A review of the possible impact of biomass production from agriculture on water

Background paper for the conference "WFD meets CAP - Looking for a consistent approach"

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Policy Summary

Bioenergy is becoming a more important energy source for Europe in order to reduce greenhouse gas emissions and reduce reliance on foreign sources. Targets set by the EU for increasing biomass production necessitate substantial growth in agriculture production, which has led to a debate concerning potential benefits to the environment as well as possible conflicts with objectives of other EU policies, such as the Water Framework Directive (WFD). Large-scale bioenergy cropping may add considerable additional pressure on land use intensity in Europe, with negative impacts on water quantity and quality.

Current bioenergy production focuses on well-established first generation technologies, such as fermentation of agricultural crops to produce ethanol and combustion of biomass to produce heat and power. Most of today's biomass agriculture production uses "classical" food crops, such as maize and oil seeds, and production requirements are very similar compared to when used for feed and food. This can lead to increased environmental pressures if land use intensity or area is increased. However, on the other hand energy crops may provide some opportunities for reducing soil erosion and nutrient leaching risks from agricultural land use.

When assessing the environmental impacts of bioenergy cropping, it is necessary to take into account three main issues:

- Potential land use changes as a result of the increasing bioenergy demand
- The different input (e.g. water and nutrients) requirements of the crops and the related management practices.
- The impacts production processes have. Biogas as a transport fuel or for the generation of heat or power is more efficient than many of the production paths of bioethanol and biodiesel.

The relationship between bioenergy production and its impact on the environment is very complex. One of major issues when estimating the environmental impacts linked to agricultural biomass production is that such effects are very context and site specific. Biomass production impacts depend on the current land use they are replacing and on the environmental vulnerability of the location in question. Despite this, potential impacts have been identified and can be summarised as follows:

- Current trends indicate that cultivated area in the EU-27 will expand as a result of increased interest in bioenergy, which could have serious implications for nutrient leaching and soil erosion rates, especially when this involves the conversion of permanent grassland.
- Further there is a risk that with increased bioenergy cropping the production becomes more intensive (esp. pesticides) because quality requirements as for food crops do not need to be met.
- Water needs differ for different conversion processes. Bioethanol plants use large amounts of water for fermentation, cooling and washing. Furthermore, particular attention needs to be paid to river basins facing water scarcity problems. Irrigation for bioenergy crops or the higher demands of perennial energy crops could increase water stress in some regions.

A number of potential benefits to the environment have also been identified:

- SRC plantations and perennial energy grasses offer significant potential in reducing water pollution risks. Depending on the crop type, water abstraction needs can be reduced compared to food crops. It should be kept in mind, however, that some varieties do have high water requirements.

- Multiple cropping systems have high potential in bioenergy production, which could enhance diversity and reduce pesticide input. Higher water demand for such systems has to be considered. Bioenergy cropping allows for specific, more environmentally friendly cropping approaches. Such cropping systems allow for harvesting several times a year, and if applied extensively, could combine low environmental pressures with high yields.

- Bioenergy production offers a number of win-win situations for the implementation of the WFD. Bioenergy crops might be used to establish buffer strips, which aid in flood retention and uptake of excessive nutrients. Some bioenergy crops, such as perennials, can withstand flooding better and may be planted in (expanded) flood retention areas allowing farmers to gain more profit from such areas.

This evaluation highlights a number of potential synergies and conflicts between different policy areas. However research in this area is still at an early stage and several open questions remain. It is important to consider the risks when implementing or revising biofuel targets and water management strategies. There is no doubt that bioenergy cropping will increase in the future. Future decision-making must consider impacts on land use and water resources, so that impacts on the environment can be reduced or mitigated. In this context, cooperation and coordination are required between three policy areas: energy, agriculture and environment[1].

[1] European Council conclusions of 8/9 March 2007: http://www.consilium.europa.eu/ueDocs/cmsData/docs/pressData/en/ec/93135.pdf

1 Introduction and purpose

Like other parts of the world Europe faces many challenges in its environmental, energy, and agricultural policies. Since 2000 these policy fields have experienced important changes which were not always linked to each other. However, achieving the set objectives in one field often requires substantial effort and support from the other policy areas. This is particularly evident in the case of bioenergy production, which has an increasing importance for all three policy areas.

This paper aims to clarify potential links, both positive and negative, between these three policy areas with respect to bioenergy. It builds on previous work by the European Environment Agency and others, but remains only a first attempt to draw out the key interlinkages between the objectives of the EU Water Framework Directive (WFD), EU bioenergy policy and agricultural land use. The document has been developed on the basis of an extensive literature review and expert consultation. Consequently, it points to initial results where possible, and outlines further research needs where necessary.

The paper is targeted mainly at policy makers from the European and national levels that are responsible for designing water management and bioenergy policies. However, it includes relevant information for those who are working on water basin management plans or regional biomass action programmes.

The recent price rises on global food and energy markets show that there is already a high demand for agricultural biomass for traditional and novel uses. It is also widely known that agricultural land use has important consequences for the environment, whether this relates to biodiversity or soil and water resources. Achieving the WFD objectives requires various measures in the agriculture sector to be taken to limit water use and pollution from farming (Commission of the European Communities, 2007a). In this context, it is necessary to evaluate the potential consequences of the recently established EU bioenergy policy targets for achieving the objectives of the WFD.

This paper aims to evaluate current bioenergy policy objectives in the light of the WFD by analysing critical issues and proposing measures that generate benefits for both sides. Both policies are currently in a stage of development and implementation, which still allows for adjustments to be made to maximise potential synergies and minimise potential risks. This report hopes to contribute to an informed discussion of the policy choices that still have to be made in both policy areas. In particular, it addresses the following questions:

a) What is the potential impact of bioenergy production on water quality and quantity in Europe?

b) Are there differences in impact of the different biomass production and conversion pathways?

c) What are the potential synergies that exist or can be developed between bioenergy production and water protection?

d) How can the implementation of the WFD respond to potential synergies with, and challenges from, bioenergy production?

e) What options exist in bioenergy policy to develop water-friendly production pathways?

f) What research needs still exist?

The paper's outcome should help strengthen the understanding and co-operation between actors in energy, environment and agriculture policies in order to develop sustainable solutions for potential conflicts. It will hopefully also provide a useful base for decision makers and planners when designing river basin management plans (RBMPs) as well as national or regional biomass action plans.

2 Background on policy and general agricultural and bioenergy issues

2.1 EU Water policy

The Water Framework Directive (WFD) entered into force in December 2000 and is the key EU policy instrument for ensuring the protection of EU water resources. The issues covered by the Directive extend to all aquatic systems, surface waters (rivers and lakes), groundwater and coastal waters. Land eco-systems containing groundwater are also included in the protection of the quantity and quality of groundwater. Thus it goes beyond previous water protection instruments which were based on sectoral approaches and aims for an integrated approach to water management. The WFD has the following main objectives:

- expanding the scope of water protection to all waters;
- to achieve the "good status" of all waters in the Community by 2015 and ensure that there is no deterioration in the status (Art. 4);
- water management based on river basins across national boundaries, choosing an integrated approach within river catchment areas;
- "combined approach" of emission limit values and quality standards, plus the phasing out of priority hazardous substances;
- introduction of incentive water pricing policies to help achieve objectives and the polluter pays principle;
- getting the public more closely involved in water issues, which means interested parties must have opportunities to participate; and
- streamlining water legislation; and establishing a coherent managerial framework for all water-related legislation (e.g. energy, transport, agriculture, fisheries, regional policy, tourism), thus allowing for consistency in planning and measures.

Following the objectives of the WFD, river basin management plans, including summaries of programmes of measures, have to be drawn up to reach the main goal of "good status" of all waters. The programmes of measures can be considered as the principal mechanism for the implementation of the environmental objectives of the WFD and have to be developed for each river basin district. These programmes have to be established by 2009, made operational by 2012 (Art. 11 WFD) and should be based on a risk assessment (Art. 5 WFD). Their preparation also provides an opportunity to ensure a further integration of sustainable water management into other policy areas, including agricultural policy. This includes the need to ensure an efficient use of EU and national funds to improve water management. Future adjustments of the Common Agricultural Policy CAP and the Health Check of 2008 could also provide opportunities to examine how to further integrate water issues in the relevant CAP instruments.

In addition to the WFD, the Communication on water scarcity and droughts adopted by the Commission on 18 July 2007[2] highlights that all agricultural production including biomass production

[2] http://ec.europa.eu/environment/water/quantity/scarcity_en.htm

and all economic activities should be adapted to the amount of water available locally. One of the options identified in the Communication aims at further assessing the inter-linkages between biofuel development and water availability.

The development of river basin management plans and programmes of measures under the WFD have to take into account the potential future impacts linked to new or expanding land use for bioenergy cropping. This analysis must result in the setting up of appropriate measures in order to avoid potential negative impacts coming from bioenergy cropping. To be effective, however, such measures would also have to be included in national or regional biomass action plans as these will be the principal drivers for land use changes linked to bioenergy cropping.

2.2 Agricultural bioenergy production: EU policies and environmental aspects

The European Union and its Member States are committed to increasing the use of renewable energy sources with the aim of reducing emissions of greenhouse gases and dependence on imported fossil fuels. Specific targets have been set for renewable electricity and for biofuels. The EU Biofuels Directive (Directive 2003/30/EC) set an indicative target for 2 percent of transport fuels to consist of biofuels by the end of 2005 and 5.75 percent by the end of 2010.

On January 10, 2007 the European Commission proposed a new energy policy for Europe (Commission of the European Communities, 2007b). At the spring meeting of the European Council in Brussels on March 8–9, 2007, the EU heads of state and government endorsed the Commission proposals, including:

- a binding 20% target for the overall share of renewable energy in 2020 – the effort to be shared in an appropriate manner between Member States; and
- a binding 10% target for the share of biofuels in petrol and diesel in each Member State in 2020, contingent on 2nd generation technology becoming commercially available and biofuel production being ‘sustainable’ (Council of the European Union, 2007).

To achieve the renewable energy policy goals mentioned above, the European Commission has proposed a Directive on the 23 January 2008 (Commission of the European Communities 2008). Three sectors are implicated by renewable energy: electricity, heating and cooling and transport. It is up to the Member States to decide on the mix of contributions from these sectors to reach their national targets, choosing the means that best suits their national circumstances. They will also be given the option of achieving their targets by supporting the development of renewable energy in other Member States and third countries. The Directive also aims to remove unnecessary barriers to the growth of renewable energy - for example by simplifying the administrative procedures for new renewable energy developments – and encourages the development of better types of renewable energy (by setting sustainability standards for biofuels etc).

Achieving these targets thus implies very strong growth in the use of biomass; the share of biofuels in transport fuel use stood at 1,4% in 2005 (Commission of the European Communities, 2006a). Nevertheless, biomass from forestry, agriculture and waste accounts for two thirds of total renewable energy use in the EU and it is expected that it will maintain a high share. Furthermore, biomass has some advantages compared to other renewable energies: it can easily be stored, is one of the few options to create renewable heat and is currently the only option to create renewable transport fuels.

In order to achieve these targets, the European Union developed a Biomass Action Plan and an EU strategy on biofuels. The **Biomass Action Plan** (Commission of the European Communities, 2005), put forward in December 2005, aims to increase the biomass production potential from 69 Million Tons of Oil Equivalent (Mtoe) in 2003 to 186-189 Mtoe in 2010. It outlines 31 measures to promote biomass in heating and cooling, electricity production and transport (biofuels). The main actions proposed include:

- new EU legislation on the use of renewable energy, including biomass for heating and cooling;
- a possible revision of the Biofuels Directive to set national targets for the share of biofuels and to oblige fuel suppliers to use biofuels[3];
- encouraging Member States to develop national biomass action plans;
- developing an industry-led research agenda with the launch of a "biofuel technology platform"; and
- research into second-generation biofuels to power vehicle engines (biomass-to-liquids).

In conclusion, the Biomass Action Plan sets the framework for future activities and may influence other related policy areas such as the Common Agricultural Policy.

On 8 February 2006 the Commission published a Communication entitled "**An EU Strategy for Biofuels**" (Commission of the European Communities, 2006a). The Strategy complements the Biomass Action Plan and responds to a threefold objective: further promotion of biofuels in the EU and in developing countries, preparation for the large-scale use of biofuels and heightened cooperation with developing countries in the sustainable production of biofuels. This threefold objective breaks down into seven policy areas which encompass the priorities envisaged by the Commission. Referring to environmental issues, the strategy clearly states that "*it is essential to guarantee that feedstock for biofuels is produced in a sustainable manner, both in the EU and in third countries, particularly with regard to the protection of biodiversity, water pollution, soil degradation and the protection of habitats and species.*"

The quote above reflects the fact that the production and use of biomass can lead to greenhouse gas savings[4] but also increase other environmental pressures compared to current land use patterns. There are three main environmental considerations to be taken into account when reviewing the overall environmental effects of bioenergy production. These relate to:

a) the potential to reduce emissions of greenhouse gases, taking into account the whole bio-energy production pathway;

b) the air pollutant emissions of the production process, again compared to the fossil alternative;

c) the impact of biomass production on soil, water quality and quantity as well as biodiversity.

The development and implementation of bioenergy policies, therefore, also involves other policy areas. Figure 1 shows different aspects relevant to the development of a bioenergy strategy, the final choices often requiring difficult trade-offs.

