus on a new and differently targeted programme of R&D which will enable the development of new food supply models built around the principle of eco-efficiency aimed at production with least environmental cost (Ambler-Edwards et al., 2009). This will require a diversity of scientific approaches using and if possible integrating the modern tools of biotechnology, advanced knowledge of ecological processes, and more traditional crop and animal production knowledge and practices (using agronomic and agroecological methods).

The development of new technologies for sustainable intensification will require a cross-disciplinary approach combining new disciplines of molecular biology and genomics along with traditional subjects such as agronomy, plant physiology, soil science and entomology (The Royal Society, 2009). Across Europe, there is a growing shortage of expertise in universities and research centres in these traditional subjects and there is a serious danger that valuable skills in these areas will disappear as researchers and lecturers retire. There is an urgent need for universities and research institutes to take urgent action to reverse the decline in these critical areas of food production.

This necessary transformation will not happen in the short term, and in light of this, we propose that two parallel and overlapping approaches are needed to ensure the realisation of the elements of a long-term vision for European agriculture outlined above.

7.2.1. Building on existing technologies and knowledge systems

The first approach expands and intensifies ongoing research on productivity and sustainability. This approach is referred to by NRC (2010) as the "Incremental Approach" and by The Royal Society (2009) as 'Sustainable Intensification'. In exactly the same way that yields can be increased with the use of existing technologies, many options currently exist to reduce negative externalities. Fundamentally, it involves an expansion of ongoing research aimed at improving productivity while enhancing natural resources and addressing environmental concerns. The goal of this 'component-type' research is to identify and develop farming techniques that can improve specific aspects of sustainability. Such practices include: conservation (or reduced) tillage systems; cover cropping; crop diversity, including rotations, intercropping, and using different genetic varieties; new strategies for water conservation; nutrient management plans; precision agriculture; integrated pest management; and genetic improvement of livestock. This type of research would be funded from both private and public resources.

The adoption and impact of these practices could be accelerated by further biophysical, social and economic research, which would enable farmers to adapt their systems to changing environmental, social, market, and policy conditions to ensure long-term sustainability. In particular, there is a lack of research on the economic and social dimensions of agricultural sustainability, which would complement the work on productivity and environmental sustainability. Such socio-economic research is needed in developing the knowledge base to design systems that balance various sustainability goals and strengthen overall sustainability (NRC, 2010). This type of research would rely on public resources.

There is a growing consensus that many of our existing technologies have neglected important pieces of knowledge and retarded or prevented innovative solutions to emerging problems. In some cases, capacity building in some fields of research has to be recreated from scratch, as in the field of agroecology. Research policies should give specific emphasis to building research capacity on ecosystem services looking at the ecological, social and economic conditions of production. At the same time, a much greater emphasis should be placed on socio-economic impact assessment of technologies, with specific reference to the impact on scarcities.

The socio-economic and cultural dimensions should be integrated with the technological dimensions of production from the very beginning of research processes. There are many new technologies which don't work because they have been applied to unsuitable socio-technical systems. If in the past the most common approach was to adapt socio-technical systems to new technologies, it is now time to overturn the approach by starting from specific conditions of existing socio-technical systems and developing appropriate technologies to fit.

Conditions for a higher productivity in terms of ecosystem services should be based on awareness of the importance of four dimensions: a) farmers' knowledge, values and practices: farmers are the most important resource managers and potential nodes of information and knowledge networks; b) rural socio-economic configurations that provide the mechanisms of production and reproduction of livelihoods and ecosystem services at territorial level; c) agricultural and food systems that provide the conditions of food production, consumption and marketing and for their sustainability; d) priority of ecosystem services and functions, in particular for regulation and as buffer, over production functions in vulnerable zones.

Accordingly, the Expert Group recommends that sufficient publicly funded research be maintained at EU and national levels to ensure the development and adoption of new technologies that will enable farming practices to meet the diverse challenges of sustainability and increased production demands. We would also recommend that increased support be provided for research on the economic and social dimensions of these new technologies and farming practices. Approaches that promise building blocks towards low-input high-output systems, integrate historical knowledge and agroecological principles that use nature´s capacity, should receive the highest priority for funding.

