SCAR Foresight Group

AGRICULTURE AND ENVIRONMENT

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INTRODUCTION

Agriculture is the most dominant land use in Europe, covering twice as much land as forestry and more than 10 times as much as urban areas (EEA 2005). There has been a transformation of areas of traditional rural landscape into modernised, more intensive agriculture largely due to the EU’s Common Agricultural Policy (CAP). In the past years, CAP has been reorientated towards a wider rural policy perspective aiming at better integrating environmental issues and rural development perspectives.

The general trend towards more intensive and industrialised agriculture in Europe has a profound impact on the environment, including emissions to air and water, quality and quantity of surface water and groundwater, soil erosion, pollution due to large-scale use of pesticides, and loss of biodiversity and habitats. In the near future, agriculture may also gain a significant role in the production of biofuels and renewable energy (EEA 2006a, EEA 2006b). The potential shift in the production from food to biomass production for biofuels and energy raises many open questions regarding the sustainability and cost-efficiency of the biofuel production.

According to Alcamo (2001), scenarios are alternative images of how the future might unfold. Future scenarios can be used as tools for analyzing how driving forces in the field of agriculture can influence e.g. biodiversity and other key ecosystem services (see also Reidsma 2006, Verboom 2006). In identifying future development lines and key strategic issues for agriculture, the longer range environmental impacts must be included. Agricultural activities are a continuous interaction between their ecological, economical, political, social and technological dimensions (Bruinsma 2003). All these dimensions should be considered in an integrative manner when building future scenarios for agriculture.

Environmental and agroecological research is currently focussing on understanding the cause-consequence relationships between e.g. specific agricultural practices and land use and the responses at different levels of ecosystems. In addition, modelling approaches and methodologies of experimental ecology are being used in testing the impacts of agriculture on for example biodiversity and ecosystem services. Only a few attempts have been made to build scenarios on how potential changes in agriculture would impact different aspects of the environment (see Sala et al. 2000, Tilman et al. 2001, Reidsma et al. 2006, Van Meijl et al. 2006, Verboom et al. 2006, Verburg et al. 2006). The scenario approaches have been predominantly linked to assessing the impacts of climate change on agriculture and ecosystem services. The EURURALIS project has been a multidisciplinary effort in building scenarios on the impacts of land use change on biodiversity for 25 EU countries (Reidsma et al. 2006, Verboom et al. 2006).

The aim of this paper is to provide a brief overview of the environment-related issues that will contribute to shaping European agriculture by the year 2025. The paper discusses briefly the key impacts of agriculture on the environment (biodiversity, leaching of nutrients to water, emissions to air, water availability and soil degradation and pollution) and the development trends. Based on existing scenario studies the paper identifies key drivers affecting future agriculture and agricultural practices in Europe. These environmental drivers, in addition to climate change and bioenergy production, contribute to shaping the area of *agriculture and environment*. The climate change issue will be covered in detail in the contribution by Olesen (2006) of this foresight exercise. Bioenergy issues will be covered in much more detail in the contribution by Schenkel (2006). Finally, the paper provides a brief discussion of the implications of the conclusions for research and innovation.

MAJOR ENVIRONMENT-RELATED DRIVERS FOR EUROPEAN AGRICULTURE

LAND USE CHANGE AND BIODIVERSITY

Land cover change in agriculture has shown diverging trends during the past ten years: intensification of agriculture and at the same time farmland abandonment taking place even in the same regions and countries (EEA 2005). Land use change is an important driver of biodiversity change as natural areas are converted to agriculture or urban areas (e.g. Sala et al. 2000). As a general trend, there is an increasing pressure on biodiversity in rural areas of Europe, which is likely to continue in the near future (Verboom et al. 2006, Tilman et al. 2001). However, throughout history agriculture has also significantly contributed to the development of specific habitats which support unique communities of flora and fauna, but which are now becoming vulnerable due to diminishing agricultural activity in some rural areas as marginal agricultural sites are being abandoned.

Agricultural production is based on utilizing biological diversity. About 7,000 plant species have been cultivated and collected for food by humans since agriculture began about 12,000 years ago. However, today, only about 15 plant species and 8 animal species supply 90% of the global demand for food. Rapidly growing global human population and changing consumption patterns have stimulated the evolution of agriculture from traditional to modern, intensive systems. Nearly one third of the world's land area is used for food production, making agriculture the largest single cause of habitat conversion on a global basis (www.biodiv.org).

Biological diversity has fundamental importance in supporting agricultural production and sustainability. Genetic diversity provides access to seeds and planting material better adapted to future climatic conditions (e.g. drought-resistant traits or resistance to pests and disease), and is the basis of adaptation as needs and environmental conditions change. Microbial and fungal diversity are crucial e.g. to the functioning of soil processes (e.g. nutrient cycling). Soil fertility and soil quality can be improved by the planting of appropriate cover crops. On the other hand, many wild plant and animal species have during their evolutionary history adjusted to utilizing various agricultural environments created by man.

