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Mandatory requirements in relation to air, soil, or water protection: analysis of need and feasibility

Final Report (Tasks 3 & 4)

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Summary

This report presents the results of Task 3, the **Analysis of the need to introduce mandatory requirements in relation to air, soil, or water protection** and Task 4 **the Analysis of the feasibility to introduce mandatory requirements in relation to air, soil or water protection** in the context of the overall project for the Commission "Study on the operation of the system for the biofuels and bioliquids sustainability scheme" (ENER/C1/2010-431).

The main intention in encouraging an increase in biofuel use is the delivery of environmental and climate benefits. The Renewable Energy Directive (RED) set a target of 10% renewable energy in transport in all European Union (EU) Member States, which is envisaged to stimulate an increase in biofuel production and use. The increase in feedstock production is expected to take place both within the EU and outside. As such, it is appropriate for the RED to consider criteria that ensure that the cultivation of feedstocks used for biofuel consumption in the EU does not cause negative environmental impacts. The RED already contains mandatory sustainability criteria related to GHG emissions, biodiversity and carbon stock.

This report explores the impacts of expansion and intensification of agricultural production for biofuel purposes on soil and water resources leading to air pollution. Criteria for addressing soil quality have been proposed, for example, by the "RED plus" sustainability criteria developed under the Biomass Futures project and the indicators suggested are to "avoid erosion" and "maintain SOC"[1]. Given the need to avoid negative environmental impacts of biofuel use, it is important for the European Commission (EC) to understand the potential risks for soil, air and water resources in countries producing biofuels and/or their feedstocks. This is expected to facilitate the development of an appropriate policy response with the aim of ensuring the environmental integrity of biofuels and bioliquids consumed in the EU.

An assessment presenting the environmental risks of some of the main crops used as feedstocks for biofuel production is presented in this report, and has informed the analysis of the need for mandatory criteria to protect soil, air and water. Following that, the feasibility of introducing mandatory criteria is discussed.

The report concludes that considerable potential risks to sustainability from biofuel cultivation exist, particularly risks to soils and to water quality and water availability. Given these risks to valuable non-renewable resources, introducing some form of environmental safeguards is necessary to avoid further aggravation of existing adverse impacts. Mitigation of these risks is critical not only for the sustainability of the resource base but also for ensuring continued provision of associated societal needs, including food and other ecosystem services. It is evident that the soil, water and air risks from feedstock cultivation for biofuel are on the whole the same as the risks from any kind of agricultural expansion. However, the study has found that in many situations, biofuel markets bring additional pressure on the areas under existing agricultural use and have acted as an important driver in the intensification and expansion of intensive agriculture into areas with challenging soil

[1] Available to download at: http://www.biomassfutures.eu/public_docs/final_deliverables/WP4/D4.1%20Sustainable%20Bioenergy%20-%20criteria%20and%20indicators.pdf.

conditions in particular. Promoting good agricultural practices for the production of feedstocks used for biofuels, both within and outside the EU, through the RED, is likely to contribute to the mitigation of the risks identified.

Good agricultural practice will vary depending on the type of crop and the prevailing bio-physical, environmental, and climatic conditions in diverse farming systems and has to be carefully targeted to these conditions. Applying mandatory quantitative criteria under the RED for protection of soils, water and air is therefore not feasible. This study recommends that greater emphasis be placed on targeted management practices to mitigate potential impacts on soils, water and air.

We present in this report our key recommendations for soil, water and air. Apart from the specific recommendations, we propose that a minimum basic pre-condition on compliance with relevant existing legislation is put in place for soil, air and water: **Biofuel production is required to be in compliance with national, regional and local soil/air/water protection legislation**. The practicability of such a basic compliance criterion is demonstrated by its inclusion in many existing voluntary schemes. Compliance with national, regional and local legislation is also an element of, for example, the EU No 995/2010 Timber Regulation.

A mandatory criterion requiring the existence of **management plans (see Box 2) at farm level is proposed as a feasible way forward for soil and water management**. In these plans, the farmer takes responsibility for identifying risks and designing management schemes which appropriately address the specific risks. It is recognised that management plans are not currently common practice in all countries, not even in the EU, and issues of effectiveness and enforceability must be addressed. However, management plans are already used in many countries and for many crops. Voluntary schemes, for example, already use the management plan requirement and report having achieved positive outcomes. Similarly, the EU Nitrates Directive requires nutrient management plans for farms in nitrate vulnerable zones. Consequently, this appears to be a feasible approach that provides a mandatory framework for improving management in specific farming systems involved in feedstock production whilst it gives sufficient flexibility to farmers to make choices about management practices that are adapted to their agronomic environmental, climatic and other bio-physical conditions.

To take explicit account of risks to water availability from biofuel feedstock cultivation in **sustainability criteria for water scarce regions** is not straightforward. It may be hampered by political sensitivities and the fact that mitigation requires large scale approaches. However, there are some feasible solutions. For example, the EU Water Framework Directive contains the concept of river basin management plans (RBMPs), which identify regions at risk. Within those, farmers are being informed of effects of agricultural management on water in the region. The recently published EU Water Blueprint refines the understanding of priority actions to be taken in these regions and offers further opportunity for specifying sustainability criteria on the efficient use of water in agriculture for these regions. Water stress index maps are produced for regions outside the EU, which could serve as a basis for developing appropriate sustainability criteria for the imported feedstocks.

Regarding **air quality**, three key recommendations are made to reduce risks from biofuel crops cultivation. Firstly, it is recommended to eliminate (where possible) open air burning. This entails avoiding or eliminating open-air burning of residues, wastes or by-products, and burning to clear the land. Permission to allow burning should be clearly limited and justified, for example: if workers' health and safety is at stake, or no viable alternative is available or affordable in the local context, or if burning is meant to prevent natural fires. The second recommendation on air is to reduce risks from processing facilities and from agrochemicals, and air emissions limits can be set for different production stages (e.g. at the farm, at the mill, at the processing facility) at national level. Monitoring systems must be put in place to ensure the emissions limits are met. The final recommendation is to reduce risks from agrochemicals by implementing management plans for agrochemical application following international standards and agreements.

We also note that for the EU Member States, the existing mandatory RED criterion in Article 17(6) requires adherence to cross compliance requirements under the Common Agriculture Policy (CAP). We recommend clarifying that this provision of the RED will continue to apply to the revised cross compliance provisions given the forthcoming reform of the CAP.

Finally, we note the important role **voluntary schemes** can play in advancing and implementing standards on soil, water and air. The voluntary schemes recognised by the EC allow certifiers to check an operator's compliance with the existing mandatory RED criteria. The advantage of this approach is that many of the existing voluntary certification schemes reach much further than the EC currently does in defining and certifying broad-based sustainability for bioenergy. Furthermore, some schemes are targeted to a particular feedstock and/or regional conditions and therefore have the local expertise needed to define management requirements targeted at local conditions.

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List of Acronyms

AAPRESID	Argentinean Association of Farmers
BMP	Best management practice
C	Carbon
CAP	Common Agricultural Policy
CO	Carbon Monoxide
DG ENER	Directorate General Energy (of the European Commission)
EC	European Commission
EEA	European Environment Agency
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
GAEC	Good Agricultural and Environmental Condition
HM	Heavy Metals
ILUC	Indirect land use change
ISCC	International Sustainability & Carbon Conservation
GBEP	Global Bioenergy Partnership
HAP	Hazardous Air Pollutant
K	Potassium
Mt	Mega tonne
N	Nitrogen
NOx	Nitrogen Oxides
P	Phosphorous
PAH	Polycyclic aromatic hydrocarbons
PM	Particulate Matter
RBMP	River Basin Management Plan
RED	Renewable Energy Directive
RSB	Roundtable on Sustainable Biofuels
RSPO	Roundtable on Sustainable Palm Oil
RTFO	Renewable Transport Fuel Obligation
RTRS	Round Table on Responsible Soy
SAN/RA	Sustainable Agriculture Network/Rainforest Alliance
SMR	Statutory Management Requirements
SOC	Soil organic carbon
SOM	Soil organic matter
SOx	Sulphur oxides
US EPA	United States Environmental Protection Agency
VOC	Volatile Organic Compound
WFD	Water Framework Directorate
WSI	Water Stress Indicator
WTO	World Trade Organization

1 Introduction

This study focusses on the environmental impacts, both within and outside Europe, associated with the agricultural management of biofuel feedstocks consumed within the European Union (EU). It is clear that within a given crop system, whether production is for food, feed or fuel feedstocks, the risks to soil, water and air are the same. It is difficult to be specific about the proportion of agricultural production that is used to feed the biofuel sector and hence to be precise about the environmental impacts that can be specifically attributed to the production of biofuel feedstocks. A rigorous analysis would need to compare these impacts to a counterfactual scenario, i.e. the situation without biofuel production. Such data is unavailable at present.

However, there is ample anecdotal evidence to indicate that existing environmental impacts in agro-ecosystems, particularly those associated with soil and water, are driven partly or aggravated by demand from the biofuel sector, adding to existing pressures from the food and feed sectors. Adverse effects are often caused by the increased output of arable crops which had already supplied food and feed in a country/region, accompanied by diversion of a certain share of output to bioenergy. It is apparent that the drivers of such adverse effects go beyond the agricultural commodity markets themselves and that EU policy in the form of the renewable energy targets in the Renewable Energy Directive (RED) has played a particularly important role in recent years.

This study has focussed on an examination of the environmental effects associated with crops that:

- Represent the prevailing cropping type in a country/region and are already produced in intensive agricultural systems and in zones with vulnerable soil/water conditions; and
- have become the prevailing feedstocks to supply the EU biofuel markets.

Effects of biofuel production are closely linked with changes in land use. These are highly diverse and outside the scope of the study, but they should not be forgotten. In some situations, biofuel feedstocks replace existing production (for example the cultivation of maize expanding onto forage grass, former set-aside or displace production to other regions/countries.

It is also important to bear in mind the cumulative effects associated with producing crops for biofuel feedstocks at the same time as crops for biogas production for heat/electricity and solid biomass such as short rotation coppice in the EU. Effects from the cultivation of energy crops supplying the heat/electricity sector and soil biomass are outside the scope of the study. However, they cannot be fully separated from the impacts of crops that supply production of liquid biofuels per se. All these bioenergy sectors, demand land and may expand onto similar areas. For example, rapeseed for biofuel and silage maize for heat/electricity, have both been introduced onto former set-aside land in the EU. The co-existence of the biofuel and biogas sectors is therefore another critical factor in extending the areas under the specific cropping systems or in intensifying agricultural management. In non-EU countries, there are additional risks to soil, water and air from expansion of biofuel crops onto new land brought into production.

How to read this report

The report starts with an overview of key biofuel crops and focus countries within and outside the EU (Section 2). Section 3 provides an overview of soils risks from biofuels consumed in the EU. It sets out the type of risks arising from the cultivation of biofuel feedstocks within Europe and in non-EU countries, provides information from case studies on actual risks arising in the selected countries, as well as considering the scope and effectiveness of existing provisions for soil protection. A synthesis of the estimated risks per region for different types of risks concludes the section. Section 4 sets out water risks associated with the identified biofuel crops in the selected EU and non-EU focus areas. Similarly to the soil section, the assessment of existing provisions for water protection addresses their scope and effectiveness in containing the pressures from biofuel feedstock production and concludes with a synthesis estimating the actual risks. Section 5 provides a corresponding analysis of air quality risks. Section 6 discussed the feasibility of introducing additional sustainability criteria in the RED to mitigate identified risks to soil, water and air and overall concludes the study.

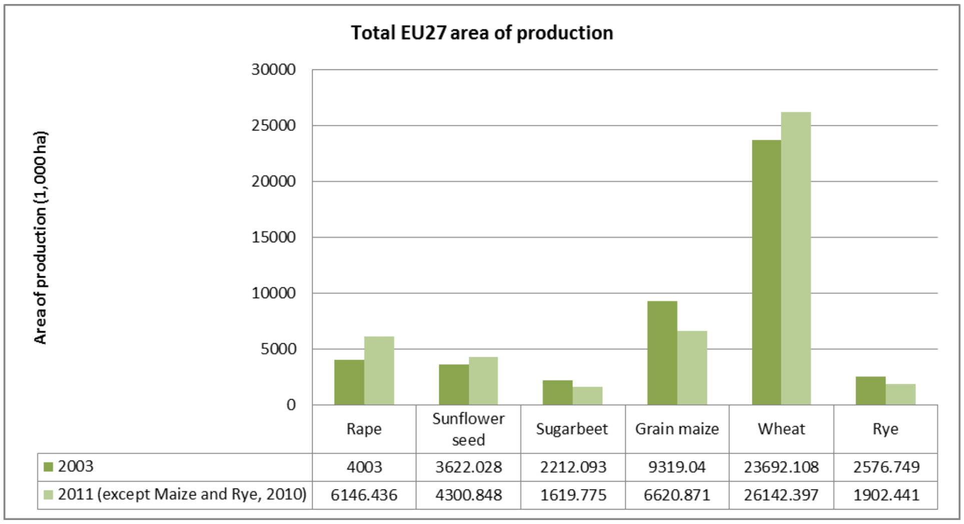
2 Key biofuel crops and focus countries

2.1 EU biofuel production

The analysis presented in this report focuses on the impacts, and ensuing environmental risks, associated with the cultivation of six key biofuel crops. The six crops are **rapeseed, sunflower, wheat, grain maize, sugar beet** and **rye**. Rapeseed and sunflower are the most important crops produced in the EU which are diverted to **biodiesel** production. The other four crops represent the key domestically produced feedstocks that supply EU **bioethanol** production, with wheat being the key crop and rye having a more marginal role than others (see Annex 1). Although the importance of grain maize as a bioethanol feedstock has been relatively limited compared to its food and feed use, it has a considerable growth potential in the key maize producing Member States (Section 3.3.4).

Taking into account the potential scale of risks associated with the cultivation of the above crops, and where these crop systems already represent a significant share of cropland in Member States, this study focuses on ten countries which are important for biofuel production, either as feedstock producers, processors or both. These are: **Czech Republic, France, Germany, Hungary, Italy, Poland, Romania, Slovakia, Spain and the United Kingdom.**

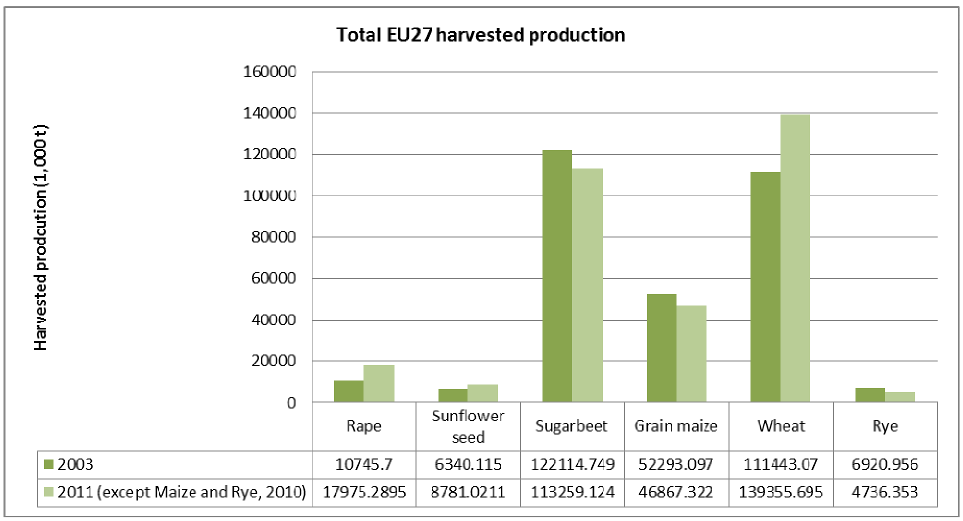
Based on official statistics, Figure 1 and Figure 2 show the EU production trends for these six crops between 2003 and 2011, in terms of the total area of production and the total harvested production. They illustrate that production has increased significantly for rapeseed and wheat, there has been less of an increase in sunflower production, and that there has been a decrease in grain maize, sugar beet and rye production. However, the figures do not indicate the proportion of area/production associated with each crop that is being utilised for biofuels. At present no such systematic data exist at EU level. Figures 1 and 2 therefore reflect total crop production levels in the EU and can be used as a proxy to identify where the production of these key crops is most significant.



	Rape	Sunflower seed	Sugarbeet	Grain maize	Wheat	Rye
2003	4003	3622.028	2212.093	9319.04	23692.108	2576.749
2011 (except Maize and Rye, 2010)	6146.436	4300.848	1619.775	6620.871	26142.397	1902.441

Figure 1: Total EU-27 area of production of key biofuel crops in 2003 and 2011

Source: Eurostat, 2012



	Rape	Sunflower seed	Sugarbeet	Grain maize	Wheat	Rye
2003	10745.7	6340.115	122114.749	52293.097	111443.07	6920.956
2011 (except Maize and Rye, 2010)	17975.2895	8781.0211	113259.124	46867.322	139355.695	4736.353

Figure 2: Total EU-27 harvested production of key biofuel crops in 2003 and 2011

Source: Eurostat, 2012

The crop production trends presented above cover the period starting with the adoption of the EU Biofuel Directive[2] in 2003 (repealed when the RED was adopted). It is worth keeping in mind that future trends may significantly differ from these historical trends. For example, data on current crop production trends cannot account for the barriers that existed in the structure of the energy sectors in some EU-12 countries. An example might be the lack of infrastructure for the production of biofuels in certain countries with large agricultural sectors such as Poland, Romania and Bulgaria at

[2] Directive 2003/30/EC of the European Parliament and of the Council of 8 May 2003 on the promotion of the use of biofuels or other renewable fuels for transport. Official Journal L123/42, 17.5.2003.

the time of the adoption of the RED in 2009 and even more so in 2003. Such barriers are likely to have slowed down the expansion of biofuel cropping in EU-12 compared to the EU-15, for example France and Germany. Similar infrastructure issues have probably played a role in non-EU countries too. It was not possible to estimate potential future changes in production trends due to growing biofuel installations in this study, however important research has been carried out, for example by the European Environment Agency (EEA) (Elbersen et al., in preparation). Our study also could not take into account the changes proposed in the RED in relation to indirect land use change (ILUC) effects[3].

A good indication of the share of the cultivated area devoted to biofuel production is provided in another current study for the European Commission (Ecofys et al., 2012). An overview is presented in Table 1 and Table 2. Full datasets for each crop are shown in Annex 1. Table 1 shows the areas of production for the key biofuel crops and the share devoted to biofuel production in the fourteen Member States that are leading biofuel producers in the EU[4].

Table 1: Areas of production of six biofuel crops in 2010 and the area and share devoted to biofuel production in 14 Member States[5]

	Biofuel type	Total ('000 ha)	To EU biofuels ('000 ha)	% for biofuels
Rapeseed	biodiesel	5,885	2,209	38%
Sunflower seed	biodiesel	1,493	348	23%
Sugar beet	bioethanol	1,020	147	14%
Grain maize	bioethanol	6,267	124	2%
Wheat	bioethanol	20,238	305	2%
Rye	bioethanol	n.a.	n.a.	n.a.

Source: Ecofys et al., 2012

Table 2 shows the key countries for the production of the selected biofuel crops in the EU-27. These have been identified according to two criteria, namely the total area devoted to the production of each crop and the share of the domestic crop area diverted to biofuel production. The first criterion sets out the Member States with the largest areas of these crops in a cross country comparison[5]. All leading EU crop producers are within this group, for example Germany, France and Poland for rapeseed and wheat and Romania for sunflower. Hungary features as an important player in the grain maize sector. The second criterion identifies the Member States where the environmental effects of a significant share of the crop area are clearly driven by biofuel production. Although these Member States may not be leading EU crop producers, their crop sectors may be largely or entirely oriented towards the biofuel sector, as well as representing critical arable sectors in domestic agriculture.

[3] Proposal for a Directive of the European Parliament and of the Council amending Directive 98/70/EC relating to the quality of petrol and diesel fuels and amending Directive 2009/28/EC on the promotion of the use of energy from renewable sources, 17 October 2012, COM (2012) 595.

[4] The fourteen countries considered in Ecofys et al. (2012) include all ten considered in the present report, and additionally Austria, Belgium, Sweden and the Netherlands.

[5] It is assumed that these countries experience more concentrated environmental effects of land use under particular crop systems than others.

Rapeseed sectors in Slovakia and the Czech Republic are such examples. The complete dataset is provided in Annex 1.

Table 2: Key Member States in EU biofuel production

Crop type	Biofuel type	Member States with largest total areas devoted to the crop (2011, except maize and rye, 2010)	Member States with important share of crop area supplying biofuel sector (2010)	
			Member State	Share of crop area (%)
Rape	biodiesel	**DE**, FR, PL, UK, CZ, RO	NL, **SK**, **CZ**, HU, SE, AT; ES, RO, DE, FR[6]	100-60; 50-30
Sunflower	biodiesel	**RO**, ES, BG, FR, HU	FR[7]	45
Sugar Beet	bioethanol	DE, FR, PL, UK	UK, HU[8]	50-30
Grain maize	bioethanol	RO, FR, IT, **HU**	marginal[9]	
Wheat	bioethanol	**FR**, DE, PL, RO, **UK**, IT, ES	marginal [10]	
Rye	bioethanol	**PL**, DE, ES	n.a.	

Source: Own elaboration based on Eurostat, 2012 and Ecofys et al., 2012

Note 1: For countries in bold, the specific crop represents a more dominant share of cropland than in other Member States.

Note 2: FAOSTAT data was consulted on total area of rye production, as Germany does not have recent data entries in Eurostat for rye area.

2.2 Non-EU biofuel production

It is important to keep in mind that the EU **biodiesel** sector also uses imports from non-EU countries. These are mainly based on **rapeseed**, **soybean oil** and **palm oil**. For the EU **bioethanol** sector, key imported crops are **sugar cane** and **grain maize**. The risks associated with the non-EU production of the key imported crops are therefore discussed as part of this report.

Non-EU countries selected for the assessment in this report include:

- **North America:** US, Canada
- **Central America:** Guatemala
- **Latin America:** Argentina, Brazil, Paraguay
- **Asia:** Indonesia, Malaysia
- **Central Europe:** Russia, Ukraine
- **Africa:** Tanzania

[6] Another country where rape is used as a biofuel feedstock is Poland, where it is 25% of crop area is used for this purpose.
[7] Spain and Italy also use sunflower to produce biodiesel, but on less than 5% of their sunflower area.
[8] Three other countries – France, Czech Republic and Germany – cultivate sugar beet for the purpose of biofuel production on less than 15% of their sugar beet area.
[9] 2-10% of area under grain maize is used to cultivate bioenergy feedstocks in Poland, Slovakia, France, Germany and Hungary.
[10] France and Austria use 2-6% of their wheat area for biofuel production.

3 Soils risks from biofuels consumed in the EU

3.1 Introduction

Land degradation is defined by the FAO as a 'process which lowers the current and/or potential capability of soil to produce goods and services'. Agriculture affects many aspects of soil health and functionality since the majority of farming systems utilise the soil as a growing medium, source of nutrients and as a resource for breaking down wastes. If intensified or concentrated beyond a sustainable limit, agricultural production can lead to the degradation of soils. The functionality of agricultural soils is determined by the proportion of organic matter, the level of susceptibility to erosion by wind and water, the soil's structure and capacity for infiltration, the health of its biota and its level of pollution. Six main soil degradation processes (water, wind and tillage erosion, decline of soil organic matter (SOM), compaction, salinisation and sodification, pollution, and declining soil biodiversity), as well as the increasing risk of build-up of pest and pathogen in soils, are affected by agriculture (Louwagie et al., 2009, FCEC, 2010).

The soil impacts in a given cropping system vary according to local conditions, including the environmental, bio-physical and climatic characteristics of the soil and according to other factors, such as the type of crop in production and the management practices applied. Table 3 below sets out how these factors may interact in the process of soil degradation within the EU. Most of these factors are applicable beyond the EU as well (see Section 3.4).