7.2.2. Developing radically new farming systems

This second approach will require the development and extension of S&T which recognises agriculture as a vital component in the management of natural resources, and emphasises the importance of a holistic and systems-based approach to knowledge production and sharing. "Systems are needed that enhance sustainability while maintaining productivity in ways that protect the natural resource base and ecological provisioning of agricultural systems" (IAASTD, 2009, p.5). The current knowledge infrastructure has historically excluded ecological, environmental, local and traditional knowledge and the social sciences. Agricultural science will need to embrace a much broader set of understandings and data if future knowledge challenges are to be addressed. The challenges ahead demand more emphasis on management systems-from crop to whole farm to natural resource area, landscape and catchment scales.

This approach is based on designing farming systems that balance the various dimensions of sustainability from the beginning. The resulting systems must, of necessity, differ in significant respects from current mainstream production systems. Developing these new systems will result in a different approach to farming practices and the natural environment, the use of scarce resources, food markets and the ecological systems in which the systems are operated. Systems could include those with higher dual contributions, i.e., to both food production and aims such as bio-energy, landscape and biodiversity values. These new approaches will need to be based on multidisciplinary research, and the challenge will be to develop new practices that maintain or increase productivity whilst also advancing environmental, economic and social goals with maximum synergies and minimal trade-offs (NRC, 2010). Here the consumer can play an important role as well as payments for environmental services and public goods in the future CAP.

Accordingly, we recommend that priority funding be allocated to integrated research and extension on farming systems that takes account of the interactions between productivity, environmental, economic and social sustainability goals and how such systems can be made more robust and resilient in the long run. Furthermore, in order to enhance two-way information exchange and strengthen adoption of new technologies, we recommend that new systems research programmes should involve participation by farmers or farmer-managed trials as one element. As these approaches only work if they are embedded in the regional context, they could be developed in pilot regions (cf. LEADER programmes). In general, this type of research does not attract private funding, so will need to be funded by EU and Member States.

This approach to future research would build on the many interlocking strengths of natural systems and would aim to encourage agricultural diversity, which is fundamental to creating resilient agricultural systems (Netherlands Environmental Assessment Agency and Stockholm Resilience Centre, 2009). CAP post-2013 must aim to include diversity as one of its strategic objective": this is essential in maintaining and increasing current agricultural productivity in the EU, as well as providing a buffer against shocks… and in helping to maintain biodiversity and cultural landscapes that define Europe" (Netherlands Environmental Assessment Agency and Stockholm Resilience Centre, 2009, p.16). Therefore, payments for ecosystem services and for targeted programmes in vulnerable zones and hotspots of environmental problems have to become a major building block of the future CAP.

7.2.3. Sustainable intensification of crop and animal production

Science, especially publicly funded science, must play a key role in the sustainable intensification of food production. It is not our intention here to provide a long list of research priorities; such are to be found in, for example, The Government Office for Science (2010); European Technology Platform (2007); FACCE (2010); TP Organics Technology Platform (2009). However, it is important to highlight how and where science can contribute to addressing constraints on crop and animal production and how to better use nature´s mechanisms for smart production systems.

Crop production will have to increase by 70-100% to meet growing food and feed demand by 2050 (FAO, 2009a) unless consumer choices deviate from current projections. Moreover, because of limits on land and water resources, a significant increase in production must be derived through the acceleration of the rate of technological change by optimised input-output ratios on land that is already in agricultural use. There is widespread agreement that what is needed is not a single technological direction, but a varied range of technological options based on a wide variety of systems that are appropriate to a range of specific agroecological and socioeconomic contexts (The Royal Society, 2009).

In the area of crop production, we need genetic improvement of crops and new crops and soil management practices. Genetic improvements to crops can occur through breeding or genetic modification to introduce new desirable traits. Genetic methods have the potential to introduce both incremental and radical improvements to crops; the latter could be achieved, for example, by raising the photosynthetic efficiency of plants. More traditional crop management and agricultural practices can also address key constraints in existing crop varieties. New cultivars with durable disease resistance and other characteristics to adapt to changing conditions need to be developed. Better nutrient and water management needs to be adopted. Genetic modification is only one of several technologies that will play a role here.

Livestock provide a valuable source of food and play important agricultural and cultural roles in societies worldwide. Livestock support almost one billion of the world's poorest people. With livestock constituting the world's largest user of land resources (80% of all agricultural land is under grazing or feed crops) and 8 % of global water use, the sustainability of livestock production systems is increasingly being addressed (Steinfield et al., 2009). There are arguments on health, environmental and food efficiency grounds to reduce overall meat consumption in the western diet, but global demand for meat and dairy products is predicted to continue rising at a rapid rate, and so science must address how to address the many challenges facing the sector.