Agriculture has changed significantly in terms of the production patterns and structure and a significant trend has been the development towards fewer and larger holdings with more intensified and specialized production. This development has included an increased mechanization and use of fertilizers and pesticides. Biodiversity has been affected negatively both by the physical changes in the landscape and by the changes in the production methods. As the agricultural production has intensified, all levels of biological diversity (genetic, species, and habitats) have declined in farming environments. The more intensive land use corresponds for example to the decrease in the populations of farmland birds (Fig. 1, Fig. 2, EEA 2005, OECD 2001).

Key factors causing the decline in biodiversity include habitat disturbance and changes in the food chain. In general, there are fewer species in intensive plant production regions with little diversity in the landscape structure as compared with mixed farming and livestock production regions (e.g. Di Giulio et al. 2001, Donald et al. 2001). Patches of natural habitats in cultivated landscapes may increase assemblages of some species in the fields (Jeanneret et al. 2003). Due to the decrease in grazing and animal husbandry, organisms that depend on meadows and forest pastures have declined and become endangered (Luoto et al. 2003, Pykälä 2004, Pykälä et al. 2005). For example, farmland butterflies have shown a nearly 30% decresing trend during the past twenty years (Fig. 1, EEA 2005).

Figure 1. Trends in birds and butterfly populations in EU25 Member States (% decline). EEA State and Outlook 2005.

A recent study based on a 25-year long data base shows that wild bees and the flowers that they pollinate are declining in the Netherlands and United Kingdom (Biesmeijer et al. 2006). The even as high as 80% loss of bee diversity could have important implications for farming, as many crops (fruits, vegetables, nuts, seeds, herbs) are directly dependent on insects for their pollination (Biesmeijer et al. 2006). The study is one of the few where time series analysis has indicated a significant change in a key functional group - wild bee pollinators - providing a substantive ecosystem service.

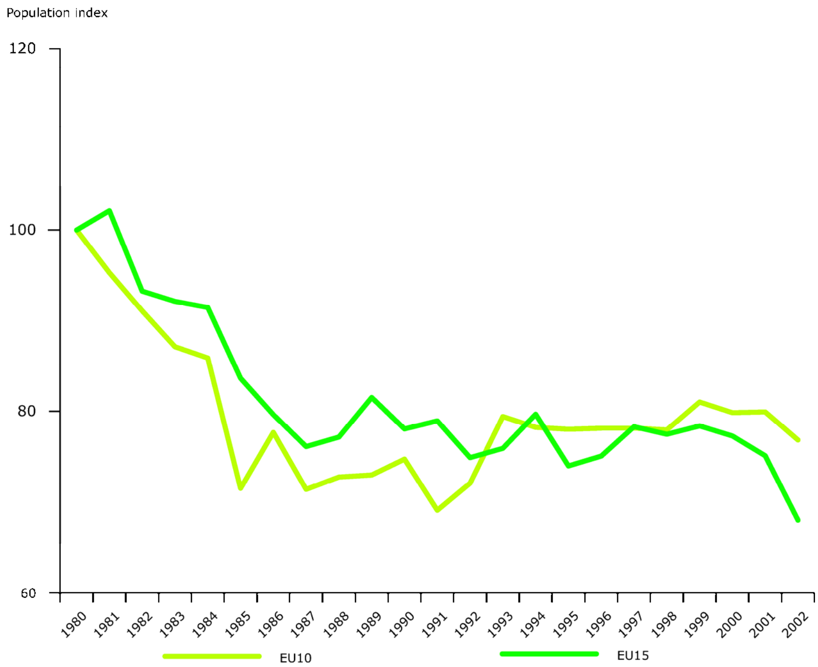

Figure 2. Common farmland bird trend from 1980 to 2002 in EU15 Member States and EU10 Member States. EEA State and Outlook 2005 (May 2006 assessment draft).

According to the results of the EURURALIS project, biodiversity was projected to decrease by the year 2030 in most of the studied 25 EU countries and for all the four EURURALIS scenarios used (defined as *Global Economy*; *Continental Markets*; *Global Cooperation*; and *Regional Communities*, where the dimensions were the degree of government regulation and the degree of regionalization) (Verboom et al. 2006). This result emphasizes the urgent need to develop new measures in order to even turn the trend of biodiversity decline towards the 2010 biodiversity target (e.g. Council of the European Union 2004).