Table 3: Overview of the causative factors of different key soil degradation processes

Anthropogenic Pressures Driving Degradation	Environmental Factors affecting the Level of Degradation
Soil erosion	
• Cropping sloped areas with crops that are high erosion risk (maize, rape and row crops) • Late sowing of winter cereals • Changes in land structure (concentration of fields into large units, land levelling, disappearing of landscape elements such as hedges, shelterbelts and abandonment of terraces • Tillage (use of heavy machinery) • Inappropriate irrigation methods on slopes • Overstocking • Ploughing up-and-down slopes • Bare soil • Inappropriate use of heavy machinery • Reduced diversity of crops and reduced crop rotations	• Rainfall patterns and climatic conditions (e.g. long dry periods followed by intense rainfall on fragile soils, such as in the Mediterranean area) • Land cover patterns • Steep slopes
Decline of SOM	
• Deep ploughing of arable soils causing rapid mineralisation of labile components of OM • Soil erosion, by water and wind • Leaching • Drainage of peatlands and wetlands • Poor crop rotation • Insufficient plant residue management • Accelerated mineralisation due to management practices such as continued tillage • Conversion of grassland to arable land	• Clay content (influences the capacity of soils to protect organic matter against mineralisation and therefore influences rates of change in organic matter content) • Vegetation pattern • Soil biodiversity • Climatic conditions
Other soil risks	
Pollution by diffuse sources • Use of pesticides and fertilisers • Spread of sewage sludge and compost	• Buffering capacity • Filterability • Drainage • Soil structure • Vegetation and soil biodiversity • Climatic condition
Salinisation • Inappropriate irrigation practices, e.g. with salt-rich irrigation water and/or insufficient drainage • Over exploitation of groundwater (coastal areas)	• Low rainfall • High evapotranspiration rates • Physical or chemical weathering
Compaction • Inappropriate use of heavy machinery (e.g. wheels, racks or rollers)	• Soil structure • Macro porosity • Bearing capacity
Decline in soil biodiversity • Intensive soil tillage, pesticide • Replacement of rotated cropping systems with continuous systems • Other forms of soil degradation, in particular soil erosion, pollution, acidification, salinisation and compaction	• Low SOM content • Chemical properties of soils (e.g. amount of soil contaminants or salts) • Physical properties of soils such as porosity (affected by compaction or sealing)

Source: Adapted from Bowyer et al., 2009

3.2 Risk assessment – methodology

We have applied a step-wise approach to the assessment of the risks to soils presented by the key biofuel feedstocks. This assessment is intended to provide a picture of the nature of observed risks to soils whilst taking into account the inherent risks associated with the different crops under consideration, the risk profile of the soils in the regions of interest, and the management techniques in place that may exacerbate or mitigate against soil risks.

The five key steps are as follows:

- Step 1 – Identify key crop types used for biofuel production.
- Step 2 – Define relevant soil risks (including an analysis of the type of soil conditions in the key regions) and the extent to which these soils are under threat already and so may become more vulnerable to degradation.
- Step 3 – Discuss the impact of management techniques (including the way in which management techniques can either limit or exacerbate the extent of the soil degradation challenges posed by the different crops).
- Step 4 – Combine soil characteristics, crop characteristics and management techniques into specific risk factors in the key regions.
- Step 5 – Includes an assessment of existing provisions that might help limit the risks to soils. It has been considered whether these provisions are adequate for ensuring that soils are managed appropriately in reality.

3.3 Soil risks in the EU

This section presents the relevant risks to soils in the EU, first on a generic level including the role of management practices (section 3.3.1) then based on crop type (sections 3.3.2 and 3.3.3). Annex 3 provides a detailed overview of the risks per Member State. Section 3.3.4 provides a synthesis and presents 'colour-coded' threat assessments for row and field crops. It should be kept in mind that many of the risk factors are common to agricultural production whether for food and feed or biofuel feedstocks. However, information specific to those crops grown specifically for biofuel production has been sourced and collated where available.

3.3.1 Problems facing Europe's soils

In Europe, soil erosion and declining levels of SOM are two of the most critical soil issues associated with agricultural production. Other issues such as salinisation, compaction, diffuse soil pollution and the build-up of pathogen and pest risk in soils may also occur, often concentrated in certain farming systems in specific localities or regions.

Soil erosion

The extent and scope of soil erosion risk differs depending on crop type, specifically whether they are row or (distributed) field crops (Box 1).

Box 1: Row crops versus (distributed) field crops

Row crops are planted in rows, with the distance varying from 60 to 90 centimetres. This agronomic method allows better access by machinery, more space for the roots to pick up nutrients and better exposure to sunlight. However, row crops are also particularly susceptible to soil erosion. Of the crops considered in this study, **maize, sunflower** and **sugar beet** are row crops. Recommended management actions to address soil erosion are reduced tillage, integration of catch crops to improve soil coverage or shortened periods without soil coverage (Louwagie et al., 2009; Evans, 2005 in Nowicki et al*.,* 2009).

(Distributed) field crops provide a relatively dense vegetative cover during the growing period. Member States with a strong focus on field-crop cultivation are Sweden, Denmark, Finland and Poland (Nowicki et al*.,* 2009). Of the crops analysed in this study, **rapeseed**, **wheat** and **rye** are field crops. In field crops, increased erosion tends to occur where land management does not include permanent vegetation cover.

Accelerated rates of erosion occur where the natural rate of erosion by water and wind has been significantly increased by human activity. Soil erosion is most commonly associated with bare soil. In field crops, increased erosion tends to occur where land management does not include permanent vegetation cover. As well as causing damage to the soil itself, soil erosion has a number of adverse knock-on effects, most notably the washing out the high organic matter content from the topsoil, triggering run-off with risk to water quality and releasing soil carbon through the disturbance of the soil, thus affecting climate. Soil erosion problems are expected to worsen with climate change as a result of heavier rainfall events and longer drought periods (EEA, 2003).

16% of Europe's total land area is at risk of water erosion and this represents 2.8 tonnes of soil lost per ha every year (Jones et al., 2012; European Commission, 2012; see Annex 3). In southern Europe, severe water erosion risk prevails, in northern Europe there are generally moderate rates of water erosion risk and in central and eastern Europe variable rates of erosion can be found. Hot spots, areas where erosion is most serious, occur in all zones. The countries most affected by severe water erosion (over 7 t/ha/year) are Italy, Portugal, and Greece. Moderate soil erosion rates (around 5 t/ha/year) are observed in in Austria, Slovenia and the United Kingdom. Although the average erosion risk is relatively limited in France, Germany and Poland, measured erosion losses can be a substantial problem here too. Low erosion (below 1 t/ha/year) has been observed in Ireland, Latvia, Lithuania, the Netherlands, Finland and Sweden (European Commission, 2012; Louwagie et al., 2009).

Considering the scale of erosion risk associated specifically with agricultural land use, the data suggest that about 11.5 million ha (7%) of land under arable and permanent crops suffers from a risk of moderate to severe erosion (>11 t/ha/yr) compared to 2% of permanent grassland in the same Member States (JRC/Bosco et al., 2012). Since the data excludes Cyprus, Greece and Malta, the actual percentage is likely to be even higher. Studies demonstrate that the highest levels of soil erosion risk are on irrigated arable land (Louwagie et al., 2009). The available data do not however differentiate the kinds of land management practices applied in practice. Thus, they cannot indicate the extent to which the erosion risk can be attributed to inappropriate management and the extent to which it is a function of non-anthropogenic factors linked to soil, climate etc.

The most extensive and most severe wind erosion has been mapped in south-eastern Europe. Also for the regions in the sand belt of Europe, including England, the Netherlands, northern Germany, northern UK, Denmark and Poland, a very high number of erosive days has been documented on bare soils (EEA, 2003). Moderate wind erosion has been observed in the Czech Republic, France, the UK and Hungary. As with water erosion, wind erosion is a natural phenomenon that can be significantly accelerated by human actions, such as unsustainable farming practices. An example is the increase of wind erosion in row crops such as maize (Louwagie et al., 2009).

Soil organic matter

Soil organic matter (SOM) is a complex mixture of plant and animal residues and organisms in which soil organic carbon (SOC) is a major component. Since SOM levels are difficult to measure accurately, they are calculated by measuring SOC and applying conversion factors (typically ranging from 1.72 to 2.0 g SOM per g C). The soil's capacity to accumulate and dissipate SOM varies by soil type and is regulated by soil organisms, vegetation cover, rainfall, temperature, soil texture and soil mineralogy. For example, sandy soils generally have a lower organic content than finer soils such as clay; poorly drained soils tend to have higher organic content than regularly drained soils and SOM decay is quicker in warm humid climates than in cold wet ones. The soils of bog and moorland habitats retain far more organic matter than deciduous woodlands or lowland heathland habitats.

Given the diversity of climatic conditions, soils and land use across Europe, the quantities of organic matter varies widely between European soils ranging from less than 35 tonnes C/ha to more than

1,250 tonnes C/ha (Gobin et al., 2011). The north of Europe is dominated by soils with higher SOC matter, in particular those found in peatlands and peat-topped soils (Schils et al., 2008). By contrast, large parts of Europe's land area (45%) have very low levels of organic matter (categorised as below 2% of SOC in surface soil, see Annex 3)[11]. Indeed some regions in south and west Europe suffer from complete organic matter depletion (EEA, 2010). However, it should be noted that certain agricultural systems have preferences for soils with relatively low carbon content, for example the sandy soils in East Anglia or southern Spain which are used for horticulture.

The importance of SOM for ensuring continued soil fertility has long been recognised. There are also multiple important linkages between SOM and soil erosion. While erosion often washes away the part of the topsoil that contains the most valuable organic matter, an increase in erosion is linked with decline in SOM. On the other hand, soils with low levels of SOM have a generally lower infiltration capacity and are less able to ensure stability against erosion than soils with good levels of SOM (Wurbs and Steininger, 2011).

Salinisation

The risk of salinisation on arid and semi-arid soils in south-western Europe (Spain, southern France) and in eastern parts of Hungary (see Annex 3) has grown over the past decades. Certain land management practices (such as excessive fertiliser use and irrigation from saline aquifers), particularly associated with horticultural agricultural systems, can cause salinisation, thereby heightening the risk (Calatrava et al., 2008).

Compaction

Compaction affects the soil's capacity to conduct water and air, severely affecting its fertility. The threat of soil compaction varies according to soil type, with some soils having a greater capacity than others to withstand compaction. This presents a natural risk to soil compaction that is particularly great in the Netherlands, Belgium, parts of Spain and the UK and a moderate risk in Italy and central France (see Annex 3). However, land management will also affect soil compaction, with certain practices posing a greater threat than others; for example, heavy machinery is a key factor causing soil compaction.

Soil pollution

Diffuse soil pollution is largely caused by nutrient loading, nutrients from both organic and inorganic sources, and pesticides. It poses a threat to soils due to increased concentrations of nitrates and phosphates. To a lesser extent, waste materials, plastics, heavy metals and sewage sludge are also sources of pollution. The main sources of pollution from land management practices are the application of manure or slurry, overuse of agro-chemical inputs and soil compaction and capping that reduces the soil's capacity absorb nutrients, reducing the infiltration of nutrients and subsequently increasing overland flow. Furthermore, inappropriate timing of slurry and inputs can be particularly damaging along riparian edges and on bare soils, for example application during periods of intense rainfall (Louwagie et al., 2009).

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[11] The threshold of 2% which is used in available pan-European datasets is only indicative and needs to be interpreted in light of regionally specific conditions.

To mitigate this risk, land managers can select appropriate inputs, crops and management practices and use precision methods to reduce levels of fertilisers and pesticides. Organic farming systems are particularly positive for reducing soil pollution. Where slurry is applied, the correct rate of application and form of storage can limit pollution. For example, slurry is often applied to soils to increase the SOM content; however, it has high levels of heavy metals. By injecting the slurry into the soil rather than spreading it, there is a lower risk of runoff. Whilst the Nitrates Directive addresses the application of slurry in designated nitrate vulnerable zones, there is a lack of technical equipment and training that hinders this practice from becoming common place (Louwagie et al*.*, 2009).

Loss of soil biodiversity
Soil biodiversity is important for maintaining production levels and managing and regulating nutrient and sediment cycles. It is particularly beneficial for agricultural production as it facilitates organic matter decomposition, it benefits soil structure by breaking down toxic compounds and transforming inorganic inputs, it limits pests and diseases and supports pollination (Gardi and Jeffery, 2009). The loss of soil biodiversity is a significant threat across the EU-27 and is caused by the processes outlined above, particularly the loss of SOM, erosion and pollution; however, research shows that even polluted and disturbed soils may sometimes support significant levels of biodiversity.

Build-up of pests and pathogens in soil
The increased use of continuous cropping systems, in particular for maize, can result in an increased risk of building up pests and pathogens in the soil. *Diabrotica virgifera virgifera* (Western Corn Rootworm) is considered as a serious threat to EU agriculture, with nine Member States affected (data from 2007) and the pest being established in some neighbouring non-EU countries (FCEC, 2009). Specific to south-western Europe, there is also a risk of the spread of first generation of Mediterranean Corn Borer (*Sesamia nonagrioides Lefèbvre*) in continuous maize systems. For all EU regions, a reduction in crop diversity and reduced heterogeneity of landscape brings a limited enhancement of natural enemies, and partly as a result, the build-up of specific weed, pest and disease populations in continuous systems. Mycotoxin pollution is also more likely in continuous systems and in maize/winter wheat rotations than in more diverse landscapes and rotated systems. Continuous systems have increasingly been shown to develop herbicide resistance.

Potential of crop management to exacerbate or mitigate soil risks
Management practices are a very important factor, alongside other factors such as the type of farming system (organic, conventional) as well as climatic, environmental and biophysical conditions, which all co-determine the impacts on soils of a particular cropping. The information above on the generic soil risks is indicative and needs to be interpreted in light of the management applied.

In relation to soil erosion and SOM, the management practices that tend to result in additional pressures have been reviewed by several recent studies (Louwagie et al., 2009; Hart et al., 2011; Poláková et al., forthcoming).

They include:

- bare soil;
- large field sizes situated along the slope incline;
- high degree of mechanisation, often accompanied with heavier machinery and compaction through machinery use;
- reduced crop rotations and number of crop types;
- crops with lower cover density;
- continuous arable production, rather than in rotations, and reduced use of grassland breaks;
- continuous specialist crop production such as wheat or maize resulting in longer periods of bare ground;
- reduced return or additions of organic matter residues e.g. manures, crops residues;
- repeated tillage; and
- abandonment or removal of terraces, banks and landscape features.

The management practices beneficial to SOM content and erosion in arable systems include[12]:

- ensuring appropriate soil cover;
- contour ploughing;
- conservation tillage or no-tillage;
- appropriate crop rotations, especially those including fallow or legumes;
- arable stubble management;
- no burning of crop residue (including straw);
- ploughing-in crop residues;
- erosion prevention strips;
- run-off furrows;
- keeping fallow land;
- intercropping;
- limited or banned fertiliser and lime application; and
- no machinery in certain situations or time periods.

Land preparation and post-harvest management are particularly important factors influencing the extent of soil exposure and the associated adverse effects to soils. Methods for post-harvest management across the EU are diverse and Member States have the flexibility to design requirements specific to their conditions, including subsequent crops, traditional practices, weather, environmental management needed, and the farming system. Cereal straw can be either left and incorporated in soil after harvest or used for other purposes both within and outwith agriculture (Kretschmer et al., 2012). Straw incorporation is a valuable method of improving levels of SOM and stability against erosion, although there are limits to which straw can be incorporated into the soil. The ability to incorporate straw also depends on the technical capacity of the farm and the perceived benefits of incorporation. Similar diversity can be observed in stubble management across the EU. In many farming systems it is common for farmers to plough cereal stubbles directly following harvest

[12] The primary sources reviewed by Poláková et al, forthcoming, comprise: Flynn et al., 2007; Frelih-Larsen et al., 2008; Smith et al., 2008; Louwagie et al., 2009; Gobin et al., 2010; FAO, 2011; Hart et al., 2011; Turbé et al., 2011.

which result in bare soils over the winter period. These are particularly susceptible to erosion as a result of rainfall. In organic systems and where specifically required or incentivised for environmental management, stubbles are maintained over winter. The stubble binds soils, helps reduce erosion period and is ploughed in prior to the spring sowing. From biodiversity perspective, it provides food resource for birds (Donald et al., 2001). Alternatively, winter or cover crops can provide similar benefits.

3.3.2 Soil risks per crop (field crops)

Field crops (rapeseed, wheat, rye) largely cover soils during the main growth phase. Table 4 provides an overview of risks associated with field crops and the main mitigating practices that can be employed. Annex 4 presents detailed information.

Table 4: Risks associated with field crops (rye, wheat, rapeseed) and main mitigating practices

Risk factor	Soil impact	Management practices that can mitigate risk
Ploughing and drilling	• Break up of soil structure and exposure of soil potentially leading to erosion risk • Soil compaction through use of machinery • Loss of organic matter	Low tillage
High fertiliser application during final maturing phase	• Risk of leaching to water courses or if poorly balanced decline in organic matter	Timing of application Precision farming
Inappropriate irrigation	• Irrigation may be necessary in some areas during early growth when water demand is high • Inappropriate management of irrigation can lead to salinisation	Use of drip irrigation Irrigation management
Inappropriate crop rotation	• Decline in organic matter (and development of soil pathogens in the case of rape)	Rotations
Use of machinery	• Potential for compaction leading to risk of erosion in localised areas	Appropriate machinery Timing of harvest to limit compaction
Post harvest management	• Removal of residues leading to exposure of soils, hence erosion risk and risk of decline in organic matter	Stubble management Incorporation of residues

Source: Own compilation

Rapeseed

The area under rapeseed cropping within the EU increased 54% from 2003 to 2011. Rapeseed is the crop with the highest share of its area, i.e. 38%, devoted to biofuel production among the leading fourteen biofuel-producing countries. Rape is a crop well suited to a temperate climate, hence its extremely important role in arable sectors in Germany and France. These two countries are leaders in the EU, with the largest areas under rape, 1,461 ha and 1,465 thousand hectares respectively, and in terms of annual outputs. Almost 30% of these areas support the biofuel sector. In Slovakia, the Czech Republic and Hungary, the scale of areas under rape cultivation is smaller in absolute terms but a predominant part of their rape crop area (from 90 to 60%, respectively) supply feedstocks for the biofuel sector. On the other hand, Poland uses only about 25% of the rape cultivated domestically for biofuel production, however the total area under rape cropping systems are on the scale closely following France and Germany. In southern Europe, rape cultivation is much less common and some Member States (Portugal, Greece, Cyprus and Malta) do not produce rape at all.

Unlike other field crops, rape exacerbates the risk of soil erosion in the early stages of growth, particularly when used on large fields and in sloping terrains. The erosion risk derives from the fine seeds needing a very fine seedbed exposing the field to erosion risk during the first month after sowing (KBU, 2008). Soil overflow caused by erosion results in a decline in SOM. The use of crop rotations, full-cycle soil preparation and avoidance of continuous rape cropping systems are very important to avoid erosion risk, but indications are that these management practices are largely not used. Rapeseed has high nutrient requirements and high plant protection requirements (KBU, 2008), it therefore increases the pressure on soils through diffuse pollution by fertilisers and pesticides. Winter rapeseed is one of the most nitrogen demanding plants. The optimum dose of nitrogen for proper rapeseed production is around 240 kg N/ha, dependent on soil pH, precipitation in winter, the type of crop that precedes in rotation, the type of fertiliser, plant protection agents used previously and the rapeseed variety to be planted. Summer rapeseed, on the other hand, is very susceptible to droughts. A potential environmental benefit from rape cultivation arises in the areas where rape is used in rotations to diversify continuous crop systems (KBU, 2008; EEA, 2006).

Wheat

The total area under wheat cropping has increased within the EU by 10% between 2003 and 2011. In terms of annual output, some 21 regions account for over half the wheat production in the EU. Alongside food, biofuel production is only one of the end uses of wheat output. Two per cent of the wheat area in the fourteen leading countries is devoted to biofuel production. Bulgaria, Czech Republic, UK, Slovakia and Denmark are the Member States with the largest share of cropland under wheat cultivation, whilst France, Germany, Poland, Romania, UK, Italy and Spain are the countries with the largest overall areas of wheat.

In temperate climates, wheat cultivation is not a significant risk factor for soil erosion. However, due to its poorly developed root system, it has some of the highest fertiliser requirements among all the cereals, particularly for nitrogen. Winter varieties have higher fertiliser demands than spring varieties. A reduction in the typical fertiliser requirements in wheat grown for biofuels is due to the fact that it does not require the build-up of protein to the same extent as wheat for flour milling. Wheat is also highly susceptible to pests and diseases, particularly during the early growing phases, with consequent impacts for water quality and soil pollution by pesticides and herbicides.

Rye

Rye is grown in large areas of temperate and cold climatic regions, mainly in the northern parts of the EU. It is also a typical crop in certain regions of south-western Europe. For a long time it has been predominantly used for food and forage, and in smaller amounts for the distillation industry. The total area under rye cropping within the EU has decreased by 26% since 2003, although it has recently been used as a feedstock for the bioenergy sector. Poland, Germany and Spain have the largest areas under rye cultivation in absolute terms.

Compared to most other commercial cereal varieties, rye can be grown on a much wider range of soil types. This makes it an important crop on sandy or peaty soils in particular. Rye cultivation poses a relatively low risk to soil erosion. On the other hand, it can suffer from a large number of diseases during the growing phase and requires use of disease prevention chemicals prior to sowing. Fertiliser requirements for rye depend on a range of factors such as soil quality, weather conditions, the production technology and yield (EEA, 2006).

3.3.3 Soil risks per crop (row crops)

Row crops (maize, sunflower, sugar beet) present generally greater risks to soils than cereals. This is largely due to wide row spacing and significant exposure of bare soil. Erosion is a particular issue especially when the row direction is in line with the orientation of slope. Pre-cultivation techniques (for example the turning of soils for maize) can also exacerbate soil erosion and the loss of organic matter. Like cereal straw, the stover or stems of sunflowers and maize can be used for energy production or can be shredded and to some extent given the highly fibrous nature of the stover ploughed back into soils. Table 5 presents the main risk factors for field crops, their impacts on soils and key management practices to mitigate the risk.

Table 5: Risks associated with row crops (maize, sunflower, sugar beet) and main mitigating practices

Risk factor	Soil impact	Key management practices to mitigate risk
Row cultivation and bare soil	• Exposed soil during growth phase leading to high risk of erosion and loss of SOM	• Cover crops if appropriate • Contour management • Establishing breaks within field to avoid soil loss (maize and sugar beet)
Ploughing, drilling/harrowing and soil loosening	• Break up of soil structure and exposure of soil potentially leading to erosion risk • Soil compaction through use of machinery • Loss of organic matter	• Low tillage • Timing of ploughing (sunflower)
High fertiliser application	• Risk of leaching to water courses or if poorly balanced decline in organic matter • Particular risk for sunflower due to high demands	• Timing of application • Precision farming
Inappropriate irrigation*	• Given relatively high temperature and moisture demands, irrigation could lead to salinisation of the soils	• Drip irrigation • Irrigation management

Risk factor	Soil impact	Key management practices to mitigate risk
Use of machinery	• Compaction leading to risk of erosion in localised areas	• Use of appropriate machinery • Timing of harvest to limit compaction risk
Post-harvest management	• Removal of residues leading to exposure of soils, hence erosion risk and risk of decline in organic matter	• Management of residue • Ploughing in (maize and sugar beet) • Soil cover during peak period of erosion risk (maize)

Source: own compilation
*Does not apply to sugar beet

Grain maize
Maize is a key EU crop, with grain and silage maize being the main varieties. Overall, the largest areas of grain maize are in Romania, France, Italy, Hungary, Poland, Spain and Bulgaria. In several of these countries grain is the dominant maize variety, cultivated on over 80% of the maize area (see Table 6). The area of grain maize cropping within the EU has seen a decline of 29% from 2003 to 2011. Grain maize is a summer crop, and therefore can be used also in systems which cultivate cereals as winter crops, particularly in northern Europe where other summer crops cannot be grown. In Poland, Slovakia, France, Germany and Hungary, 2 to 10% of the area under grain maize is cultivated as bioenergy feedstocks. For the fourteen leading biofuel producing countries, 2% of the grain maize area is devoted to biofuel production. Whilst grain maize increasingly supplies the bioethanol sector, silage maize has become an important feedstock for biogas for heat and electricity (in Germany in particular).

Table 6: Structure of production of maize in key Member States

Member State	Total conventional maize area (1,000 ha)	Grain		Silage	
		1,000 ha	%	1,000 ha	%
France	3127.6	1639.6	52.4%	1414.4	45.2%
Romania	2819.6	2774.0	98.4%	33.2	1.2%
Germany	1738.9	434.5	25.0%	1300.1	74.8%
Italy	1411.7	1128.2	79.9%	274.7	19.5%
Hungary	1308.5	1139.5	87.1%	111.3	8.5%
Poland	656.7	334.5	50.9%	315.5	48.1%
Spain	507.4	414.5	81.7%	89.5	17.6%
Bulgaria	380.9	350.0	91.9%	30.3	7.9%
Czech Republic	281.3	97.5	34.7%	182.5	64.9%

Source: FCEC, 2009

Maize is increasingly cultivated in highly intensive continuous systems, sometimes depending on irrigation. Grain maize (unlike silage maize) is easy to transport, which allows for cultivation in the most favourable climatic and agronomic conditions, irrespective of where it is processed. This in turn has led to increase in the average field size under continuous cultivation (FCEC, 2009). In northern Europe (Germany, Denmark, The Netherlands, Poland), maize is mostly cultivated as non-irrigated continuous maize or rotated with grasses or winter wheat, and less frequently used for biofuels. In France and in central and central-eastern Europe (Czech Republic, Slovakia, Hungary), the prevailing systems are based on non-irrigated continuous grain maize or in rotation mostly with winter wheat. In southern and south-western Europe (Spain and Italy), irrigated maize predominates, sometimes with winter wheat rotations as well as in continuous systems (FCEC, 2009; Vasileiadis et al., 2011).