The livestock sector faces many challenges, such as the need to adapt to climate change. Furthermore, the sector generates 37% of anthropogenic methane, in addition to carbon dioxide (9%) and nitrous oxide (65%). (Steinfield et al., 2009). The options for specific livestock systems will need to be defined and the trade-offs assessed. Solutions are needed that are matched to diverse livelihood systems so that they can meet the demands for livestock products in an environmentally sound and economically sustainable manner.

Technological progress in the production, processing, and distribution of livestock products will be central to the realisation of positive outcomes to the rapidly growing demand for livestock products in developing countries. Rapid advances in feed improvement and genetic and reproductive technologies can potentially overcome many of the technical problems posed by increased livestock production. Institutional and regulatory initiatives will also be needed to secure desirable environmental and public health outcomes (Delgado et al., 1999).

In particular, research must pay renewed attention to the exploitation of feed resources in order to develop feed sources that are not competing to the same extent as they currently do with humans for food, in particular by taking advantage of the ability of ruminants to produce high quality products from grassland that is not suitable for other food crops and by maximising the use of by-products and co-products in non-ruminant systems. In this regard, extensive pasture-based production systems are inherently more sustainable than intensive feedlot systems (Purvis et al., 2011).

7.2.4. Resource scarcities and research priorities

In order to take scarcity seriously, a new set of priorities should drive research policies. In an era of scarcity, the imperative cannot be to respond with production to increasing and changing food and resource demand, but rather to address production and consumption jointly in order to introduce the necessary feedbacks among them. As prices do not signal scarcity in an efficient way – and even less so with increasing globalisation – research in agriculture and food area will have to deal with the need to reframe consumers' choices. This implies, first of all, developing a process of change of values, knowledge, information, and material infrastructures. Ideally, consumers should be able to have all the necessary skills and information to assess the effects of their choice on their health and on the environment. There is a strong acceleration of the debate about strengthening the links between food, health and environmental research. From these research fields a new approach to consumers' needs may emerge, and a concept of 'sustainable diets' could be developed. Social, economic and political research can help identify enabling conditions how to influence dietary choice and establish stronger food-health links.

Sustainable food production needs a systemic and integrated approach. Food research cannot separate production from packaging, transportation, conservation, and waste management without losing the capacity to assess present and potential costs, benefits, conflicts and dilemmas. There is an increasing demand for access to reliable and simple-to-use information about the sustainability of processes and technologies, but in order to make this information easily accessible new knowledge is required as well as new approaches to communicating with consumers about the food they eat.

A transition to sustainable consumption requires a strong effort to develop a cross-disciplinary agenda of research, linking together agricultural, environmental, social and health concerns under the principle of sustainability and applying them to daily consumption practices. Cross-disciplinary frameworks should look at the complexity of food production and consumption to put into evidence invisible links, possible synergies and critical points for change. They may foster innovation from society itself, to encourage good practices and facilitate their diffusion through support to learning processes, institutional and regulatory facilitation and technology brokerage. At the same time, they could give enterprises new instruments to face the competition in a new scenario.

Lines of research under this chapter could apply the criteria of sustainability to lifestyles, diets, consumption technologies and food provision systems. They could also provide enterprises with necessary knowledge to redesign products and processes in a sustainable way and to communicate relevant messages to consumers and to the public.

Reducing waste and improving efficiency of resource use are other major challenges under conditions of scarcity. There is a pressing need to find new ways of reducing waste throughout the food supply chain. Post-harvest losses are estimated to be currently 40% worldwide, with waste and losses occurring in storage, during transportation and processing, from the retail sector and by consumers. Novel research on how to minimise food wastes during food process, transport and retail is required, while options for recycling and reuse (e.g., composting and bioenergy) should also be further explored, while taking account of health issues (JPI Scientific Advisory Board, 2010).

Primary production on agricultural land must be seen as a precious, scarce resource itself. Therefore, uses that target the quality of the resource, e.g. for food, feed or specific chemical compounds must be given a priority over mass uses, e.g. for energy. This priority also holds for competing uses further down the recycling cascade. The rationale for such a prioritisation is that the biomass use most efficient when it is kept in the use system as long as possible, opening a wide range of re-use options. Furthermore, recycling and cascading uses help reduce the pressures on productive land from competing uses.