Reidsma et al. (2006) considered three processes for the assessment of future trends in agricultural land use intensity: land use change, conversion of production into organic farming, and changes in the crop and grassland production. Based on the analysis of the four EURURALIS scenarios, they came to the conclusion that the ecosystem quality supporting biodiversity will drop quickly especially in the *Global Economy* scenario, whereas in the *Regional Communities* scenario the opportunities for increasing biodiversity in the agricultural landscapes are the best

(Reidsma et al. 2006). In general, low productivity and more environment friendly production techniques (e.g. organic farming) will support biodiversity and improve ecosystem quality of agricultural landscapes (Reidsma et al. 2006). Even though the intensification of agriculture would leave more land for nature (through farmland abandonment), the impact intensified production on overall biodiversity was generally negative.

In Europe, the amount of land devoted to organic agriculture has grown quite rapidly (EEA 2005): organic farming covers now about 4% of the total agricultural area in Europe (Fig. 3, EEA 2005).

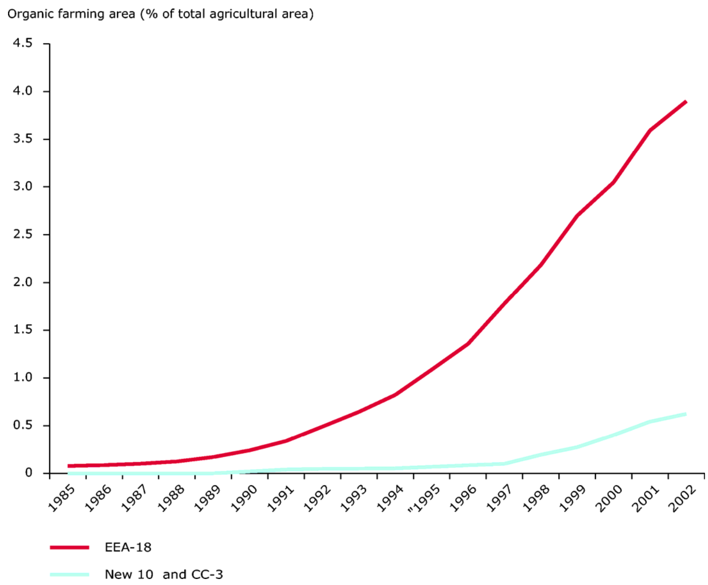

Figure 3. Development of organic farming area in Europe (years 1985-2002). EEA State and Outlook 2005.

Organic farming is a farming system that has been developed to be environmentally sustainable and is governed by verifiable rules (Council Regulation EEC No. 2092/91). Organic farming, by definition, should promote and enhance agroecosystem health, including biodiversity, biological cycles and soil biological activity (e.g. according to FAO). Organic farming focuses on sustainability, environmental protection and animal welfare by reducing or eliminating chemical inputs such as fertilizers, pesticides and growth promoters and the use of genetically modified organisms (GMO). Organic farming promotes regional approaches, where both production and consumption occur within a logistically limited range. Regarding species abundance in organically farmed landscapes, Bengtsson et al. (2005) estimated an increase in mean species abundance by 50% compared to very intensive conventional farming. Their study was based on an in depth meta-analysis. Reidsma et al. (2006) reported an average of 2.7 times increases in species abundances in pair-wise comparisons between conventional and organic farming.

Current agri-environmental measures in Europe are not likely to be able to halt the negative environmental effects caused by the development towards more intensive farming practices. There is a need to revise the agri-environmental measures towards more supportive measures in order to maintain biodiversity of agricultural areas. In doing so, biodiversity should be considered as part of the natural capital which supports key ecosystem services that also agricultural production is dependent upon (Perrings et al. 2006). The agri-environmental measures require a system level understanding on the role of biodiversity in the provisioning of the ecosystem services. In addition to the agri-environmental measures of CAP, other mechanisms that aim at supporting the approaches to halt biodiversity loss include the Natura 2000 network and various rural development programs. It has been suggested that the overlap between Natura 2000 areas and agri-environmental schemes could be improved to better achieve environmental objectives (EEA 2006b). Also shifts in agricultural production strategies towards multifunctionality and specified production as well as organic farming could have a positive contribution on changing the decreasing trend of agrobiodiversity (see also Scenar 2020).

Based on existing studies and review, it can be concluded that by 2025 there is an increasing pressure on biodiversity in rural areas of Europe, and biodiversity is projected to decrease in most of the EU 25 member states. According to Reidsma et al. (2006), the ecosystem quality supporting biodiversity will drop especially under conditions where global economy is a strong driver. Regionalization and the strengthening of regional markets could provide the best potential for supporting biodiversity in agricultural landscapes.