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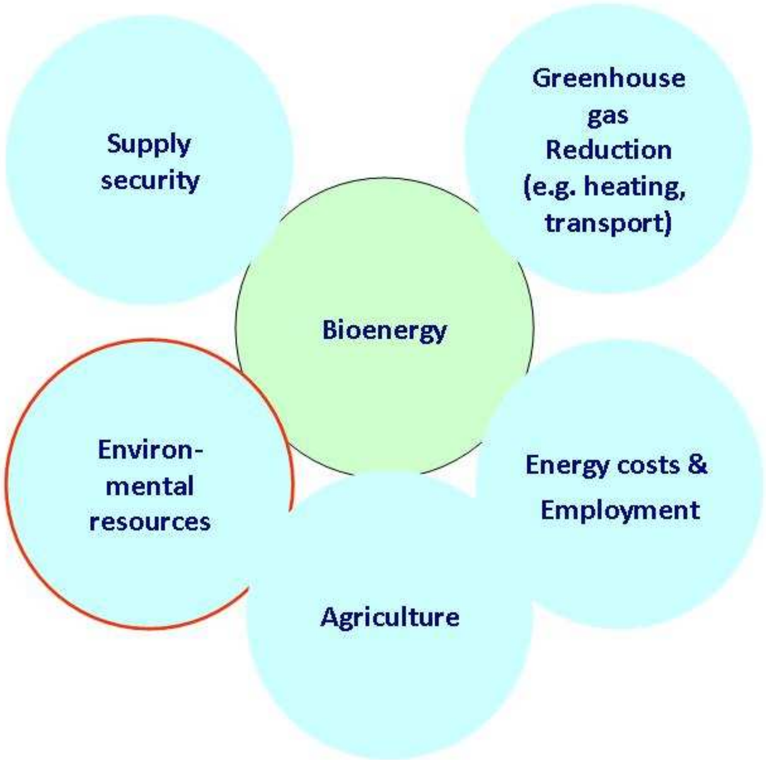
[3] This revision is currently taking place.

[4] The reduction potential of GHG emissions for some biomass use is currently under debate. For an overview see Ecologic *et al*, 2008.

Figure 1: The links between bioenergy production and other policy areas

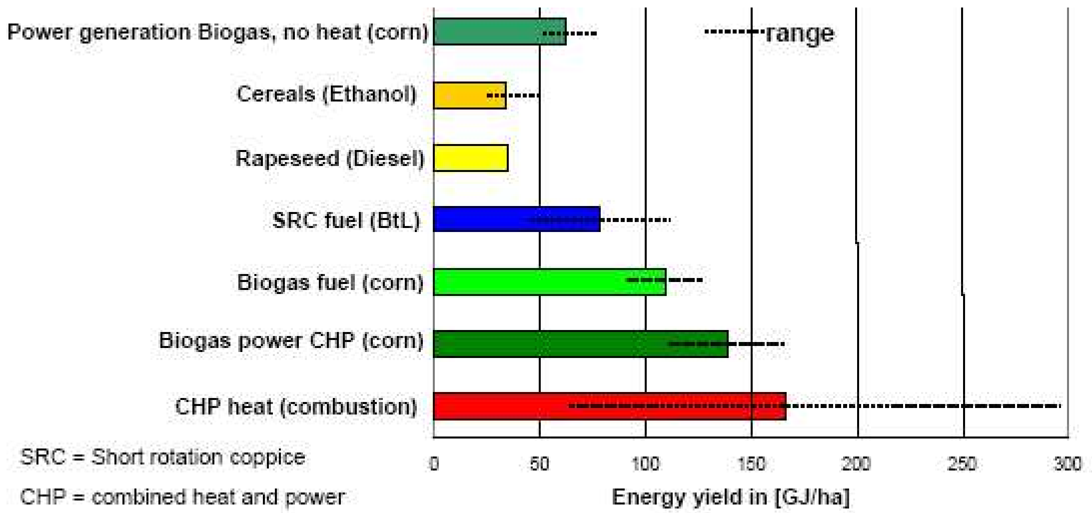


Some studies show[5] that there can be trade-offs between achieving a greater security of supply in transport fuels and the level of greenhouse gas savings associated with different energetic uses of biomass. For example, with regard to energy yields per hectare and reduction of greenhouse gas emissions, biogas as a transport fuel or for the generation of heat or power[6] is more efficient than many of the production paths of bioethanol and biodiesel (see Figure 2). A choice may also be necessary between the costs of different bioenergy pathways and their respective impact on environmental resources. This paper aims to contribute to the evaluation of potential trade-offs in the interaction between EU water protection policies and the development of bioenergy production from agricultural biomass.

[5] E.g. SRU 2007, Plank 2006, EEA 2008.

[6] Particularly the decentralized use of biomass in combined heat and power (CHP).

Figure 2: Energy yield per hectare of renewable resources from biomass for different production paths[7]



2.3 Agricultural policy: land use and environmental aspects

As a major land user in Europe (approx. 50% of total land area), agriculture has a significant impact on environmental resources such as water. Consequently, it has an important responsibility for maintaining or improving the quality and quantity of water resources to reach the standards required by the Water Framework Directive[8].

However under Article 5 of the WFD, Member States had to produce an environmental and economic analysis by December 2004. These analyses have been assessed by the Commission and led to a Communication on the first stage of implementation of the WFD[9]. The outcomes confirm that the most significant and widespread pressures are diffuse pollution, physical degradation of ecosystems and, particularly in Southern Europe, overexploitation of water. In detail, the following pressures on water caused by agriculture are pertinent (Herbke *et al.,* 2006):

- ***Nutrient load***. In the National Synthesis of the submitted Article 5 reports of the EU Member States, nutrient inputs originating from diffuse sources (mainly from agriculture) and eutrophication in all categories of surface water are listed as the second most important pressure (WRc, 2005). A similar picture can be drawn from the EEA literature study on source apportionment, which shows that agriculture is typically responsible for 50 to 80% of the total nitrogen load observed across European freshwaters (EEA, 2005a). Similar to nitrogen, phosphorus loading differs between European countries and catchments[10]. According to the EEA literature study on source apportionment (EEA, 2005a), the total area-specific loading of phosphorus (kg P per hectare per year) is highest in those countries and catchments with high

[7] SRU (2007)

[8] For more information, see Herbke *et al*. (2006).

[9] http://ec.europa.eu/environment/water/water-framework/implrep2007/index_en.htm

[10] It should be noted here that some data refer to country level, while others give the value for a whole river catchment.

population density and a high proportion of agricultural land, with agriculture contributing about 50% of total phosphorus loading.

- ***Pesticides*** are present in surface waters and groundwater at concentrations that, in certain cases, are of potential concern with respect to drinking water and that can adversely affect aquatic organisms. There is limited information available on pesticides at the European scale and the information available is controversial. According to the EEA (2004), all countries that reported on the pesticide situation (Austria, France, Slovenia, Germany, UK, Denmark, Slovakia, Romania, and Lithuania) in their State of Environment reports, with the exception of Sweden, mention a danger of pesticide pollution of groundwater. With respect to the WFD Art 5 reports, most Member States did not report pesticides as a pressure.

- ***Water abstraction for irrigation***. Extensive abstraction of water for agricultural purposes increases the risk of over-exploiting available water resources. Water demand for irrigation shows a strong regional distribution. All regions with the highest use of water for agricultural purposes are located in southern EU Member States, such as France, Greece, Italy, Portugal and Spain. In Mediterranean countries, irrigated farming accounts for a large share of total water withdrawals (83% in Greece, 68% in Spain, 57% in Italy, and 52% in Portugal), while it represents less than 10% in northern European countries (Ecologic *et al*., 2007). Between 1990 and 2000 the irrigated areas increased in size, especially in France, Greece, Italy, Spain. The irrigable area in the EU-12 increased from 12.3 million hectares to 13.8 million hectares between 1990 and 2000 (an increase of 12%) (EEA, 2005b).

- ***Hydro-morphological changes*** due to current agricultural activities pose significant pressures on surface water bodies. These hydro-morphological changes (e.g. drainage) predominantly serve irrigation needs but also include the reclamation of land for extending agricultural production.

The EU Common Agricultural Policy (CAP) has an important influence on farming in the European Union even though wider economic, social and technological trends also have a significant impact. The CAP has gradually integrated environmental concerns into its policy structure. Farm income support has largely been decoupled from agricultural production, which allows farmers a freer choice in the crops they grow. The measures that address the integration of environmental concerns into the CAP encompass environmental requirements (cross-compliance) as well as targeted environmental measures that form part of the rural development policy (e.g. agri-environment schemes, support for environmental farm advice or capital aids for environmental investments on farms).

Several measures that directly or potentially support the production of bioenergy crops are part of the current CAP policy framework. These can be divided in direct support measures under the first pillar of the CAP and optional instruments under rural development policy. The first pillar includes two key energy measures:

- Up to the marketing season 2006/7, most EU arable farmers had an obligation to set-aside 10% of their arable land. These fields can be planted with oilseeds or other bioenergy crops as long as the produce is contracted solely for the production of biodiesel or other industrial products and not sold to either food or feed markets. On the 6th September 2007 European Union agriculture ministers approved the Commission's proposal to set at 0% the obligatory set-aside rate for autumn 2007 and spring 2008 sowings. The change comes in response to the increasingly tight situation on the cereals market. It should increase next year's cereals harvest by at least 10 million tonnes (Commission of the European Communities, 2007e).

- According to Council Regulation 1782/2003, the production of energy crops is eligible for a premium of 45 Euro per hectare. To establish a budgetary ceiling on such premiums, the energy payments are restricted to a maximum guaranteed area of 1.5 Mha. If fully implemented on 1.5 Mha, the programme would cost 67.5 million Euro. In 2005, an estimated

0.5 Mha received the energy crop payment (38% of the total area) (Commission of the European Communities, 2006b).

Under the latest Rural Development Regulation (Council Regulation 1698/2005) a range of measures could be used to aid specific bioenergy production approaches. These measures are linked to all three thematic axes of the RDR:

- Axis 1 (Improving Competitiveness) provides measures with the aim of developing new outlets for agricultural and forestry products, which include the development of renewable energy materials, biofuels and processing capacity. It also covers support for the establishment of environmental farm advisory services and their use by farmers.

- Axis 2 (Land Management/Environment) can be used to support the environmentally friendly production of energy crops (e.g. agri-environment schemes) or to establish agro-forestry systems (which could have an energy purpose);

- Axis 3 (Diversification, Quality of Life) includes measures for training and education as well as the diversification into non-agricultural activities.

- Lastly, it would also be possible to use the cross-cutting LEADER measure[11] for the development of locally developed and diversified renewable energy programmes from agricultural and other sources.

[11] LEADER is a method to implement local development strategies that is designed to help rural actors consider the long-term potential of their local region. Under LEADER, regional networks of local groups can be set up and act as knowledge brokers, promotional platforms and instruments of political negotiation at the interface between local actors, administrations and other segments of society, e.g. professional organisations or training institutions.

3 Background on bioenergy production, key pathways, crop characteristics and production outlook

Renewable energies have developed strongly during the last decade, and so has the agricultural sector's production of biomass for energy. While in 1990 renewable energies accounted for only 4.4% of total EU-25 energy consumption, this increased to 6% in 2003 (EEA, 2006a) although the total energy demand presented an overall rise of 11.6% (EEA, 2006b) during the same time. The primary energy production from agricultural sources in the EU-25 in 2005 represents 0.6% of total primary energy produced. (EEA, forthcoming). This biomass for energy is grown on about 3.6 million ha of agricultural land, which is about 2.3 percent of the total arable land in the EU-25. The majority (83%) of the land used for bioenergy production is devoted to biodiesel and oil crops; the remainder is used for the production of ethanol crops (11%), biogas (4%), and short rotation forestry (2%) (EEA, forthcoming).

In the following sections some key factors of agricultural energy cropping are discussed to provide background information and to prepare for the following chapters. The chapter discusses the characteristics of the various energy crops with respect to water, fertiliser and pesticides, impacts of other agricultural feedstock (manure and residues) as well as recent and potential future developments of agricultural bioenergy production.

3.1 Main agricultural feedstock to produce bioenergy

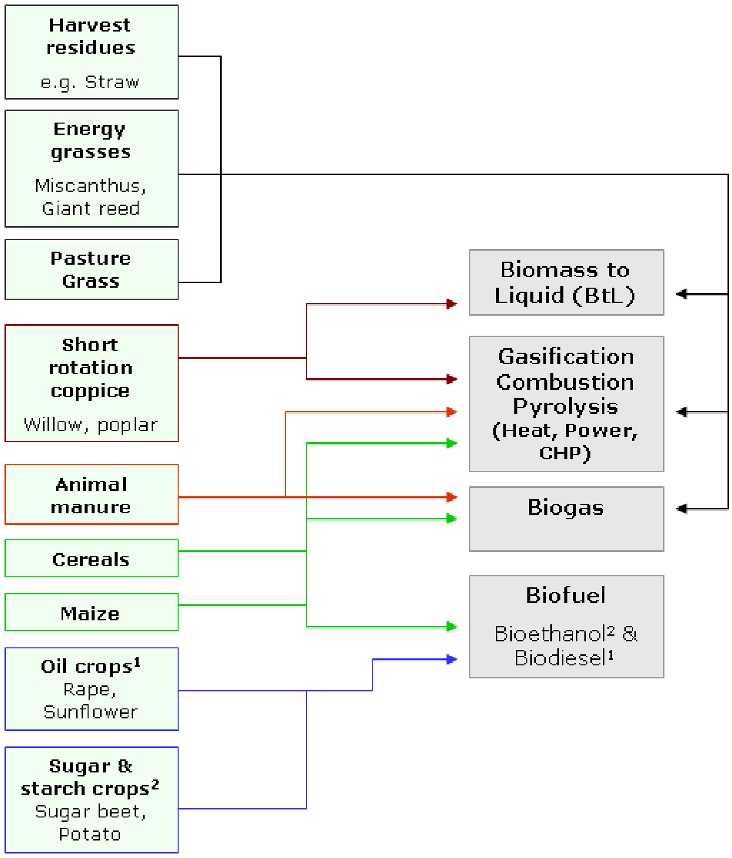
It is important to understand the variety of options available for producing power, heat and transport fuels from biomass, as the technology chosen will have implications on costs, carbon mitigation potential, environmental quality and economic impacts. It is beyond the scope of this report to provide detailed technical descriptions of each technology and the many variants that may exist therein. Rather, this section aims to provide a general introduction to the feedstock used for the main conversion technologies.

Bioenergy from agriculture can in theory be produced from all types of plants (crops, trees, grassland cuttings and crop residues) and from animal waste. In practice only a few sources from agriculture are used in the EU for bioenergy because of (current) technical limitations in the conversion process or limitations in growth[12]. The main sources used are oil crops (e.g. rapeseed), maize, wheat, rye, barley, sugar beet, leguminous plants (e.g. alfalfa or lupins), and energy grass (e.g. miscanthus and switchgrass). Some of the plants are perennials, others are annuals and for each the growth requirements are different[13]. The utilised manure comes mainly from pigs, although cattle can be regionally important. A more detailed assessment is given in the following subsections.