7.2.5. Climate change

Climate change is now one of the greatest challenges facing humanity and it will impact agriculture in many ways, some positive and some negative. The already difficult challenges of producing more food employing fewer inputs is compounded by the need for agriculture to adapt to climate change, whilst also reducing GHG emissions from agriculture in order to mitigate climate change. Agricultural systems in the coming decades must develop resilience to climate change as a significant element of sustainability, particularly in those areas expected to experience ecological changes due to a changing climate at critical limits of traditional crop and animal production. The Agriculture, Food Security and Climate Change Joint Programming Initiative (JPI) addresses the scientific priorities involved in integrating adaptation, mitigation and food security in the agriculture, forestry and land use sector in Europe and identifying measures to reduce emissions and increasing resilience of farming, forestry and biodiversity to climate change (FACCE, 2009). It aims to develop scientific understanding to assist European farmers in adapting locally to climate variability and climate change and to ensuring that European farming and food systems contribute to reducing GHG emissions.

7.2.6. Bioenergy and biofuels

First-generation biofuels competing with food crops are not sustainable. Agro-bioenergy in general does not match the criteria of sufficiency. Arable land resources are limited and further expansion into forest, grassland and woodland areas will result in significant carbon emissions, which offset the primary justification for using biofuels. The main challenge for commercial second- generation biofuels is to develop conversion technologies at industrial scale and at competitive prices that do not use primary biomass but rather waste and residues from the food and feed production chain. These technologies, still at the laboratory experimentation and demonstration stage, require large scale feedstock supplies and pose logistical and sustainable management challenges. A substantial potential for producing lignocellulosic feedstocks also exists on currently unprotected grassland and woodlands worldwide, but its exploitation is likely to increase pressures on biodiversity and ecosystems. Integrated studies on land use changes and competition between food and non-food production systems will be required, assessing the consequences of European policies for a range of options concerning bioenergy and biofuels targets. Moreover, integrated systems combining food and energy production will be studied and assessed in terms of climate change adaptation and mitigation and contribution to global food security.

7.2.7. Research priorities for the KBBE

The KBBE Conference held in Brussels in September 2010 concluded that "developing the Knowledge-Based Bio-Economy is the way forward for a prosperous, sustainable future for Europe." The Conference also concluded that investment in multidisciplinary research will need to be increased. Continued investment in research is also needed to fulfil the potential of agriculture to underpin the bio-economy. The report launched in association with the conference recommends an increase in the level of R&D funding in the bio-economy through multidisciplinary research programmes at both national and European level and encouraging more cooperation between the private and public sectors. The report also identifies the need for better integration of the different research areas and public-private partnerships to stimulate innovation.

7.2.8. Technology transfer and innovation

Innovation lies at the heart of the Europe 2020 Strategy, underpinning the Strategy's objective of smart, sustainable and inclusive growth. The "Innovation Union" is one of the seven flagship projects identified in the 2020 Strategy. This initiative identifies innovation as representing the best way of tackling major societal problems, including resource scarcity. It sets out an integrated and strategic approach in which innovation is seen as the overarching policy objective for the Union.

It is particularly important that in the context of a future R&D programme that the focus is firmly fixed not only on the generation of new knowledge, but also on ensuring that the supports and mechanisms are in place to help convert this new knowledge into viable new products and services, particularly in the context of creating the KBBE and in addressing critical challenges such as climate change and resource scarcities. Innovation will be fundamental in enabling farmers to deliver increased yields while using more resilient and sustainable practices. Joint research and an active involvement of farmers and extension services from the very beginning of research, e.g. via on-farm research has to be strengthened.

Agricultural extension services are a vital component of a strategy to ensure that science developments and innovative practices are appropriately developed and targeted. These services provide a means for informing farmers about innovative technologies, as well as providing a channel for feedback from farmers to researchers.

7.3. Implications for future research policies at EU and Member State levels

Arising from our discussions in the current and previous chapters, we identify the following as being significant implications for future research policies at EU and national levels:

- In view of the absolute priority for producing a secure supply of safe and quality food in Europe and globally, the case for increasing the current low level of priority accorded to agri-food research is overwhelming. The body of evidence supporting the value of investing in such research is substantial, whilst new advances in science and technology present new opportunities to address the environmental and resource challenges which now threaten the security of our future food supplies.

- The Eighth EU Framework Programme should accord a much higher level of priority to research in agriculture and food, funding research on both component technologies and the development of sustainable and competitive new farming systems. Funding must also be provided for the social sciences.

- Pursue multiple scientific approaches to achieve growth in sustainable intensification and sustainability and climate change adaptation; and rigorously assess the benefits and safety of novel technologies. A broad perspective that encompasses the entire food system is needed and a mixture of approaches will therefore be required. This should include biotechnology, but also areas of science such as agronomy and agroecology that have received less recent investment. Research in the social sciences is also essential to understand how best existing and new knowledge can be implemented by food producers.