LEACHING OF NUTRIENTS AND EUTROPHICATION OF WATERS

Agriculture has a significant role in non-point source pollution. Loading of waters is caused by crop and grassland production and livestock production. Phosphorus and nitrogen leach to rivers, lakes and the sea from arable land causing eutrophication. Eutrophication is a condition in an aquatic ecosystem where high nutrient concentrations stimulate growth of algae, since nitrogen and phosphorus are among the main growth limiting nutrients in aquatic environments. This leads to imbalanced functioning of the aquatic system causing intense algal growth (excess of filamentous algae and phytoplankton blooms), production of excess organic matter, increased oxygen consumption and consequent oxygen depletion, and, finally death of benthic organisms in anoxic conditions at bottom areas.

CASE: EUTROPHICATION AND THE BALTIC SEA

Eutrophication is one of the greatest problems of the Baltic Sea, which is the largest brackish water basin in the world and a significant marine environment in northern Europe. Due to excessive loading of nutrients, filamentous algae have grown more common and in several areas outcompeted perennial red and brown algae (Kuuppo et al. 2003, Uusitalo & Ekholm 2003, Lehtoranta et al. 2004). Offshore, the production and abundance of phytoplankton has increased creating surface accumulations and decreasing visibility. Biodegradation of sedimented algae consumes oxygen and is a factor contributing to the creation of anoxic bottoms. Many species of fish and benthic fauna in general suffer from the lack of oxygen which in addition to this dissolves sediment-bound nutrients (phosphorus) for resuspension (internal loading) elevating pelagial nutrient levels even further.

In year 2000, the total input on nitrogen to the Baltic Sea was 1 009 700 tonnes, of which 25% entered as atmospheric deposition on Baltic Sea and 75% as waterborne inputs (HELCOM 2005). The main proportion of waterborne inputs of nitrogen (59%) was from diffuse sources, especially from agriculture (HELCOM 2005). The total phosphorus inputs in year 2000 (from point, diffuse and natural background sources) were 34 500 tonnes. The main proportion of waterborne inputs (49%) was from diffuse sources such as agriculture and scattered dwellings (HELCOM 2005).

The gross nutrient balance for nitrogen provides an indication of potential water pollution (eutrophication driver, OECD 2001). The gross nutrient balance identifies at the European level those agricultural areas and systems with very high nitrogen loadings. High nutrient balances exert pressures on the environment in terms of an increased risk of leaching of nitrates. At the EU-15 level, the gross nitrogen balance in year 2000 was calculated to be 55 kg/ha, which is 16% lower than the balance estimate in 1990 (66 kg/ha). In the year 2000, the gross nitrogen balance ranged from 37 kg/ha (Italy) to 226 kg/ha (the Netherlands). All national gross nitrogen balances show a decline in estimates of the gross nitrogen balance (kg/ha) between 1990 and 2000, apart from Ireland (22% increase) and Spain (47% increase). The general decline in nitrogen balance surpluses is due to a small decrease in nitrogen input rates (-1%) and a significant increase in nitrogen output rates (10%) (Fig. 4, EEA 2005).

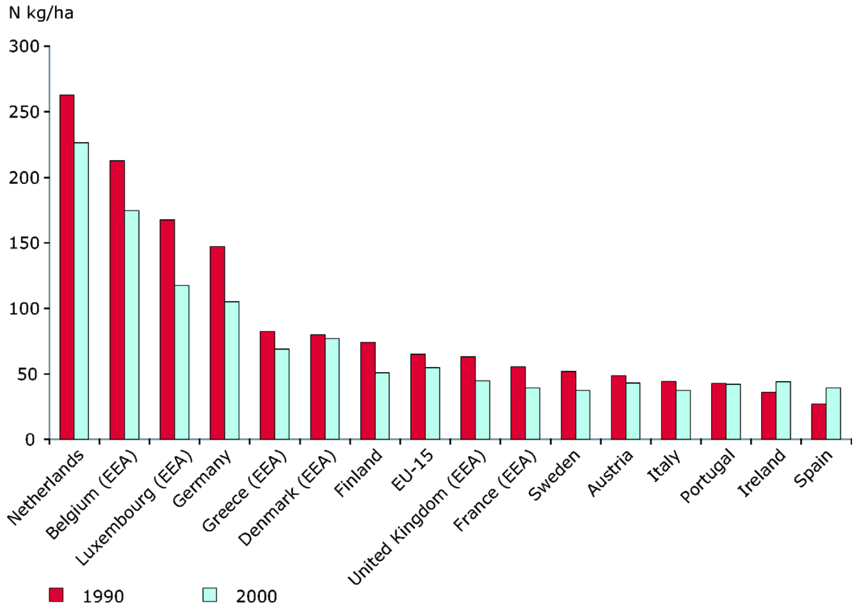

Figure 4. Gross nutrient balance for nitrogen (N kg/ha) at national level. EEA State and Outlook 2005.