[12] For example soy beans to produce biodiesel can only grow under specific climatic conditions.

[13] Different crops have different requirements of water, fertiliser and pesticides in order to be cultivated and economically profitable. It is important to take these requirements into consideration when growing biomass (as well as food). The use of certain crops can easily lead to negative environmental impacts under inappropriate cropping or management systems, or in areas where the crop requirements are higher than the supply (e.g. maize in water-stressed areas).

Figure 3: Links between main agricultural sources for bioenergy and conversion processes in the EU (Source: adapted from Schlegel et al., 2005)



[1]Oil crops are utilized for Biodiesel production
[2]Sugar or starch crops are for Bioethanol production

Figure 4 shows the links between individual feedstocks and the main bioenergy production processes. These can be the currently dominant approaches (which include biofuels from annual crops and biogas) and technical processes that are still under development (the so-called second generation technologies). Current approaches include:

a) **Biofuels** for transport is not only one of the most energy-demanding sectors, it is also the most heavily dependent on oil and its derivatives. Currently, the main feedstocks to generate biofuels in the EU are oil seeds (rape, sunflower) for biodiesel, starch crops (maize, wheat, rye, potatoes) and sugar crops (sugar beet) for bioethanol.

- Biodiesel produced by transesterification, with a production rate of 4.89 million tonnes in 2006 (EU-27), remains the leading biofuel in the EU. Growth rates for biodiesel in EU are significant: capacity has increased steadily since 2002 (GAIN, 2005). Production increased by 54% from 2005 to 2006[14].

[14] http://ec.europa.eu/energy/res/sectors/bioenergy_en.htm (last accessed on 16 Sep. 2007).

- Bioethanol can be produced from biomass by hydrolysis and sugar fermentation processes and is the second biofuel in the European Union. Total EU15 production of bioethanol in 2005 amounted to 720,927 tons, an increase of 70.5% with respect to 2004.

b) For **biogas** production, mainly starch crops (maize and cereals), or animal manure are used**.** Other feedstocks include harvest residues (straw), energy grasses (miscanthus, giant reed) and grassland cuttings. In 2005 4.7 Mtoe of biogas were produced in the European Union, but the share of biogas production from agricultural sources is still of minor importance. Nevertheless, the production of biogas from anaerobic digestion of agricultural crops and residues has increased significantly in a number of EU-25 Member States, mostly due to changes in legislation in relation to co-digestion (which makes anaerobic digestion more efficient and economically profitable) and premium payments for renewable electricity production.

In the short term, investment and growth in bioenergy production is likely to take place through both the wider uptake of well-established 'first generation' technologies, such as fermentation of agricultural crops to produce ethanol, and simple combustion of biomass to produce heat and power.

In the longer term, there is considerable potential for expanding the output, efficiency and cost effectiveness of bioenergy systems through the uptake of 'second generation' technology. In the category of second generation technologies, biomass gasification, pyrolysis and combustion systems (used only to a limited extent commercially today) are included, as well as the use of non-food 'cellulosic' crops or waste materials for biofuel production:

- Thorough direct **combustion, gasification and pyrolysis,** as well as combined heat and power (CHP), a fuel intermediate, which can be gaseous or liquefied, can be produced from biomass. The energy contained in biomass is released by oxidation to produce heat, which then drives a turbine/engine coupled to a generator or drives a generator through steam production to produce electricity. The possible feedstock consists of SRC, energy grasses, cereals, maize, manure, harvest residues and pasture. The main established feedstocks in use for combustion are wood or woody residues as well as straw and cereals.

- While bioethanol and biodiesel options currently represent the main means of reducing greenhouse gas emissions in the transport sector in the near future, new technologies are being developed that are capable of converting biomass into a range of different products, including transport fuels. These technologies are gasification-based and utilise biomass to produce a product gas known as syngas (synthetic gas). Syngas can be used as a feedstock in gas-to-liquid (GTL) systems to derive fuels. The fuels that can be produced in this manner are known as **biomass to liquid (BTL)** fuels. At present, there are major BTL plant demonstrations underway in Germany, Sweden and Austria (Kavalov and Peteves, 2005).

3.1.1 Classical crops

Today's agricultural biomass production for bioenergy mainly derives from "classical" food crops such as maize, wheat, barley, sugar beet, potatoes and oil seeds (rape, sunflower). The production requirements of these crops when used for bioenergy are not very different than when they are used for feed and food (EEA, forthcoming) and are related to existing pressures on water as described in section 2.3. Turley *et al*. (2004) state that managing oilseed rape for biodiesel or cereals for bioethanol

[15] The main EU production countries with their production rates in 2005 in kilo tonnes are: Spain (240), Sweden (130,2), Germany (120), France (99,8), Poland (68), Finland (36,8), Hungary (11,8), Lithuania (6,3), The Netherlands (5,9), Czech Republic (1,1), Latvia (0,9) (EU Commission 2007).

production offers only little opportunity to reduce fertiliser and pesticide inputs compared to their management for food.

Special attention also has to be paid to the environmental risks of new varieties and species (Genetic Modified Organism or not). These risks should not be underplayed, as the impact of pests and diseases on populations could be significant. New genetically modified varieties, for example, could result in higher pesticide demand, which could be harmful to the environment (see Box 1). Further new varieties (e.g. for maize) could increase environmental problems. Energy maize, for example, has more vegetative mass (greater leaf area means higher water use), than conventional maize does and needs more fertilization (Schittenhelm, 2007).

Box 1: Genetic modified crops – a special case

Genetically modified (GM) crops with more cellulose, less lignin, and better agronomic performance are being developed and used because of the desire to increase yields and reduce the need for water and pesticides. The potential impact of GM plants is the subject of extensive research and debates, but the uncertainties are high and consequently there is no consensus. Among the possible benefits of GM crops, studies cite the potential for higher yields, qualitative improvements in crops and diversification of plant uses. However, potential benefits of GM crops must be weighed carefully against the risks they pose to wildlife, wild and organically cultivated plants, soil organisms and human health. Studies have shown that GM crops can have severe implications for wildlife[16]. Others contend that GM crops could accelerate the pesticide treadmill - whereby pervasive cultivation and spraying of herbicide-tolerant crops builds resistance in weeds, requiring ever-increasing applications of herbicides and introducing hardier weed varieties into the environment (WWI, 2006 and Schlegel and Naumann, 2007).

3.1.2 New crops

Several research projects have started to investigate new, alternative crops like Jerusalem artichoke (*Helianthus tuberosus),* Sweet sorghum (*Sorghum bicolor)*, Cynara (*Cynara cardunculus*) or Castor bean (*Ricinus communis).* These plants can provide considerable opportunity for increasing bioenergy production in the future, given parameters such as biomass yield and low inputs. Further development work is needed, however, to establish these new crops for a widespread cultivation (see JRC/EEA, 2006).

3.1.3 Perennial crops

Perennial crops, covering ligno-cellulosic crops (short rotation coppice, e.g. poplar and willow) and biomass energy grasses (e.g. reed canary grass) generally have lower environmental pressures than most annual plants have (EEA, 2007) (see chapter 4). The high hemi-cellulose and cellulose content of woody biomass from short rotation coppice results in favourable net energy conversion ratios.

Perennial grasses (Miscanthus, Reed canary grass, Giant reed, Switch grass) and Short Rotation Coppice (SRC) (e.g. willow and poplar) are recognised to present a considerable opportunity for more sustainable bioenergy production but their use is currently severely limited. The technology for an efficient conversion of these crops will not be available in the three to five years and hence the introduction of these crops at a larger scale will only happen after 2010.

[16] See http://www.defra.gov.uk/environment/gm/wildlife/

3.1.4 Grass land cuttings

Recently, livestock numbers, especially in the dairy sector, are decreasing in EU-27 and this trend is expected to continue in the future. It is estimated that about a quarter of the existing grassland area will not be utilised any longer for livestock fodder production but will be available for other uses. This might also affect marginal production areas, such as mountains, most strongly. The use of grassland cuttings for energy purposes could become an alternative perennial source of biomass and could be beneficial in terms of continuing the management of permanent pastures in order to maintain land area and functions (EEA, 2007).

The practical use of grass biomass for biogas production at the economic scale is already implemented in a number of European regions (Erdmanski-Sasse, 2007). Several research projects have looked into options for the energetic use of grass biomass from seminatural grasslands. These aim to combine nature management objectives with the utilisation of biomass for energy at both the theoretical and practical level. A wide variety of options are available to utilise this biomass for energy and other products. These options include several thermal conversion options like gasification, pyrolysis, hyro-thermal-upgrading (HTU) or biogas production. Another option is the biorefinery concept, which can generate a variety of products including transportation fuels.

Each energetic use requires specific substrate qualities of the biomass which are achieved by different management practices of grassland, e.g. different species mixtures or mowing times and frequencies. For example, fermentation in biogas plants requires high raw protein and fat content and low lignocelluloses content (same requirements as for dairy production), which implies fertiliser input, early and frequent mowing. This process is in contrast to the burning process for electricity and heating, where poor protein, high lignocellulose content, low chlorine and dry-matter content of more than 50% are required. For the latter use, no fertiliser input would be required and grass would be mowed late and dried on the field.

3.1.5 Residues (straw)

Agricultural biomass residues such as straw are the organic by-products of green plants used for food and fibre production and processing. Straw is already being used in Europe as a bioenergy resource. With an increased utilisation of biomass for energy production, crop residues will become economically more and more valuable, especially under the 2nd generation of bioenergy.

Increased extraction of agricultural residues may reduce soil quality, leading to negative impacts for water. Therefore, one of the most important questions to be clarified in the near future is how much residue can be removed for bioenergy whilst maintaining soil quality and functions. This is currently under scientific discussion, and the discussion is far from providing exact numbers. Nevertheless, there is little doubt that sufficient amounts of crop residue must be left on the soil to avoid negative environmental impacts. Sustainable removal rates will vary by region and sometimes with fields as well as between management systems, depending on the climatic conditions and the specific crop rotations (FAO, 2005).

However, another approach is to pyrolise the straw to create the so-called ‘Black Carbon’ (effectively charcoal) and return that to the soil. This delivers about 80% of the energy and a very valuable residue to the soil (Lehmann, 2007).

3.1.6 Animal slurry or manure

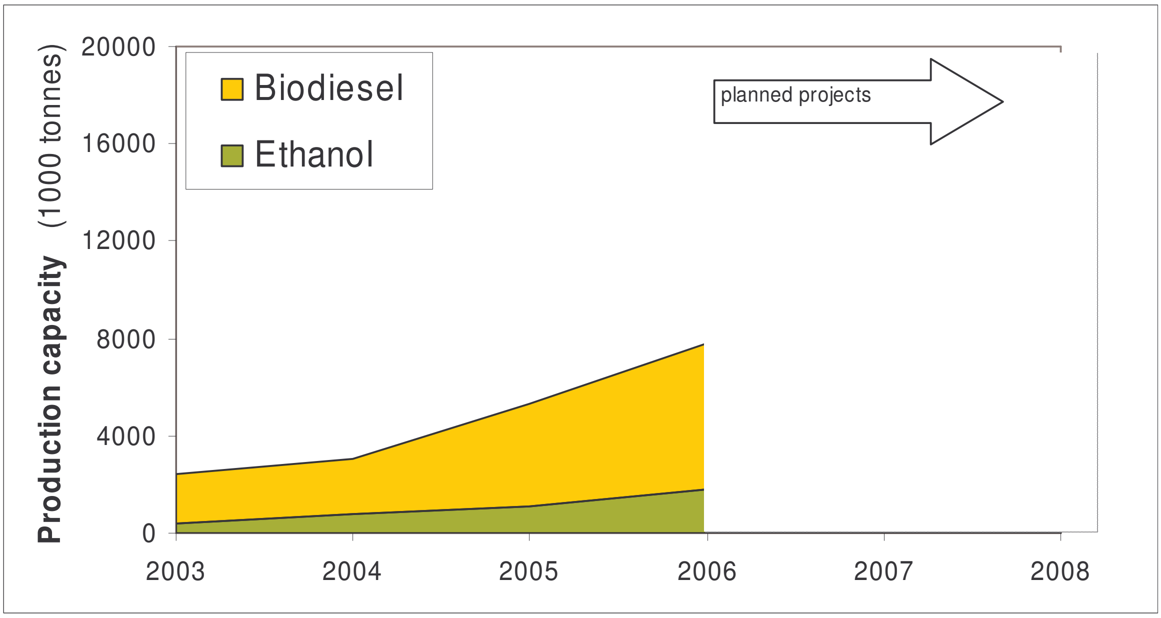
Wet slurries or manure from pigs, cows and poultry can be processed by anaerobic digestion (AD) to give a biogas that can be used to generate heat and/or electricity. Environmental considerations are the main driver for this production, such as reducing pollution arising from spreading slurries on land as well as associated issues of odour control. The high water content of wet slurries means that large amounts of energy are required to burn them, rendering them inefficient for power production through combustion. Under anaerobic conditions, bacteria digest organic matter in the absence of oxygen to produce a gas consisting of methane (40-60%) and carbon dioxide, with a liquid digestate as a co-product. This is processed into an organic fertiliser and recycled onto agricultural land.

Anaerobic digestion is usually on a farm level rather than on a larger scale. This can change in the cases where feed-in tariffs exists. Nevertheless, community-level scales have become increasingly popular where farmers pool their manure resources into a central anaerobic digestion plant. In the Dutch province of Friesland, a farming cooperative uses anaerobic digestion to supply power to a community of 25,000 people (Gorter, 2005).