- There is a critical need to prioritise research on climate change adaptation and mitigation in agriculture.

- Sustainable intensification means simultaneously raising yields, increasing the efficiency with which inputs are used and reducing the negative environmental effects of food production. It recognises the multifunctionality of agriculture and requires a redirection of research to address a more complex set of goals than just increasing yield.

- Researchers and research policy makers must communicate in a more effective manner with the public, specifically to build trust in new technologies. New technologies, including GM and nanotechnology, must form part of the portfolio of technologies to address the goal of "sustainable intensification", but these technologies must be accepted by the public and consumers.

Modern extension services are needed to deliver innovation in technologies and practices in the food chain. They must be accompanied by investment in agricultural training to ensure the next generation of researchers, extension workers and farmers. The revitalisation of extension services to increase the skills and knowledge base of food producers is critical to achieving sustainable increases in productivity .

- Our current food system relies on the provision without cost of a variety of ecosystem services. The food system may negatively affect the environment and hence harm the same ecosystem services it relies upon, or affect those that benefit other sectors. Incorporating the true costs (or benefits) of different productions systems on ecosystem services is a powerful way to incentivise sustainability.

- New partnerships and better coordination and integration are needed between the three sectors engaged in research and development to create and drive the multiple processes required to achieve sustainable productivity and innovation in the agri-food sector.

7.4. Conclusion

Global food production has, to date, maintained pace with population growth. However, the scale of this challenge will be exacerbated in the future owing to increasingly unpredictable weather events and the changing pattern of disease in crops and livestock caused by anticipated climatic changes. Impacts of further biodiversity losses or even collapse of marine food webs are potentially even larger and less predictable. This, combined with an increased level of competition for scarce natural resources, particularly energy, land and fresh water, creates the scenario described by Professor John Beddington, the UK Government's chief scientific adviser as the 'perfect storm'. "Navigating the storm will require a revolution in the social and natural sciences concerned with food production, as well as a breaking down of barriers between fields. The goal is no longer simply to maximise productivity, but to optimise across a far more complex landscape of production, environmental, and social justice outcomes" (Godfray et al., 2010).

Europe and its Member States cannot divorce themselves from these dynamics. Europe cannot take its own long-term food security and high level of feed imports for granted, nor can it withdraw from its responsibility to contribute to meeting the food security needs of poorer countries unable to raise their own food output. Europe cannot be immune from the impacts of disruption to food trade in the future and disruption in supplies of essential inputs such as phosphates. Neither can it close its eyes either to the growing health costs arising from poor diets nor the care costs of a growing ageing population whose capacities could be extended through a healthy diet.

These various challenges arise as climate change is both a product of and an influence on agricultural production. Continued investment in R&D and translation into innovation are crucial for the long-term production of sustainable and safe food in Europe and meeting food security globally.

A radical change in food consumption and production in Europe is unavoidable to meet the challenges of scarcities and to make the European agro-food system more resilient in times of increasing instability and surprise. Europe has already taken up the climate change challenge in industry and has succeeded to make new energy technologies a win-win-win strategy for market, labour and human welfare. Now the agro-food sector has an opportunity to positively take the challenge and be the first to win the world market for how to sustainably produce healthy food in a world of scarcities and uncertainty.

8. CONCLUSIONS

8.1. Building a vision for 2050

It is clear from the foregoing that a new vision for agriculture is required. In this concluding section, we will put forward what we consider to be the main building blocks for such a vision. A new vision itself must be based on a definition of a core **purpose** which is based on the core societal needs from agriculture on the one hand and the core principles or **values** with which these needs should be achieved. Both purpose and values will require a collective input by all relevant stakeholders. At present, Europe is characterised by a wide variety of visions for a future agriculture, and it will not be easy to formulate a clear uncontested vision. Accordingly, we will confine ourselves to identifying what we consider to be the basic building blocks for a long-term vision and highlight key priority areas of research needed to put these building blocks in place.

The Commission's Communication on the CAP toward 2020 recommend the following strategic aims (European Commission, 2010b):

- To guarantee long-term **food security** for European citizens and to contribute to growing world food demand
- To provide European citizens with quality, value and diversity of food produced **sustainably**, that is, in line with requirements of natural resources and public health
- To maintain viable rural communities, thus contributing to employment and to **territorial balance**.