The implementation of load reduction measures (e.g. EU's Nitrate Directive and the Water Framework Directive, environmental support measures of CAP) will support further reductions in nutrient inputs from agriculture. There is, however, a considerable time-lag between the implementation of agricultural water protection measures and before the full biological and chemical effects are measurable and visible in inland water bodies and in sea ecosystems. This is partly due to the nutrient reserves (especially phosphorus) existing in agricultural soils and bottom sediments of aquatic basins (e.g. Ekholm et al. 2005). The ability of the current EU legislation in controlling and reducing the impacts of agriculture on aquatic systems depends very much on how well the measures are targeted to specific *hot spot* -areas of nutrient leaching.

If the target of the Water Framework Directive regarding the good ecological status of surface waters is not reached sufficiently, there will be a strong pressure to develop the current EU legislation and the agri-environmental measures of CAP towards more targeted measures. In addition, public pressure will push agricultural production systems towards closed nutrient cycles and energetic self-sufficiency (e.g. through utilization of manure for biogas production on farms).

WATER AVAILABILITY AND INCREASING DEMAND FOR WATER

In the near future, water availability will be one of the key factors determining agricultural productivity. Especially in Southern Europe, reaching and maintaining high agricultural yields will require utilization of newly established irrigation schemes including building of dams and reservoirs. Environmental problems associated with massive irrigation include lowered water tables, salinisation and damage to terrestrial and aquatic habitats. Restrictions in water use for agriculture are likely to be developed in many areas, especially due to the severe droughts occurring especially in the Mediterranean region. Climate change will be the ultimate driver affecting water availability. Faced with growing pressure upon freshwater resources, increased water productivity in agriculture will become essential. New ways of circulating water resources and technology development will play a key role in sustaining agricultural production.

SOIL DEGRADATION AND POLLUTION

A major problem in Europe is the degradation of soils and irreversible losses of soils due to soil sealing and erosion, continuing contamination from local and diffuse sources (including increased use of pesticides and fertilizers), acidification, salinisation and compaction. The productive capacity of soils depends on the content of mineral nutrients, organic carbon, soil structure and texture. Erosion affects all these soil properties. Loss of organic matter, soil biodiversity and consequent deterioration of soil fertility are often driven by unsustainable agricultural practices, such as deep ploughing (EEA 2003). In an experimental study, Ulen & Kalisky (2005) demonstrated that treatments with less frequent tillage or treatments without tillage significantly reduced erosion and phosphorus losses by increasing soil stability and fertility. Thus, adequate soil management reduces soil erosion and loss of phosphorus to surface waters and contributes to achieving the Water Framework Directive targets (good ecological status of surface waters by 2015).

Soil has many functions, including the capacity to remove contaminants from the environment by filtration and adsorption (EEA 2003). Soil degradation, through its impact on soil organic matter, has also an influence on the release of CO2 into the atmosphere and thus on global carbon cycling (EEA 2003).

GREENHOUSE GAS EMISSIONS TO THE AIR

Climate change poses new challenges to agriculture. The measures of adaptation to climatic change are likely to affect the relative profitability of different crops and production methods. Agriculture is also an important contributor to global emissions of greenhouse gases (GHG), in particular for methane (CH_4) and nitrous oxide (N_2O). Emissions from farms with a stock of ruminant animals are particularly high due to CH_4 emissions from digestion and manure handling, and due to the intensive nitrogen cycle on such farms leading to direct and indirect N_2O emissions. In short, most of the greenhouse gas emissions from agriculture are caused by the decomposition of organic matter in the soil, the digestion of bovines and the decomposition of manure. Other minor emission sources include nitrogen fertilization, liming of arable land and use of fossil energy in agriculture.

One common feature in emissions from agriculture is that it is difficult to reduce them without directly influencing the volume of agricultural production (Niemi & Ahlstedt 2006). Olesen et al. (2006) modelled the effects of management practices and mitigation options on GHG emissions in conventional and organic dairy farms within five European agro-ecological zones. The results showed that the emissions at farm level could be related either to the farm nitrogen surplus or the farm nitrogen efficiency. The GHG emissions per product unit (milk or metabolic energy) were quite closely related to the farm nitrogen efficiency, and doubling the nitrogen efficiency from 12.5% to 25% reduced the emissions per product unit by around 50% (Olesen et al. 2006). Thus, enhancing the nutrient and energy efficiency of production systems will have significant impacts on GHG emissions.

An immediate need exists to understand which agricultural land uses and land resource types have the greatest potential to mitigate greenhouse gas emissions (Follett et al. 2005). Site-specific adaptation of appropriate conservation technologies will be needed for sequestering soil organic carbon and reducing nitrous oxide emission. Development of improved conservation technologies to reduce GHG emissions could become part of more comprehensive conservation programs aimed at environmental protection, food security, and agricultural sustainability (Follett et al. 2005).