Maize, as a row crop, is a high risk crop with regard to soil erosion and this is exacerbated when cultivation expands into environmentally inappropriate areas (on sloping terrains). The basic erosion risk comes from relatively wide rows, due to high demands for direct sunlight exposure, and from late sowing, leaving the soil bare for long periods. In high temperatures, the soil cover may get established very late (KBU, 2008). Large fields along the slope incline and inappropriate management (e.g. ploughing down the slope) increase the risk (Louwagie et al., 2009). This study has found that expanding bioethanol markets have led in some situations to the expansion of grain maize onto former grass fodder areas, particularly in Member States with declining livestock production (Janecek et al., 2012; Dumbrovský M., pers.comm). Bearing in mind that grass fodder ensures permanent vegetation cover and is generally beneficial for stabilising soils against erosion, the expansion of maize exacerbates the risk of erosion. Soil erosion tends to be accompanied also by declines in organic matter. In addition, maize has high nutrient requirements from the early growth stage. Declining levels of organic matter, where they occur, tend to be compensated by increasing nutrient inputs, which can then lead to environmental problems associated with fertiliser run-off. Pesticide run-off is another issue since weed control, due to the large size of the crop, is reliant on chemical inputs beyond the early stages of cultivation. However, pesticide application can be reduced when maize is used for energy purposes, since the presence of weeds does not affect the quality of output as much as in the case of maize for fodder. Maize grows best with high water availability, which has accompanying risks for aquifers in irrigated systems. Maize cultivation is also associated with moderate soil compaction risk from the use of harvesting machinery (EEA, 2006).

Sunflower

Sunflowers are typically grown for food and feed, and recently have been grown as a feedstock for bioenergy sectors. The area under sunflower cropping within the EU has increased by around 19% between 2003 and 2011. Romania, Spain, Bulgaria and France have the largest areas of sunflower cultivation in the countries compared for this study in absolute terms. Romania, Hungary and Bulgaria are the countries with the largest share of sunflower croplands in the total arable area. France leads in the use of sunflower seed for biodiesel production, with 45% of its sunflower area destined for the energy market in 2010.

Sunflower leaves soils bare for a relatively long time. This, and the cultivation in rows, makes it a high-risk crop for erosion (EEA, 2006). Sunflowers are nutrient demanding, for example, in comparison to rapeseed, sunflower plants require almost twice as much nitrogen and potassium. Nutrient run-off, as well as the associated loss of organic matter, are significant risks associated with sunflower cultivation. Harvesting has to be carried out when sunflower heads are fully dry, and the final stage of desiccation if frequently speeded up by the use of chemicals in the pre-harvest period.

Sugar beet

Sugar beet is a summer crop requiring relatively cool climates and characteristic for northern parts of EU temperate zones. Besides its main use for sugar, by-products are used for animal feed and distillation and, recently, as a feedstock for the bioethanol sector. There has been a considerable decline of sugar beet production due to the 2006 CMO (Common Market Organisation) reform which reduced the sugar quota, with the decline of 27% in the total area of production between 2003 and 2011. France, Germany, Poland and the UK are the countries with the largest areas of sugar beet cultivation in absolute terms. In Hungary and the UK the share of sugar beet area devoted to biofuel production is particularly high, between 30-50%. In France, the Czech Republic and Germany this share is also important, but less than 16% of their total sugar beet area. For the leading fourteen countries producing biofuels, 14% of the sugar beet area is devoted to biofuel production.

Row cultivation and relatively long periods of bare soils associated with sugar beet production make it a high erosion risk crop. In terms of fertiliser requirements, sugar beet is very demanding. Depending on soil and preceding crop type, its nitrogen demand of 230kg/N ha is comparable to rapeseed (EEA, 2006). Herbicides and fungicides are used to control weeds and pathogens during early stages of growth and there are pollution risks to water and soil associated with fertiliser and pesticide run-off. On the positive side, the maintenance of sugar beet in crop rotations may have beneficial agronomical and environmental effects for cereals that follow in the rotation. Sugar beet cultivation presents high soil compaction risks. This is due to a higher depth of tillage and the greater weight of harvesters for sugar beet than for cereals. Furthermore, the harvesting period is later for sugar beet than for cereals and generally, where sugar beet is grown in northern Europe, the soil is wetter than during the cereal harvest (Boizard et al., 2002; Poodt et al., 2003; Van Dijck and Van Asch, 2002).

3.3.4 Soil risks per country

Annex 4 provides a detailed overview of information for the ten Member States focussed upon in this study. Detailed information was collected from EU studies and datasets and, where available, national literature. This was complemented by qualitative information collected through phone interviews with experts in Member States. Table 7 to Table 16 provide a summary.

Table 7: Overview of soils risks in the Czech Republic

Key soils risks	• Moderate erosion risk; moderate decline in SOM
Scope of risk	• Half of all soils are at risk of soil erosion
Risk zones	• Sloping terrains
Crops presenting greatest risk	• *Rapeseed:* 176 kha (48% of crop area) supplies biodiesel production • *Sugar beet:* 9 kha (16% of crop area) supplies bioethanol production • *Wheat:* 17 kha (2% of crop area) supplies bioethanol production • *Grain maize:* 2 kha (2% of crop area) supplies bioethanol production
Risks from feedstock cultivation	• High nitrate losses and pesticide use in the case of rapeseed and wheat • Soil compaction and erosion from sugar beet cultivation

Trends exacerbating risks	• Field concentration (in maize in particular) • Expansion of maize and rapeseed into sloping terrains and on former grass fodder areas with erosion increase
Management exacerbating risks	• Bare soil • Ploughing down the slope • Land levelling to remove gullies and dilution of remaining topsoil by deep ploughing • Lack of mitigating management in risk zones

Source: Own compilation based on Ecofys et al., 2012; Janecek et al., 2012; FCEC, 2009; Dumbrovský M., pers.comm.

Table 8: Overview of soils risks in France

Key soils risks	Erosion; decline in SOM
Scope/degree of risk	• 12% of UAA at high or very high erosion risk • 36-53% of soils in N and SW with low SOC (2-5%) or very low (1-2%) SOC content
Risk zones	• Areas on loamy soils (Ile-de-France, Aquitaine, Haute Normandie, Basse Normandie, and Midi Pyrenees and Paris basin) for erosion
Crops presenting greatest risk	• *Rapeseed:* 619 kha (42% of crop area) supplies biodiesel production • *Sunflower*: 314 kha (45% of crop area) supplies biodiesel production • *Sugar beet*: 60 kha (16% of crop area) supplies bioethanol production • *Wheat*: 101 kha (2% of crop area) supplies bioethanol production • *Grain maize:* 9 kha (2%) supplies bioethanol production
Other feedstocks cultivated	• Barley
Risks from feedstock cultivation	• High nitrate losses and pesticide use in the case of rapeseed, wheat and maize • Soil compaction and erosion from sugar beet cultivation; substantial sugar beet yield increases associated with increased fertiliser and pesticide use • Soil erosion from maize
Trends exacerbating risks	• Rapeseed replacing former set-aside and leguminous crops • Decrease of permanent grassland • Increasing replacement of rotated systems by continuous cropping systems (31% of maize area are under monoculture)
Management exacerbating risks	• Tillage on sloped arable land in SW • Bare soil (Alsace, Brittany and SW) • Lack of mitigating management in risk zones
Note: Use of rapeseed and sugar beets in crop rotation may have positive agronomical and environmental effects for succeeding cereals	

Source: own compilation based on Ecofys et al., 2012; Pointereau et al., 2008; Montanarella, 1999; FCEC, 2009; Dupraz P., pers.comm

Table 9: Overview of soils risks in Germany

Key soils risks	Erosion risk; loss of SOM; compaction on peat soils
Scope of risk	• Low SOC (1-6%) across and very low SOC (1-2%) in Eastern regions • High SOM in peat soils under arable crops in North

Risk zones	• Highest erosion risk in central Germany, BW and Bavaria • High wind erosion risk in North • Continuous maize in Lower Saxony and Bavaria
Crops presenting greatest risk	• *Rapeseed*: 595 kha (43% of crop area) supplies biodiesel production • *Sugar beet*: 21 kha (6% of crop area) supplies bioethanol production
Other feedstocks cultivated	• Wheat, maize and barley only marginally used for biofuels
Risks from feedstock cultivation	• High nitrate losses and pesticide use in the case of rapeseed , wheat and maize • Soil compaction and erosion from sugar beet cultivation
Trends exacerbating risks	• Increasing replacement of rotated systems by continuous cropping systems (one third of grain maize area is under monoculture)
Management exacerbating risks	• Drainage and agricultural management on peat soils
Mitigating management of special note	• Strict requirements for cultivation on slopes, requirements for catch crops and cover crops, and contour ploughing • Lack of mitigating management in risk zones
Note: Additional risks accrue with the use of silage maize for biogas for heat and electricity, since 22% of total maize cultivation (including minor shares of grain maize) is used for energy purposes[13].	

Source: Own compilation based on Ecofys et al., 2012; Umweltbundesamt, 2011; Wurbs and Steininger, 2011; FCEC, 2009; Gödeke K. pers.comm. and Thrän D, pers.comm.

Table 10: Overview of soils risks in Hungary

Key soils risks	Erosion; decline in SOM; compaction; soil salinisation
Scope/degree of risk	• Water erosion affects 25% of all soils and more than one third of UAA • 8.5% of UAA is severely eroded • Around one third of soils with low SOC (2-10%) are used for agriculture • Very high risk of compaction in SE
Risk zones	• In Great Plain, soil impacts (SOM levels, erosion) are exacerbated during severe droughts (three years out of every ten) • Eastern regions for salinisation
Crops presenting greatest risk	• *Grain maize*: 23 kha (2% of crop area) to bioethanol production • *Rapeseed*: 159 kha (61% of crop area) to biodiesel production • *Sugar beet*: 5 kha (38% of crop area) to bioethanol production
Other feedstocks cultivated	• Wheat
Risks from feedstock cultivation	• High nitrate losses and pesticide use in the case of rapeseed and maize • Soil compaction and erosion from sugar beet cultivation
Trends exacerbating risks	• Historically large fields • Early harvest (most areas by the beginning of July) • Potential expansion of maize or rapeseed area cannot be achieved without adverse effects, such as abandonment of rotations (currently only 10% of grain maize is under monoculture)

[13] http://www.nachwachsenderohstoffe.de/uploads/media/RZ_FNR_0064_Maisgrafik_300_rgb_neu.jpg

Management exacerbating risks	• Bare soil during extended critical summer period • Lack of mitigating management in risk zones
Note: Increasingly severe drought years interrupted by wet ones are likely to be a lasting weather pattern, with impacts on erosion and SOM levels during droughts, and compaction in wet years. Although significant investments have been made into bioethanol facilities around the Danube, with plans to utilise domestic maize surplus, the changing pattern of extreme weather makes it doubtful if high maize yields can be sustained.	

Source: Own compilation based on Ecofys et al., 2012; Kertész, 2009; Nowicki et al., 2009; Pepó & Kovačević, 2011; NHRDP, 2007; FCEC, 2009; and an input by Hungarian Soil Science and Agricultural Chemistry.

Table 11: Overview of soils risks in Italy

Key soils risks	• Very low SOM levels; soil erosion
Scope/degree of risk	• Severe SOM depletion in South, coastal regions and in Po Valley • Low SOM levels in other regions • High water erosion risk in Central Italy
Risk zones	• South, coastal regions, Po Valley (SOM) • Hilly regions in Central Italy, on clay soils in particular (erosion)
Crops presenting greatest risk	• *Grain maize:* 2 kha, i.e. 2% of crop area to bioethanol production. • *Wheat:* 17 kha, i.e. 2% of crop area to bioethanol production.
Other feedstocks cultivated	• Sunflower
Risks from feedstock cultivation	• High nitrate losses and pesticide use for wheat and maize • Soil erosion from maize
Trends exacerbating risks	• Concentration of maize feedstock production (for biogas) in the Po Valley is in competition with food and feed production • Over 40% of maize is grown in monoculture
Management exacerbating risks	• Bare soil • Tillage on sloped arable land • Land levelling to remove gullies and dilution of remaining topsoil by deep ploughing • Lack of mitigating management in risk zones
Note: Cultivation of energy crops is mostly concentrated in North, with around 10-20,000 ha of land under biofuel feedstock cultivation, mostly rapeseed and sunflower, around the Po Valley. The main use of maize grown in the region alongside food and fuel is biogas for heat/electricity, while the share of maize diverted to ethanol production is small.	

Source: Own compilation based on Ecofys et al., 2012; Nowicki et al., 2009; FCEC, 2009; Povellato A., pers.comm; Pieri et al. (2007)

Table 12: Overview of soils risks in Poland

Key soils risks	• Moderate SOM decline; soil erosion; compaction
Scope/degree of risk	• Low levels (2-5%) of SOC in central Poland, medium levels (5-10%) elsewhere; • 7% of UAA at severe water erosion risk;* • High wind erosion in North
Risk zones	• Hilly areas in central Poland (for water erosion) • Peat soils in North and East (mainly grasslands)

Crops presenting greatest risk	• *Rapeseed*: 176 kha (26% of crop area) to biodiesel production. • *Grain maize*: 22 kha (7% of crop area) to bioethanol production.
Other feedstocks cultivated	• Wheat
Risks from feedstock cultivation	• High nitrate losses and pesticide use in the case of rapeseed, maize and wheat • Soil erosion from maize
Trends exacerbating risks	• About 30% of maize is under monoculture • No notable expansion of area of rapeseed and maize or major intensification so far.
Management exacerbating risks	• Bare soil • Tillage on sloped arable land • Land levelling to remove gullies and dilution of remaining topsoil by deep ploughing • Lack of mitigating management in risk zones
Note: 1. Rapeseed is particularly sensitive to weather conditions, which leads to fluctuations in the supply of domestically produced rapeseed and the use of imports 2. In North and East, there are 12,500 ha of peat soils of which three quarters are under grasslands. The risk of expanding arable production onto these soils (and drainage) would have immense potential costs to climate, soil carbon content, hydrological regime and biodiversity.	

Source: Own compilation based on Nowicki et al., 2009; Gobin et al, 2011; Wawer, Nowocień and Podolski, 2010; FCEC, 2009; Maciejczak M., pers.comm.

* Calculation is based on EU level data which underestimate the actual pressures (Wawer and Nowocień, 2007)

Table 13: Overview of soils risks in Romania

Key soils risks	• Some water erosion risk*; wind erosion; SOM depletion; potential salinisation*
Scope/degree of risk	• Eastern and southern regions more affected by erosion • Severe and extensive wind erosion • Low levels (2-5%) of SOC in South and South-East, medium levels (5-10%) of SOC elsewhere • Compaction in North West
Crops presenting greatest risk	• *Rapeseed*: 134 kha (25% of crop area) to biofuel production
Other feedstock cultivated	• Maize, wheat and soybean
Risks from feedstock cultivation	• High nitrate losses and pesticide use in the case of rapeseed
Trends exacerbating risks	• Almost 40% of grain maize is cultivated in monoculture
Management exacerbating risks	• No data available

Source: Own compilation based on Ecofys et al., 2012; European Commission, 2011; FCEC, 2009

*There is lack of data for the degree of risk.

Table 14: Overview of soils risks in Slovakia

Key soils risks	• Medium water erosion risk; medium SOM decline
Scope/degree of risk	• 8-21% of UAA is on soils with moderate levels of SOC (2-10%) • Medium water erosion affects 21% of UAA; strong or extremely strong water erosion affects 3% of UAA • Medium and strong wind erosion affects 5% and 2% of UAA
Crops presenting greatest risk	• *Rapeseed*: 147 thousand ha (89% of crop area) supplies biodiesel production • *Grain maize*: 26 thousand ha (15% of crop area) supplies bioethanol production
Other feedstock cultivated	• Wheat
Risks associated with feedstocks	• High nitrate losses and pesticide use in the case of rapeseed and maize • Soil erosion in maize
Management exacerbating risks	No data available

Source: Own compilation based on Ecofys et al., 2012; Nowicki et al., 2009; FCEC, 2009; Bielek et al., 2005;

*There is lack of data for the degree of water erosion risk

Table 15: Overview of soils risks in Spain

Key soils risks	• Erosion risk; desertification; SOM depletion; salinisation
Scope/degree of risk	• Low (1-2%) SOC levels in southern regions • Medium (5-10%) SOC levels in the North and North West
Risk zones	• High water erosion risk at southern coast (Andalucía and Murcia), the North West (Asturias, Cantabria and Galicia) and North East (Catalonia) • Wind erosion risk concentrated only in central Navarra, South West Andalucía and the Balearic Islands • Southern regions for SOM depletion • Compaction risk in Aragon and parts of Extremadura
Crops presenting greatest risk	• *Sunflower:* 32 kha (5% of crop area) to biodiesel production • *Wheat:* 27 kha (1% of crop area) to bioethanol production • *Barley:* 23 kha (1% of crop area) to bioethanol production • *Rapeseed*: 11 kha (57% of crop area) to biodiesel production
Other feedstock cultivated	• Grain maize
Risks from feedstock cultivation	• High nitrate losses and pesticide use in the case of rapeseed and wheat
Management exacerbating risks	• Hill slope cultivation • Irrigation with saline water • Bare soil • Abandonment of terraces and land abandonment • Burning of stubble • Lack of mitigating management in risk zones
Note: It is doubtful if biofuel crop production (of conventional crops) can be scaled up since due to irrigation requirements	

is not economically feasible in Spain. This is why Spain heavily relies on imported feedstocks.

Source: Own compilation based on Ecofys et al., 2012; Calatrava et al., 2008; Sistema de Información del Banco de Datos de la Naturaleza (BDN); CARM, 2007; Garrido,A. pers. comm..

Table 16: Overview of soils risks in the United Kingdom

Key soils risks	• Water and wind erosion; loss of SOM; compaction
Scope/degree of risk	• Low (2-5%) SOC levels across UAA* • Medium (5-10%) SOC levels in the North and North West • 72 thousand ha of peat soils under cropland or temporary grassland
Risk zones	• North and west affected by increasing water erosion • Coastal areas and Northern UK affected by strong winds • Small area of peat soils is under intensive arable management in the East of England.
Crops presenting greatest risk	• *Rapeseed*: 81 thousand ha (12% of crop area) to biodiesel production. • *Sugar beet:* 44 thousand ha (48% of crop area) to bioethanol production.
Other feedstock cultivated	• Wheat, grain maize
Risks from feedstock cultivation	• High nitrate losses and pesticide use in the case of rapeseed and wheat • Soil compaction and erosion from sugar beet cultivation • Soil erosion from maize cultivation
Trends exacerbating risks	• Intensification of existing crop production • Cropping on marginal land and grassland • Replacement of former set-aside by biofuel crops
Management exacerbating risks	• Lack of mitigating management in risk zones
Note: All the exacerbating trends resulted from overall demand and supply dynamics in the agricultural market and cannot be pinned down to biofuels. However, marginal land and grassland is an exception since their conversion to maize cultivation, is clearly driven by demand for maize for bioenergy.	

Source: Own compilation based on Ecofys et al., 2012; European Commission, 2011; Gobin et al, 2011; Letts J., pers.comm.
*Except in peatlands which are largely grazed.

3.3.5 Synthesis

The resulting synthesis of risks from field and row crops summarised in Table 17 and

Table 18 is informed by the information presented in previous sections including the expert interviews. Expert judgement of the study team has been used to fill in the gaps. The synthesis intends to estimate actual risks specific to each geographic region. It is inevitably schematic, due to multiple environmental, climatic and agronomic factors affecting the soil risk and should not be understood as a full overview of the relative risks in different regions.

Table 17: Risks from the cultivation of field crops

Geographic region	Inherently vulnerable soils in the region	Risk factors linked to management	Soil erosion (by water and wind)	Loss of SOM	Compaction	Other soil risks*
EU-27			**Medium to high**	**High**	**Medium**	**High**
Southern and South Western Europe *(*Spain, Italy, S.France etc)	Arid soil conditions, low rain, low SOM, erodible soils	Large areas of continuous cropping systems with reduced or no rotations, machinery, deep tillage in many areas, high use of inputs	**High** Erodible soils under rape in early growing phase	**High** Due to low levels of SOM in sandy soils and effect of soil erosion on SOM levels	**Medium to high** Machinery use and arid soils with poor structure	**High** Fertilisers, herbicides, pesticides, salinisation issues
Northern and North Western Europe UK, N. and NW. Germany, N. Poland etc)	Mineralised peat soils under cultivation/ drainage with on-going high losses of SOC	Large areas of continuous cropping systems with reduced or no rotations, machinery, deep tillage less frequent, high use of inputs	**Medium** Rape in early growing phase, high in areas with flash floods	**High to medium** High risk on cultivated peat soils, moderate on other soil types and where min till applied	**High** Machinery use on clay soils in particular	**High** Fertilisers, herbicides, pesticides
Western Europe (France etc)	Upland soils with higher erodibility, generally low SOM content	Large areas of continuous cropping systems with reduced or no rotations, machinery, high use of inputs	**Medium** Erodible soils in areas under rape cultivation in early growing phase	**High** Poorer soil organic content and effect of erosion on SOM levels	**Medium** Machinery use	**High** Fertilisers, herbicides, pesticides, salinisation issues

Geographic region	Inherently vulnerable soils in the region	Risk factors linked to management	Soil erosion (by water and wind)	Loss of SOM	Compaction	Other soil risks*
Central Europe (S. and E. Germany, SW. Poland, Czech Republic, Slovakia)	Upland soils with higher erodibility	Large areas of continuous cropping systems with reduced or no rotations, machinery, deep tillage and ploughing up and down the slope where applied; high use of inputs	**High to medium** High on sloping soils under rape in early growing phase, high in areas with flash floods	**Medium** Particularly in areas affected by erosion	**Medium** Machinery use and deep tillage	**Medium** Fertilisers, herbicides, pesticides
North Eastern Europe (N. and E. Poland, Baltic countries)	Mineralised peat soils under cultivation/drainage with on-going high losses of SOC	Large areas of continuous cropping systems with reduced or no rotations, machinery, deep tillage, high use of inputs	**Medium to high** High in areas with flash floods	**High to medium** High risk on peatsoils converted to arable use, moderate on other soil types	**Medium** Machinery use	**Medium** Fertilisers, herbicides, pesticides
Central and South Eastern Europe (Hungary, Romania, Bulgaria)	Arid or semi-arid soil conditions, low rain, low SOM, erodible soils	Large areas of continuous cropping systems with reduced or no rotations, machinery, deep tillage and ploughing up and down the slope where applied, high use of inputs	**Medium to high** Due to erodible soils in areas under rape in early growing phase	**Medium** Moderate to high due to low levels of SOM in sandy soils, higher risk in loam soils and where residue is not returned	**Medium to high** Machinery use	**High to medium** Fertilisers, herbicides, pesticides, salinisation issues

*Other soil risks include diffuse soil pollution, salinisation, soil biodiversity and acidification.

Note: Levels of risk are estimated according to the most relevant local factors which are multiple and highly specific. In effect, the colour coding highlights risks arising in the given locale for which mitigation measures are missing or not sufficient. It does not intend to primarily capture the relative cross-country comparisons.