Based on these three aims, the Commission has formulated three objectives for the future CAP: (1) viable food production, (2) sustainable management of natural resources and climate action and (3) balanced territorial development.

it is clear that future food and agricultural systems in Europe will have to be as productive as at present or more productive, but they will also have to be more sustainable. This basic requirement for the agriculture of the future will necessitate a radical transformation of agricultural and food systems, and of the knowledge and innovation system supporting them. This is consistent with the conclusions and recommendations of a wide number of influential reports and policy documents published in the recent past (IAASTD, 2009; The Royal Society, 2009; NRC, 2010; The Government Office for Science, 2011). On the basis of the conclusions emerging from the analysis conducted in the foregoing chapters, we have derived a set of principles upon which our food system in general and research concerning our agriculture and food system in particular should be based:

1. **Well-being:** food and agricultural systems should serve the well-being and quality of life of all stakeholders involved: farmers and agribusiness should earn a sufficient income producing secure, safe and healthy food for consumers as well as public goods (environmental services); fair access by all to a healthy food is critical for food security and well-being.
2. **Resource use efficiency and optimality:** given the increasing scarcities in vital resources, resources should be used as efficiently as possible (by avoiding waste, recycling and reducing our footprint), but they should also be used optimally, that is, where their contribution is greatest (by applying the cascading principle of resource contribution); this might imply radical changes in the way we look at the use of resources, shifting from an approach in

terms of productivity to an approach in terms of sufficiency, where important changes in consumption patterns play an important role.

3. **Resource conservation**: to avoid the irreversible loss of natural resources, critical natural resources, including biodiversity, land and water should be maintained, taking into account the interaction between scarcities.

4. **Diversity and inclusion**: food and agricultural systems should reflect the territorial diversity present within the EU and worldwide; diversity may be instrumental for the resilience of our systems, but should also enhance the equitable access to affordable and healthy food and to natural resources.

5. **Transdisciplinarity:** research and innovation underpinning future food and agricultural systems should be truly interdisciplinary, that is, fully integrating the various sciences, including the social sciences and humanities, but be also transdisciplinary, that is, fully integrating the end user into research and innovation. Only in this way, the innovation gap between finding and adopting novelties can be overcome.

6. **Experimentation:** in order to develop the key breakthroughs needed to address the Grand Challenges of our time, research should be diverse, that is, ranging from blue sky research (fundamental research with no immediate applications) to applied research, but also based on different paradigms and narratives. Transdisciplinary research should have sufficient room for experimentation, not only in the technological realm, but also in the social.

7. **Coordination and impact evaluation:** research should be better coordinated across thematic domains as well as Member States. At the same research impacts should be better monitored and evaluated.

8. **Public involvement:** strong public investment in research remains crucial to safeguard all previous principles.

A radical change in food consumption and production in Europe is unavoidable to meet the challenges of scarcities and to make the European agro-food system more resilient in times of increasing instability and surprise. Inspired by the fact that Europe is taking up the climate change challenge in industry and is intending to make new energy technologies a win-win-win strategy for market, labour and human welfare, the agro-food sector should now consider that there is an opportunity to positively take the challenge and be the first to win the world market for how to sustainably produce healthy food in a world of scarcities and uncertainty.

8.2. Main messages

To conclude the FEG3-experts would like to formulate the following main messages:

1. **The increasing scarcity of natural resources and destabilization of environmental systems represents a real threat not only to future food supplies, but also to global stability and prosperity, as it can aggravate poverty, disturb international trade, finance and investment, and destabilise governments.** Price volatility, access restrictions and the interconnectedness of global commodity markets, as well as the increasing vulnerability of food production systems to climate change and loss of agrobiodiversity, will make food even more inaccessible for the poor in the future.

2. **Many of today´s food production systems compromise the capacity of Earth to produce food in the future.** Globally, and in many regions including Europe, food production is exceeding environmental limits or is close to doing so. Nitrogen synthesis exceeds the planetary boundary by factor of four and phosphorus use has reached the planetary boundary. Land use change and land degradation, and the dependence on fossil energy contribute about one- fourth of Greenhouse Gas emissions. Agriculture, including fisheries, is the single largest driver of biodiversity loss. Regionally, water extracted by irrigation exceeds the replenishment of the resource.

3. **Drastic change is needed in regard to both food demand and supply.** In an era of scarcity, the imperative is to address production and consumption jointly in order to introduce the necessary feedbacks among them and to decouple food production from resource use. Efficiency and resilience are the new priorities over production levels. This transition cannot be met by following the common narrative of increasing productivity. The narrative of "sufficiency" opens opportunities for transition into sustainable and equitable food systems by a systemic approach that deals with the complex interactions of the challenges founded on a better understanding of socio-ecological systems.