CLIMATE CHANGE

Climate change is one of the key factors affecting the agro-food production and agricultural practices in Europe and worldwide. Scientific evidence shows that temperature changes and increased extreme events such as flooding and drought, are likely to have profound negative consequences for the natural systems and their functioning and provisioning of ecosystem services, for the human society and global economy (e.g. Olesen 2006). According to for example EEA (2004) and Stern (2007), climatic changes in Europe may have positive impacts on the agricultural production and ecosystem productivity in the northern and mountain regions by e.g. the increase of annual yields, expansion of production areas, and the adoption of new more productive cultivars, whereas southern regions of Europe will face severe challenges related to extreme temperatures, fire, droughts and water availability. In the foresight paper by Olesen (2006), climate issues also related to environment are discussed in detail.

BIOENERGY PRODUCTION

EU Member States aim to increase the use of renewable energy to 12% by 2010 (EU COM (97) 599 final). Bioenergy is hoped to contribute to reaching various key objectives namely reducing greenhouse gas emissions, ensuring sustainable energy supply, increasing entrepreneurship, employment, and rural viability in agricultural areas.

European trends in land use change may offer opportunities in sustainable management of agroenvironments for bioenergy production under climate change scenarios. Schröter et al. (2005) used a range of ecosystem models and scenarios of climate and land use change to conduct a European wide assessment. Changes in climate and land use resulted in significant changes in ecosystem service supply. Some of these trends could be positive (e.g. increases in forest area and productivity) and could offer new opportunities such as diverting “surplus land” (current increases in forest area) to bioenergy production.

There are possibilities for synergies between large scale production of biomass and nature conservation. Innovative biomass crop systems and use of perennial grasses could combine high yields with lower environmental impacts (especially nutrient loading and pesticide use) and with sustaining a higher level of biodiversity. A new study suggests that biodiversity could also significantly contribute to sustainable supply of biomass for biofuel. According to Tilman et al. (2006), ecosystems containing many different plant species are more productive than those containing only one of those species. Diverse prairie grasslands were found to be 200 percent more productive than grasslands with a single prairie species. The results suggest that the best source of biomass for the production of biofuels could be fields with a high diversity of plant species (Tilman et al. 2006).

Berndes et al. (2003) studied the contribution of biomass in the future global energy supply based on a review of 17 earlier studies on the subject. These studies have arrived at widely different conclusions about the possible contribution of biomass in the future global energy supply. The major reason for the differences was that the two key parameters - land availability and yield levels in energy crop production - are very uncertain. Also the expectations about future availability of forest wood and of residues from agriculture and forestry vary substantially among the studies. Berndes et al. (2003) arrive to a conclusion that the question on how an expanding bioenergy sector would interact with other land uses, such as food production, biodiversity, soil and nature conservation, and carbon sequestration has been so far insufficiently analyzed. It is therefore difficult to establish to what extent bioenergy is a feasible option for climate change mitigation in the energy sector (Berndes et al. 2003).

Smeets et al. (2006) estimated bioenergy production potentials by the year 2050 including three types of biomass energy sources: dedicated bioenergy crops, agricultural and forestry residues and waste, and forest growth. The bioenergy potential in a region is limited by various factors, such as the demand for food, industrial wood, traditional woodfuel, and the need to maintain existing forests for the protection of biodiversity. The results of Smeets et al. (2006) indicate that the application of very efficient agricultural systems combined with the geographic optimization of land use patterns could significantly reduce the area of land needed to cover the global food demand in 2050. A key factor in the modelling was the area of land suitable for crop production but that is presently used for permanent grazing. Another key factor was the efficiency of the production of animal products. Realization of the bioenergy potentials on surplus agricultural land requires thus significant increases in the efficiency of food production.

According to the recent EEA report on bioenergy and the environment (EEA 2006a), greater production of bioenergy could set incentives for a more intensive use of agricultural land and forests, and might counteract the objectives of waste reduction policies (EEA 2006a). There is thus a risk of additional environmental pressures on biodiversity, and soil and water resources. Developing and adopting proper measures can minimise the risks, through e.g. supporting the production of low-impact bioenergy crops and not allowing the ploughing of permanent grasslands. Bioenergy production could also reduce environmental pressure compared to intensive farmland management with the right crop mix and cropping practice (EEA 2006a). In the foresight paper by Schenkel (2006), bioenergy issues are discussed in more detail.