Table 18: Risks from the cultivation of row crops

Geographic region	Inherently vulnerable soils in this region	Key risk factors linked to management	Soil erosion (water and wind)	Loss of SOM	Compaction	Other risks (diffuse soil pollution, salinisation, soil biodiversity)
EU-27			**High**	**Medium**	**High**	**High**
Southern and South Western Europe (Spain, Italy, S. France etc)	Arid soil conditions, low rain, low SOM, erodible soils	Large areas of continuous cropping systems with reduced or no rotations, machinery, deep tillage in many areas, high use of inputs	**High** In maize and sugar beet in particular, also sunflower	**High** Low levels of SOM in sandy soils and effect of soil erosion on SOM levels	**High** Machinery use	**High** Fertilisers, herbicides, pesticides, salinisation issues
Northern and North Western Europe UK, N. and NW. Germany, N. Poland etc)	Mineralised peat soils under cultivation/ drainage with on-going high losses of SOC, in other regions low SOM content	Large areas of continuous cropping systems with reduced or no rotations, machinery, deep tillage less frequent, high use of inputs	**High** In maize and sugar beet in particular, also sunflower	**High to medium** High risk on cultivated peat soils, moderate on other soil types and where min till applied	**High** Machinery use on clay soils in particular	**Medium to high** Fertilisers, herbicides, pesticides
Western Europe (France etc)	Upland soils with higher erodibility, generally low SOM content	Large areas of continuous cropping systems with reduced or no rotations, machinery, high use of	**High** In maize and sugar beet in particular, also sunflower	**Medium to high** Higher risk in S due to poor SOC in soils and effect of erosion, moderate risk	**High** Machinery use	**High** Fertilisers, herbicides, pesticides, salinisation issues

Geographic region	Inherently vulnerable soils in this region	Key risk factors linked to management	Soil erosion (water and wind)	Loss of SOM	Compaction	Other risks (diffuse soil pollution, salinisation, soil biodiversity)
		inputs		in N where min till applied		
Central Europe (S. and E. Germany, SW. Poland, Czech Republic, Slovakia)	Upland soils with higher erodibility	Large areas of continuous cropping systems with reduced or no rotations, machinery, deep tillage and ploughing up and down the slope where applied; high use of inputs	**High** In maize and sugar beet in particular, also sunflower	**Medium** Particularly in areas affected by erosion	**High** Machinery use	**Medium** Fertilisers, herbicides, pesticides
North Eastern Europe (N. and E. Poland, Baltic countries)	Mineralised peat soils under cultivation/drainage with on-going high losses of SOC	Large areas of continuous cropping systems with reduced or no rotations, machinery, deep tillage, high use of inputs	**Medium to high** In maize and sugar beet in particular, also sunflower	**High to medium** High risk on peatsoils converted to arable use, moderate on other soil types	**High** Machinery use in maize and sugar beet on clay soils in particular	**Medium** Fertilisers, herbicides, pesticides

Geographic region	Inherently vulnerable soils in this region	Key risk factors linked to management	Soil erosion (water and wind)	Loss of SOM	Compaction	Other risks (diffuse soil pollution, salinisation, soil biodiversity)
Central and South Eastern Europe (Hungary, Romania, Bulgaria)	Arid or semi-arid soil conditions, low rain, low SOM, erodible soils	Large areas of continuous cropping systems with reduced or no rotations, machinery, deep tillage and ploughing up and down the slope where applied, high use of inputs	**Medium to high** In maize and sugar beet in particular, also sunflower	**Medium to high** Higher risk in sandy soils with low levels of SOM, lower risk in loam soils	**Medium** Machinery use	**Medium to high** Fertilisers, herbicides, pesticides, salinisation issues

Note: Levels of risk are estimated according to the most relevant local factors which are multiple and highly specific. In effect, the colour coding highlights risks arising in the given locale for which mitigation measures are missing or not sufficient. It does not intend to primarily capture the relative cross-country comparisons.

3.4 Soil risks in non-EU countries

3.4.1 Problems facing non-EU soils

A summary of factors that impact soil health/quality, probable impact on soils, and management practices to mitigate those risks is presented in Table 19. The risk factors and their impacts are general, and they exist everywhere, except deforestation, which is common in Southeast Asia and South America. Other exceptions include plantations that include perennial tree crops, pastures, and semi-perennial crop, such as sugarcane, where tillage effects are minimal and vegetative part is largely unaffected. Most of the other risk factors relate to cultivation practices common in raising field crops. Use of machinery and agricultural chemicals is common in the United States, Canada, European countries, and large farming operations in South America. Where large investments are made, farming is based on operational efficiency and practices designed to ensure targeted production level. Consequently, soil compaction, soil pollution, groundwater pollution, loss of organic matter, and loss of soil biodiversity are common where farming is based on machinery, tillage, and chemicals. Soil erosion is a problem that occurs everywhere to some degree. However, it is serious on unprotected slopes, especially where rainfall is high, and fields that are subject to excessive soil disturbance due to tillage or harvesting operations, e.g., sugar beet and other crops that require deep disturbance of the soil. Irrigation is necessary where natural supply of moisture during the cropping season is inadequate. However, irrigation management is problematic. If not well controlled, it can cause erosion on the soil surface and leaching of nutrients. Salinisation, related to irrigation, is a problem in most dry areas due to activation of native salts and additions of salts from irrigation water. Soil acidity occurs where nutrients are leached due to excessive rainfall, or where vegetative biomass is constantly removed resulting in mining of base nutrient cations. It can also occur where acid-forming fertilisers are used.

Table 19: Risk factors, their impact on soil resources, and management practices to mitigate the soil risks

Risk factors	Impact on soil	Management practices to mitigate risks
Deforestation	Erosion, loss of biodiversity, loss of organic matter	Leave natural forests as shelterbelts between deforested swaths.
Tillage	Erosion, loss of biodiversity, loss of organic matter, imbalance of microbial population	Minimum tillage, no-till planting
Machinery	Soil compaction, runoff and erosion, negative impact on soil structure and infiltrability of soil	Minimise use of machinery, special design , minimum tillage
Slope	Erosion, landslide	Terracing, contour bunding contour hedgerows, contour planting
Bare soil between cultivation cycles	Water and wind erosion	Cover crop, crop residue as surface mulch
Fertilisers, herbicides, pesticides	Soil and groundwater pollution, acidification, negative impact on microorganisms and their function	Minimise use of chemicals, inter-row cultivation, crop diversity and rotation, disease and pest-resistant varieties, promote IPM
Irrigation	Salinisation, acidification	Moisture conservation, drought-resistant varieties
Climate Wet/Dry/warm/cold	Leaching of nutrients in high rainfall areas, higher incidence of pests and diseases requiring higher use of chemicals, loss of soil fertility, soil acidity, salinisation in dry climates	Choose planting time to avoid periods of high rainfall amounts and frequency, minimise chemical pesticides, promote IPM, soil amendments, e.g., liming
Removal of vegetative biomass	Mining of nutrients, loss of fertility, acidity	Judicious application of fertilisers, return and incorporate biomass into the soil
Monoculture	Soil-borne diseases, loss of biodiversity	Polyculture, crop rotation

This section of the report concerns only the non-EU countries, which are listed below along with the feedstock they export to EU.

North America: USA (soybean and maize); Canada (rapeseed)
Central Europe: Russia (rapeseed); Ukraine (rapeseed)
Latin America: Brazil (soybean and sugarcane); Argentina (soybean); Paraguay (soybean)
Central America: Guatemala (sugarcane)
Asia: Indonesia (palm oil); Malaysia (palm oil)
Africa: Tanzania (sugarcane)

It should be noted here that biofuel crops are the same crops that are produced traditionally for other purposes. Therefore, threat to soil resource should be attributed to common agricultural practices, and not to biofuels per se. Available production data (e.g., FAOSTAT, 1961-2010) combined with trends in exports of biofuels to EU show that, at present the share of EU biofuel feedstock as a percentage of total crop area is <2%.

The threat to soil resources results from an interaction of four basic factors, including natural soil characteristics, landscape and climatic conditions, type of crop, and cultivation practices. In the following we reflect on these factors.

Effect of typology of different crops
As can be seen from the list of countries, we are dealing with vastly different climatic conditions. The crops of interest also involve varying cultivation practices. Palm oil is a tree crop and it is very different from other field crops. Sugarcane is semi-perennial and usually occupies the land for 5 to 7 years. Most other crops are annual and their cultivation involves similar field practices, i.e., tillage, sowing/seeding, fertilisation, weed and pest control, irrigation (where practiced), and harvesting. The listed crops are also produced in a farming system on large scale, and all are based on mechanisation and high use of chemical inputs. Thus, apart from inherent soil vulnerabilities, most crops are likely to impact the soil from the effects that result from use of machinery and chemicals.

3.4.2 Soil risks per country

The impact of biofuel crops on soils is expected to vary widely depending on geographic location, inherent soil vulnerabilities, and agriculture practices. A brief discussion of soil conditions and potential risks to soils in non-EU countries is given below. It is to be noted here that detailed information is not available for several of the countries, as it is for EU countries.

Brazil
Brazil's main exporting crops are sugarcane and soybean. The main areas of sugarcane production are in the Central East Brazil and a small area in the North. Brazilian soils are characterised primarily by low nutrient holding capacity in the north, seasonal moisture stresses in the middle with patches of seasonally excess moisture and high temperatures. In the south there are areas of low nutrient holding capacity and excessive leaching. The impact of biofuel feedstock crops in Brazil relate to land

clearing and agricultural management practices. Although there appears to be a shift from traditional to no-till cultivation, which reduces erosion and improves soil quality, there is a growing trend toward mono-cropping in crops grown for biofuels, especially sugarcane and soybean. This reduces soil fertility and increases crops' vulnerability to pests and diseases, as well as other environmental impacts. Erosion under sugarcane is low due to the semi-perennial nature of this crop. Soybean, on the other hand, may impact soils through the effects of mechanisation and use of chemicals.

Malaysia

The major soil stress is due to deforestation and excessive leaching. There are areas of high P, N, and organic retention. There is also impeded drainage along parts of the coastline, high organic retention, and acid sulphate condition. Soil impacts related to palm oil arise primarily from land conversion and replanting. Burning is a common practice for preparing land for replanting. At present there is a trend toward zero-burning, which allows plant material to be recycled. Use of machinery in the oil palm industry is common due to labour shortages. With increased demand for oil palm, it is now being grown on a wider range of soil, including marginal environments.

Indonesia

The major soil stress in oil palm growing areas in Indonesia is excessive leaching due to highly weathered soils and high rainfall. Additional stresses are due to high temperatures, high aluminium, low nutrient holding capacity, and steepness of land. There is increased risk of erosion when forests are cleared to grow oil palm, especially during periods of planting, establishment, and replanting. Drainage of peatlands results in loss of retention capacity and emission of greenhouse gases. Acid sulphate conditions exist along many parts of the coastline.

United States

United States contributes corn and soybean to EU biofuel. The leading corn producing states in the U.S. are Iowa, Illinois, Nebraska, Minnesota, and Indiana. Soybean growing states are in the Mid-west, Mid-south, and Southeast. Soil erosion is a major concern related to pre-planting soil preparation. In addition, there are areas of low organic matter, soils of low nutrient holding capacity, acidity in coastal areas, areas of seasonal moisture stresses, and areas of seasonally excess moisture; however, in most cases, these limitations are overcome by management and investment of inputs. No-till planting and conservation tillage are popular, and they have shown considerable improvements in terms of reducing soil erosion and conserving soil moisture. However, there are concerns that demand for biofuel crops will lead to intensification of management practices, including mono-cropping, increased fertiliser use, and intensive tilling. Major soil risks relate to use of machinery and excessive use of chemical inputs.

Argentina

Soybean acreage in Argentina has been increasing steadily. From 1986 to 2011 yearly production of soybean has increased from 7.0 to 48.0 million metric tons/year. The main producing areas are located in the humid Pampa region, where soils and climatic conditions are generally favourable. About two thirds of Argentina is dominated by arid climate, where crop production is constrained by limited supply of soil moisture. Most growers (almost 80%) in the Pampa region have adopted to no-till farming, which has shown promising results in terms of reducing soil erosion, conserving soil moisture, and improving soil fertility. The system of no-till planting has been promoted by the Argentinean Association of Farmers (AAPRESID), which has joint research projects with research and technological centres, universities, and agricultural extension. The concerns regarding land degradation are related to intensification of agriculture (e.g., introduction of the double annual cropping wheat-soybean), the change from the rotation cattle-agriculture to continuous agriculture, and untimely tilling sometimes along the slopes.

Paraguay

Soybean occupies the largest acreage of agricultural lands. Paraguay's major soybean producing states are Alto Parana, Itapua and Canindeyu, respectively producing 2,036,618, 1,411,313 and 1,401,086 tons soybeans per year, according to figures for 2009. The rapid expansion of soybean production has been causing several social and environmental problems in Paraguay: land conflicts and violence, agrochemicals, GM soy, deforestation, and food security and food sovereignty. Drought has also been a major problem, which affects yields. Each year in Paraguay about 9,000 rural families are evicted by soy production and a million acres of land are turned into soy fields. For those who remain on the margins of huge, industrial plantations, farming becomes next to impossible, as fumigations of the soybean plantations damage crops and health, and water becomes increasingly scarce as local resources are used up in irrigation. Until 2004 Paraguay registered the highest deforestation rate in the Americas and second in the world. Nearly 7 million ha of Atlantic Forest was lost to slash-and-burn for agricultural and ranching use in close to four decades. In 2004, Paraguay brought into force a Zero Deforestation Law (Ley de Deforestación Cero), which prohibits the conversion of native forests to agricultural areas or areas for human settlements in the Upper Parana Atlantic Forest (UPAF).

Soil fertility is one of the main problems in soybean soils of Paraguay. They exhibit low pH, low organic matter, and low P and K availability. Mechanised agriculture is the main user of technology. Soils are generally acid at the opening of the fields. Lime applications are carried out at the opening of the fields and soil acidity is checked every four years. Annual precipitation in the area averages 1,500 to 1,700 mm. Most of the precipitation in Paraguay falls between October and April but it can rain at any time of the year. December to March is extremely hot and humid. From July to September, temperatures are extremely variable and it can be cold in the daytime and very cold at night.

Canada

Environmental Sustainability of Canadian Agriculture: Agri-Environmental Indicator Report Series - Report No. 3 (2012) provides general trends in health of Canadian soils. According to this report, the risk of soil erosion on Canadian cropland steadily declined between 1981 and 2006, and the trend continues. The improvement in soil erosion risk reflects a reduction in all forms of soil erosion. However, the reduction in tillage erosion risk exceeded that of wind and water erosion (17% increase in the very low risk class, compared to increases of 12% for wind erosion and 3% for water erosion). Improvements in farm management resulted in a dramatic shift from a position of neutral SOC during the mid-1980s to a situation in 2006 in which the majority of cropland had increasing SOC. The

Prairies saw major increases in carbon over this time from adopting reduced tillage practices, and reducing summer fallow. From Ontario eastward however, there was an overall loss in SOC from 1981 to 2006. Overall, the management changes resulted in Canadian agricultural soils shifting from a net source of 2.5 mega tons (Mt) of CO_2 emissions per year in 1981 to a net sink of 10.7 Mt of CO_2 per year in 2006. The Soil Cover Indicator was estimated for each census year between 1981 and 2006. Over that 25-year period, average levels of soil cover in Canada have increased by 7%. This improvement came primarily as a result of widespread adoption of reduced tillage and decreased use of summer fallow in the Prairie provinces. However, increases in soil cover associated with reduced-tillage practices were offset to a considerable degree by cropping intensification (shifts from perennial to annual crops) and by increases in the proportion of land under crops such as potatoes, canola and soybeans, which have generally shorter durations of full canopy cover and produce less crop residue than corn, cereal grains and forages.

Because farming in Canada is based on mechanisation and use of chemicals, effects of these practices continue to be reflected on soil health.

Russia

Rapeseed in Russia is grown primarily in Krasnodar and Stavropol territories, where nearly all of the country's winter rape is grown. Total production for 2012-13 is forecast at 1.0 million tons, 5% below last year's, and the harvested area is estimated at a record 0.9 million hectares. As elsewhere, agriculture in Russia is mechanised and chemicals are used for different purposes. Current agriculture practices are believed to have contributed to increasing anthropogenic influence on soils and lands. Andronikov (2000) lists soil erosion, decline in soil fertility, compaction, impeding layer, dryness, low water-holding capacity, salinisation and water-logging, overgrazing and desertification, and soil pollution as the chief soil degradation processes in Russian soils. He attributes soil degradation to the lack of juridical and socio-economic rules and laws in agriculture, migration of population from rural to urban areas, lack of infrastructure development in rural areas, unbalanced agricultural investment policy, as well as decision making in agriculture from top-down.

Ukraine

Rapeseed production is expected to keep declining in Ukraine. The following factors influence this change[14]:

- Rapeseed production is quite risky for Ukrainian climate conditions and recent high winter kill figures reduced attractiveness of this crop to the producers.
- Production of rapeseed in Ukraine has become quite expensive, mostly due to an increase in fertiliser costs in the recent years. Return on investment of this crop dropped to approximately 13%, while other agricultural props' profitability remained higher.
- Ukraine's largest rapeseed buyer was the EU. However, EU's bio-fuel production regulations have changed recently that led to changes in their rapeseed buying patterns.

[14] http://www.thebioenergysite.com/reports/?category=39&id=463

Typical farm size in Ukraine is 5,000 ha+, which is roughly 5 times the average European farm size. Machinery is used for tillage, planting, harvest, and transport. However, a chronic lack of modern harvesting equipment remains one of Ukraine's main obstacles to increasing grain output and quality. In the late 1980s, the Ukrainian winter wheat harvest could be finished in roughly three weeks, but now takes twice as long to complete, and both yield and grain quality suffer as a result of the delays. Farm managers estimate that 10 to 20% of the standing crop is typically lost due to outdated, inefficient machinery. Many farmers are compelled to sell grain shortly after harvest when prices typically are lowest.

Prior to 1991, Ukrainian agriculture used mineral fertiliser intensively (e.g., 141 kg/ha in 1991), which led to nutrient leaching. However, due to the economic crisis the use of mineral fertilisers fell to low levels (e.g., 22 kg/ha in 2003). The use of pesticides in agriculture has had two effects: leaching to the surface and groundwater, and the presence of pesticide residues in products. Pesticide use diminished in the 1990s, but is expected to increase again. Ukraine's agricultural sector is estimated to cause 35 to 40% of all environmental degradation (The World Bank, 2007). After the 1986 meltdown at the Chernobyl Nuclear Power Plant, 8% of agricultural lands were removed from production because of radiation contamination. Products grown in these areas are subject to radiological monitoring, and many farms in the contaminated territories have become non-profitable. Ukraine's famously fertile and extensive black soils are suffering from serious erosion and deterioration after many years of intensive production. Many soils are eroded, depleted, acidic, saline, or alkaline due to unsustainable agricultural practices. Irrigated land has decreased by approximately 15% over the past 15 years, and water losses have increased due to inefficient management. Nutrient runoff from both improper fertiliser application and inadequate manure management pollutes Ukraine's water bodies and contributes to the eutrophication of the Black Sea. Although pesticide use has dropped significantly since the 1990s, a quarter of agricultural lands are contaminated by pesticides, and stockpiles of obsolete pesticides pose serious health hazards. Ukraine's soils are prone to erosion, and over 30 million hectares (i.e. about half of Ukraine's total territory) of land is strongly affected by erosion.

Guatemala

According to an account given by Carlos Salvatierra[15] of World Rainforest Movement there were 14 sugar mills in operation in 2007, sugarcane and plantations covered 216,000 hectares. Most of the sugar mills are located very close to the Puerto Quetzal[16]. Five of them produce ethanol (primarily for export to the EU). According to Salvatierra sugarcane in Guatemala is grown in a monoculture system and one of the most serious problems of monoculture plantations is the total destruction of the ecosystems where they are located. In Guatemala this has led to the disappearance of vast areas of forest. The trend at the present time is continuous expansion. Guatemala's sugarcane region is located on its southern coastland in volcanic lowlands and coastal valleys. In the upper and middle parts of the region, high amounts of precipitation are common. Andisols and sandy soils with low K levels dominate. In contrast, the alluvial soils of the coastal valley generally have moderate levels of K. Most sugarcane growers do not consider application of K in their fertilisation program, although K

[15] www.saviaguate.org

[16] http://gain.fas.usda.gov/Recent%20GAIN%20Publications/Sugar%20Annual_Guatemala%20City_Guatemala_3-22-2011.pdf

is extracted in large amounts by the sugarcane crop. About 40% of the area is irrigated. Some reported problems of flooding exist due to irrigation canals near communities. Water scarcity is reported in some areas previously occupied by forests. Burning is common.

Because sugarcane occupies the land for several years, has dense root system, and provides good cover during the growing season, the risk of erosion from sugarcane fields should be minimal. However, clearing new lands from the forests for sugarcane plantations could trigger erosion problems where none existed, and result in serious loss of biodiversity.

Tanzania

About 12,000 small-scale farmers and major companies, including Illovo Sugar Ltd., Africa's biggest sugar producer, grow sugarcane in central and north-western parts of Tanzania. The contribution of small-scale farmers to the industry has gradually increased in recent years. The area under sugarcane is estimated around 42,000 ha to 50,000 ha[17]. Total land area identified for possible expansion of sugarcane is about 314,000 ha. The soils are predominantly loamy, sandy loam, and loamy clay. The temperatures are not limiting for sugarcane production, but rainfall may be. For example, the Morogoro Region, which is the largest sugarcane growing area, the annual rainfall is only 725 mm. In Kilimanjaro and Kagera (regions with third to half the acreage in Morogoro) the annual rainfall amounts are about 1,100 mm and 1,920 mm, respectively. Thus, there is potential for irrigation in low rainfall areas, and irrigation-related problems of soil quality should be anticipated. The sandy top soil is susceptible to erosion during land preparation and early stages of crop establishment. Other limiting factors include low organic matter, phosphorus, and potassium. Establishment and operation of large sugarcane estates entail land clearing, mechanised cultivation, irrigation, fertiliser application, use of pesticides, and e mechanised harvesting. These operations are likely to have negative impact on soil physical and chemical properties, including exposure to erosion, compaction, and losses of organic matter, natural fertility, and biodiversity.

3.4.3 Soil risks per crop

The non-EU countries present three different groups of crops – trees (palm oil), semi-perennial (sugarcane), and grain crops (soybean, maize, and rapeseed). The productive life of palm oil trees is about 20 to 25 years. The palm oil plantations exist chiefly in Indonesia and Malaysia. The negative effect of establishing a plantation (e.g., erosion) occurs during land clearing and initial stages of establishment. Thereafter, there is little disturbance of the soil, except for control of undergrowth and fertiliser application. In addition, chemicals are applied to control pests and diseases, which has the potential of causing toxicity in the soil as well as harmful effects on biodiversity. Since the plantations are in high rainfall area, leaching of nutrients and development of acidity is natural. Transport of fruit using trucks and tractor-trailers can cause puddling of the surface, and poorly maintained roads produce surface runoff.

Sugarcane is a semi-perennial crops. It occupies the land for 5 to 7 years. In this case also, risks of erosion exist during land preparation and early stages of canopy development. Compaction can result during tillage operations prior to planting. Erosion can also occur from irrigation channels where

[17] http://www.mbendi.com/indy/agff/sugr/af/ta/p0005.htm#5

irrigation is practiced, if not well controlled. Sugarcane plants develop massive root system and bind the soil firmly, thus probability of erosion in fully developed sugarcane field is minimal. Use of fertilisers and chemicals to control diseases and pests is a widespread practice, thus chemical pollution and loss of biodiversity is a potential risk. Burning of the fields prior to harvest of cane used to be a practice in Brazil and elsewhere. This practice resulted in loss of nutrients in the forage material and exposed the soil to forces of rainfall. Burning of sugarcane fields is now being phased out in Brazil.

Soybean happens to be a very important biofuel crop in the United States, Brazil, Argentina, and Paraguay. It is a row crop, which means bare soil left exposed between the rows until the canopy is full. Cultivation practices involve use of machinery in traditional tillage, cultural operations, and harvesting. Use of fertilisers and chemicals for control of pests and diseases is common. Thus, the consequences of machine and chemical based production system should be expected. Compaction, erosion, chemical pollution, loss of organic matter, and negative effects on biodiversity are real possibilities. In the recent times, however, no-till planting, cover crop, and stubble mulching have become popular among the producers in Brazil, Argentina, and the United States.

Rapeseed is another important biofuel crop that is exported to the EU from Canada, Russia, and Ukraine. Its cultivation is like wheat and other closely planted small grain cereals. Nutrient requirement for rapeseed is high, and the crop is susceptible to pests and diseases. Thus, like other crops that are based on mechanisation and chemicals, rapeseed cultivation has the potential of producing negative effects on soil resources, such as soil toxicity, chemical pollution, loss of organic matter, and negative effects on biodiversity. Because it is a closely planted crop, the risk of erosion is less after the crop canopy is full, but exists in the early stages of growing.