3.2 Future developments of bioenergy cropping and biofuel production

It is widely agreed that energy cropping is going to increase in the near future in order to achieve the political set targets and to cope with future energy demands. Figure 5 illustrates the trends in land use, crop area, residue management and farming practices that can be expected for the next few years:

Figure 4: Expected production increase for biodiesel and bioethanol to 2008 (Wiesenthal *et al.,* 2007)



- From 2006 to 2007 rapeseed increased by +13.6% (+31.5% compared with 2002-2006 average). Rapeseed is now the fourth most important crop by area in the EU, after wheat, maize and barley. The largest producers of rapeseed, France, Germany and Poland, are estimated to have increased their areas under rapeseed by 11% (to 1.5 million hectares), 7% (to 1.5 million hectares) and 8% (to 674 000 hectares) respectively.[17]

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[17] Romania is estimated to have tripled its area under rapeseed, from 110 000 hectares in 2006 to 349 000 hectares today, becoming the fifth largest rapeseed area in the EU. Other Members States are expected to follow: Denmark, Hungary and Slovakia, for instance, are expected to increase their areas by 65% (to 184 000 hectares), 56% (to 223 000 hectares) and 19% (to 147 000 hectares) respectively. See http://epp.eurostat.ec.europa.eu/cache/ITY_OFFPUB/KS-SF-07-086/EN/KS-SF-07-086-EN.PDF

- The production of cereals in the EU is expected to reach 281 million tonnes in 2007, a rise of 5.2% relative to 2006. Areas under cereals increased slightly, +1.5%, in comparison to 2006 to 57.9 million hectares[18]. This increase is probably related to high prices on the cereals market influenced by higher demands caused by biofuel production (Ollier and Utz, 2007).

- According to data provided by DG Agriculture, 0.6 Mha of biofuel crops were actually grown on rotational or permanent set-aside land in 2004, and this figure was 0.9 Mha in 2005 (source: MEMO/06/65, 08.02.2006). This amount is equivalent to 17% of the total set-aside land in the EU-25. As has been stated in section 2.3 the set-aside obligation is currently suspended and may be completely eliminated in the future.

- Currently in the EU-27 most of the straw is used for cattle, is incorporated to increase organic matter or gets burned. Bigger installations to produce bioenergy only exist in Denmark, UK and Spain (JRC, 2006). Straw use for energy is likely to expand as new conversion technologies are developed such as ethanol from ligno-cellulose.

In the medium to long term future bioenergy production might change considerably depending on the breakthrough of different technologies as well as the support for different types of bioenergy production pathways. If ambitious bioenergy targets are pursued the land requirements for energy crops will be high. Comparing the results of different studies, the required land potentials range from 20 to 59 million hectare. Most of the reference studies calculate the bioenergy potential assuming higher prices for energy and CO_2 certificates and consider the competition with exports of feed and food. The land potential estimated by the EEA (EEA, 2006c) (20 million hectares) is the lowest, but two other studies, which also incorporated environmental considerations (Thrän *et al*., 2006; WBGU, 2004) show similar though somewhat higher land potentials (22 and 29 million hectare, respectively).

Table 1: Studies concerning land potential for energy crops in the EU

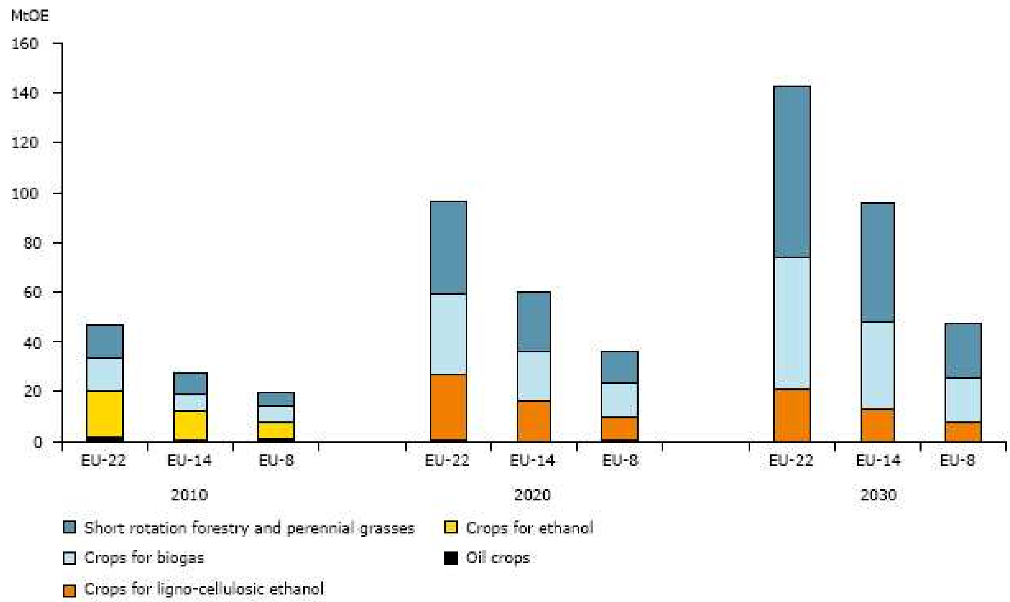
Authors	Potential	Time horizon
Lehmann *et al.*, 1996	40 mio ha in EU-15	from 2010 on, food and fibre first
VIEWLS, 2004	35-44 mio ha in EU-10	2020; food and fibre first
WBGU, 2004	22 mio ha in EU-25	ecological constraints (fallow/released land)
Yamamoto, 2001	30 mio ha in Europe	by 2025, food and fibre first
Thrän *et al.*, 2006	59 mio ha in EU-25	2020 *bottom up*
Thrän *et al.*, 2006	29 mio ha in EU-25	2020 *bottom up*+ ecological constraints: lower yields and nature conservation
EEA 2006c	20 mio ha in EU-25	2030 *bottom up*+ environmental constraints

However, most of the above studies have not looked closely at the agronomic limitations that also exist with biomass crops. In particular soil quality and the availability of water strongly influence the potential of biomass production and will be the main limiting factor in semi-arid regions (Vannini and Venturi, no year). The expansion of bioenergy production in these areas will strongly depend on the development or adaptation of new energy crops that can cope with low water availability. Further research in this area is needed to avoid the use of irrigation for energy crops.

[18] For example areas in the EU under grain maize are estimated to have increased by 3.2% to reach 8.8 million hectares with total production expected to reach 60.3 million tonnes. Romania, the third largest grain maize producer in the EU after France and Italy, has the greatest area under grain maize, 2.5 million hectares (-0.6% in comparison to 2006). See http://epp.eurostat.ec.europa.eu/cache/ITY_OFFPUB/KS-SF-07-086/EN/KS-SF-07-086-EN.PDF

According to a scenario study carried out by the EEA (2006c), the crop mix could change drastically over time if environmentally favourable technologies are promoted (see Figure 5). While in 2010 some 40% of the agricultural bioenergy potential could be dedicated to bioenergy crops for conventional arable biofuels production, this could decrease rapidly after 2010 with the assumed introduction of advanced conversion technologies and dedicated energy crops. These crops include different types of perennials, as well as rotational crops harvested as whole plants. Crops used as feedstock for biogas installations (such as maize or double cropping systems) will increase after 2020, particularly in the countries of the Atlantic and Continental zone. For 2030 it is assumed that there will be an overall higher share of the more drought resistance perennial biomass crops in the Mediterranean countries, especially of reed canary and switch grass.

Figure 5: Estimated bioenergy potential and energy crop shares 2010 - 2030 (EEA, 2006c)



4 Potential effects of agricultural bioenergy production on water resources

This chapter aims to evaluate the potential effects of bioenergy production on water quality and quantity within a logical analytical framework. In developing such a framework one is confronted with a very complex set of relationships between bioenergy production and water at different levels. Consequently, choices have to be made between analytical completeness and clarity in the presentation of results. The framework utilised below aims to cover the most important interactions and to keep the information presented readable for non-specialists. It should be noted that some potential interactions could not be analysed due to lack of data and/or modelling capacity. Such issues and remaining gaps in the analytical framework are briefly discussed in a section on further research needs at the end of this document (see Box 2).

Box 2: Estimating indirect and location-specific effects of bioenergy production on water

A further difficulty in estimating the environmental impacts linked to agricultural biomass production arises from the fact that most agri-environmental effects are very context and location specific. Their impact will depend on the current land use they are replacing and on the environmental vulnerability (to soil erosion or nutrient leaching) of the specific location within which the change is taking place. Site specific changes are not discussed here, however, as it would require detailed agro-economic modelling to distinguish bio-energy effects from other ongoing agricultural trends. Further detailed spatial data, which is difficult to obtain would therefore be required to come up with precise estimates of the environmental impacts of different energy crop options. The data, expertise and resources to carry out such modelling were unfortunately not available for this paper. The analytical challenge is even greater due to the fact that it is not easy to predict farmers' decisions, which ultimately drive new cropping patterns. Consequently, the impact of different cropping systems or management practices could only be discussed in general terms.

The complexity of the relationship between bioenergy production and water arises at different levels: The first major factor is the potential land use change associated with biomass production and its impact on water quality and quantity. The second major influence is the choice of bioenergy pathways and crop types. The third important factor is the cropping practices applied to energy crops. Fourthly, the effect of using animal manure or agricultural 'waste', such as straw, for bioenergy production needs to be investigated. Fifthly, the environmental impact of the conversion process from biomass to energy end use (fuel, heat or power) is important from an emissions perspective. In this document only some key relationships at each level could be discussed; further work is required at national level and in the research field.

The following evaluation of the possible effects of bioenergy production proceeds from the global to the field level and it follows the production pathway from biomass cultivation to the final conversion to energy. In each step the analysis covers potential negative and positive interactions. The reference level taken is either current cropping practices and patterns or an 'ideal' land use in the context of WFD objectives.

4.1 Potential land use changes associated with increased bioenergy cropping

The ambitious bioenergy targets in Europe and other parts of the world add considerable additional demand to already buoyant agricultural markets. High crop prices and the expectation of strong future demand often lead to agricultural intensification and, where possible, expansion of the agricultural area. Furthermore, the introduction of new energy crops and technologies may offer the possibility of energy crop plantations on currently uneconomic areas, at least in the medium term. Consequently, the risk of substantial land use change due to energy cropping exists. In Europe this may involve little or no expansion into non-agricultural land uses (such as forests or steppe grasslands); but there is a significant potential for land use change associated with agricultural intensification, principally the conversion of grassland into arable land[19]. Among other environmental consequences, an expansion of the arable land area would have serious implications for nutrient leaching in particular.

4.1.1 Expansion of agricultural cultivation

The recent OECD-FAO Agricultural Outlook 2007-2016 (OECD, 2007) predicts strong prices for agricultural outputs associated with a further expansion of the cereals and oilseed areas over the next 9 years. The strong additional demand for biofuels worldwide is considered a key factor for this trend. The OECD-FAO study also predicts that the EU set-aside area will be used for the production of biomass for energetic purposes. In fact, the European Commission has already proposed the suspension of the EU set-aside regime in the next two planting seasons to respond to the increased demand on the world agriculture (and bioenergy) markets[20]. Even though energy crops have already been planted on part of the EU set-aside area during the past years, this measure will increase the cultivated area in the EU-25 significantly.

A second potential land reserve comprises the significant areas of land no longer being used for agriculture and therefore no longer incorporated into agricultural statistics, in particular in the new Member States and the Mediterranean (e.g. DG Agriculture, 2002). The extent of this land is difficult to estimate; but it seems to cover a significant area in the EU-27. Most of the land affected is below average productivity, often it is the wetter fields and steeper slopes as well as poorer soils that are abandoned first. Higher crop prices and strong biomass demand are likely to make the cultivation of at least a part of this land reserve attractive to farmers.

The third potential land reserve is the area of permanent crops that becomes surplus to future food demand. The 2006 EEA study on the EU bioenergy potential estimates that up to 5 million ha of 'grassland and olive groves' in the EU-25 will be surplus to food requirements by 2030. Under several environmental aspects (water and soil conservation, biodiversity and landscapes) the future use of part of the permanent crop area is very important. Whether vineyards, for example, are converted to arable crops or planted with permanent grasses or short rotation coppice obviously makes a major difference in water protection terms.

In summary: on current trends it seems likely that some expansion of the cultivated area will occur in the EU-27 over the coming years. This will probably affect environmentally sensitive areas more strongly than others. With respect to water protection the conversion of permanent grassland to arable land is one of the main concerns. This issue is discussed in more detail in the next section.

4.1.2 Conversion of grassland

Due to its importance as a land use category and for water protection, grassland is discussed in a separate sub-section. The overall extent of permanent grasslands in Europe has been falling gradually for several decades due to many factors, including afforestation, the intensification of livestock

[19] Depending on future conversion technologies there is also a potential to change grassland into forest.

[20] On the 16 of July 2007 the EU agricultural Commissioner announced the intention to submit to the Commission a proposal to set at 0 % the obligatory set-aside rate for autumn 2007 and spring 2008 sowings, in response to the increasingly tight situation on the cereals market caused by the a combination of bad harvests in important cereal producing countries as well as growing demand for cereals and in particular maize for the production of bio-ethanol. See: http://europa.eu/rapid/pressReleasesAction.do?reference=IP/07/1101&type=HTML&aged=0&language=EN&guiLanguage=en

farming, development of sites for housing, etc. In the context of current agricultural trends and the de-coupling of many livestock payments, the EU cross-compliance rules include a standard not to convert permanent grassland to arable production, with a maximum flexibility of 10% grassland loss per Member State (EC Regulation 1782/2003).

With regard to bioenergy cropping a conversion of permanent grassland due to ploughing up would pose significant water protection problems. Initially, there is a massive release of nutrients following the decomposition of the considerable quantity of organic matter in the upper layers of the soil. After a meadow has been ploughed up, the nutrients in the roots and leaves decomposing on or in the top-soil layer (phosphorus, potassium and nitrogen), together with carbon, are often released into the environment through volatilisation, leaching or runoff. Subsequently, the complex ecosystem of the meadow environment is upset in terms of water management, causing problems such as infiltration, replenishment of water tables, flood limitation, transpiration[21].

In addition turning grass land into arable land can drastically increase soil erosion rates depending on the cropping patterns and management. Table 2 shows different estimates of soil erosion rates for 20 European sites. Similar figures have been reported from the UK where annual soil erosion losses from tillage land are generally less than five tonnes/ha and year, but can occasionally exceed 100 t/ha and year.