4. **The average Western diet with high intakes of meat, fat and sugar is a risk for individual health, social systems and the environmental life support systems.** Obesity, type 2 diabetes, hypertension, osteoarthritis, and cancer are wide-spread diet-related diseases. The promotion of a healthy diet also reduces the environmental footprint of food consumption in Europe and globally.

5. **Coherence between food, energy, environmental and health policies and across all levels of governance are prerequisites for a timely transition to sustainable and equitable food systems**. A new quality of governance is needed at local, national and global level, with a substantial contribution by the State and civil society. Research should strongly support this improvement, and the role of social sciences may be crucial.

6. **Diversity and coordination are key for increased efficiency and resilience of the future agro-food systems.** It is a fact and a strength that food consumption and production systems are diverse. This diversity has to be maintained, or diversification be fostered, between different regions and farming systems. Diversity in research directions will keep all options open for reacting to surprises.

7. **Research, innovation and agricultural knowledge systems must be fundamentally reorganized.** To speed up transitions, tightly and actively integrate 1) multiple disciplines from ecology, economy, agronomy, social science, 2) research, innovation and

communication, 3) farmers, food retail, technology, industry and agricultural research, and organise research and innovation as learning processes.

8. **Make Europe the world leader in efficiency and resilience research of food consumption and production**. Ensure a strong role of public research, in particular to guarantee a better understanding of the underlying processes of ecosystem services and the interactions among the scarcities. The continuation of cooperative thematic research in environmental topics and food production and consumption is as critical as the maintenance and further development of European research infrastructures in these areas.

9. **Sufficiency-oriented research, innovation and communication must become the priority.** Explore new opportunities and ecological approaches to boost research and innovation on efficiency in resource use in agricultural production, including new farming systems that balance the three dimensions of sustainability, and food processing, including cascading uses and waste reduction. Address consumer behaviour and supply chain strategies (including information and communication) in favour of healthy sustainable diets that save food and feed resources and can help curb the increase in global food demand.

10. A radical change in food consumption and production in Europe is unavoidable to meet the challenges of scarcities and to make the European agro-food system more resilient in times of increasing instability and surprise. Europe has already taken up the climate change challenge in industry and is intending to make new energy technologies a win-win-win strategy for market, labour and human welfare. **Now the agro-food sector has an opportunity to positively take the challenge and be the first to win the world market for how to sustainably produce healthy food in a world of scarcities and uncertainty.**

Key-words: efficiency, resilience, reduced demand side pressure, reconciliation between production and other ecosystem services, active stakeholder integration in research, strong continued public research, systems understanding, sufficiency transitions, healthy diets.

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ANNEXES

Annex 1: Mutual interactions between scarcities

Impact of scarcity of … on …	Use of fertile land	Freshwater	Energy	Phosphorus	Nitrogen	Climate change *	Biodiversity	Economic development	Urbanization	Agricultural knowledge	Governance
Use of fertile land	Supply, access, distribution, degradation	FB	FB	?	FB	FB	FB, TP	FB	FB	FB, TL	FB, TL
Freshwater	FB	Supply, access, distribution, quality	FB	FB	FB	FB, TP	FB	FB	FB	FB, TL	FB, TL
Energy	FB	FB	Supply, access, distribution, alternatives		FB	FB		FB	FB	FB	FB
Phosphorus	FB			Supply, access, distribution, pollution		FB		FB	FB	FB	FB, TL
Nitrogen	FB				Access, distribution, pollution			FB	?	FB, TL	FB, TL
Climate change	FB, TH	FB	FB		FB	Trend, variability	FB, TP, ?, TL	FB	?		FB, TL
Biodiversity	FB	FB	FB	FB	FB	FB, TP, TH, TL	Supply, resilience, tipping point	FB	?		FB, TL
Food	FB	FB, TH	FB	FB, ?, TH, TL	FB	FB, TH, TL	FB, TP, ?, TL	FB	FB	FB	FB, TL
Urgency of transition	FB	FB	FB	FB	FB	FB	FB, TP	FB	Pressure or chance on demand side	FB, TL	FB, TL
						* including ocean acidification		Trend, pressure on demand and prices	Trend, lifestyle and consumption	Adoption of new knowledge, move from productivity to sufficiency	Decision-making mechanisms, change in culture