FUTURE NEEDS FOR INTEGRATED APPROACHES TO AQUACULTURE AND AGRICULTURE

Human-dominated marine ecosystems are experiencing accelerating loss of populations and species, the consequences of which are still largely unknown. Marine biodiversity loss could impaire the ocean's capacity to provide food, maintain water quality, and recover from perturbations. Worm et al. (2006) analyzed local experiments, long-term regional time series, and global fisheries data to test how biodiversity loss affects marine ecosystem services across temporal and spatial scales. Overall, rates of resource collapse increased and recovery potential, stability, and water quality decreased exponentially with declining diversity. Restoration of biodiversity, in contrast, increased productivity fourfold and decreased variability by 21%, on average (Worm et al. 2006). If the ability of the marine ecosystems to provide food is severely impaired, the development of sustainable aquaculture becomes highly important. Aquaculture products may become more important also in Europe in gaining markets and partly replacing e.g. animal products.

The wide variety of goods and services provided by the coastal zone (e.g. food, nutrient recycling, control of flooding) account for its many uses such as fisheries, aquaculture, agriculture, human settlements, harbors, ports, tourism, industries. Half of the total global aquaculture yield comes from land-based ponds and water-based pens, cages, longlines and stakes in brackish water and marine habitats (Primavera 2006). The environmental impacts include e.g. loss of natural habitats, introductions and transfers of species, spread of parasites and diseases, misuse of chemicals, and release of wastes. In order to attain sustainable aquaculture that could also have integration with agriculture in coastal regions, a key approach is Integrated Coastal Zone Management (ICZM). The EU's new strategy on the marine environment and a related draft directive stress the need to apply an "ecosystem approach" to improve the state of the Europe's seas. Such an approach involves comprehensively examining the impacts of all human activities on marine and coastal environments, including agriculture practised in the coastal zone and drainage basins.

Prein (2002) studied the status of integrated agriculture-aquaculture in Asia, with an emphasis on rural small-scale systems. Based on examples from Bangladesh, China, India and Thailand, Prein (2002) concluded that considerable potential exists for further aquaculture integration with agriculture. Integrating aquaculture with agriculture requires new kind of thinking and innovations. Bender and Phillips (2004) discussed the potential of microbial mats for multiple applications in aquaculture, agriculture and energy production. Microbial mats occur in nature as stratified communities of cyanobacteria and bacteria, but they can be cultured on large-scale and manipulated for a variety of functions. They are complex systems, but require few external inputs. Regarding aquaculture, microbial mats have been shown to produce protein, via nitrogen fixation, and being capable of supplying nutrition to tilapia and having a role in the nitrification of nutrient-enriched effluents (Bender and Phillips 2004). Furthermore, the use of mats in biohydrogen production has been verified, but is still in an early phase of development (Bender and Phillips 2004, Gavala et al. 2006, Zhang et al. 2006). Focusing on integrated aquaculture and agriculture systems may have interesting future potential for sustainable energy production, such as development of biogas facilities.

INCREASING PRESSURE FOR RECREATIONAL USE OF AGRI-ENVIRONMENTAL AND RURAL AREAS

Agricultural landscapes are widespread across the European continent, with broad patterns of arable land seen in e.g. Denmark, the Netherlands and the United Kingdom. Pastures and more mosaic rural landscape patterns dominate in e.g. the Alpine and other mountain regions in Europe (MacDonald et al. 2000), and also eastern and northern regions (EEA 2005). During the past decade (1990-2000), the overall agricultural area has decreased resulting from a range of changes in land use.

Land cover change in agriculture shows highly contrasting trends in different areas of Europe: farmland abandonment, farmland transformation to other land uses and intensification of farming. The main trend has been towards a conversion of arable land and permanent crops to pasture, set-aside and fallow land (EEA 2005). There are three key issues behind: the conversion of agricultural land to urban development, conversion within agriculture from arable land to pasture and vice versa, and withdrawal of farming (Fig. 5, EEA 2005). At the European level, conversion of forest and natural land to agriculture is balanced by withdrawal of farming with or without woodland creation. However, variability at national level is significant. Around 1 million hectares of new forested land were created in Europe in the 1990s, with about 25% as the result of the withdrawal of farming (EEA 2005).

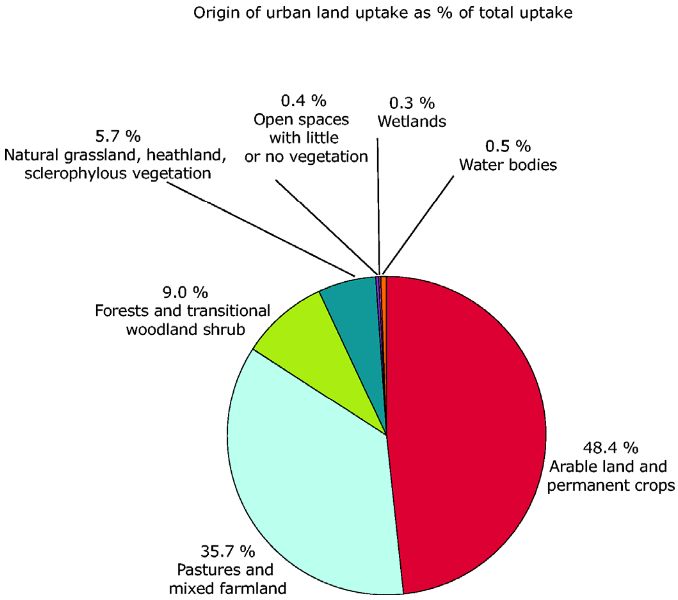

Figure 5. Relative contribution of land-cover categories to uptake by urban and other artificial land development. EEA State and Outlook 2005.