Table 2: Estimates of soil erosion rates (t per ha and yr) for 20 European sites and three crop types, derived from ImpelERO soil erosion models[1]

	Wheat	Sugar beet	Sunflower
Mediterranean			
Portugal	67·0	87·3	99·9
Portugal	147·9	150·0	150·0
Portugal	3·9	4·9	6·0
Spain	2·8	3·8	4·6
Greece	3·9	4·9	6·0
Italy	4·4	5·9	7·1
Italy	78·0	100·1	115·7
Atlantic			
Ireland	9·8	18·4	29·4
England	1·4	1·4	1·8
Scotland	1·4	1·4	1·8
Netherlands	1·4	1·6	2·0
France	1·4	1·6	2·0
Continental			
France	1·4	1·6	2·0
France	1·4	1·4	1·8
Germany	1·4	1·6	2·0
Germany	4·0	4·6	5·7
Denmark	3·8	4·0	4·9
Denmark	1·4	1·4	1·8
Luxembourg	1·4	1·6	2·0
Luxembourg	1·4	1·6	2·0

These rates could have a deleterious impact on terrestrial and aquatic ecosystems increasing the nutrient enrichment (particularly phosphorus) of watercourses, lakes and reservoirs. Furthermore, surveys of trout spawning beds in southern England have shown that 29 out of 51 river reaches contain more than 15 per cent of fine sediments, a threshold at which half the eggs and larvae are likely to die[22].

The 2006 EEA bioenergy study assumes that a substantial amount of grassland (several million ha) will be taken out of use in the period to 2030. To derive an environmentally-compatible bioenergy potential the EEA postulates in its study that this land has to remain under grassland cover (or under permanent crops), with grass cuttings being available for bioenergy production. However, without strong policy intervention this scenario is unlikely to become reality as livestock systems intensify further or become uneconomic. Further, a reliable market for such grass cuttings has to be created, allowing farmers to gain margins from grassland. It would appear wise, therefore, to consider promoting relevant bioenergy technologies (see also section 4.2) such as biogas or advanced conversion processes to liquid fuel, which enable a continuing use of existing grass cover, without the need for ploughing or re-seeding.

4.1.3 Potential effects of SRC plantations

When compared with the conversion of grassland to classical crops or a continuation of current cultivation, SRC plantations and perennial energy grasses offer a significant reduction of water

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21 http://ec.europa.eu/agriculture/envir/report/en/evo_cu_en/report.htm

22 http://www.environmentsensitivefarming.co.uk/media_files/pollution/defra_soil_factsheetv4.doc.

pollution risks (Christian and Riche, 1998; Kristensen, no year). However nitrate leaching has to be considered in the first year of planting in the first year as ground cover is poor and nitrate from former plantings might be washed out (Christian and Richie, 1998). In addition, there is a significant potential for a sudden release of nitrogen from the mineralisation of organic matter (a so-called nitrate flush) to occur when SRC plantations are renewed at the end of their lifetime (JRC-EEA, 2007).

Depending on crop type (especially for Miscanthus and switchgrass), biofuels crops can also reduce water abstraction needs substantially compared to annual food crops (EEA, 2006c; Kleinschmit, 2007). So depending on the margins that farmers can archieve on the market and the price of water, SRC might also be an economically attractive alternative to irrigation of conventional crops in some regions.

However, some SRC can have high water requirements, which could exacerbate water shortages. Evidence from a number of studies suggests that Miscanthus and SRC are able to extract water from as deep as 2 and 3 m respectively and those trees are able to supply much of their water requirement from ground water when it is within the root zone (Hall *et al*., 1996). Deep rooted energy crops grown on soils with large available water content will cause substantial reductions in the amount of water percolating below the root zone. Soil water deficits of up to 250 mm may develop over the growing season and in drier areas there may be insufficient rainfall during the winter months to rewet the soil to field capacity (Stephens et al., 2001).

Particular care must therefore be taken in wetland areas (Land use Consultants, 2007), where hydrological regimes may be altered, with negative impacts on habitats and downstream water dynamics. Some non-native species, such as eucalyptus, are also very effective at taking up water in dryer conditions which could pose a risk to hydrological regimes beyond specific wetland systems (even if one ignores the strongly negative biodiversity effects of Eucalyptus plantations).

4.2 Choice of bioenergy pathways and crop types

Energy crops for transport fuels dominate the bioenergy sector currently. However, other energy pathways lead to higher greenhouse gas savings and need to be developed to meet renewable energy targets in other sectors. Furthermore, in the medium-term (to 2020) the introduction of 2nd generation technology should allow the use of most types of cellulosic biomass for transport fuels (and other purposes) - see also section 3. It is worthwhile, therefore, to discuss the implications of different bioenergy pathways and crop types on energy cropping systems and their likely impact on water. It matters in environmental terms whether one uses SRC or conventional crops for biofuel production, maize or grass for biogas, wheat grain or cellulosic pellets from semi-natural grassland for heat generation etc.

This section cannot provide an exhaustive discussion of the potential the water related effects associated with all possible bioenergy pathways. Instead two examples are presented that show options for using bioenergy production as a lever for cropping system changes. The key idea here is to use bioenergy production as a tool for introducing a more environment-friendly farming approach. The economic return from an energy crop with positive environmental characteristics can potentially allow farmers to diversify crop rotations or to achieve a better use of their organic manure. However, such an integration of bioenergy production with environmentally friendly farming approaches will not happen by itself - it requires appropriate research and support as well as relevant training and advice for farmers. To promote environmentally better energy cropping systems may also require financial incentives to farmers in terms of higher feed-in tariffs, for example.

An important aspect in this context is to ensure that such more environmentally friendly production patterns in one place do not favor more environmental harmful practices in other places. The energy yield and greenhouse gas saving that can be obtained per hectare should be considered. The baseline for comparison becomes important here: what energy pathways would be possible and what (conventional) land uses are being replaced? So if extensive production with a low energy yield per hectare requires larger cropping areas the environmental problems avoided in one region might just be shifted to another if there is a fixed bioenergy demand. However, policy choices have to be made and the ideal system that combines high energy yields and greenhouse gas savings with transport fuel energy security and agri-environmental benefits does not (yet) exist.

4.2.1 Expanding of crop rotations via biogas production

The area of dedicated energy crops for biogas is increasing strongly in parts of Europe, with maize as the main plant grown for biogas. The biogas boom in Germany is already leading to local maize monocultures with associated negative consequences for biodiversity, water consumption, use of pesticides and nutrient leaching risks (Schöne, 2007). Specific biogas crops and crop rotations could be developed conceived in order to reduce the negative effects of narrow crop patterns, especially with monoculture. Since biogas can use any plant, the digesters may be fed with mixed crops, a crop of legumes to fix N, cover crops or grass from permanent meadows. Nevertheless, such crops do not achieve the same energy yields as maize and they do not automatically deliver a very positive energy or greenhouse gas balance - this depends to a large degree on the design and size of the biogas plant concerned[23].

The first potential advantage of developing bioenergy pathways that require less use of maize would be the reduction of soil erosion and nutrient leaching risks associated with this crop. The second major effect could be a widening of crop rotations beyond the currently dominant cereal crops. This would lead to a reduction of disease and weed pressures and could enable a reduced use of fertilisers, pesticides, and the plough. If one could use cover crops, exploit better soil cover and/or rooting systems by the biogas crop in the rotation there would be positive effects on water quality. Such an approach would turn biogas production into a potential advantage rather than a threat to water quality and could help improve agricultural management on a significant part of the agricultural area.

New research shows, however, that farms that specialize in energy cropping for biogas may build up a high stock of biogas digestate that can lead to nutrient leaching risks (B. Osterburg, pers. Comm.). This arises from the fact that this digestate has an even higher N concentration than slurry and in a form that mineralizes very fast. Consequently, the effective use of this organic manure on crops is difficult to manage, especially when weather or soil characteristics limit slurry application periods.

4.2.2 Establishment of multiple cropping systems

Another option for re-thinking cropping systems in the context of bioenergy production is the concept of multiple cropping systems (an approach not uncommon up to World War II). This involves the growing of two or three crops simultaneously on the same land. This would enhance crop diversity and can increase the efficiency of biomass cropping systems (due to the optimal exploitation of nutrient resources by the mix of crops and the possibility for multiple harvesting per year). If the crop mixes include legumes for nitrogen fixation, no or very low fertiliser inputs are required. Further there is a lower need for pesticides and herbicides inputs because there is lower pest pressure (no monoculture). The possible higher water demand of multiple cropping has to be considered and would allow the use of such an approach only in regions with sufficient precipitation.

[23] Co-generation of heat and electricity (also known as Combined Heat and Power, CHP) by biogas installations is essential for achieving the maximum energy gain. In addition, maize-fed biogas plants will have unfavourable greenhouse gas and energy balances if they require the feedstock to be transported from beyond a radius of 40-50 km. (Kelm and Taube, 2007)

4.3 The effect of management practices

The management practices actually applied in the field often determine the final environmental impact of a specific crop or farming system. The management of energy crops may be very different compared to conventional food crops; or rather similar. A comparison of management practices appears particularly important for annual energy crops that are also used in food systems. They are, however, also an important factor to analyse with regard to novel energy crops. These could have a significant impact if they required large amounts of inputs, whether for fertilisation or irrigation.

Agricultural management practices are often closely linked to the type of cropping system, and the two concepts overlap to some degree. Cropping system refers to the temporal and spatial arrangements of crops and to the management of soil, water and vegetation in order to optimise the biomass/agronomic production per unit area, per unit time and per unit input. Management practices can be defined as the farm operations on the field once the decision for specific crop rotations and choice of crops has been taken. For example, the decision to grow maize in a monoculture system implies a fairly limited range of specific seeding, fertilisation and pest control practices. On the other hand, the choice of a wider crop rotation that includes cover crops, legumes or root crops allows the farmer to opt for extensive soil conserving practices but could also be associated with high input levels to maximise yields.

The information presented in this section is again limited to certain issues as an exhaustive discussion is beyond the scope of this paper. Further information on the environmental ranking of specific crops and their associated practices can be found in a technical report by the EEA (2007). It has to be said that there is generally little information on the management practices associated with energy crops, in particular the novel crop types, such as SRC and energy grasses.

4.3.1 The influence of management practice

As such, the production of bioenergy crops is not limited to the conventional cropping systems for food production which have often lead to environmental problems in the past. Depending on the type of crop, bioenergy cropping allows for specific, more environmentally friendly cropping approaches, without losing profit margins[24]. For example, while the harvesting of food crops takes place once or twice a year, biomass cropping systems allow for harvesting several times a year, as immature plants can also be used. If applied extensively, such multi-cropping options could combine low environmental pressures with high yields. Table 3 gives examples of environmentally friendly innovative cropping approaches for the production of bioenergy feedstocks. However, there is no doubt that the cropping approaches presented below are strongly linked to the land use and management practices applied. Only if such cropping systems are used with environmentally-oriented farming can environmental benefits be achieved.

Table 3: Different bioenergy cropping systems

Examples of environmentally friendly innovative cropping approaches for the production of bioenergy
Mulch systems/minimum-or-no-till systems: Tillage is not applied at all or reduced to a minimum. Once the crop is established the main result of this practice is total or near-to-total soil coverage all year round. This type of system is particularly well suited to biomass production, where the quantity and/or the starch of the crop are more important than the quality. Compared to conventional rotational arable cropping systems the water holding capacity of mulch systems/minimum-or-no-till systems is higher because of year-round soil coverage. This increases water infiltration, reduces evaporation and reduces soil erosion and the risk of flooding[25].

[24] See for example: http://www.grainlegumes.com/aep/special_reports/economic_and_environmental_value_of_grain_legumes (last accessed on 16. Sep. 2007)

[25] http://www.ecaf.org/First.html#3.c (last accessed on 16. Sep. 2007).

Double cropping: In agriculture, double cropping is the practice of growing two or more crops in the same space during a single growing season. Double cropping is found in many agricultural traditions and has been adapted to modern farming systems in the last two decades, e.g. in Germany (Scheffer und Karpenstein-Machan, 2001; Heinz et al., 1999; Karpenstein-Machan, 1997) The systems fit in an environmentally-orientated farming system, e.g. by reducing nitrate leaching to groundwater, and combining the production of high biomass quantities with a whole year green cover, limited input use and cultivation efforts. Both crops are harvested green to produce silage for biogas. Requirement for pesticides and herbicide use is also low, as weeds also constitute biomass. Negative impacts on environment may be caused by higher mechanisation intensity because of harvesting twice annually. This may lead to increased soil compaction particularly after late harvest of second crop in autumn. However, since double cropping is often practiced with minimum tillage this reduces mechanisation intensity again. But minimum tillage often requires herbicide application before seeding the second crop. The possible higher water demand of double cropping has to be considered. Therefore the system is restricted to regions with enough water availability.
Multiple cropping: To increase the efficiency of biomass cropping systems, several researchers are looking into multiple cropping systems, which involve the growing of two or three crops simultaneously on the same land (EEA, 2007). This can enhance crop diversity. If the crop mixes include legumes for nitrogen fixation no or very low fertiliser inputs are required. Further there is a lower need for pesticide and herbicide inputs because there is lower pest pressure (no monoculture). The possible higher water demand of multiple cropping has to be considered (U.S. Congress, Office of Technology Assessment, 1993).
Row, strip, or alley cropping: In these systems, perennial biomass crops (SRC or tall biomass grasses) are grown in linear strips in arable agricultural landscapes, e.g. around fields and along rivers and canals. They deliver ligno-cellulose material for different bioenergy uses (e.g. gasification, bio-electricity, Fischer-Tropsch biofuels). The main environmental advantage of creating such strips is that they increase landscape diversity, which will enhance biodiversity in farmlands, and help prevent (wind and water) erosion and decrease nitrate leaching to surface waters.

4.3.2 Management practices in annual crops

At present there are no specific energy varieties among the annual crops grown for bioenergy production. Amongst conventional annual crops, cereals (rye and barley) and sunflowers usually have a better environmental profile (EEA, 2006c and Commission of the European Communities, 2007b), whereas wheat, grain maize, potatoes, sugar beet and oilseed rape have a relatively high negative impact on the environment. Nutrient input is generally high for these crops but varies strongly between countries and farming practices (EEA, 2006c).

However there is a need to consider the different quality demands in order to estimate the environmental impacts. It is also likely that most farmers apply the same cropping practices as for equivalent food crops but this might change in the future. For example, in cereal production a high starch and low protein content is required for seeds delivered into ethanol production. Therefore less N-fertilisation is needed (KTBL, 2006). Further environmental impacts might also be reduced where grasses or crop mixes are grown for biogas production and there is less need to eliminate weeds. On the other hand, there are also concerns that environmental impacts could become worse in several areas due to bioenergy production. As biomass production for energy purposes has as its main aim the production of high quantities without any quality requirements, it is likely that regulations in relation to inputs used (e.g. pesticides) are generally less stringent than for feed and food products. As a result, the use of inputs could be higher. While the use of nutrients is often limited by measures under the Nitrates Directive (Council Directive 91/676/EEC) and linked to Cross Compliance regulations, pesticides and herbicides could become an issue. Whereas many farmers are concerned that pesticides in food production could affect public health, these concerns could see themselves diminished when growing bioenergy crops.