3.4.4 Synthesis

This section presents the overall effect of combined soil characteristics, crop characteristics, and management techniques on risk factors and presents potential risks to soils from cultivation of biofuel crops in non-EU countries, summarised in Table 20. Based on climatic conditions of the feedstock producing regions, inherent soil vulnerabilities, and known risk factors associated with agriculture practices, the table provides an educated rating of different soil risks as high, medium, or low. Because there are numerous growing regions for a given crop, with variable soil characteristics, landscape settings, and climatic conditions, an objective assessment based on these factors alone is not possible. However, because agriculture in all of the producing regions is mechanised and chemical based, the assessments presented are based primarily on consequences of mechanisation and high-input production systems. Where possible, effects of soil and climatic conditions have been taken into consideration.

Table 20: Potential risks to soils from cultivation of biofuel crops in non-EU countries

Country/region	Biofuel crop	Inherent soil vulnerability	Risk factors linked to management	Risks					
				Erosion	Soil compaction	Contami-nation	Loss of organic matter	Loss of biodiver-sity	Salinity/ acidity
USA Midwest	Soybean	Low OM and seasonally excess water	Machinery, High use of chemicals	**Low**	**Medium**	**High**	**Low**	**High**	**Low acidity**
USA Central Atlantic	Soybean	Seasonally excess water, nutrient leaching	Machinery, high use of chemicals	**Medium**	**Medium**	**High**	**Low**	**High**	**Medium acidity**
USA Delta	Soybean	Highly weathered soils, nutrient leaching, seasonally excess water	Machinery, high use of chemicals	**High**	**Medium**	**High**	**High**	**High**	**High acidity**
USA Corn Belt	Maize	Wide range of soils, seasonally excess water	Machinery, high use of chemicals	**Medium**	**Medium**	**High**	**Low**	**High**	**No info**
Canada	Rapeseed	Soil prone to erosion from wind and neutral SOC	Machinery, high use of chemicals	**Low to medium**	**Medium**	**High**	**Low**	**High**	**Low acidity**
Russia	Rapeseed	Wide range of soils, salinisation and logging	Machinery, high use of chemicals	**Low to medium**	**Medium**	**High**	**Low**	**High**	**High salinity**

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Country/region	Biofuel crop	Inherent soil vulnerability	Risk factors linked to management	Risks					
				Erosion	Soil compaction	Contami-nation	Loss of organic matter	Loss of biodiver-sity	Salinity/ acidity
Ukraine	Rapeseed	Wide range of fertile soils prone to erosion, nutrient loss and salinity, previously contaminated land	Machinery, high use of chemicals	**Medium to high**	**Medium**	**High**	**Medium**	**High**	**High salinity**
Brazil West-Central	Soybean	Highly weathered soils, leaching, low fertility, acidity and Al-toxicity	Machinery, high use of Chemicals	**Low**	**Medium**	**High**	**Medium**	**High**	**Medium acidity**
Brazil South Central	Sugarcane	Weathered soils, wetter climate, low fertility, leaching, soil acidity	Machinery, high use of Chemicals, burning of leaves	**High**	**High**	**Low**	**High**	**High**	**Medium to high acidity**
Brazil South (similar to West central)	Soybean	Highly weathered soils, leaching, low fertility, acidity and Al-toxicity	Machinery, high use of chemicals	**Low**	**Medium**	**High**	**Medium**	**High**	**Medium acidity**
Brazil Northeast	Soybean	Ultisols, some Alfisols, seasonal dryness, high temperatures	Machinery, high use of chemicals	**Medium**	**High**	**High**	**High**	**High**	**Medium acidity**

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Country/region	Biofuel crop	Inherent soil vulnerability	Risk factors linked to management	Risks					
				Erosion	Soil compaction	Contami-nation	Loss of organic matter	Loss of biodiver-sity	Salinity/ acidity
Brazil Northeast	Sugarcane	Ultisols and Alfisols, low fertility, drier climate (drought)	Machinery, high use of chemicals	**Low**	**High**	**High**	**Low**	**High**	**Medium acidity**
Argentina Buenos Aires, La Pampa, Santa Fe, Entre Rios, Cordoba	Soybean	Soils mainly Mollisols and Inceptisols, Salinity-alkalinity, seasonally excess water and dry periods	Machinery, high use of chemicals	**Low**	**Medium**	**High**	**Medium**	**High**	**Medium acidity**
Paraguay	Soybean	Low soil fertility and flooding leading to soil acidity	Machinery, high use of chemicals	**Low**	**High**	**High**	**Medium**	**Medium**	**Medium acidity**
Indonesia Riau, Sumatra Selatan, Sumatra Utara	Oil Palm	Mostly Oxisols and Ultisols, leaching, low fertility, acidity, Al-toxicity, pests and diseases	Machinery, high use of chemicals, poor management of slopes	**Low**	**Low**	**High**	**High**	**High**	**High acidity**
Indonesia Kalimantan	Oil Palm	Conditions very similar to those in Sumatra	Conditions very similar to those in Sumatra	**Low**	**Low**	**High**	**High**	**High**	**High acidity**

Country/region	Biofuel crop	Inherent soil vulnerability	Risk factors linked to management	Risks					
				Erosion	Soil compaction	Contami-nation	Loss of organic matter	Loss of biodiver-sity	Salinity/ acidity
Indonesia Sulawesi (only 2% of total oil palm)	Oil Palm	Information not available, but oil palm environment and related issues are most probably similar to those in Sumatra and Kalimantan	No info	**No info**	**No info**	**No info**	**No info**	**No info**	**No info**
Malaysia Peninsular (Johor, Pahang)	Oil Palm	Weathered Ultisols, some coastal Histosols, high rainfall, steep slopes, leaching, low fertility, acidity and Al-toxicity, acid sulphate along the coast	Machinery, high use of chemicals, poor management of slopes	**High**	**Medium**	**High**	**High**	**High**	**High acidity**
Malaysia Eastern (Sabah, Sarawak)	Oil Palm	Weathered Ultisols, some coastal Histosols. high rainfall, steep slopes, leaching, low fertility, acidity and Al-toxicity, acid sulphate along the coast	Machinery, high use of chemicals, poor management of slopes	**High**	**Medium**	**High**	**High**	**High**	**High acidity**

Country/region	Biofuel crop	Inherent soil vulnerability	Risk factors linked to management	Risks					
				Erosion	Soil compaction	Contami-nation	Loss of organic matter	Loss of biodiver-sity	Salinity/ acidity
Guatemala	Sugarcane	Andisols and sandy soils with low potassium	Machinery, high use of chemicals, poor management of slopes	**Medium**	**Medium**	**High**	**Medium**	**High**	**Low**
Tanzania	Sugarcane	Sandy top soil, low fertility, low organic matter	Poor soil management	**Medium**	**Medium**	**Medium**	**High**	**High**	**Low**

Source: Own compilation

3.5 Coverage by existing provisions

The following sections focus on existing policy provisions, mainly legislative, that aim to protect soils. These sections introduce the relevant provisions in the EU and third countries and comment on their scope and effectiveness. With regard to voluntary provisions, it could not be established in a systematic way what the coverage of (biofuel) crop production by the different schemes is. Where we have received specific information from country experts or from elsewhere, this is included below or integrated in the Task 4 report (see chapter 6). Some existing voluntary schemes which address soil issues have been reviewed in another project for the EC and reference is made to this work as part of Task 4 of this project.

3.5.1 Soil provisions in the EU

Within the EU, both legislative and voluntary provisions are used. Certain legal requirements that result in the protection of soils through the limitation of land use, are not focused directly soil protection. Some have been adopted under the Water Framework Directive (2000/60/EC) which requires river basin management plans to include measures against water pollution and flooding, both of which are closely related to soil condition, soil cover and the prevention of erosion. The Nitrates Directive (91/676/EEC) limits inputs to soils in designated nitrate vulnerable zones and promotes better management of fertiliser inputs. Others have been adopted, for example under the Habitats Directive, which can require the protection of land or certain management practices to protect land deemed of biodiversity value. A full list of EU policies that indirectly impact on soils is provided in Bowyer et al. (2009).

Legislative requirements directly focused on agricultural soils are stipulated through Good Agricultural and Environmental Condition (GAEC) standards under the CAP. Within the EU, Single Farm Payments are distributed to farmers according to the area of land farmed or by historic entitlements[18], irrespective of the type of production. In order to ensure a minimum level of protection for the environment, the system of cross-compliance requirements aims to ensure that farmers receiving the payments comply with certain requirements or face a reduction/complete loss of payments. Cross-compliance requirements comprise two distinct elements. Firstly, a suite of Statutory Management Requirements, which are based on selected articles from 19 pieces of pre-existing items of EU legislation, such as the Birds Directive (79/409/EEC) and the Nitrates Directive, whose implementation is required in all 27 Member States. Secondly, a set of GAEC standards must be applied. Although, the general structure of GAEC standards is provided at EU level, their design is determined at the national level by each Member State. This flexibility is provided to Member States so that the GAEC requirements reflect locally specific agronomic, environmental, bio-physical and climatic conditions. Table 21 below provides examples of the provisions applied in Germany, Poland and Spain. A full set of requirements for each of the ten case study countries is provided in Annex 5. As part of the on-going reform of the CAP, GAEC requirements are under review, however, the reform had not been finalised at the time of writing this report.

[18] The system of CAP direct payments will be reformed after 2013.

Table 21: Examples of GAEC requirements in three Member States relating to the protection or management of soils

Minimum soil Cover	
Germany	• Ploughing restrictions during winter season to ensure a share of arable land is not ploughed.
Spain	• Ploughing restrictions on dry plots with herbaceous winter crops and sloped land with olive groves. • Must maintain and ensure adequate green cover for woody and native crops on sloped land and/ or fallow land.
Poland	• Minimum management requirements on arable land to ensure cultivated or mown if kept fallow. • Winter cover on a minimum share of arable land prone to water erosion.
Minimum land management reflecting site-specific conditions	
Germany	• Same ploughing restrictions as outlined for minimum soil cover. Exceptions can be granted for land prone to wind erosion and row crops sown in an appropriate fashion.
Spain	• Ploughing restrictions for herbaceous crops, vineyards, olive groves, and nut crops on sloped land. • Avoid any structural changes to terraced plots, particularly in areas at risk of erosion.
Poland	• In the case of arable land located on slopes with a gradient exceeding 20°, the land is not used for cultivation of plants which require maintaining ridges along the slope or the land is not maintained as bare fallow. • In the case of perennial plants plantations located on slopes with a gradient exceeding 20°, it is recommended to retain the plant cover or to mulch in inter-rows, or to cultivate on the basis of terraces.
Standards for crop rotations	
Germany	• Minimum three crops (including fallow areas) in a crop rotation in which each crop or fallow area must cover at least 15% of arable land. Or, requirement to provide proof of an annual humus balance showing levels of SOM have been maintained.
Spain	• No data
Poland	• In the case of wheat, rye, barley and oat, the same plant species cannot be cultivated on the same area on the holding for more than 3 years • *Exceptions can be authorised for 4th and 5th year.*
Arable stubble management	
Germany	• Prohibition of burning stubbles. Exception allowed where needed for plant protection with appropriate approval from competent authority.
Spain	• Prohibition of burning stubble and cuttings. Exception allowed where needed for plant protection with appropriate approval from competent authority
Poland	• Prohibition of burning on agricultural land.

Source: JRS GAEC database (mars-wiki, accessed May 2012)

Note: A full list of GAEC requirements in ten Member States is provided in Annex 5.

It is important to bear in mind that the GAEC framework is not intended as a policy countering all the risks from intensive crop sectors. Its goal is to set minimum requirements through simple management actions that are at a low cost to farmers. Agricultural and agri-environmental experts interviewed in several countries highlighted that the majority of current GAECs in the key Member

States are insufficient to prevent a greater prevalence of risks to soils associated with the expansion of biofuel crops.

The GAEC addressing soil erosion is considered as rather weak in a number of Member States with maize, sugar beet and rape cultivation for the biofuel sector. It is implemented primarily via slope criteria, and these are often considered to be set too high to prevent erosion damage from the expansion of high erosion risk crops such as maize and sugar beet into medium sloping terrains. As has been noted above, these crops frequently replace marginal grasslands or fodder croplands in uplands which were beneficial for countering soil erosion in these terrains, for example in the Czech Republic, some German Länder and the UK. A basic instrument such as GAEC is not adequate to mitigate this sort of accelerated negative impacts.

The GAEC relating to soil structure has so far had a weak response in Member States according to interviewees, and therefore it is currently not considered to be an adequate tool to prevent or substantially mitigate soil compaction, which is one of the major risks associated with sugar beet cultivation. In addition, Member States have so far also been reluctant to map areas of compaction risk which would have allowed for a more targeted approach to setting appropriate management requirements under GAEC. The GAEC standard relating to heavy machinery use is no longer compulsory for Member States.

The GAEC focussing on SOM consists in a simple ban on burning arable stubble. This is entirely insufficient for addressing the risks to declining levels of SOM that are associated with erosion trends in many of the affected areas and with the generally declining return of crop residue or manure into soil. A revised GAEC framework for the post 2013 period may allow for more differentiated approaches to the minimum management of SOM levels, bearing in mind that the requirements will depend on the discernment of Member States.

The GAEC standard relating to crop rotation, which is in theory relevant for mitigating risks from intensive biofuel crop systems, is an optional element of the framework. The crop rotation standards which have been adopted in some Member States are not demanding enough to counter trends toward intensification of, for example, maize and are therefore insufficient as mitigating measures such as build-up of pest risk (FCEC, 2009). Potential future requirements under the 'greening measures' within the reformed Pillar 1, relating to crop diversification and permanent pasture in particular, may be of certain relevance for intensive energy cropping systems in the future.

It has been also noted that high prices for biofuel crops could reduce the reliance of farmers on direct payments in areas specialising in intensive biofuel cropping. Whilst compliance with GAEC requirements is a condition for putting biofuel crops on the market (RED Article 17(6)), the Directive does not foresee that some EU producers could be outside CAP direct payments. It is not therefore clear how compliance with environmental standards would be monitored if farmers opt out from direct payments[19]. Such an alternative has been identified as a possible route for some farms in

[19] This would be an issue for all forms of agricultural production.

certain regions of France, Germany and UK. If farmers opt out from direct payments, GAEC does not apply. This would be an unwelcome development in relation to maintaining soil standards.

Currently, there are very few voluntarily adopted soil management standards in the EU and there is no information available on the extent of their adoption by farms engaged in the production of biofuel crops[20]. Agri-environment schemes implemented by Member States within their rural development programmes are incentive payments to which farmers can opt into. Agri-environment schemes go beyond the minimum requirements set out in GAEC standards and include some more advanced management approaches to mitigating environmental risks, including for soils. Given that the current payment rates for environmentally beneficial management under agri-environment schemes cannot compete with market prices for energy crops, they have a limited impact on countering the pressures from productive sectors.

3.5.2 Soil provisions in non-EU countries

The importance of protection of soils has been recognised in many developed countries, as is evidenced by numerous laws and regulation in the United States, Canada, and the European countries (see previous section). In the following we review the legislative provisions in non-EU countries.

In the non-EU countries, covered in this report, there appear to be no regulations directed specifically at the protection of soils. In most cases regulations refer to natural resources, e.g., air, water, or environmental protection in general, and soils may be considered a part of the natural resource depending on how the regulations are interpreted and applied. In many countries multiple agencies may be involved and no one is entirely responsible for implementation or monitoring. Effectiveness is also compromised due to widespread corruption. Annex 6 lists legislative provisions in different non-EU countries that may have relevance to soils, either directly or indirectly. The review shows very few instances where one can interpret the law as being applicable to soils in some direct or indirect ways. There is no instance where detailed regulations have been handed out to producers and/or farm managers to follow specific guidelines regarding field operations, ground cover and stubble management, or crop rotations along the line that exists in Europe. Furthermore, it is very difficult to assess how well existing regulations have been implemented.

There is very little in terms of voluntary provisions. Among those that exist, there are a couple of good examples. The Federal Conservation Program in the United States has led to widespread use of no-till planting in soybeans, and it has reduced soil erosion by 40%. Similar results have been achieved by AAPRESID in Argentina. The practices promoted by this association have been effective in reducing erosion and enhancing carbon sequestration in the soil.

However, despite the importance of legislative measures and the value of voluntary provisions, it may not be feasible for the EC to undertake drafting legislation for the protection of soil in the non-

[20] Some examples of existing voluntary provisions for agricultural producers have been identified in the UK, for example Campaign for the Farmed Environment that encourages farmers to increase the uptake of agri-environment options for productive crop sectors,

EU countries. At present the crop area shared by biofuel feedstock amounts to an insignificant fraction of the total crop area. Thus, the administrative burden may not be proportionate to achievable results. While it is tempting to suggest that EU importers of biofuels or biofuel feedstock from non-EU countries should demonstrate that the source country has in place soils impact protection comparable to that afforded under the CAP for agricultural land within the EU, it is not practical since many non-EU countries have no regulation that directly addresses the issue of soil protection. The regulations that do exist are so vague that one can interpret them to serve the interest of the importers and exporters, thus defeating the ultimate purpose. Our suggestions in chapter 6 will therefore focus on good practices to be applied by producers globally.

3.6 Conclusions

While there are some overarching messages and conclusions that can be made regarding soil risks much of the actual risk will be determined at a highly localised level for specific agricultural systems. This will be based on small scale variation in natural risk (linked to soil type, slope, climatic conditions) but critically on management practices, given the important role of management techniques in mitigating or aggravating risks. Within this report attempts have been made to identify the key potential risks associated with given cropping systems. Many of these are common, at least within the key classes of crops considered, i.e. annual, perennial, row crop or distributed. Recent research (e.g. Louwagie et al. 2009) at the EU level into controlling and limiting soil risks in agriculture have concluded that it is critical to have ***nutrient and soil management plans for cultivation*** that take adequate account of soil conditions and adapt management practices to protect soil resources. This is an important recommendation in line with the findings in this report. Box 2 explains the concept of a management plan at farm level and is further discussed in chapter 6.

Box 2: Management Plan at Farm level

A **management plan** (for soil, air or water) is a tool designed at farm level to provide guidance to farmers in their day to day operations. It sets out a set of conservation practices targeting a particular objective, or set of objectives, and is tailored to the specific farming system and climatic, environmental and bio-physical conditions. It provides practical information to the farmer, e.g. on the appropriate timing of practices. Most often the plan is designed by specialised advisors. The practices may, for example, focus on the efficient use of fertiliser/manure, on farm water use, or sustainable soil management, thus allowing for good nutrient supply to crops, protection against the potential adverse impacts of manure overuse on water and soil, protection or enhancement of the status of surface and underground water bodies, or maintaining and enhancing soil structure, soil erosion, SOM levels. Several voluntary schemes require a management plan to be in place at the farm level (e.g. Roundtable for Sustainable Biofuels, Roundtable on Sustainable Palm Oil). In addition, a number of recent studies highlight the benefits of using plans for nutrient management, soil management and whole farm environment management (Dworak et al, 2009; Louwagie et al, 2009; BIO Intelligence, 2012; Farmer et al, 2012).

The most important risks arising from the analysis of the ***EU situation*** are soil erosion, loss of SOM and compaction. There is a very high erosion risk (as well as nitrogen leaching) associated with maize cultivation, but also with other row crops such as sugar beet and sunflower. Rapeseed cultivation poses some erosion risks in the first month after sowing but later on is considered a crop that fixes soils well. It is important to note that the expansion of rapeseed, sugar beet and sunflower is in many Member States taking place at the expense of former marginal grasslands (UK), and temporary grasslands and fodder croplands that experience a drop in demand due to a significantly diminishing livestock sector (Germany and Central Europe). The consequence is that the types of croplands which were favourable for preventing erosion are being replaced with energy crops with very high to moderate erosion risk. Wheat and rye have low erosion risks. Soil erosion is closely interlinked with the decline of SOM, and the sediment run-off poses threat to the status of surface water bodies. Decline in SOM in the affected areas has a concomitant effect of steeply increasing use of fertiliser, with a knock-on effect on water quality. The use of machinery in sugar beet and (to a more moderate extent) maize cultivation poses high risks for soil compaction.

An important key message that was confirmed by talking to agricultural and agro-environmental experts is the critical role of management techniques. The risks arising are of the order of magnitude that requires massive response by putting in place complex soil-water protection by specifically designed management approaches and actions. While some of these management actions are available to mitigate the risks in theory, they are not systematically applied in practice. It appears that in some Member States there are regions where there is an adequate uptake of e.g. anti-erosion measures in cropping systems for bioenergy (for example in some German Länder), but this is not the general case even within those Member States and, at the EU level, adequate mitigation approaches by management techniques enforced through legislation or encouraged through voluntary schemes are almost non-existent. Some simple management actions to mitigate soil risks are required under the CAP as part of GAEC standards. However, observations on the ground indicate that these standards have other purpose and are insufficient for mitigating the risks arising from maize, rape, and sugar beet cropping in particular. In particular they are considered inadequate for preventing severe to moderate degradation of soil and water through soil erosion, loss of SOM, compaction and diffuse soil and water pollution. Following the cross reference to GAEC standards in the RED Article 17(6), these standards need to be adhered to for EU biofuel feedstock cultivation even where farmers do not receive direct payments. But it is not clear who would monitor their compliance in such cases.

More advanced management techniques are deemed necessary to tackle some risks identified. These may include measures to reduce exposure of bare soil, contour ploughing, minimum tillage or no-tillage regimes, appropriate crop rotations (especially those including fallow or legumes), erosion prevention strips, intercropping, and strict protection of semi-natural grasslands and peatlands. Some more advanced management approaches to mitigating these risks are part of agri-environment schemes in Member States. However, the current payment rates for environmentally beneficial management under agri-environment schemes cannot compete with market prices for energy crops so they have a limited impact on countering the pressures from productive crop sectors.

In the context of non-EU countries, it needs to be noted that, at present, the share of EU biofuel feedstock as a percentage of total crop area is <2% (Ecofys et al., 2012). Yet, there is concern that biofuel market may have negative impact on soil functionality, and this concern is based on the premise that increased demand for biofuel feedstock will encourage expansion of cropping area, shift from diversity to monoculture, and increased use machinery and chemical inputs. However, there are no studies to establish a direct link between biofuels and soil health. Therefore, soil related issues are largely those concerned with general agro-ecological factors, agro-economic considerations, and prevalent agricultural practices.

The processes of soil degradation in non-EU countries are similar to those in EU countries, including erosion, loss of fertility, loss of organic matter, loss of biodiversity, compaction, acidity/salinity, and soil pollution. However, here we are dealing with a much wider range of climatic, soil, landscape, and agro-economic environments. Unlike EU countries, where crop management issues concern row vs. continuous planting patterns, biofuel crops across non-EU countries present a wider array of crop management issues. They include perennial tree crops (oil palm in Indonesia and Malaysia), semi-perennial crops (sugarcane in Brazil, Guatemala, and Tanzania), and annual crops (soybean and maize in the United States, soybean in Brazil, Argentina, and Paraguay, and rapeseed in Canada, Russia, and Ukraine).

Except for the United States and Canada, scientific articulation of specific soil degradation issues are not available for many of the non-EU countries. Soil degradation problems, as stated above, have been recognised, but they are largely qualitative and based on impressions. Biofuel crops in non-EU countries are grown on large scale farms, where use of machinery and chemicals is as common as in the United States and European countries. Based on these two factors and climatic conditions, a crude assessment indicates erosion, compaction, loss of organic matter, and diffuse pollution by agrochemical inputs as outstanding issues in relation to soil health.

Legislative measures and voluntary provisions to specifically protect soil quality are almost non-existent. There are a few general provisions designed for general environmental or natural resource protection, but their implication for soils is indirect. Setting standards for soil attributes may be possible, but will require detailed scientific data, which may not be available in many of the non-EU countries. In addition, implementation and monitoring of compliance would seem impossible. Therefore, a pragmatic approach would be to promote *good agriculture* practices based on local conditions and local farming experience.

Based on this analysis, and given that ultimate impacts on soil from crop cultivation depend on management to a large extent, we deem it necessary that any new mandatory RED criteria on soil incentivise the use of appropriate management techniques, as outlined in chapter 6.

4 Water risks from biofuels consumed in the EU

4.1 Introduction

Water, food, land, and energy resources are deeply interconnected. For example, agricultural production today uses 37.7% of global land surface (World Bank 2012) and about 7000km^3 of water annually, or about 3000L per person per day (Postel 1998). These values stand to increase by as much as 110% by 2050 (De Fraiture, Wichelns et al. 2007) – even more if current biofuel expansion plans are fully implemented (Hoff 2011). Water supplies worldwide are strained, with 1.8 billion people predicted to be living in absolute water scarcity and two thirds of all people predicted to be experiencing some water stress by 2025 (UN Water 2007). This pressure is increasing rapidly, as population growth and dietary changes are projected to drive a 70-90% increase in demand for water worldwide in the next 50 years (Molden 2007). Climate change also stands to exacerbate water stress in many regions, intensifying desertification, reducing glacial storage, and increasing the frequency of extreme events such as droughts and floods (Hoff 2011).