The countryside surrounding towns and cities offers an important recreation setting. The recreational use of nature is directed both to the immediate surroundings of people's homes in smaller cities and villages and nature sites located further away. Managed arable lands are typically appreciated as landscape features, but, contrary to forested areas, traditionally agricultural land has not generally been understood as an important element for recreation. There are expectations for rural tourism to become a significant industry in the countryside of some parts of Europe. Therefore it is important to consider how the agricultural environment could be developed as an attraction especially in rural tourism sites and at the same time sustaining biological diversity and traditional landscapes.

Farming practices that promote landscape values and outdoor recreation would increase the benefits from outdoor activities. In specific areas, agricultural land could be increasingly managed with attention to environmental protection and recreation (see e.g. MacDonald 2000, Hampicke 2006) as well as sustainable production. Promoting the recreational use of nature and nature tourism has not so far been included in the objectives of the agri-environmental schemes. However, certain basic and special measures contribute to outdoor recreation in farming areas. These measures include, for instance, traditional biotopes, plant cover during winter, riparian zones, biodiversity of arable lands, and development and management of landscapes.

PUTTING EMPHASIS ON BIOSECURITY IN AGRICULTURE

Biosecurity in agriculture and the agrifood sector has recently become very topical in all Europe (e.g. spread of avian influenza in 2005). Biosecurity can be defined as the protection of production (including agricultural and food production), the environment and human health against various kinds of pathogens, weeds and pests. In addition, the public interest in biosafety issues has also focussed on the discussions surrounding the use of genetically modified organisms, very specifically on the use of transgenic plants in agriculture. According to Bartsch & Schuphan (2002) there is no evidence that the use of genetically modified plants would contradict sustainable agriculture and nature conservation per se. However, the effect of GMOs on the environment is a politically and scientifically much debated issue.

Biosecurity will become increasingly important in the modern world. Protecting supply security against diseases and pests spread unintentionally or intentionally is in itself a matter of security policy. Biosecurity has significant impacts on the profitability of agriculture, state of the environment, and finances of the consumers and tax-payers (Niemi & Ahlstedt 2006). The problem of control of new and reemerging infectious diseases, the need for new vaccines and control of transport require new research inputs and results (Doblhoff-Dier & Collins 2001).

SOME IMPLICATIONS FOR RESEARCH AND INNOVATION

- Developing measures that will encourage flexibility in land use. Crop management in relation to climate change is a key topic of global concern. A research priority is the development and further tailoring of climate models that would better incorporate agroecological and socio-economical parameters.

- Assessing the economic viability and macro-level impacts of different forms of bioenergy and biofuel production. An integrated research approach is required to assess the green house gas and energy balances of different biofuel production chains. Research and innovation policies need to support development of new solutions for bioenergy, including new technologies, a portfolio of energy production systems and also farm-level regional approaches that promote energy-efficiency.

- Increasing water management efficiency in order to sustain agricultural production under changing climatic conditions.

- Improving nutrient cycling and nutrient use efficiency as well as development of new nutrient management tools technologies, including targeted measures. Agricultural nutrient abatement measures have received considerable attention in existing research. Future research should emphasize the practical point of view focussing on how nutrient abatement measures can be implemented and abatement targets achieved when heterogeneity of farms and regions is accounted for? Research should focus on the costs and benefits of nutrient abatement measures and result in the development of integrated tools that would take into account the ecological and socio-economic sustainability.

- Identification and preservation of plant and animal genetic diversity as key natural resource sustaining future agrifood, aquaculture and bioenergy production. Tackling the challenges in maintaining biodiversity at various spatial scales when the size of agricultural production units and holdings is significantly increasing. Assessing the social cost of biodiversity loss in agricultural landscapes and developing new measures for promoting biodiversity in rural areas (e.g. nature value trade; conservation as a product of agriculture, landscape management activities) will require multidisciplinary research efforts.

- Integrating agricultural, environmental and cultural policies to preserve the heritage of rural environments. Research on the joint impacts of agricultural, environmental and cultural policies on the environment at the EU and global level is needed to redirect and build synergistic integrated policy approaches.

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