FB Feedback — Feedback means intensification or acceleration of system dynamics
TP Tipping point — Tipping point means an irreversible catastrophic change of the system
TH Threshold — Threshold means that if systems move beyond a certain limit they reach a new state, e.g. lose their suitability for agriculture
TL Time lag — Time lag can mean that system react with a long delay time or that the depletion of the supply causes irreversible damage

No interaction
Interaction likely, interaction small
Interaction significant
Interaction strong
Interaction very strong, fast or critical for agriculture
Interaction can be positive or negative, depending on type of interaction

Annex 2: Regional priorities and mechanisms of resource and environmental scarcities in food systems and their societal contributions

Impact of … on food systems in…	Fertile land	Freshwater	Energy	Phosphorus	Nitrogen	Climate change	Biodiversity	Economic development	Urbanization	Agricultural knowledge	Governance
EU		Variability, regional differences	Bioenergy	Access, excess regions versus shortage	Excess regions versus shortage, pollution	Variability, regional differences, diseases	Loss of genetic resources and resilience	Less meat?			Environmental issues in EU policy reforms
Mediterranean	Desertification	Drought, variability	Irrigation	Access: Morocco´s resorces; excess regions versus shortage		Drought, variability	Loss of genetic resources and resilience			Uptake of innovation in irrigation	Water access and management
Coastal cities	Flooding from sea level rise, pollution	Pollution, distribution, floods		Pollution	Pollution	Sea level rise, floods, increased storm activity, intensity	Damage to coastal ecosystems	Dynamic urban growth, more food, more poor people			Management of urban pollution and the urban metabolism
Southeast Asian megadeltas	Flooding from sea level rise, pollution, flooding	Pollution, salinization, distribution, floods		Access, pollution	Pollution	Sea level rise, floods, increased storm activity, intensity	Damage to coastal ecosystems and coral reefs	Dynamic urban growth, more food, more poor people			Management of urban pollution and the urban metabolism
Dry central Asia	Erosion	Drought, variability		Access: China´s resources; excess regions versus shortage		Flloods, drought, variability in precipitation	Loss of genetic resources and resilience				
Monsoon Asia	Nutrient mismanagement (too much, too little, degradation	Drought, floods, variability	Irrigation, partly mechanisation, maybe bioenergy	Access: China´s resources; excess regions versus shortage	Excess regions versus shortage, pollution	Drought, floods, increased storms, melting of Himalayan glaciers	Loss of genetic resources and resilience	Very fast development, changing lifestyle, more meat in China			Tendency of resource nationalism
Subsaharan Africa	Degradation	Drought, variability	Mechanisation	Access, shortage except South Africa	Shortage	Floods, drought, variability in precipitation, diseases, yield loss	Loss of genetic resources and resilience				Political instability, corruption, nepotism, armed conflict, land tenure issues
Latin America		Variability, trends	Bioenergy	Access except Chile?	Excess regions versus shortage, pollution	Variability	Loss of genetic resources and resilience	Deforestation and intensification for cash crops and beef			
USA + Canada		Variability, regional differences	Bioenergy	Access, excess regions versus shortage	Excess regions versus shortage, pollution	Variability, regional differences, diseases	Loss of genetic resources and resilience				

Annex 3: Main fields of applications in nanotechnology

Application	Technology	Function	Product	Concerns
Nanosized ingredients / additives	Processing to create nanostructure	- Improved texture, flavour, taste - Reduction in the amount of salt, fat, sugar, and other additives - Enhanced bioavailability/ health benefits	Nano additives (colours, flavouring agents, preservatives, antioxidants) - Nano-salt, WOW Mayonnaise	Need to show that they are solubilised/ digested in the gut and that insoluble free nanoparticles do not enter the blood
Ingredients additives and supplements	Nanoencapsulation	Taste masking, protection from degradation during processing • Enhanced bioavailability of nutrients/ supplements • Antimicrobial and other health benefits	Food additives (benzoic acid, citric acid, ascorbic acid), Supplements (vitamins A and E, isoflavones, ß-carotene, lutein, omega-3 fatty acids, coenzyme-Q10) Tip Top UP Bread contains microencapsulated tuna fish oil	• Need to ensure that greater bioavailability does not lead to increased health risks • Tissue distribution is not different from that of conventional forms
Food packaging	Incorporating nanoparticles into plastics	To improve flexibility, durability, temperature/ moisture stability, barrier properties * antimicrobial properties * monitor condition of the food	Several types of package	Potential risks due to migration of ENPs into food and drinks