About 70% of all water withdrawn annually by humans is used for agricultural purposes – up to more than 90% in some less developed countries (UNESCO 2009). This level of reliance on an increasingly scarce resource is beginning to constrain productivity in some globally important agricultural areas including California, South Asia, Mexico, Australia, and parts of China (Rosegrant, Cai et al. 2002; Shah, Burke et al. 2007). Water resources are already being withdrawn to such an extent that several important rivers, including the Yellow (China), the Syr Darya (Central Asia), the Colorado (Southwestern USA, Mexico), and the Murray-Darling (Australia), no longer reach the sea during some periods (Molle, Wester et al. 2007). Beyond the direct constraints it places on human activity, water scarcity also has important effects on ecosystems. Notable impacts include aquatic and wetland habitat degradation, pollution effects, and soil salination. This compromising of ecological integrity is also indirectly detrimental to human wellbeing through reduction of ecosystem services.

There are times when a synergy exists between water conservation and energy policy goals. The water sector offers policy options that can accomplish both preventative and adaptive goals in the face of global climate change. For example, water efficiency measures can help us adapt to increasing water scarcity in some regions, while at the same time reducing the GHG emissions associated with current water infrastructure. On the other hand, circumstances often exist in which the achievement of energy or climate goals and the preservation of water resources may be at odds. For example, concerns about indirect land use change in bioenergy systems could lead to irrigation of existing biomass crops, or to extensification of agriculture into uncultivated grasslands so as not to displace current production. These outcomes would mean net expansion in total water demand. Minimising these conflicting incentives in water and energy, while at the same time taking advantage of the synergies between related goals, will require truly integrated resource and policy planning.

In relation to biofuel crop production, water resources have been referred to as the "Achilles heel" of biofuel production (Keeney and Muller, 2006) with potentially important impacts on both quantity and quality of the resource base.

The water requirements of bioenergy systems range from 70 to about 400 times greater than those for fossil fuels and for other renewables such as wind and solar power (Gerbens-Leenes, Hoekstra et al. 2009). Because they are such a small part of the energy system, biofuels today exert very little pressure on water resources at a global level – accounting for only about 1% of all agricultural consumptive water use (De Fraiture, Giordano et al., 2008). However, the global water resource impact of these systems is expected to increase as bioenergy utilisation continues to grow (De Fraiture and Berndes, 2009). The role of water is critical in the sustainable production of biofuels; water availability and quality are necessary for rural development, food security, and ecosystem services.

Biofuel production could contribute to or exacerbate water scarcity in river basins, hindering agricultural production, domestic sanitation, and ecosystem health. Harmful impacts could occur if:

- Biofuels increase total cultivated area in water scarce regions;
- Biofuel demand displaces existing agriculture with more water-intensive cropping systems;
- Other water efficiency measures (e.g. regarding irrigation) are not put in place or are insufficient to address the problem.

4.2 Types of water use

Withdrawal

The removal of water from a natural system or a managed resource base - regardless of its eventual fate – is termed withdrawal. Irrigation is the primary driver of water withdrawal globally, using about 70% of all water withdrawn by humans. In the United States, irrigated area has expanded over five-fold in the last 100 years (USDA, 2009). In India, which relies to a large degree on groundwater for irrigation, its extraction increased almost a hundred fold in the latter half of the twentieth century (Hoff, 2011). This rapid global expansion is due to the immense productivity improvements that can be gained through uptake of irrigation. While only about 15% of total cultivated land area is irrigated today, this area accounts for almost half of total crop production (Molden, 2007).

The source from which water is drawn is also an important characteristic in assessing the impact of its use. For example, withdrawal of cooling or irrigation water from surface flows has very different implications than if it were drawn from groundwater sources, and both of these are very different than the withdrawal of a comparable volume of seawater.

Consumption

Not all of the water that is withdrawn for use by humans is necessarily consumed in the process.[21] Furthermore, not all of the water that is consumed by human activities has necessarily been applied. In fact, about 80% of all crop water requirement globally is met by rainfall (De Fraiture and Berndes, 2009). Cropping systems consume water in two ways: through evaporation from the soil surface and through transpiration, which is essentially the productive evaporation of water through plant tissues. These two processes are collectively referred to as evapotranspiration (ET). Industrial processes consume water through evaporation in a broad array of activities, particularly cooling.

In accounting for different types of water consumption, researchers frequently make use of the concept of Green, Blue, and Grey water. **Green water** consumption refers to the use of rainwater and soil moisture that is naturally available *in situ* to the plant. **Blue water** is the consumed fraction of any water applied through human intervention – irrigation in the case of agriculture. **Grey water** refers to pollution, which can be considered a consumptive use of water since it removes water from later productive use. A "grey water footprint" is considered to be that volume of freshwater required for dilution of total pollutant load to below a defined ambient water quality standard.

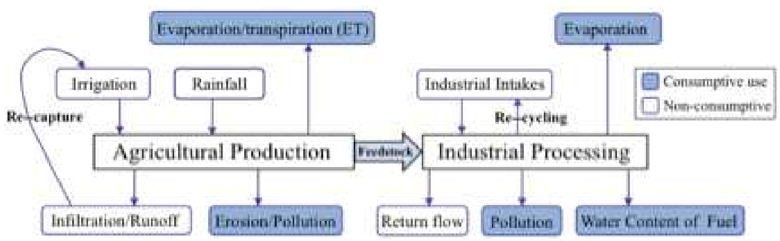

Figure 3: Schematic of water consumption in the biofuel life cycle (Fingerman, Torn et al, 2010)

4.2.1 Feedstock cultivation[22]

Feedstock cultivation accounts for at least 99% of the consumptive water use of most biofuel life cycles (Fingerman, Torn, et al. 2010). Some recent studies of biofuel water impact (King and Webber, 2008; Chiu, Walseth et al., 2009; Service, 2009; Wu, Mintz et al., 2009; Scown, Horvath et al., 2011) focus their analyses on water applied to agricultural fields as irrigation. When irrigation water is taken as the basis for calculating agricultural consumption, estimated life cycle water use for biofuels ranges from 10-324 l H_2O/l fuel. The low end of this range represents the refining and transport consumption associated with biofuels made from un-irrigated crops and waste materials (Service 2009).

[21] Use of the term "consumption" is complicated by the fact that most of the processes being considered do not actually destroy water molecules. We rely here on a commonly used definition of water consumption; water is considered consumed when it is removed from the usable resource base for the remainder of one hydrologic cycle. Evaporation, therefore, is a form of consumption because although the water has simply changed phases, we do not control where evaporated water will fall next, so the water is functionally lost to the system.

[22] Use of waste/residue feedstocks for second generation biofuels can also have water resource implications, including for example soil erosion caused by the removal of anchoring biomass residues from agricultural or natural systems. However, this study focuses on a set of feedstock crops that are significant contributors to the EU fuel mix, so these biomass fuels are not considered here.

Irrigation water is a vital and unique resource, but rainwater is also of value. Many major biofuel crops are rainfed, including most Brazilian sugarcane and U.S. corn as well as the majority of global oil palm, cassava, and rapeseed production (De Fraiture and Berndes, 2009). This fact does not, however, mean that these crops consume no water. If not devoted to biofuel feedstock production, this green water could be allocated to other crops, to environmental services, or to reservoir and/or groundwater recharge (Molden, 2007; Fingerman, Torn et al., 2010). For this reason, some studies have looked at all crop ET in an effort to comprehensively account for biofuel water consumption. This is typically done using some form of the Penman-Monteith model (Allen, Pereira et al., 1998), which estimates ET through a combination of crop physiology and climatic conditions such as solar radiation, wind speed, humidity, and temperature. Where crop ET is used to quantify agricultural water use, estimates of life-cycle water consumption for biofuels range from 380 to over 1500 l H_2O/l EtOH (Dominguez-Faus, Powers et al. 2009; Gerbens-Leenes, Hoekstra et al., 2009).

Several water quality impacts can also result from biofuel feedstock cultivation. Nutrient pollution and resultant eutrophication effects are of particular concern, as feedstock cultivation frequently employs high inputs of chemical fertilisers. Feedstock cultivation can also create toxic chemical pollution as agricultural chemicals such as pesticides and herbicides can find their way into ground and surface waters.

4.2.2 Refining

The industrial phase of biofuel production requires much less water than feedstock cultivation. However, because refining activity is spatially concentrated compared to feedstock production, this phase can have a significant local impact even when its share of the total life cycle water intensity is low. For each 1 million gallons per year of production capacity, U.S. corn ethanol plants use enough water to support a town of approximately 5,000 people (Keeney and Muller 2006). Over half of the water consumed in a typical biorefinery is used for cooling (Wu, Mintz et al. 2009). Another important use can be drying of any co-products such as soy meal or distillers grains from maize. Some water is also consumed through “drift” (loss of liquid water to air flow through the cooling tower), and “blowdown” of accumulated salts from boilers and cooling systems[23]. Figure 8 presents the relative fractions of water consumed through different processes in an ethanol biorefinery.

[23] So-called “second generation” biofuels, derived from waste or purpose-grown lignocellulosic biomass, have very different water consumption dynamics than the agricultural fuels discussed here. While these fuels may prove important in the future, they are not within the scope of this study.

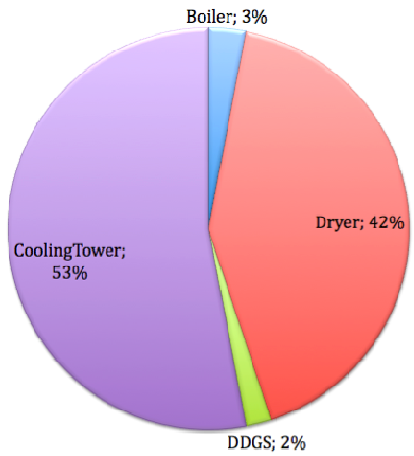

Figure 4: Water consumed in a corn dry mill ethanol refinery - data from (Wu, Mintz et al. 2009)

In general, biodiesel production facilities use significantly less water than ethanol production facilities, as their feedstocks are hydrophobic oils, so no water is used in the conversion processes. Instead, water is used primarily to "wash" the finished product – removing any impurities such as remaining glycerine or incompletely reacted lipids. While water use in biodiesel production varies, it averages about 1 litre per litre of finished fuel (Pate, Hightower et al. 2007).

Conversion of feedstock into biofuel can also have important water quality impacts. Where process water is derived from groundwater sources, purification is typically employed creating a brine effluent that must be disposed of. A similar brine results from the blowdown of deposits left on the surfaces of cooling towers and boilers by the on-going evaporation of mineral-laden water Keeney and Muller 2006; McMahon and Price 2011). Wash water from biodiesel post-processing is also an important potential source of water pollution as it contains nutrients and glycerine and can have a very high biological oxygen demand (GAO 2009). Some producers recycle this water, though it must be purified, creating a further concentrated waste stream.

4.3 Risk assessment – methodology

We have used varying methodology for the EU and non-EU analysis. Quite detailed data are available with coverage at the European scale, and agriculture in the EU is optimised in ways it is not in some non-EU regions under study. For this reason, the EU analysis uses approach set out in Section 4.4.

For non-EU countries, we have assessed water scarcity on the basis of the Water Stress Indicator (WSI) (Figure 9) developed by Smakhtin et al*.*, (2008). This metric is developed using the ratio of withdrawal to availability, while accounting for the Environmental Water Requirement (EWR) – that fraction of the flow that must be left in-stream for the maintenance of ecological integrity and environmental services. By overlaying water stress metrics of various types we identify those areas where either physical or economic water strain is an issue for humans and the environment. This is then overlapped with irrigation areas so as to distinguish those areas where stress largely results from and is likely to impact irrigation demand[24]. A similar analysis was performed to assess water quality risk. Regions with already high fertiliser runoff rates are at elevated risk for eutrophication, so we mapped spatial data on nutrient loading and eutrophication to areas of interest for biofuel/feedstock production (Figure 10).

The national scale water footprint values used in this study, as well as the global spatial datasets of water stress and nutrient loading were chosen because of their global coverage and repeatability. It is worth noting that a more detailed, nuanced, and disaggregated analysis would be possible in many of the places under consideration, and should be conducted if possible. However, because of the global nature of this analysis and the limited amount of time and resources with which to conduct it, we have chosen to follow the approach described herein.

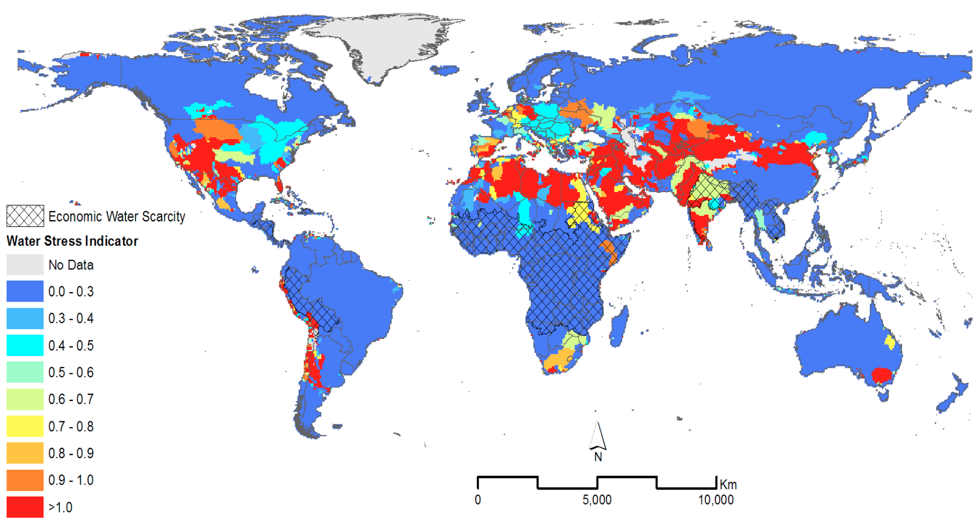

Figure 5: Water Stress Indicator per Smakhtin et al., 2008

[24] Data sources: UNESCO/ UNH – Mean annual relative water stress index (http://wwdrii.sr.unh.edu/); Smakhtin/IWMI WSI and Environmental Water Requirements maps (Smakhtin, Ravenga, et al, 2004); IWMI "Comprehensive Assessment" economic water scarcity maps.

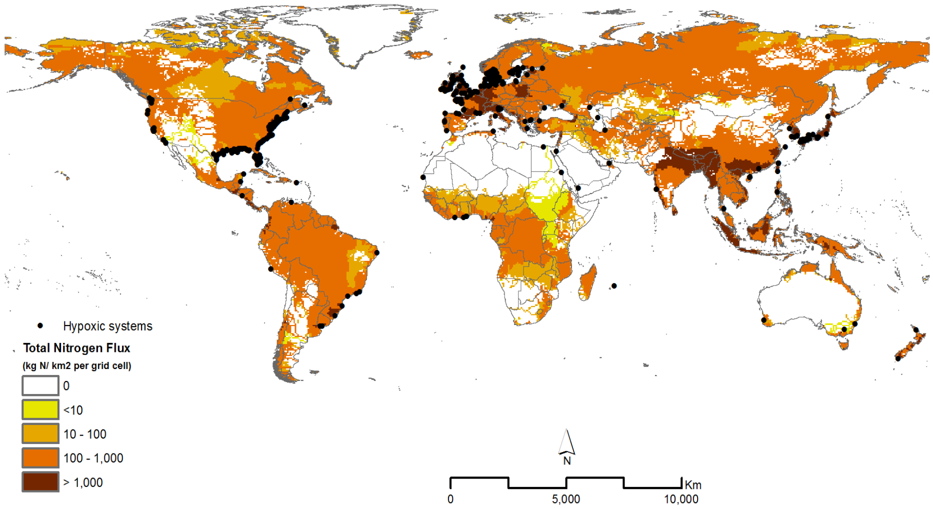

Figure 6: Total Nitrogen flux (kg N/km²) – data from World Water Development Report II/University of New Hampshire Water Systems Analysis Group

4.4 Water risks in the EU

The context for assessing the interaction between biofuel production and water impacts is addressed differently for the EU than for non-EU countries in the previous section. This is for two major reasons. The first concerns the scale of information available. Information on water quality and water stress and its interaction with agricultural production is available at a finer scale (e.g. river basin) as is that for agricultural production (e.g. NUTS 2 level). Given the amount of analysis being undertaken on these issues, it is necessary to present information at a more detailed scale to make it policy relevant. Working with data at this scale also corresponds to the approach of Eurostat and the EEA. Secondly, the EU water policy has developed over a number of years in a way which needs to be taken into account in considering any potential sustainability criteria.

This section, therefore, begins by examining the main pressures on Europe's waters and how these vary across the EU. The section then examines the impacts of crops grown for biofuels on water quality and quantity and the CAP provisions relating to water management that may potentially address such impacts. The section continues with an examination of EU water policy, the gaps in relation to pressures from biofuel production and considers whether there are gaps for which sustainability criteria are needed. The section also discusses the specific issue of water footprinting and whether this is a sufficiently robust tool by which to establish sustainability criteria.

4.4.1 Problems facing Europe's waters

Europe's waters face a number of pressures. Those arising from agriculture include a number of elements, but the two addressed here are water use and nutrient pollution.

Water use through irrigation can result in altered flows, low flows, or, in extreme cases, no flows of waters in river basins. The main measure for the acceptability of abstraction for water use is the water exploitation index which compares abstraction to available water. Figure 7 is a map of Europe recently published by the EEA examining the extent of water stress in river basins across Europe. It can be seen that water stress is widespread in southern Europe and parts of western Europe. The data do not attribute stress to particular water uses, however it is known that in southern Europe irrigation is by far the largest user of water (EC, 2007).

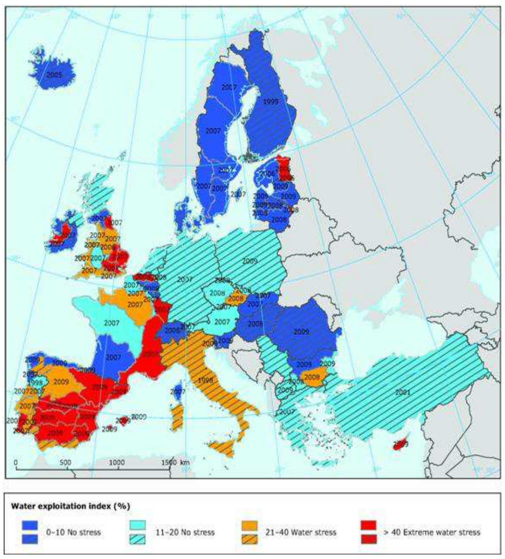

Figure 7: Water Exploitation Index in Europe

Source: EEA, published March 2012, http://www.eea.europa.eu/data-and-maps/figures/water-exploitation-index-2014-towards

With regard to nutrient pollution causing eutrophication it is important to note that while agriculture is an important source of both nitrogen and phosphorus, there are also important point sources (such as sewage) in rural and urban areas. The EEA (2005) noted that discharges of pollutants from point sources had decreased significantly over the past 30 years. It also identified the relative proportion of different sources to the overall nitrogen and phosphorus discharges (Annex 7). Although the distribution of diffuse agricultural sources varies significantly across the EU, in some Member States they can form the majority of the discharges of nitrogen and phosphorus.

In freshwaters the EEA (2010) found that average nitrate concentrations in European ground waters increased from 1992 to 1998, and have remained relatively constant since then. The average nitrate concentration in European rivers decreased by approximately 9% between 1992 and 2008 (from 2.4 to 2.2 mg/l N) (Annex 7). Average orthophosphate concentrations in European rivers have decreased markedly over the last two decades, being almost halved between 1992 and 2008 (47% decrease) (Annex 7). Therefore, while there has been some improvement, eutrophication remains a stress in Europe and agriculture is an important contributor.

Potential of management practices to mitigate risks
Ample descriptions of complex mitigation strategy including water quality and quantity risks are available in literature (Louwagie et al, 2009; Berman et al., 2010). Such management practices include:

- Manure management;
- Input reduction and precision farming (including timing and application rates);
- Riparian buffer strips;
- Use of crop rotations particularly with legumes;
- Infiltration belts (grassed non-riparian strips within fields with high erosion risk crops), grassed waterways and run-off furrows;
- Cover corps and intercropping; and
- Treatment wetlands.

4.4.2 Water quantity risks

In order to determine if the cultivation of specific crops for bioenergy use would impact on water use, it is necessary to know crop water efficiency and the scope and intensity of water abstraction for irrigation. Official pan-European data on total irrigable area per Member State provided by Eurostat show large diversity of irrigable area across Member States and very limited data on the irrigable area for specific crop types. Comprehensive pan-European information about the extent and intensity of irrigation for different crop systems has been compiled by the Joint Research Center (Wriedt *et al.,* 2008). It demonstrates that maize, rye and sugar beet are often grown in irrigated systems, particularly in arid and semi-arid areas. ***Maize*** irrigated systems are very frequent across the EU and characterised by high intensity water requirements. In the Mediterranean region, 80% of maize croplands are under irrigated systems, whilst in the Atlantic region, the share is 40% of total maize croplands. ***Rye*** irrigated systems are much less frequent, covering less than 20% of total rye croplands in both the Mediterranean and Atlantic regions. However, where rye is irrigated, the intensity of the practice is very high. In ***sugar beet*** croplands, three quarters of the total crop areas in the Mediterranean region and about 10% in the Atlantic region are under irrigation. The intensity of irrigation is very low in both regions. Only 15% of sunflower area in the Mediterranean region is under irrigation (Wriedt *et al.* (2008), however it is concentrated in several hot spot areas, including the leading French producing regions.

Other biofuel crops are mostly grown in rain-fed systems. Only 3% of sunflower area in the Atlantic region is irrigated and the intensity of practice is very low. Also, the ***rape*** and ***wheat*** cropping systems are largely rain-fed and irrigated systems cover a very small area (less than 10%) in both regions, with an insignificant intensity of practice (Wriedt *et al.,* 2008).

Some specific information in relation to biofuel crops has been gathered by means of the interviews. One expert identified irrigated maize as adversely affecting water availability in Mediterranean countries, a more general fact earlier corroborated by a pan-European study on plant health in maize sector (FCEC, 2009). A Spanish expert stated that due to irrigation requirements biofuel crop production (of conventional crops) is not economically feasible in Spain, which is why Spain heavily relies on imported crops (Garrido A., pers.comm).

An EEA report currently under preparation (Elbersen et al., in preparation) uses the irrigation requirements and share provided by Wriedt et al. (2008) as a baseline and calculates the impacts on water quantity from meeting the EU renewable energy target in 2020 based on different bioenergy storylines about the nature of bioenergy use. The modelling considers bioenergy use for heat and electricity generation in addition to the demand for transport fuel. EU production of first-generation biofuels is only present in storyline 1 ('Market first') due to strict GHG savings requirements in the other storylines that would not be met by EU biofuels. As part of storyline 1, the largest irrigation water demand in 2020 is predicted to derive from biofuel crop production in South-western France, and in particular from maize and sunflower cultivation. It is concluded that in general the storyline 1 scenario would not lead to large additional pressures on water availability in the EU, although other impacts, such as on farmland biodiversity, would take place. Irrigation requirements are much higher in storyline 2 ('Climate first') due to increased production of switchgrass and miscanthus triggering increased irrigation (Elbersen et al., in preparation).

Recently there has been considerable attention given to the concept of water footprints relating to supply chains and its potential use for biofuel production. However, the recently published EU Water Blueprint, a major review of European water policy, highlights that footprinting is suitable to use as a corporate management tool rather than a tool for EU-wide or national water policies (

Box 3).

Box 3: Using water footprinting as a tool – An EU policy perspective

Several studies with a global focus recently examined the concept of water footprints (Gerbens-Leenes et al., 2009; Gerbens-Leenes and Hoekstra, 2010). A water footprint of a product is the 'sum of the domestic water use and net virtual water import' (Hoekstra and Hung, 2011). There are currently three general approaches to calculating water footprints:

- Volumetric approach which is based on an overall assessment of the volume of water associated with a production activity;
- Stress weighted approach which combines an assessment of the amount of freshwater consumed by a production activity with an assessment of the consequences of that consumption in relation to water stress;
- Life cycle assessment approach which uses an inventory analysis of volumetric consumption with some impact assessment.