Beyond the risk of increasing diffuse pollution, water availability might prove another key concern. Agriculture is already a significant user of water resources in the EU, in particular for irrigation. The impact of irrigation differs between countries and regions, due to climatic conditions and land uses. In terms of area irrigated and amount of water used, water demand for irrigation is relatively insignificant in Ireland and Finland, modest in Sweden, Luxembourg and Denmark, of increasing regional importance in the UK, Belgium, the Netherlands, Germany, Austria and France and nationally significant in Portugal, Spain, Italy and Greece. Irrigation for agriculture accounts for over 80% of total water abstractions in Greece, 72% in Spain, 60% in Italy and 59% in Portugal. This often leads to water scarcity in areas with intensive agriculture (Commission of the European Communities, 2007f) and there are concerns that bioenergy cropping will increase this water stress in several areas due to increasing irrigation.

In such cases of water restriction due to summer droughts, the type of classical crop grown can influence the level of water stress. While some crops have a high water demand in summer when water is generally low, for some crops the cropping calendar is centred on the autumn and winter months when soil water reserves are high. This reduces the risk of crop failure and water stress in summer. For example, the maize flowering period (during the summer) is particularly sensitive to drought events and requires high amounts of irrigation. Maize has a high water use efficiency and the same water requirement as wheat (around 500 l/m^2/year), but whereas wheat has a long cropping cycle, maize water demand is concentrated during the peak-demand summer months. Oilseed rape, winter wheat and winter barley also form part of this category. High water demand from fast-growing perennial energy crops was also identified as a key environmental risk in a recent expert workshop on short rotation coppice and energy grasses (JRC-EEA, 2007).

As stated above, further information has to be built up on energy cropping practices. Annex I provides one possible system that assesses relevant factors, developed by the EEA (2007). While it is certainly not the final solution it could be a starting point for further research.

4.3.3 Management Practices in perennial energy crops

The management practices of perennial energy crops with a rotation time of at least 15 years require harvesting of the biomass after two to five years. This reduces machinery requirements compared with arable crops, reducing soil compaction and erosion. However, the harvesting of Miscanthus in winter time can lead to structural damage to soils and to soil erosion if the grounds are not frozen or at least very dry during the harvesting operation (WCL, 2007).

Further weed control is required for short rotation coppice before cultivation, shortly after planting (Tubby and Armstrong, 2002). Similarly, Miscanthus only requires pesticide application during the early establishment phase to keep out competitors (Bullard and Metcalfe, 2001). For most of the growing cycle, therefore, no additional pesticide is required, resulting in lower probability of contamination of groundwater sources through pesticide than with annual food crops.

Box 3: Some comparison between perennial crops and conventional crops

Research carried out by the Danish Institute of Agricultural Sciences (DIAS) on perennial crops showed very low levels of nitrate leaching over a seven-year period; this was also the case in optimally fertilised crops for willow and Miscanthus. The results indicate that a shift from conventional agricultural crops to perennial energy crops can potentially reduce nitrate leaching by 70%. The extended growing season of perennial crops means that they are particularly effective at minimising nitrate leaching from animal manure[26].

[26] http://www.agrsci.dk/ny_navigation/nyheder/nyheder/a_shift_to_biofuels_may_reduce_the_environmental_impact_of_agriculture (last accessed on 16. Sep. 2007).

Pimentel and Krummel (1987) estimate that erosion resulting from short rotation woody crops is less in magnitude than from row crops, while hayland (or switch grass) causes less erosion compared to woody crops. The decrease in erosion with SRC may be greater if a cover crop is used to stabilise soils during the first two growing seasons (Ranney and Mann, 1994). In addition, conversion of cropland could have significant impact on the quantity of runoff. Woody crops have a larger leaf area than annual crops and maintain that leaf area for a considerably longer portion of the year. This factor, plus their deeper rooting depth, could result in substantially greater evapotranspiration and less potential for runoff and leaching (Green *et al*., 1996), but in water scarce areas this can also have negative effects.

4.4 The use of animal manure and agricultural residues

Using animal manure for energy production can have important benefits if this reduces current surpluses of organic manure that can be found in intensive livestock systems, or renders the management of N-resources on farms more efficient. However, the use of agricultural by-products (e.g. such as straw) can have negative impacts if this reduces the organic matter content or cover of soils due to the increased harvesting of biomass (e.g. via straw removal). All these interactions need to be carefully analysed.

4.4.1 Using biogas for treatment of slurry and manure

Manure, which often contains high levels of nutrients, is a resource that enhances plant growth and adds organic matter to improve soil structure. It is therefore important to enhance the recycling of these nutrients and to optimise its utilisation in agricultural production through proper collection and storage routines and through proper application methods. This can reduce the application of mineral fertiliser and allows the closure of local material flow loops.

On the other hand the use of manure on intensive livestock farms carries considerable environmental risks as it mineralizes progressively when applied to the field depending on weather and soil parameters. All the mineral nitrogen released by the organic nitrogen will not be absorbed by the vegetation: the non-used fraction will be leached to the water (nitrate) or released to the atmosphere. According to the latest implementation report of the Nitrate Directive regionalized estimates of the application rate of nitrogen from manure show amounts exceeding the threshold of 170 kg/ha year in Belgium (Flanders) and the Netherlands, but, also, at local level, in Italy, France (Brittany), Spain and Portugal. Manure nitrogen application rates at regional level between 120 and 170 kg/ha are also found in Denmark, United Kingdom (England), a few counties of Ireland and in Southern Germany. All the above mentioned areas also have the highest total nitrogen and phosphorus application rates (manure plus chemical fertilisers) with values exceeding respectively 240 kg nitrogen and 90 kg phosphate per hectare per year (Commission of the European Communities, 2007c) leading often to high levels of nutrients in the water.

Besides high levels of nutrients, the pathogens in manure can also make water unsafe to drink or to use for recreation. Dairy farms, livestock holding areas and feedlots are often areas of concentrated animal waste which can be washed off of land surfaces by rain and irrigation into local rivers and streams, and end up contaminating the local groundwater.

The anaerobic digestion of animal manure in biogas plants is a way to produce energy from biomass without loss of its fertilising value: both the humus value and the mineral fertilisers (nitrogen, potassium, phosphorus) are preserved. Anaerobic digesters can convert the energy stored in organic materials present in manure into biogas, which can be fed directly into a gas-fired combustion turbine to produce electricity or gas for heating. During anaerobic digestion, the readily biodegradable organic matter is converted into biogas, and the stable organic matter remains. After digestion, the digestate is usually stored and spread in the fields like a manure or a compost. In some cases, digestate may be processed further, for example: sieving to separate a solid fraction and a liquid one.

Considering the above mentioned issues, biogas production from manure tends to be compatible with soil conservation and raising soil carbon content if used properly. The availability of nutrients in digestate is higher than in untreated organic waste. Nutrients are mineralised and allow a higher uptake[27]. So a smaller proportion is lost to water and air, reducing the pollution due to nitrogen. In other words the use of manure for energy production may be a cost effective measure to reduce diffuse pollution in regions with high manure surplus. Short transport routes between farm and biogas plant have to be ensured in order to guarantee a positive CO_2 balance. However there is also the risk that additional accumulation of nutrients in farms with biogas plants takes place due to additional import of substrate (or of feedstock for cattle, if the maize goes into the biogas plant).

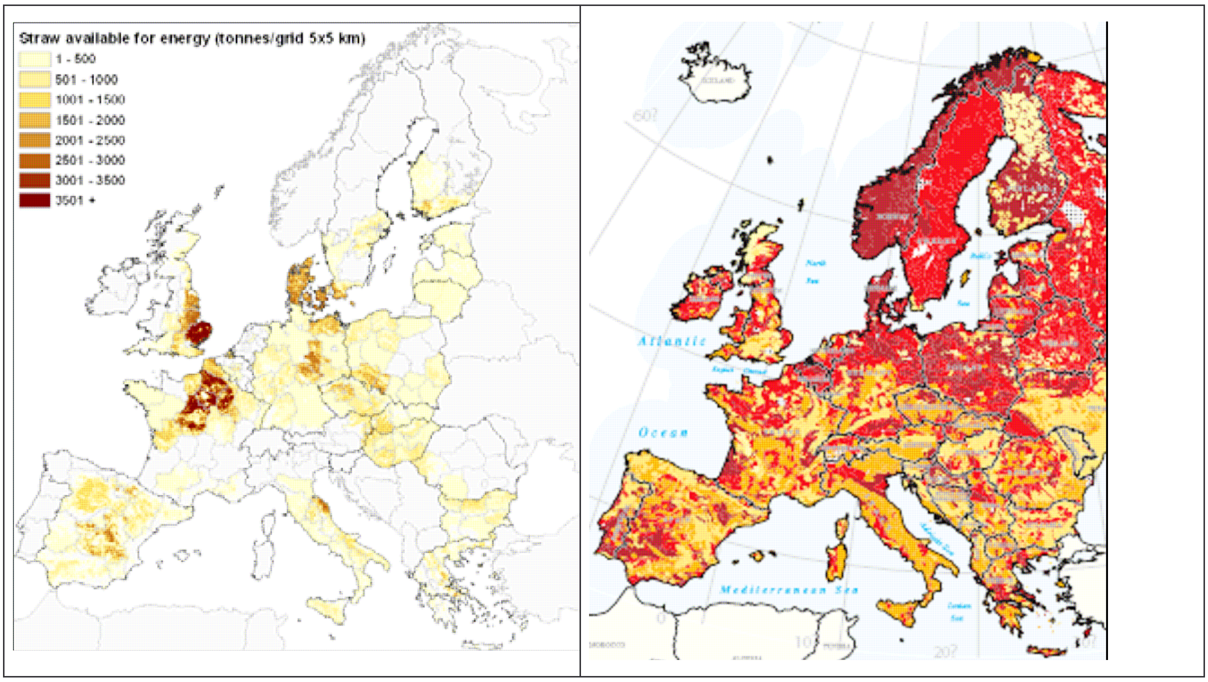
4.4.2 Use of agricultural residues

Residues help intercept nutrients and chemicals and keep them in place until they are used by the crop or degrade into harmless derivatives In most cases agricultural residues are a largely untapped resource. This low cost feedstock is more abundant and contains greater potential energy than simple starches and sugars. Currently, agricultural residues are ploughed back into the soil, composted, burned or disposed of in landfills. According to a study by the JRC, the future potential to use straw for bioenergy is considered as high (Edwards *et al.*, 2005, see Figure 6). The potential was estimated based on straw production (1000 tonnes/region) in 2003 reduced by the straw used per head of cattle in the same region. The possible effects of systematic straw collection on environmentally sensitive soils has not been addressed by the study.

As by-products are not produced specifically for use as a bioenergy resource, their use does not generally increase environmental pressures. However, these materials play important agri-environmental functions. Leaving crop residue, such as wheat straw, olive husk, sunflower stalk, rice straw or tobacco stalk, on the soil surface reduces runoff and soil erosion, through sheltering the soil with a non-erodible material (cover), conserves soil moisture, helps keep nutrients and pesticides on the field, and improves soil, water, and air quality (Steiner, 1994). Excessive harvesting of residues can also reduce the ability of rainfall to infiltrate the soil and replenish groundwater supplies (Kartha, 2006). Consequently, the level of co-harvesting strongly influences soil quality and soil erosion, leading to negative effects on water quality.

[27] See http://www.landbrugsraadet.dk/view.asp?ID=2281

Figure 6: Net availability of straw for energy (left) and soil erodibility classes (right). (Source: Edwards *et al.*, 2005 (left) and European soil data base[28] (right)).



Legend: yellow: low straw availability for energy/ erodibility; red: high straw availability for energy/ erodibility

If one compares the two graphs in Figure 6 a high straw availability for energy purposes is indicated in areas with high erodibility. From this comparison it comes clear that agricultural residues removal rates and the quantity that must be left on the land have to be assessed in detail, considering climate conditions (wind patterns, rainfall patterns), and local site suitability (soil type, soil fertility, land slope, risk of soil erosion) and farming practices (culture crop rotation, tillage practices) in order to avoid further negative environmental impacts.

4.5 The impact of conversion processes

Industrial bioenergy conversion technologies can be classified broadly into the following three fundamental forms of biomass energy use (Woods and Hall, 1994).

- "Modern thermal industrial", in which industries are using technologically advanced thermal conversion technologies with conversion efficiencies between 30 and 55%.
- Newer "chemical conversion" technologies ("fuel cell"), which are capable of by-passing the entropy-dictated Carnot limit which describes the maximum theoretical conversion efficiencies of thermal units.
- "Biological conversion" techniques, including anaerobic digestion for biogas production and fermentation for alcohol.

[28] http://eusoils.jrc.it/ESDB_Archive/ESDBv2/fr_thema.htm (last accessed on 16. Sep. 2007).

The water needs and the resulting wastes are different depending on the type of conversion technology and the type of fuel produced. In this context one of the biggest challenges for almost all conversion technologies is the high variability in mass and energy density, size and moisture content of the biomass sources used.

4.5.1 Use of Water

While the moisture content of fuel for the production of electricity or heat by **thermal plants** should be rather low, such plants use large quantities of water for steam production to run the generator and for cooling (up to 189 500 l/MWh produced). Conventional cooling methods such as once-through cooling need large natural bodies of water (ocean, sea or major river) for disposing the waste heat into them, causing thermal pollution. Evaporative (wet) cooling towers require less water than once-through systems, but significant amounts of water are still evaporated into the air (Myhre, 2002). The use of dry cooling systems completely eliminates the need for cooling tower make-up water. Emitting only warm and clean air, these dry systems have no adverse environmental effects, while at the same time freeing power plants from dependence on water sources. Such dry cooling systems have three main advantages:

- They allow for full power in cases of water shortages or water temperature fluctuations.
- They can be used in water-scarce areas, as they do not impact local water resources.
- They imply no costs for water in areas where water pricing policies are established.