DG ENV commissioned a major review study (RPA, 2011)[25] of the potential use of water footprints in policy development, including whether footprinting could be taken forward as a specific EU policy tool. The study looked at different methodologies and policy formulations. The study recognised that water footprinting 'has been valuable in raising awareness over the need for sustainable water consumption and the extent to which countries export or import water as part of international trade'. However, it suggests that it is best considered as a corporate management tool rather than one of governmental or EU policy. Furthermore, even as a corporate tool there are 'issues regarding lack of consistency, clarity and transparency with the use of the methods'. The study concluded 'care should be taken in promoting its use more generally, and especially as a tool to support agricultural products' until the issues are resolved.

Recently published EU Water Blueprint examines the ways to take water footprinting forward. However, it does not prescribe action in this area due to the uncertainties. Furthermore, at best the tool is useful for labelling of products to inform businesses and consumers. Its use for regulation or other legislative approaches are not yet feasible since the footprinting is not robust enough to be defended within any agreed market regime, such as the EU internal market or WTO. Therefore, with regard to biofuel production, water footprinting is a potential useful analytical tool to assess relative water consumption for different crops and/or for different countries/regions which might help inform future policy analysis. However, it is not sufficiently robust to define specific sustainability criteria at this stage.

The JRC is currently conducting a major study on the water footprint of bioenergy development in Europe based on bioenergy demand scenarios from the National Renewable Energy Action Plans (NREAPs). However its results have not been available in time for the present report.

[25] RPA (2011). *Assessment of the efficiency of the water footprinting approach and of the agricultural products and foodstuff labelling and certification schemes*. Report for DG ENV.

4.4.3 Water quality risks

Pan-European datasets on water quality risks specifically from biofuel productions are limited. Of the six crops under review in this study, maize, sugar beet and rapeseed pose a high risk to water through nutrient leaching and pesticide pollution (EEA, 2006). While the threats from maize and rapeseed systems are considered most severe, sugar beet ranks a little better but still between severe and medium risk. Wheat and rye are considered of medium or in some situations low risk (EEA, 2006). Further expansion of these crops would exacerbate the situation given the already serious undersupply of clean water in intensively farmed regions due to nutrient and pesticide run-off (see Section 4.4.1).

Further information was gathered from national literature and expert interviews. A French researcher stated that the degradation of water quality is the main environmental impact of biofuel crop production in France (Dupraz P., pers.comm). To a large extent, biofuel crop production in France, which is based mainly on rapeseed, takes place on (about half of the area of) former compulsory fallow lands and elsewhere replacing the cultivation of leguminous crops which were beneficial for water quality. The replacement of former fallow land and grassland has had detrimental environmental effects, amongst others driving increase in negative impacts from nitrogen and pesticide/herbicide use. Furthermore, biofuel crops are mainly grown in nitrate vulnerable zones (Bordet et al., 2006). Another adverse indirect effect from increased rapeseed cultivation is the availability of large amounts of rapeseed cake, depressing its price and benefitting in-house livestock farming compared to grassland based systems, as was witnessed in recent rapeseed booms. The increased nitrogen loads from intensive in-house livestock raising cause increases in water pollution, often in nitrates vulnerable zones (Dupraz P., pers.comm). On the other hand, where rapeseed cultivation diversifies formerly simple crop rotations, certain improvements in water quality (and other environmental) impacts may result from decreases in fertiliser and pesticide use (Bordet et al., 2006).

The increase in intensification and subsequent increases in leaching and diffuse pollution of water bodies was recognised by experts in several Member States. Water pollution from nitrogen and sediment run-off in maize cultivation systems have been underlined as key risks from maize cultivation throughout a number of interviews. In Poland, water pollution from pesticide and fertiliser, especially nitrogen, from increased intensity of production in general and from maize cultivation systems is a particular concern (Macziejczak, M., pers.comm). It was acknowledged that a varying share of maize used for energy goes into biogas production. This holds for example for Germany, the Czech Republic and Italy. In the Po valley, energy maize cultivation aggravates water quality problems associated with nitrogen loads from intensive cropping systems. A Czech researcher noted that for all row crops, including maize and sugar beet, and partly also for rape (in the early growing phase), there is a strong correlation between increase in water erosion and water pollution. Besides the sediment run-off, water pollution caused by fertiliser has increased in these cropping systems due to the increasing need to compensate soil nutrients washed away with the topsoil in areas affected by erosion (Dumbrovsky M., pers.comm).

Where rapeseed expands onto previous wheat areas, the risk to water quality is larger since rape is a crop with relatively high nitrate loss (70 g/ha compared to 40 g/ha for wheat). Also, rape cultivation relies heavily on inputs (pesticides such as Carbetamide, Propiconazole, slug pellets) which represent large pressures on water quality. Also, rape cultivation is usually followed by wheat cultivation in rotation and both have similar input requirements posing prolonged threat to water quality (Letts J., pers.comm[26]).

Elbersen et al. (in preparation) model 2020 water quality impacts for three different bioenergy storylines. They chose nitrate (NO_3) leaching as an indicator for water quality. They conclude that differences in water quality between the three bioenergy storylines in 2020 are small compared to modelled changes over time. In the majority of Member States, the highest leaching rates in 2020 are found for storyline 1 given the production of first-generation biofuels based on rotational crops with higher nitrogen needs and subsequently higher levels of NO_3 leaching.

4.5 Water risks in non-EU countries

Water consumption and pollution have implications that vary both spatially and temporally. Due to variation in plant physiology and agricultural practices, cultivation of different crops requires very different amounts of water, as does cultivation of a single crop in different locations.

4.5.1 Water quantity risks

In order to assess the net impact of biofuel cultivation in the context of existing water resource conditions, Water Stress Indicator (WSI) values have been derived for the countries in question and these are then arranged into stress categories[27]. This was then compared to the net irrigation demand and total net water footprint associated with a shift from average cropping[28] to cultivation of the biofuel feedstock listed. The net irrigation demand reported here is the change in *consumptive use* of irrigation water that results when biofuel feedstock cultivation replaces existing average cultivation practices. Net water footprint is the % change in the sum of blue, green and grey water footprint for the same displacement (Table 22).

[26] Environment and Business Advisor, UK Environment Agency (England and Wales)

[27] We have classified water stress based on WSI in crop regions – derived from 2009 MODIS classification – rather than the national average values, which we also report here. This is because this work is concerned with water stress caused by and impacting agricultural water use. Given that water cannot be shifted over large distances, except at great expense, scarcity in agricultural areas is the more relevant measure for our purposes.

[28] Net effects are reported here for a shift from "average cultivation" to biofuel feedstock. In order to characterise the average cultivation, we used FAOSTAT data to identify the set of crops that comprised at least 1% of area under cultivation in each of the countries under consideration in 2010. We then used the area-weighted average of these crops to represent the "average hectare" for our analysis. Recognizing, however, that crop yields and water consumption are subject to the vagaries of a variable climate and other factors, we averaged the previous 20 years of cultivation data (1991-2010) to describe factors such as yield and water consumption for each crop in each country.

Table 22: Net impact of biofuel cultivation as compared to water stress (as WSI) in agricultural regions and nationwide for the countries under consideration

	Country	Feedstock	WSI (cropland only)	WSI (country average)	Net irrigation demand (m^3 per ha)	Net water footprint (% change per ha)
High stress	**Ukraine**	Rapeseed	0.81	0.80	-65	24%
	USA	Soybeans	0.69	0.78	-231	-16%
Moderate stress	**Canada**	Rapeseed	0.29	0.06	-10	22%
	Russia	Sunflower seed	0.27	0.06	-86	-12%
	Malaysia	Palm Oil	0.24	0.06	-198	12%
Low stress	**Indonesia**	Palm Oil	0.19	0.03	-340	75%
	Argentina	Soybeans	0.09	0.36	-32	7%
	Brazil	Sugarcane	0.04	0.03	261	74%
		Soybeans			-8	39%
	Paraguay	Sugarcane	0.03	0.03	1064	114%
	Tanzania	Sugarcane	0.05	0.02	-56	90%
	Guatemala	Sugarcane	0.01	0.01	1014	97%

It is important that we recognise that not all water is the same and that while irrigation (blue) water is a unique and important resource, rain (green) water is also valuable, as is the water pollution that is captured through "grey" water quantification. If not devoted to biofuel feedstock production, green water can go to other productive uses – to cultivation of another crop, to environmental services, or to groundwater recharge (Hess, 2010).

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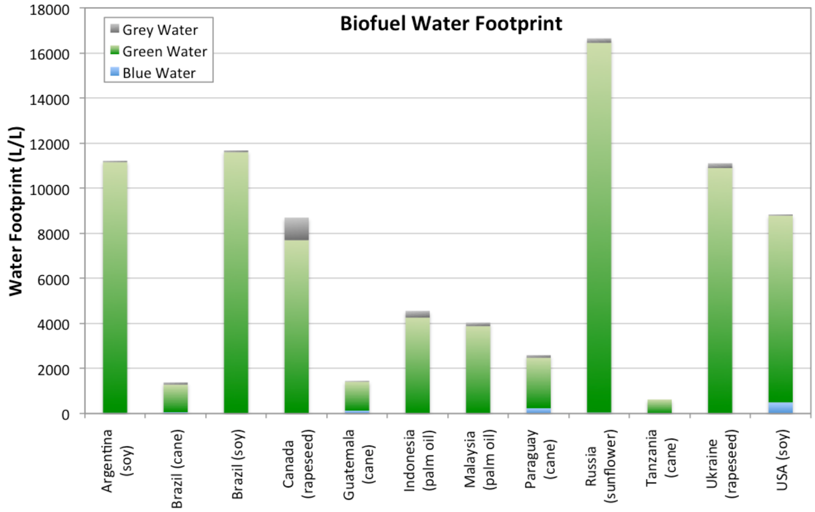

Figure 8: Biofuel water footprint in selected countries

While the water footprint values reported in Figure 8 tell one side of the story, the amount of water consumed per unit of crop production is not the only relevant metric for understanding water impact. Consumption per unit area tells a different story, indicating a pattern that is in many ways opposite of the one above (see Figure 9).

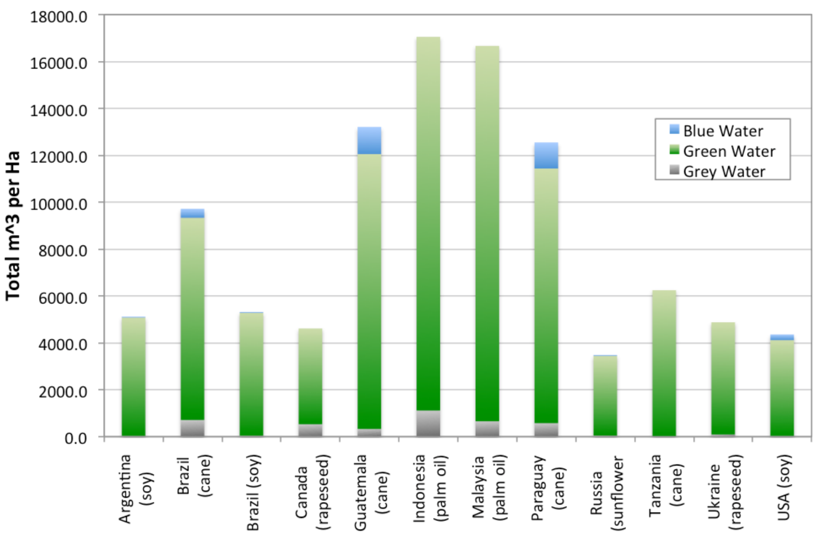

Figure 9: Biofuel crop water consumption in selected countries

Gross consumption per unit area is only truly useful when compared to the water consumption that would have occurred were biofuel feedstocks *not* cultivated. In the absence of bioenergy crops, the land in question could either have been uncultivated or used for production of other crops. In the case of extensification into uncultivated land, blue and grey water consumption can be assumed to be all net increase, while the net effect on green water is much more complex given that the vegetation on fallow agricultural land or natural landscapes also consumes rainwater[29]. In the case of displacement of agricultural production, we have used the water intensity of existing average cultivation (area-weighted average of all crops representing >1% of cultivated area in each country), given that we do not know what specific crops are being replaced by biofuels in each location.

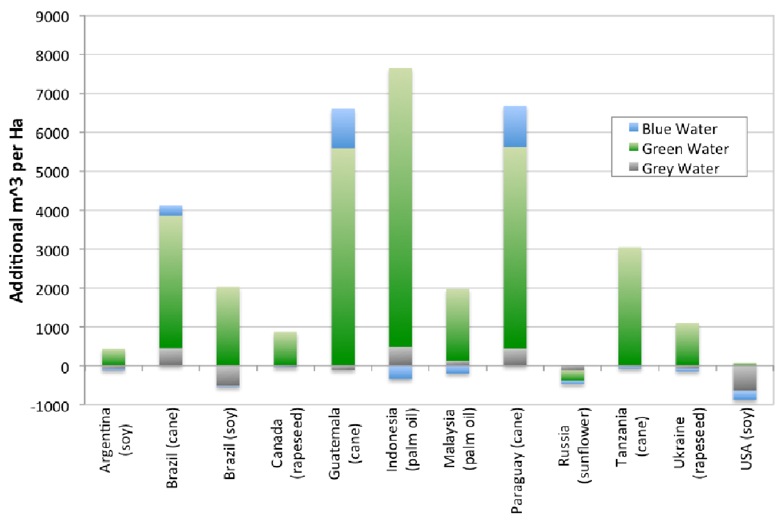

Figure 10: Net effect of biofuel expansion on water in selected countries

4.5.2 Water quality risks

Within the biofuel life cycle, the agricultural phase poses the greatest threat to water quality. Major factors affecting agricultural nutrient export to surface water flows include soil type, proximity to water bodies, tillage practices, crop rotation, and the use of tile drainage (US EPA, 2010). Feedstock choice will also strongly affect the water quality impacts of biofuel production. For example, biodiesel feedstocks, such as soybeans, as well as cellulosic feedstocks such as miscanthus, switchgrass, and poplar, are expected to have much lower fertiliser application rates than corn, significantly lowering projected water quality impacts (US EPA, 2010).

The U.S. Environmental Protection Agency expects increases in corn production for ethanol, for example, to lead to increases in the occurrence and concentration of nitrate, nitrite, atrazine and other contaminants in drinking water (US EPA, 2010). Donner and Kucharik (2008) showed that the U.S. corn ethanol targets in the 2007 Energy Independence and Security Act (EISA) could lead to a 10-34% increase in the export of dissolved inorganic nitrogen (DIN) from the Mississippi and

[29] In many cases, extensification of rainfed agriculture could result in a net *reduction* of green water consumption, as diverse natural vegetation has evolved to make more efficient use of available rainwater than will agricultural landscapes. Quantification of ET from natural vegetation to determine net green water consumption from extensification is a detailed, location-specific biometeorological issue that is beyond the scope of this study

Atchafalaya Rivers. This would exacerbate eutrophication in the Gulf of Mexico, expanding a "dead zone" that already extends up to 18,000km^2.

Table 23: Summary of water quality in selected countries

N pollution level	Country	Feedstock	Average N flux (kg/km^2) - cropland regions	% change in grey water consumption
High	**Indonesia**	Palm Oil	1531.3	77%
	Guatemala	Sugarcane	829.6	-24%
	Malaysia	Palm Oil	720.0	23%
Moderate	**USA**	Soybeans	371.0	-96%
	Brazil	Sugarcane	296.3	171%
		Soybeans		-94%
	Ukraine	Rapeseed	284.8	-46%
	Argentina	Soybeans	226.7	-75%
Low	**Russia**	Sunflower seed	175.2	-74%
	Paraguay	Sugarcane	102.0	330%
	Canada	Rapeseed	99.1	-5%
	Tanzania	Sugarcane	90.9	-100%

4.5.3 Synthesis

Out of the eleven cases under consideration, the six using palm oil and sugarcane as feedstock were found to be the most "water efficient" in terms of consumption per unit output. However, the same six cases were the most consumptive on both gross and net basis per hectare under cultivation. This is due to the relatively high productivity of sugarcane and palm oil cultivation. While these systems consume a great deal of water – more than other bioenergy feedstock cultivation – they are productive enough to offset this consumption when considered on a per-unit-output basis. This pattern clearly shows the importance of functional unit choice when using life cycle assessment to evaluate impacts.

Overall, a shift from average cultivation to biofuel feedstock cultivation was found to increase total water consumption in all but two of the countries/feedstocks combinations considered. This increase, however, appears to come mostly in the form of green water consumption. Consumptive use of irrigation (blue) water was shown to be *reduced* in all but three cases. Further, the three countries in which blue water consumption was expected to increase with a shift to biofuel cultivation (Brazil, Paraguay, and Guatemala) all exhibited overall low levels of water stress, meaning that the available resource base may be able to absorb the projected increase. Further, the two cases in which a shift to bioenergy feedstocks was found to decrease total water consumption (Russia and the USA) are two of the four most water-stressed countries in this study. A reduction in water demand for agriculture in these places could be a welcome change[30].

Other countries that are not within the scope of this study, but which are nonetheless important bioenergy trade partners for the EU present a very different case. In Egypt, for example, a shift to bioenergy feedstock production creates a larger gross and net water impact than in any of the countries included here, and almost all through consumption of blue water. This would prove a critical constraint to bioenergy expansion in Egypt, where agriculture accounts for about 95% of all blue water consumption and is the source of 18% of GDP and 31% of all employment (Attia, 2004).

On the issue of water quality effects, similar insights can be gleaned through evaluating expected net grey water consumption from a shift to biofuels in light of background nutrient pollution levels. Of the three countries where our study found croplands to be highly polluted by fertiliser runoff, only two would be expected to increase their pollution with a shift to biofuel feedstock. These are Malaysia and Indonesia; both large oil palm producers. Oil palm is one of the most fertiliser-intensive crops grown in many tropical regions. This intensity, combined with the fact that it is one of Malaysia's key commodity crops, has led to the circumstance wherein approximately 80% of all nitrogen fertiliser applied in Malaysia is applied to oil palm. Our results show that further expanding oil palm production in Malaysia would lead to further pollution of already polluted watersheds – a problem that is largely due to *existing* oil palm production. On the other hand, in all three cases where soybeans were the biofuel crop under consideration, we predicted steep (75-96%) decreases in fertiliser pollution. This is due to the low level of fertiliser application required for cultivation of this nitrogen-fixing crop. When soy displaces more nutrient-intensive crops, such as maize and sugarcane, we expect a reduction in total fertiliser application.

4.6 Coverage by existing provisions

4.6.1 Water provisions in the EU

EU Water Policy

It is important to stress that objectives for water in Europe are framed at river basin level. The assessment of characteristics of water bodies, objective setting, understanding pressures and developing programmes of measures are all within River Basin Management Plans (RBMPs) under the 2000 Water Framework Directive (WFD). If there is a problem meeting the objective (good status for surface or ground waters), then measures should be taken by Member States. This is clear in the Directive on quantitative objectives for groundwater and nutrient pollution for both surface and ground waters. Currently the first RBMPs are being implemented. A major assessment is underway at the moment to examine the assessment of different pressures and measures adopted in the plans

[30] It should be noted that the reduction described here is due to displacement of existing average cultivation. The demand for this cultivation will not disappear and must still be met. These "indirect effects" are discussed in more detail later in this section.

and results from this assessment are being examined by the EC. In the recently published EU Water Blueprint, the Commission does not foresee any immediate amendment to the WFD, but to support Member States through provision of better water accounting tools, etc.

A particular approach for example, being promoted by the Water Blueprint to help understand the link between abstraction and surface waters is the concept of environmental flows – the water flow regimes necessary to meet good ecological status of waters. With such an approach it would be possible to determine if levels of abstraction (quantity or timing) are inconsistent with the required flow regime. From such a determination criteria for agricultural activities (including energy crops) could be developed – but only at river basin level.

It has to be noted that under the WFD, Member States can effectively derogate difficult decisions to the third river basin planning period (2021-2027). However, at this stage pressures will need to be contained, including those from agriculture. The WFD is a legal obligation on Member States and, therefore, using its objectives as a basis for sustainability criteria for bioenergy crops (and other pressures) is the obvious starting point. Indeed, it is not clear if sustainability issues regarding agriculture and water in river basins that are compliant with the Directive would remain outstanding in 2027. Assuming compliance as the overall objective, additional criteria would not be needed in theory as farmers would simply do what is required of them to meet the obligations of EU law. This is, however, not the case at present.

There are particular concerns with the implementation of the WFD and this will be highlighted in a forthcoming Commission Communication on implementation. Thus sustainability concerns remain. Overcoming issues in the implementation of water policy in the immediate future may be facilitated by suitable non-burdensome criteria which would help mitigate pressures from intensification trends driven by energy policies and commodity markets.

Nitrates Directive

The risks relating to water quality from agricultural sources are to some extent addressed by the requirements under Nitrate Action Programmes for the nitrate vulnerable zones, implemented under the Nitrates Directive. Requirements limit fertiliser application to and equivalent of 170 kg nitrogen /hectare/year which could be surpassed under specific conditions through derogations. In the majority of Member States the designation of these zones is localised, e.g. within the ten Member States of focus only Germany has a whole country approach to implementing these programmes of measures. Although the Nitrates Directive has been in place for decades, its implementation and associated reduction in risks is slow. It is a common situation that the nitrates vulnerable zones are situated in areas with highly productive agriculture. Whilst in some of these areas biofuel crops replace other types of cropping (often with a crop with higher risk to water such as maize replacing a crop with lower risk such cereals), in other places feedstocks for biofuels increase crop production, in both cases with additional pressures to water resources in these zones. For example in France, cultivation of biofuel feedstocks, rapeseed in particular, is mainly concentrated in these zones (Bordet et al., 2006), and due to the increased use of pesticides and fertiliser that rape requires, it further increases pressures on water resources.

Pesticides Framework Directive

The risks from pesticides use are addressed by the Directive adopted in 2009, however its full implementation is foreseen from 2014. The Directive promotes principles of integrated pest management (IPM) including active measures for prevention of harmful organisms, setting out of threshold values, preference for non-chemical methods, reduced inputs, keeping records and monitoring. Member States are required to develop National Action Plans with quantitative objectives, targets, measures and timetables to reduce risks and impacts of pesticide use on health and the environment and to encourage the development and introduction of IPM. There are additional requirements on putting in place appropriate measures to protect the aquatic environment and drinking water supplies, and to minimise the pesticide risk in specific areas such as zones set out in RBMPs and zones protected under the Habitats Directive. First information on the measures developed by Member States will be available only by the end of 2013. It is too early to say if the plans include substantive measures. If they do, this would be a welcome progress for managing the risk in the areas affected by intensive energy crops.

Common Agricultural Policy

Under the CAP, farmers are required to comply with minimum management requirements set out under the GAEC framework (see Section 3.5.1). Currently, there are only two water related GAEC standards, one focusing on buffer strips and another on water authorisation introduces permits in order to use water. An optional soil GAEC standard for crop rotation might be potentially useful, where implemented.

However, there is a concern with inadequacy of the current GAEC framework to counter pressures on water quality and water quantity from the expanding intensive cultivation of energy crops in affected areas. As noted before, the goal of the GAEC framework is to require simple baseline management that comes at low cost to farmers. For example, the GAEC standard on water authorisation is in most Member States not linked to any volume limits. There are exceptions, for example France requires water metres. The introduction of the GAEC on buffer strips since 2012 has been delayed in some Member States and member States do not always require the width of the strip needed to protect water quality. The majority of Member States require 5 metre width, which can be enough in some situations but is not effective in others. Crop rotation GAEC might potentially benefit water quality, as was mentioned by the French interviewee, pointing to a French standard where crop rotation requires at least three crops or maize in combination with a nitrate catch crop (Dupraz P., pers.comm). However, this is not a general case. A pan-European study of maize sector from the viewpoint of plant health concluded that where implemented, crop rotation standards are generally insufficient to ensure a good quality management in intensive maize monocultures across Europe (FCEC, 2009).

An important factor weakening the effectiveness of GAECs related to water quality, according to the UK interviewee, is weak control system and issues in the timing of spot checks. Echoing a similar finding by the European Court of Auditors (ECA, 2008), he underlined that there are no spot checks of farms after October, whereas run-off into water bodies is more likely to be observed in the winter months (Letts J., pers.comm). This is likely to be an EU-27 wide problem.

Many interviewees noted that despite the range of EU level frameworks, strategic mitigation approaches to water quality and quantity on farm, such as set out by Louwagie et al, 2009 or Janecek, 2011, are not implemented in practice. Prevailing agricultural management is driven by short term economic objectives. As a result, the medium and long-term damage to water resource on-site and off-site is not internalised in the market prices for crop commodities and is not adequately addressed by existing policy measures.