For chemical and biological conversion processes, water is a prerequisite to run the chemical or biological processes. For **ethanol production** water is needed i) in fermentation, ii) for cooling duties, iii) for washing purposes. According to a study of the Minnesota Institute for Agriculture and Trade Policy (Keeney and Müller, 2006), consumptive water use by ethanol plants largely comes from evaporation during cooling and wastewater discharge. Ethanol plants are designed to recycle water within the plant. The quality of the cooling water is key, because of the need for high quality water in the boiler system. Minnesota ethanol plants report a wide range of water use, with most plants in a range from 3.5 to 6.0 gallons (13 – 22 litres) of water consumed per gallon (3.7 litres) of ethanol produced. Similar figures are reported by other sources:

- New cellulose ethanol technology is projected to use around five gallons of water for every gallon of ethanol produced, while corn ethanol is reported to use anywhere between 2 to 10 gallons of water per gallon of ethanol (Sheehan, 2007).
- Each litre of ethanol requires between 8 – 20 litres of water, depending on raw material, process and location[29].
- In the case of cereals, flour, and dehydrated potatoes, the production of 100 kg of raw material requires 300 to 400 l of water. The exact quantity depends on the concentration in the raw material, as well as on the mash concentration. In the case of "fresh" potatoes, it is in some cases possible to do without additional water and even drain water (Sidio, 2002).

From the figures above it becomes clear that water availability is an important issue when setting up bioethanol plants. Not only because the production of the feedstock can require high amounts of water, but also because of the water requirements of the conversion plant itself.

It should be noted that the water pricing policies to be established under the WFD by 2010 might lead to higher cost for biofuels in cases of water intensive conversion process. This might make the

[29] http://www.aiche-nlbe.org/documents/AIChE%20Bioethanol.pdf (last accessed 16. Sep. 2007).

production of biofuels in many areas economically unfeasible. However, most water used in these industrial processes is not consumed but ultimately returned to the environment. Consequently, the environmental impact may be limited if plants are not located in sensitive sites.

Less information was found for the conversion of biomass to **biodiesel**. Biodiesel needs to be "washed" before it can be safely used in most engines. Washing and polishing biodiesel is therefore an essential part of biodiesel production. The process of washing biodiesel removes impurities from your alternative fuel, such as excess lye, which can severely damage engines. Detailed water needs could not be identified within this study and should therefore be part of further research.

4.5.2 The issue of by-products

The different conversion processes of energy crops into biofuel and biogas lead to different waste products, which can have negative effects on water resources if used in agriculture again and not treated carefully[30]. Other residues, such as residues from biogas production, might be beneficial to agriculture if used appropriately. The following section tries to assess these threats and benefits from waste resulting from conversion processes. It is important to note that only a few studies exist and further research in this area will be needed.

Biogas – By-products/Remains:

The remains of the fermentation process (manure and plant residues) are usually used as fertiliser for agriculture (Kaltschmitt und Hartmann, 2001). Through the fermentation process the fermented material reaches a higher level fertiliser quality than pure liquid manure. Pathogenic germs and weed seeds are eliminated and nutrients become more readily available for the plants, rendering fertiliser from such a source a viable alternative to mineral fertilisers (FAO 2001). The good fertilising quality of the remains also adds to the economic value of the whole biogas production plant (ILN 2005).

- **Manure and plant residues**: Assuming that no over-fertilising practices are applied the use of fermented material from the biogas production process as fertiliser would have a positive effect on water quality, except. For one thing, nutrients are more readily available to the plants compared to a mineral fertiliser (Schlegel *et al.*, 2005), and are thus more likely to be absorbed by the plant instead of being washed into surface or groundwater. Compared to normal liquid manure, remains from biogas production carry less pathogens and weed seeds (Kaltschmitt and Hartmann, 2001), reducing the need to apply pesticides, which are therefore less likely to reach the aquatic environment.

- **Press water**: Sometimes it is necessary to reduce the liquid content of the fermentation remains for further use. From this, press water results as a further by-product, which can be re-used to initiate another fermentation cycle or a compost process (Kaltschmitt and Hartmann, 2001). Press water which can not be returned to a fermentation or decomposing process can be used directly for irrigation purposes due to its high nutrient levels. Before discharging into a receiving water body, however, process and press water have to be treated accordingly (Kaltschmitt and Hartmann, 2001).

Biodiesel - By-products/Remains:

Biodiesel is obtained in a two-tiered process. In a first step, oil is produced from the seeds of various biomass crops, such as oilseed rape or sunflower, by mechanical extraction. In a second step, vegetable oil is converted into biodiesel by a chemical process.

[30] The risks of land filling these wastes are not discussed in this paper, nor is the issue of waste water treatment. It is assumed that in such cases the best available techniques are applied and sources of environmental pollution are minimised to the technical maximum.

- **Press cake / extraction grist**: The oil can be extracted from the plant seeds in two ways. When cold pressing the oil from the oil seeds, a press cake is left with a remaining oil content of over ten percent, which is put to further use as a protein-rich fodder, organic fertiliser, combustable, or as raw material for biogas production (McKendry, 2002). Another method to extract the oil is to press the oil seed at higher temperatures after pre-treatment. The remaining oil is extracted from the press cake with solvents at temperatures of up to 80ºC. A so-called extraction grist is left, which can also be used as fodder (Paul and Kemnitz, 2006).

- **Glycerin**: Biodiesel is made in a second step from vegetable oil by ester interchange. Methanol is required for this process, which is mixed with the vegetable oil. In the chemical reaction, glycerine is also produced, an alcohol which is used in many industries such as the pharmaceutical and food industries and in oleochemistry (Paul and Kemnitz, 2006).

- **Further by-products** are produced in little quantities and are of less importance (Kaltschmitt and Hartmann, 2001).

None of the by-products and remains can be regarded as exerting an additional pressure on the aquatic environment, given an adequate treatment of the chemical substance glycerine.

Bioethanol - By-products/Remains:

The fermentation of starch crops produces mash as by-product. This is usually rich in nutrients and can be used as fodder or as fertiliser. Another field of application is to use mash as feedstock for biogas production (see above). The further use of mash cannot be regarded as having a negative impact on water resources.

Biomass to Liquid (BTL) – By-products/Remains:

None of the remains of the BtL process can be considered to have a negative impact on the aquatic environment through their further use, as remains are used as construction material (slag) or re-used for fuel production (wax) (Paul and Kemnitz, 2006).

Burning:

The burning of biomass for heating or electricity generation also generates residues in the form of ash. Much of the ash produced contains heavy metals, rendering the ash too toxic for reuse; however, bottom ash generally contains lows levels of heavy metals, which makes it possible to use for fertilisation of agriculture fields and forests. Recent research (Vervaeke *et al*., 2005) indicates that production processes still need to be perfected, as levels of certain heavy metals (e.g. cadmium and zinc) currently cannot be reduced enough to make the bottom ash acceptable for reuse for agricultural purposes. The reuse of ash for forest stands, however, is currently practiced (e.g. Sweden and Finland).

4.6 Develop standards for good agricultural practice for energy cropping

While for food cropping good agricultural practice requirements have been developed, the application of these standards in bioenergy cropping is not always that easy. For example, organic agriculture for food production focuses on nutrient cycles, soil protection, crop diversity and bio-control of pest and weeds in organic farms. While for energy crops the bio-control of pest and weeds can be managed in the same way as for food cropping, closing nutrient cycles with the help of composting, mulching, green manuring, crop rotation, etc. can more difficult. Nutrients exported from the farm with the sold produce can approach close to 100% (e.g. if all crop-residues are combusted) and need to be replaced in some way (Müller, 2007). Closing this gap can be done by mineral fertiliser or, if available, by waste materials from the production of bioethanol and biogas that are rich in mineral nutrient and recalcitrant organic carbon.

The main purpose of the following section is to provide suggestions for the development and implementation of codes of good practice for bioenergy cropping, which could be enforced under the programs of measures. The focus lies clearly on the issue of water, but if applied several co-benefits can be achieved for soil and biodiversity:

Soil

- Farmers should be encouraged to create organic matter balances when selecting the crop rotation, and seek opportunities for cover crops and applications of organic manures.

- For crops that are harvested in the winter, rainy periods or on very wet soils, clay soils are particularly prone to structural damage from heavy machinery[31]. Over time this can reduce the yield potential. Adjust tyre pressures for all field operations to field conditions.

- Rotations using three or more crops - combined with a conservation tillage program - improves soil structure, which in turn increases soil organic matter and water infiltration rates After harvest, a considerable amount of straw should remain on the soil surface, which decreases the risk of erosion by wind or water.

Fertiliser

- Farmers must comply with all national and European legislation regarding the use of fertilisers

- Improved nitrogen fertiliser application to reduce nutrient emissions. This includes soil testing, nutrient balancing and appropriate application techniques.

- Never apply fertilisers in frozen or water run-off conditions.

Pesticides

- The use of pesticides is strictly regulated by national and European legislation and farmers must comply.

- Using Integrated Pest Management (IPM) may help lower crop pest management input costs.

Water abstraction

- Comply with all national and European legislation.

- Obligation of metering and reporting water abstractions.

- Adapt production to the amount of water available locally.

Crop rotation

- The introduction of annual biomass crops if this requires a relative increase (as compared to the present situation) in irrigation, pesticide and fertiliser inputs and mechanization should be avoided.

[31] Unless the soil is frozen in winter.

- Perennial energy crops allow new methods of cropping which are considered more environmentally friendly.

Land use

- Energy crops should not replace land uses that are known to support aquatic ecosystems or areas that have the potential to be restored. This is particularly important under the WFD, as the Directive has a non deterioration clause and also requires the restoration of aquatic ecosystems in order to achieve the good water status.

Training and advisory services

- Regular training and the use of advisory services by farmers should be encouraged in order to ensure that the most recent knowledge is applied in the field.

An important issue when developing such good agricultural standards is the consideration of site specific conditions (e.g. climate, topography, soil conditions). Cropping should consider the ecological sensitivity of the actual land used but also adjacent land, since this can be affected as well. When developing national biomass action plans, energy crop plantings should be located in areas where environmental benefits are maximised and potential negative impacts are avoided/minimised.

5 Creating win-win situations by linking WFD measures and bioenergy production

River Basin Management Plans to be established under the WFD require programmes of measures as a response to current and potential future pressures from agriculture and other sectors. Currently most Member States are in the process of selecting these measures and at the same time several Member States are following the European Commission's invitation and are developing national Biomass Action Plans (nBAP)[32].

Although chapter 4 has mainly addressed environmental risks associated with bioenergy-related land use change, there are also some positive impacts from new bioenergy-linked land uses[33]. For example, when planted strategically and in sufficient proportion, SRC plantations or permanent grasses could help to limit soil erosion rates, attenuate peak run-off flows or minimise nutrient or pesticide leaching risks and could reduce existing agricultural pressures. Such benefits would seem particularly useful as they create win-win situations; securing farmers income and improving the environment.

In this chapter, examples of such win-win situations have been identified with the aim of supporting Member States in this process of identifying and discussing potential WFD measures. When looking at the set of measures proposed it becomes clear that the scale at which these measures can be applied varies widely. Some can be applied locally (e.g. buffer strips) some will have an effect on large European regions (e.g. water pricing). However there is little doubt that further measures exist and more research in this area is needed to understand better the agri-environmental linkages as well as the socio-economic implications.

While this chapter describes possible measures that can be taken within a programme of measures linked to the WFD, there are important decisions on the nature of bioenergy production (and its associated impact on water) that belong to the field of bioenergy policy. Some of these are reviewed in chapter 6, others require further research.

5.1 Increased use of energy crops as buffer strips

A prominent measure discussed under the WFD programs of measures is the establishment of buffer strips. Research has shown buffers to be most effective in trapping particulate pollutants but they also are beneficial in reducing the export of soluble pollutants. So, buffer strips are expected to reduce concentrations of nitrogen, phosphorus, and sediment in surface water runoff (Wenger, 1999).

Farmers often resist the notion of mandatory buffer strips, as they can cover considerable proportions of their agricultural area, resulting in losses of profit. So, in the past establishing buffer strips on a wider scale was often linked to compensation payments by public authorities using Rural Development programs or drinking water companies which reduced their treatment costs. But recent examples have shown that cross-compliance can be an appropriate tool to ensure the setting up of compulsory buffer strips in relevant sensitive areas. France has introduced in this framework the obligation for farmers to have 3% of the overall arable crop area converted into buffer strips and to put them along rivers as a priority. Such standards will prove even more important in a scenario of suppression of set aside.

32 See http://ec.europa.eu/energy/res/biomass_action_plan/nationa_bap_en.htm (last accessed on 16 Sep. 2007).

33 The benefits of producing biogas from manure have already been addressed in section 4.4.1

Riparian buffer strips with permanent vegetation, such as perennial grasses and short rotation woody crops (SRC) located within and between agricultural fields and the water courses to which they drain could create win-win situations. On one hand they improve the water quality (Shepard and Tolbert ,1996); on the other hand the crops grown can be used in ethanol production. So using buffer strips for bioenergy production could allow farmers to obtain income from buffer strips and compensation payments could be reduced or phased out.

However the application of such buffer strips has to be done with care. Broad strips of energy crops grown in riparian zones could use up to twice as much water as the same crop grown in the same spatial arrangement on an upland site without access to ground water (Stephens *et al.*, 2001). This has to be considered in particular where ground water recharge is limited due to low summer rainfall and water stress might be increased. Furthermore, there are possible implications for landscape and biodiversity values that need to be taken into account. Buffer strips may also cause pollution swapping. The nitrate is removed by denitrification, producing some nitrous oxide (Stevens and Quinton, 2008).

5.2 Creation of flood retention areas

The modification of water courses, the construction of barrage weirs and a lack of water retention due to the expansion of settlement areas, intensive farming, damaged forests in mountainous areas or the correction of small flowing waters have lead to diminishing flood plains, thus increasing the number and severity of flood events. In order to address the problems new flood protection policies aim to give rivers more space by using agricultural land as flood retention zones (Commission of the European Communities, 2004). This policy is often resisted by the farm community, because in the case of a flooding event farms can face high losses of crops and therefore of income.

Cropping perennial crops for bioenergy purposes in such cases could be a possible solution creating win-win solutions for farmers and flood protection (WCL, 2007). Studies in the US are looking at planting bioenergy crops in flood-prone areas, because as perennial crops they do not have to be re-established annually and can withstand periods of flooding. Harvesting of these crops on wet areas would have to be timed carefully to occur during dry periods to minimize rutting and compaction of the land (U.S. Congress, Office of Technology Assessment, 1993).

Further agroforestry system systems could also be used in flood prone areas. Hershey and Wallace, (1993) found that water breaks of trees planted perpendicular to the flow of high energy flood waters were economical, based solely on the reduction of damages to crops, assuming floods every 10 years.

5.3 Farm advisory and training for bioenergy cropping

The command-and-control approach has achieved limited success tackling pressures on water resources. Therefore, new governance approaches such as advisory services to farmers are seen as an important factor with respect to the WFD implementation. Such services can create a better understanding of environmental problems and will be a key part in helping farmers comply with WFD requirements by providing specific advice on environmental friendly production. Since 1 January 2007 Member States have had to set up these advisory systems in accordance with Article 13.2 of Reg. 1782/2003. These services are currently focusing on food production and in case of using conventional crops for bioenergy purposes will bring important benefits. However as described in section 3 growing bioenergy crops involves new types of plant and allows different cropping and management systems. Therefore new specific advisory services (see Box 4 Examples of farm advisory systems) are needed that address the particular environmental risk related to energy cropping.

Box 4 Examples of farm advisory systems

Encouraging biomass in the UK[34]

In 2005, the Rural Energy Trust, in cooperation with Rural Development Services and the Forestry Commission, held a series of free events across the East Midlands to inform local farmers how they can take advantage of biomass. The focus of these events was to show how farmers can utilise underused farm woodlands, energy crops and farm wastes to produce fuels to power their farm businesses as well as how to sell biofuel. At the events farmers were given demonstrations of technical equipment used to make biofuel and attended speeches from experts on how biomass systems work, types of heating available, how energy crops are cost effective and how farmers can get involved with selling biofuel.

AGWAPLAN – Denmark[35]

AGWAPLAN, an EU LIFE-Environment project running from 1.11.2005-1.11.2008, aims to promote good agricultural practice in order to reduce nitrogen and phosphorus levels in surrounding water bodies. In order to support this goal, a new advisory tool is being developed so that agricultural advisors and relevant environmental authorities can work together with farmers to come up with integrated plans for farms. The advisory tool developed in this project is an electronic map system that provides data on production and environmental conditions of a given area, as well as providing advice as to how to minimise nutrient loss. Farmers can zoom over the map to see where the risk of nutrient loss to the environment is the greatest and what steps they can take to minimise this loss. Some of the most effective measures include the creation of wetland areas for retaining run-off. Potentially these could be combined with a harvesting of resulting biomass.

The development of such an advisory system should be carried out cooperatively by agricultural and water authorities and institutions, in order to share experiences and concerns, and allow a mutual learning process on both sides. Experiences from Member States have shown that cross-compliance advice will be more efficient and/or acceptable if integrated into existing advisory systems. Further, the experiences of the existing services should be considered and analysed, in order to reduce the risk of non acceptance by the farmers[36].

5.4 Water supply issues

It is a well-known fact that the threat of water shortages is growing in various parts of Europe (Commission of the European Communities, 2007d). The future of bioenergy cropping in these areas will strongly depend on water availability. Particular attention needs to be paid to river basins facing quasi-permanent water stress or scarcity. Farming has significant impacts notably related to irrigation. Over-abstraction remains an issue and effective land-use planning therefore needs to be ensured at the appropriate levels. There is also a huge potential for water saving across Europe. Water saving must be the priority and all possibilities to improve water efficiency must be explored. Additional water supply infrastructures should be considered as an option only when other options have been exhausted, including effective water pricing policy and cost-effective alternatives. Alternative options like desalination or waste water reuse are increasingly considered as potential solutions across Europe. Any position on these options will have to be based on further work on risk and impact assessment,

[34] Source: www.gos.gov.uk/goem/news/newsarchive/cleanheat (last accessed on 16. Sep. 2007).

[35] Source: www.agwaplan.dk (last accessed on 16. Sep. 2007).

[36] Further information on farm advisory services in the EU can be found under http://www.ewindows.eu.org/cifas

taking into account the specific bio-geographical circumstances of Member States and regions. The Commission notably intends to prepare an assessment of all alternative options by the end of 2008.

If located, designed and managed wisely, energy crop plantations can, besides producing renewable energy, also generate local environmental benefits. Such benefits could arise from the nutrient content in wastewater. Theoretically, the nutrients in domestic wastewater and organic waste are almost sufficient to fertilise crops. As much as 80-90% of the major plant nutrients (nitrogen, phosphorus and potassium) in wastewater are present in toilet waste (Jenssen *et al*., 2004). This could reduce the need for additional fertiliser and increase profit margins due to lower input costs. Initial examples include willow plantations leading to soil carbon accumulation, increased soil fertility, reduced nutrient leaching and erosion, removal of cadmium from the soil, etc. Another opportunity is to use willow plantations as vegetation filters for the treatment of nutrient-rich, polluted water, such as municipal wastewater and drainage water. The purification efficiency of willow vegetation filters has been demonstrated in several countries (e.g. Sweden, Poland, Denmark, and Estonia) since the beginning of the 1990s (see Box 5).

Box 5: Willow plantations for waste water treatment[37]

The average nutrient content in municipal wastewater normally corresponds fairly well to the nutrient requirements in willow cultivation. An annual municipal wastewater load of 600 mm, containing about 100 kg N, 20 kg P, and 65 kg K, will supply not only the required water, but also the requirements of N and other macro-nutrients. The wastewater is pumped to the willow vegetation filter or to the storage ponds in the winter, so that the nutrient is recirculated to the willow plantation. The root systems will then take up 75- 95% of the nitrogen (N) and phosphorus (P) in the wastewater. The generation of sewage sludge will also be significantly reduced when willow vegetation filters are used, by up to 80%. Water deficiency is often a growth-limiting factor in willow cultivation, even in countries with significant precipitation throughout the year. The regional variation in biomass yields can be significant due to differences in water availability during the vegetation period. Thus, the biomass yield response to wastewater irrigation will be more significant in regions with relatively low precipitation during the vegetation period. In Sweden, for example, the biomass yield can increase by 4 to 8 tonnes dry matter per hectare per year, or 30 to 100 percent compared to average yields for well managed, rain-fed willow plantations on good soils. Willow vegetation filters are attractive from an economic point of view. This is due to reduced willow cultivation costs and also to the fact that willow vegetation filters provide a treatment option that is lower in cost than conventional treatment at sewage plants. The nitrogen treatment cost could be 3 to 6 Euro lower per kg N in vegetation filters, compared with in conventional sewage plants, where the nitrogen treatment cost normally amounts to approximately 10 Euro per kg N. The cultivation cost could be reduced by 1.2 to 1.8 Euro per GJ biomass, due to reduced costs of fertilisation and increased biomass yields. This reduction is equivalent to 30-50% of the cultivation cost in conventional plantations. Despite the various benefits of willow vegetation filters, several potential barriers exist against their large-scale implementation. Some of these are due to lack of knowledge, such as regarding the risk of the spread of pathogens (Carlander, 2006). Others concern the allocation of benefits and risks among the actors involved. Such a defective allocation could be overcome by developing mutual agreements between the sewage plant operator, the energy plant operator and the willow producer (farmer), which has been successfully achieved in some cases in Sweden.

[37] Information supplied by: Pål Börjesson. For further information see Börjesson and Berndes (2006); Hasselgren (1998); Aronsson (2000); Rosenqvist and Dawson (2005).

5.5 Water pricing

With the introduction of "decoupling" under the CAP reform in 2003, preliminary production choices are linked to the margins a farmer can get for certain products on the market. These margins mainly depend on prices for fertiliser, pesticides, water or seeds. Although the possibilities to shift cropping patterns towards less water consuming crops are limited in the food sector, there is a high potential in the bioenergy sector. Effective water prices as required by the Water Framework Directive and raised again in the Commissions' communication on water scarcity and droughts could be an incentive to grow species that are more water efficient and/or drought resistant (e.g. Sweet sorghum), thus replacing water consumptive conventional crops. Farmers could achieve the same margins on the market[38] by reducing the risk of over-abstraction, which can harm the environment, and lowering water stress in several areas[39]. However, further investigations are needed to better understand the functioning of water pricing mechanisms for bioenergy cropping.

[38] Rural Development Funds (e.g. modernisation of farms) could be used to support these changes and to lower the burden of investment costs.

[39] Even if most of the payments have been decoupled after the latest CAP reform some payments remained coupled fostering intensive cropping patterns and are contrary to the incentives coming from higher water prices. See Intervies *et al*., (2006).

6 Conclusions and further research needs

The need to minimise greenhouse gas emissions and to diversify energy supply has led to a growing interest in renewable energy sources. Biomass-based energy is an important option in this regard and it also offers great versatility (i.e. for heating purposes, electricity production and transport fuels). Recent decisions in European energy policy reveal the importance that policy makers attach to bioenergy sources, and the production of transport biofuels, in particular, is increasing rapidly in the EU. However, high quality agricultural land resources are limited in Europe, and the production of energy crops adds to other demands on farmland, such as the production of food, recreational and ecological functions and non-food uses such as forestry and biomaterials. Consequently, large-scale bioenergy cropping may add considerable additional pressure on land use intensity in Europe, with negative impacts on water quantity and quality.

Europe's environmental resources have substantially deteriorated from past and current intensive land use. The EU has developed environmental legislation (e.g. the Water Framework Directive) to counter such trends and has also introduced environmental instruments in sectoral policies such as the CAP. Current evidence shows that agricultural land use intensity needs to be decreased to meet EU water policy objectives and that current agriculture policy measures are unlikely to achieve this aim. This implies certain limits on the type and size of biomass production for energy purposes. On the other hand, new bioenergy crops or production systems can also potentially strengthen farming approaches that better preserve soil and water resources. The implementation of the WFD needs to take these opportunities and risks into account when plans and measures at water basin level are developed. Likewise, the EU rural development program and national biomass action plans should aim at minimizing risks to water resources from bioenergy production. Overall it is important to carefully evaluate the trade-offs and win-win situations that exist between energy policy targets and EU environmental objectives.

The European Commission is currently drafting sustainability criteria for biofuels. The Netherlands, the UK and Germany have also begun initiatives in this regard. The preliminary draft of the Commission's set of sustainability criteria was subject of a public consultation process launched in April 2007 Commission of the European Communities, 2007g). Only two sustainability issues were addressed by the first draft of the presented criteria: GHG balances and the impact on high biodiversity value areas.Additional criteria will be necessary in order to address the potential impacts of biomass production on water abstraction and water quality. The further development of EU energy policy should consider possibilities for maximising synergies with and avoiding negative impacts on EU environmental policies.

Five areas of interaction between water policy objectives and bioenergy production can be identified:

- potential land use changes;
- environmentally-friendly energy cropping systems;
- energy cropping practices;
- impacts of crop-to-energy conversion processes;
- implementation issues.

All of these are associated with a host of potential research questions and will be briefly discussed below.

a) Potential land use changes: Which are the most important land use changes associated with 1st and 2nd generation bioenergy technologies? What agro-economic models exist to analyse the increased biomass demand due to buoyant food and energy markets? What land use changes can be expected and which types of regions and farming systems are most likely to be affected? Which types of policies could limit or direct potential land use changes?

b) Environmentally-friendly energy cropping systems: What options exist to widen crop rotations or better manage animal manure with the introduction of energy crops or biogas systems on different types of farms? Much more practical investigation, including field trials in different locations around Europe is also needed in order to increase producer experience. Such research needs to take into account energy yields, environmental considerations and the potential effect of future climate change.

c) For southern Europe, research is necessary to identify new, suitable biomass crop mixes and farming practices, in particular for arid regions. To date, only a limited range of options for suitable crops appears to be available in these regions. Arable biomass crops may increase water abstraction, which is undesirable in regions where water is already the main agronomic constraint. Which perennial biomass crops are suited to biomass production under arid conditions without increasing fire risk?

d) Energy cropping practices: Agricultural management practices are an important aspect for avoiding negative environmental impacts while achieving good biomass yields. In order to better understand the link between energy cropping and environmental effects, a better understanding of specific bioenergy farming practices is required. In general, perennials seem to decrease soil erosion and nutrient leaching risks, but knowledge on cultivation options for these crops in different environmental and agronomic conditions is insufficient. Further research on yield data, water demand and long-term impacts on soil of these crops under varying climate and soil conditions is also needed.

e) Crop-to-energy conversion processes: Two important aspects need to be tackled - the level of air and water emissions as well as the use of by-products for maintaining soil fertility. While no major impact of industrial conversion processes is expected, further data have to be gathered on the resource consumption and emission factors of small and large-scale conversion plants. With respect to emission factors (technological improvements), further research is needed into recycle path options in the full biomass to energy conversion pathways that can be used to improve the sustainability of biomass cropping systems. Examples include the use of ash remaining in conversion plants as fertiliser to maintain soil fertility or the use of by-products from bio-ethanol plants, dried distillers grains as feedstuff or organic manure.

f) Implementation issues: The successful introduction of environmentally-oriented bioenergy cropping approaches often requires a major change at farm level. What are the right support mechanisms in agriculture, energy or environmental policies for achieving such a shift? Can information provided by farm advisory services help to achieve the desired change? What are the most (cost-)effective approaches? Which measures are best tackled by which policy area? How can one achieve a good synergy between measures in different policy areas? What effect would water pricing have on the choice of energy crops and the use of water in such cropping systems? To fully understand the production choices made by farmers more information is needed on the production costs and the influence of production coupled payments (e.g. payments under Art 66 of EC regulation 1782/2003) on different energy crops.

Europe can meet the challenge of sustainable bioenergy production from agriculture, but this requires all involved policy areas to offer the right incentives to market participants. Incentives that negatively impact water resources have to be removed and intervention may be needed along a number of dimensions (Sexton *et al.,* no year) to secure environmental standards. In this context, cooperation is required between three policy areas: energy, agriculture and environment. Cooperation is probably the single most crucial aspect if the further development of EU energy production from agricultural biomass is to benefit the environment.

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