Voluntary and other measures

Several voluntary measures and other initiatives were mentioned by some interviewees. These are however not widespread and have limited effectiveness. In France, mechanical weeding and non-systematic plant protection are voluntary management practices for which some examples exist, however on a rather low share of cropland under biofuel crops. A few agri-environment schemes have been designed to improve management of irrigated maize systems, with poor uptake (Dupraz P., pers.comm). The UK expert mentioned some private initiatives (e.g. water companies pay farmers to use certain slug pellets) as well as pointed out the usefulness of woodland compensation[31], given woodland is an effective buffer for leaching, more effective than grass buffer strips, but also more expensive to introduce and requiring a longer timeframe (Letts J., pers.comm).

4.6.2 Water provisions in non-EU countries

This study indicates that expansion of bioenergy production could work to the detriment of water resources in at least some contexts, meaning that safeguards would be necessary in some regions to avoid unsustainable impacts. This raises the question of whether or not those safeguards are currently in place.

The case of water quantity is complex, as it is less a matter of regulation than of allocation. Green water consumption is not controlled in any jurisdiction that we know of, since this water is naturally available in the field. The relevant quantity controls, therefore, are in the realm of irrigation (blue water). In all of the regions shown here to exhibit water scarcity, quantity restrictions are in place to manage water allocation to farms. Where those restrictions are enforced, and where restricted supply is not sufficient to cultivate biofuel feedstocks, farmers will not do so, and so impacts will not occur. Where possible, however, shortfalls could drive farmers to rely more heavily on unregulated private pumps to draw on already depleted groundwater resources. Another effect of increased demand will be elevation in the price of water rights in market systems, leading market-mediated indirect effects. In short, the coverage of water quantity impacts by existing provisions is an issue of enforcement and of indirect effects; both are beyond the scope of this study.

[31] Such as woodland creation grants and farm woodland payments, see http://www.forestry.gov.uk/pdf/ewgs7-guide.pdf/$FILE/ewgs7-guide.pdf.

Water quality impacts are more the subject of conventional regulation, and the jurisdictions studied have provisions in place to manage water pollution. At the industrial processing phase, biofuel production facilities – as point sources of pollution - are typically regulated under water pollution controls and must maintain a permit for any discharges. This is the case in all of the high and moderate pollution countries studied. In the case of Malaysia, for example, the fairly comprehensive Environmental Quality Act of 1974 contains provisions specifically aimed at palm oil refineries and has been successful at curbing their chemical effluent. Similarly, point sources of pollution in the United States must register and receive a permit from the National Pollution Discharge Elimination System (NPDES), and are regulated according to the Clean Water Act (CWA).

Water pollution resulting from the cultivation phase of the biofuel life cycle, however, is much more difficult to regulate. Despite being the leading source of water quality impairment globally, agricultural runoff is rarely regulated, as it is a non-point source of pollution. In the US, for example, runoff from farms is exempt from NPDES registration. Instead, most jurisdictions manage agricultural runoff through funding of mitigation measures rather than penalising emitters as they do with point sources. In Indonesia, for example, the country with the most polluted cropping regions in our study, extensive international expertise and money has gone into introduction of runoff mitigation and soil conservation techniques. Unfortunately, once the projects and payments end, most of these conservations techniques are typically abandoned (Gatot, 1999).

It is important to recognise that coverage by regulation – even where that regulation is robust – does not ensure sustainable management of resources. The rule of law and the enforcement of existing regulations varies greatly across the countries and regions studied. Worthy of note is the fact that the regulatory enforcement in the highest risk countries in our study – Indonesia for water quality and Ukraine for water quantity – was ranked respectively 32nd and 62nd out of 64 countries in a 2011 study by the World Justice Project (Agrast, 2011). Further investigation is warranted as to the level of management that existing safeguards ensure *in practice*.

4.7 Conclusions

Results of water impact evaluation vary greatly depending upon the functional unit chosen, and care must be taken to quantify the most relevant factor for any given evaluation. Overall, we find that for most of the non-EU scenarios considered here, a shift to bioenergy from existing average cultivation would result in a net increase in total water consumption, but a net decrease in irrigation demand for a given hectare. The analysis of the EU situation shows a diversity of trends in different climatic and biogeographic zones. So far unpublished new forecast by EEA indicates that the bioenergy scenario involving only first generation biofuels would not lead to large additional pressures on water availability in the EU overall. However, there is a great deal of heterogeneity to the effects in both the EU and non-EU situations, and where there is evidence of potential risk, the impacts should be investigated more closely because the simplifying assumptions made for this global study may not be borne out in practice. Water resource impacts will depend upon a variety of factors that cannot be generalised. These include actual crop displacement, intensification and extensification dynamics, specific agronomic practices, local climatic conditions, regional resource constraints, and other supply chain factors.

Empirical evidence from EU Member States suggests that potential expansion of irrigated intensive maize systems in the Mediterranean, such as the concentrated production in the Po Valley, would increase pressures on aquifers and water availability in the already stressed river basin. Of the trading partners in non-EU countries considered here, further study on quantitative impact is warranted in Ukraine, Canada, and Malaysia, which were found to exhibit moderate-to-high water stress, combined with expected increase in total consumption from a shift to biofuel feedstock cultivation. USA and Russia also exhibited water stress in their cropland, warranting a closer look despite the expected reduction in water demand for any shift to biofuels.

With regard to water quality in non-EU countries, palm oil fuels from Indonesia and Malaysia are cause for concern. These two countries already have impaired water quality in agricultural areas due to nutrient runoff, and any further expansion of palm cultivation is expected to exacerbate this situation. Guatemala, USA, and Brazil also warrant closer examination due to their elevated nutrient runoff in some areas and/or expected increases in that runoff from bioenergy production. In the EU water quality is affected by diffuse agricultural pollution by nitrates, phosphates and pesticides to varying degrees. In intensively farmed regions, particularly those under rapeseed, maize and sugar beet croppings, the pressure to water quality through nutrient run-off and pesticides is severe. Expansion of these crops, given the already critical undersupply of clean water in these agro-ecosystems, would aggravate the situation.

Another interesting finding is that special attention should be paid to the relationship between indirect land use and direct water use impacts. Initiatives taken on the ground to avoid indirect land use changes can inadvertently exacerbate water scarcity or hinder water quality. Extensification of irrigated agriculture into formerly uncultivated land to avoid displacing existing production will necessarily engender new demand on water resources. Intensification of existing production to increase output can lead to both water quantity and quality impacts insofar as it is achieved through additional input of irrigation water and/or agrichemicals.

In regions where a shift to bioenergy feedstock production is expected to bring with it risks to water quantity or quality, both within and outside the EU, action should be taken to mitigate those risks when incentivising expansion in bioenergy production. Investment in more efficient irrigation technology can reduce total irrigation demand as well as shifting some consumed water from evaporation to transpiration without increasing total consumptive use. Similarly, use of true waste materials, such as some crop and forestry residues as well as municipal waste streams can increase energy output without requiring new cultivation. Furthermore, employment of best management practices such as cover cropping, intercropping, crop rotation, riparian buffer zones, appropriate timing and rate of nutrient application, use of treatment wetlands, and drainage management can reduce both consumption and pollution of water resources.

Biorefineries can also improve their water efficiency, through vapour capture, heat recycling, and other process optimisation measures. Some in the ethanol industry assert that current technology could, with sufficient investment, allow for an ethanol refinery with zero net water consumption (Wu, 2008). Also, use of biomass residues such as sugarcane bagasse and corn stover for cogeneration of process heat and power displaces other electric power production and its attendant water consumption. Finally, careful siting and design of biorefineries will minimise conflicts and maximize synergies between different water uses. Co-location with wastewater treatment facilities allows biorefineries to make use of degraded effluents for many process needs. Co-location with livestock operations allows for cycling of water and waste products between the two processes, including the efficient use of wet distiller's grains as cattle feed.

In closing, while some findings of this study are promising with respect to, for example, expected impacts on irrigation resources, they must be taken in a larger context. Insofar as biofuel feedstock production results in extensification, all irrigation demand will necessarily be new, potentially straining resources. Moreover, where cultivation is displaced, while the new cultivation may use less water, the demand for the displaced production must still be met. These "indirect effects" by now familiar in the realm of land use, are no less real for water resources and, while not in the scope of this study, must not be forgotten.

5 Air quality risks from biofuels consumed in the EU

5.1 Introduction

Air is comprised primarily of oxygen and nitrogen and is vital to the functioning of plant and human life. Air quality refers to the amount of other compounds in the air and is impacted by the addition of a number pollutants, including chemical and biological compounds and particulate matter. High concentrations of air pollutants can negatively impact human and ecological health as well as impact local (e.g., creation of smog and acid rain) and global (e.g., influence temperature and rainfall patterns) climates. This section addresses the impacts that biofuels production has on air quality.

The main pollutants in Europe are sulphur dioxide (SO_2), nitrogen oxides (NO_X), carbon monoxide (CO), ammonia (NH_3), particulate matter (PM), volatile organic compounds (VOC), polycyclic aromatic hydrocarbons (PAH), heavy metals (HM), as shown in the following figure.

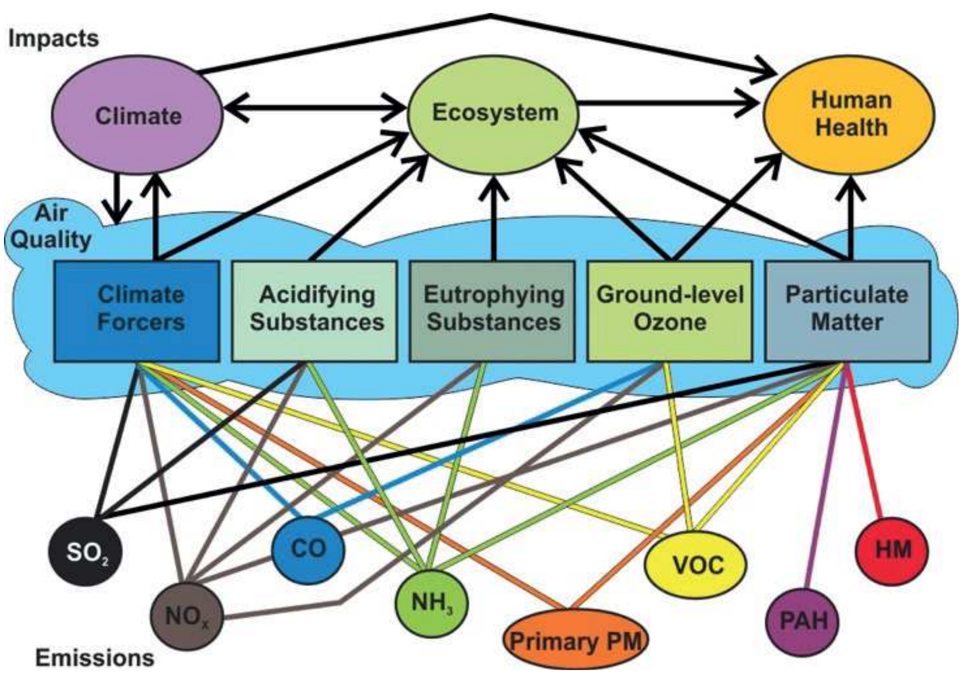

Figure 11: Major air pollutants in Europe, clustered according to impacts on human health, ecosystems and the climate. Source: EEA, 2011

The biofuel lifecycle can emit air pollutants in every stage from growing feedstocks (e.g., dust from clearing land, smoke from burnings, nitrogen from fertilisers), to transporting feedstocks and refined product (e.g., vehicle emissions and dust generation), to processing (e.g., industrial systems emissions), to use (e.g., combustion)[32]. The impacts of these pollutants depend on the local context, including the proximity to communities, sensitivity of ecosystems, concentrations of the pollutant, topography, and meteorology. However, they are a considerably lower threat than the risks to soil and water at corresponding stages of lifecycle.

5.2 Risk assessment – methodology

To determine the potential impact of EU demand for biofuels on air quality worldwide, the following steps are followed:

- Step 1: Identify potential air quality risks at each production stage, by crop.
- Step 2: Risk assessment by crop and region, considering the presence and frequency of potential risks.
- Step 3: Assess the extent to which existing provisions cover issues in regions of high and medium risks by country and region.
- Step 4: Identify remaining risks not covered by existing provisions.
- Step 5: Discuss the need for mandatory criteria (covered in chapter 6).

For the purposes of this assessment, the following factors define what constitutes high, medium, and low risks for a given region:

- Concentrations of air pollutants typically resulting from specified management practices and activities;
- Frequency and likelihood of the practice or activity for a specific crop in a region;
- Legislative and voluntary provisions that may reduce the risk associated with each threat (for Step 3).

There are other factors that would impact the risks that cannot be accounted for in this analysis, such as proximity to residential areas and baseline concentrations of the air pollutants in each region, due to the level of detail of analysis that would be required to identify those factors.

Based on the above factors, the assessment defines the categories as:

High risk - Without mitigation measures, the risk for air quality is unacceptably high due to impacts that disrupt local ecosystems of significantly threaten human health (e.g., such that there are

[32] Note that biofuel combustion (tail-pipe emissions) are considered outside the scope of this analysis since the current sustainability criteria are focused on cultivation and production.

noticeable impacts on community health indicators and/or people are required to spend less time outdoors due to the air pollution that results).

Medium risk - Without mitigation measures, the factor may result in long term changes to ecosystems or community health; however, the impacts may go unnoticed in the short term if monitoring is not conducted.

Low risk- The threat posed is unlikely to cause noticeable changes to air quality above what is currently viewed as acceptable and would go unnoticed.

The information used in this assessment was obtained through a literature review and interviews with local experts.

The following table presents potential types of air pollution from each production stage for the most common biofuels consumed in the EU. This includes both biofuels produced within the EU as well as imported from other countries.

Table 24: Potential air quality threats at each production stage for different types of biofuels in the EU

Crop	Land Preparation and Post-harvest	Cultivation	Harvest	Transportation and Processing
Rapeseed	Dust during ploughing of land for crop establishment.	High nutrient requirements therefore enhanced N_2O emissions risk from high use of fertiliser compounds. Requires significant application of pesticides and herbicides.	Wind erosion of soils following harvest if soil remains uncovered.	Emissions from hauling feedstock to facility (vehicle exhaust and dust from roads). Potential emissions of particulates during sorting and processing of seed. Potential emissions of VOCs, SO_x, hexane, CO and NO_x during processing into biodiesel (generally transesterification. Potential emissions of VOCs during subsequent storage of product.

Crop	Land Preparation and Post-harvest	Cultivation	Harvest	Transportation and Processing
Soybean	Dust from removal of vegetation/ conversion of land, or land preparation in dry seasons Particulate matter and toxins from burning residues in post-harvest.	Dust from tillage. Vehicle or machine exhaust from mechanised cultivation. N_2O from fertiliser.	Vehicle or machine exhaust from mechanised harvest.	Emissions from hauling feedstock to facility (vehicle exhaust and dust from roads). Particulate matter from handling of soybeans and mechanical extraction. VOCs during chemical extraction process and oil pre-treatment, including methanol and hexane, and during biodiesel reaction process. Combustion at flare and boiler produces PM, VOCs, HAPs, CO, NO_x, SO_x. VOCs and HAPs from storage (See NDEQ, 2007).
Oil Palm	Dust from removal of vegetation/ conversion of land, or land preparation in dry seasons. Fire hazard from peatland drainage. Fire for land preparation (clearing biomass) or of drained peatlands produces particulate matter and toxins.	Vehicle or machine exhaust from mechanised cultivation. N_2O emissions from fertiliser. Agrochemical applications[33].		Emissions from hauling feedstock to facility (vehicle exhaust and dust from roads). Palm oil processing and transesterification[34]: ash from nut/fibre separation. Flue boiler emissions: smoke and soot (black smoke if palm shell used), PM, N_2O, NO_2, CO. Incinerators' white smoke from EFBs. Emissions from effluent. Electricity generation for operations.

[33] Paraquat (gramoxone) is sprayed on oil palm tree as an herbicide. One hour after spraying the paraquat, about 11 mg per kg body weight may be retained on the labourer's skin. Insecticides are also applied. However, these chemicals are less toxic because of their degradability (Pleanjai et.al., 2007).

[34] The extraction process for crude palm oil is not inherently a significant source of air pollution. However, when solid fuel fired steam boilers utilise the fibre and shell material as the fuel and incinerators burn the empty fruit bunches for recovery of potash, there are significant air emissions. The combustion may emit excessive smoke that may cause localised air pollution problems (DOE, 1999).

Crop	Land Preparation and Post-harvest	Cultivation	Harvest	Transportation and Processing
Sugar beet	Dust from establishment of crops due to wind erosion of soils especially given sugar beet's preference for light soils.	Herbicide and fungicide application especially at early growth stages. Potentially intensive fertiliser demands depending on previous rotation and soil fertility with higher N_2O levels of emission.	Emissions from harvest machinery Particulate emissions harvesting a root crop plus soil particulates and potential for wind erosion) and practice of ploughing back in top portions of the crop.	Emissions from hauling feedstock to facility (vehicle exhaust and dust from roads). Potential emissions of particulates during sorting and processing. Potential emissions of VOCs, SO_x, CO and NO_x during processing into bioethanol - potential emissions of VOCs during subsequent storage of product.
Wheat	Dust during ploughing of land for crop establishment.	N_2O from fertiliser. Particularly high for winter wheat application of pesticides and herbicides, particularly early in the season.	Wind erosion and production of particulates during harvest esp if ground left uncovered Burning of straw/stubble.	Emissions from hauling feedstock to facility (vehicle exhaust and dust from roads). Potential emissions of particulates during sorting and processing. Potential emissions of VOCs, SO_x, CO and NO_x during processing into bioethanol - potential emissions of VOCs during subsequent storage of product.
Maize	Dust during ploughing of land for crop establishment	Row crop, therefore potential for wind erosion, especially given its preferred habit i.e. relatively high temperatures, hence particulates. N_2O from fertiliser. Agro chemical application.	Burning of stubble. Wind erosion leading to particulates if land is left uncovered i.e., stubble removed and no cover crop. Emissions from machinery harvesting the crop.	Emissions from hauling feedstock to facility (vehicle exhaust and dust from roads). Potential emissions of particulates during sorting and processing. Potential emissions of VOCs, SO_x, CO and NO_x during processing into bioethanol - potential emissions of VOCs during subsequent storage of product.

Crop	Land Preparation and Post-harvest	Cultivation	Harvest	Transportation and Processing
Sunflower	Dust during ploughing of land for crop establishment – although on-going risk will depend on whether annual or perennial crops are grown.	Row crop, potential for wind erosion and particulates. Harrowing during early establishment can lead to soil disturbance and wind erosion. N_2O from fertiliser. Agro-chemical application especially at early stages of production.	Application of chemicals for artificial desiccation process to allow drying ahead of on phase harvesting. Particulates from wind erosion if soil left uncovered. Emissions from harvest machinery.	Emissions from hauling feedstock to facility (vehicle exhaust and dust from roads). Potential emissions of particulates during sorting and processing of seed. Potential emissions of VOCs, SO_x, hexane, CO and NO_x during processing into biodiesel. Potential emissions of VOCs during subsequent storage of product.
Sugarcane	Dust from removal of vegetation/ conversion of land, or land preparation in dry seasons.	Dust from tillage. Vehicle or machine exhaust from mechanised cultivation. Nitrous oxide (N_2O) from fertiliser.	Particulate matter and toxins from pre-harvest cane burning. Vehicle or machine exhaust from mechanised harvest.	Emissions from hauling feedstock to facility (vehicle exhaust and dust from roads). Particulate matter and NO_x from bagasse boilers (more emissions for more inefficient boilers) (See Goldemberg, 2008).
Rye	Dust during ploughing of land for crop establishment.	N_2O from fertiliser, Application of agro chemicals.	Emissions associated with harvest machinery. Particulates from exposed soil due to wind erosion.	Emissions from hauling feedstock to facility (vehicle exhaust and dust from roads). Potential emissions of particulates during sorting and processing. Potential emissions of VOCs, SO_x, CO and NO_x during processing into bioethanol. Potential emissions of VOCs during subsequent storage of product.

5.3 Air quality risks

Based on knowledge of the risks identified in Table 24, this section describes the risks posed by biofuel feedstocks to air quality at each lifecycle stage. The risks are based on the relative concentrations of each air pollutant from a particular practice and the likelihood and frequency of management practices for the crop in each country (or to the extent they are known, regionally). The risk assessment assumes mitigations actions have not been implemented and policies and programs are not in place to reduce impacts. There are certain limitations to this assessment. The level of risk will be affected by management practices which may vary within a region. There are other localised factors which cannot be considered here; for example, crop residue burning is considered to have a high air quality impact however, within the scope of this analysis factors such as the relative impact of burning proximity to residential areas could not be considered. However, results in key countries indicate that generally the greatest risks to air quality are associated with burning. These are from burning of crop residues, of sugarcane pre-harvest, for clearing vegetation from land, or as a result of clearing lands. Burning creates smoke and haze which are full of particulate matter and other pollutants which may damage respiratory systems and limit visibility. High risks are also associated with some applications of agrochemicals, areas highly vulnerable to wind erosion, and gaseous emissions from processing facilities. Agricultural production in Europe is known to be an important source of PM10 particularly in rural areas and to contribute the vast majority of ammonia emissions in Europe (94% in 2009) (EEA, 2011). Emissions from the transportation stage would depend on transport distances and methods which are highly variable. However a more concrete information is unavailable.

The available data allow for identifying only the potential risks based on specific practices rather than actual impacts. A detailed breakdown with explanations of the factors resulting in the specific risk characterisation is provided in Annex 8 by country and region.

The results of the risk assessment are shown in Table 25. They demonstrate that soybean, palm oil, maize, and sugarcane have the highest overall potential risks, largely due to the presence of burning as part of their production (land preparation and pre and post-harvest). In the cultivation stage, all of the crops have high or medium risks associated with the volatisation of nitrogen compounds from fertilisers, and in some countries air pollution from volatisation of other agrochemicals raises the risks. While information on the air pollution associated with the processing stage was not obtained for many of the countries, it is assumed from general knowledge that processing facilities have a medium or high threat, depending on the control of gaseous emissions and emissions associated with other waste streams at the facilities.

5.4 Synthesis

Legislative and voluntary provisions that may address the risks identified as high and medium are listed per country in the second part of Annex 8. It also includes information on the potential to enforce the legislation in non-EU countries based on a set of four governance indicators and indication of whether the existing legislative and voluntary measures reduce the high and medium risks. The following table summarises the level of risk in each country for each stage of the biofuel production chain. The '*' in the table indicate whether the existing measures potentially mitigate the threat (although not the extent of how much that threat is lowered). In many of the cases where it is indicated that these measures do potentially mitigate the threat, we assume that legislation is well implemented.

Table 25: Key Risk Factors Linked to Practices and Processes

	Key risk factors linked to practices and processes				
Country and area planted for EU biofuels	**Land Preparation and Post-harvest**	**Cultivation**	**Harvest**	**Transport**	**Processing**
Rapeseed					
EU	Low	High*	Low	Unknown	Medium*
Ukraine (262,779ha)	Low	Medium	Medium	Unknown	High
Canada (207,393ha)	Low	Low	Low	Unknown	Medium*
Russia (128,662ha)	Unknown	Medium	Medium	Unknown	Medium
Soybean					
Argentina (867,795ha)	Low	High	Medium	Unknown	Medium
Brazil (300,353ha)	High	Medium	Low	Unknown	Medium*
United States (160,127ha)	High*	Medium*	Low	Unknown	Medium*
Paraguay (140,276ha)	High	Medium	Unknown	Unknown	Low
Palm Oil					
Indonesia (56,672ha)	High	Medium*	Very Low	Low	High
Malaysia (11,954ha)	High*	Medium*	Very Low	Low	High*
Sugar Beet					
EU	Low	High*	Medium*	Unknown	Medium*
Wheat					
EU	Low	High*	Low	Unknown	Medium*
Maize					
EU	Medium*	High*	Medium*	Unknown	Medium*
United States (33,342ha)	Medium*	High*	Medium*	Unknown	Medium*

Country and area planted for EU biofuels	Key risk factors linked to practices and processes Land Preparation and Post-harvest	Cultivation	Harvest	Transport	Processing
Sunflower					
EU	Low	High*	Medium*	Unknown	Medium*
Sugarcane					
Brazil (73,959ha)	Unknown	Medium*	High	Low	Medium*
Guatemala (44,000ha‡)	Unknown	Medium	High	Low	Medium
Tanzania (not available)	Unknown	Medium	High	Low	Medium
Rye					
EU	Low	Medium*	Medium*	Unknown	Medium*

Source: Own compilation based on data gathering in previous steps of analysis

Notes: * indicate whether the existing measures identified in Annex 8 potentially mitigate the threat (although not the extent of how much that threat is lowered).

‡ The method used to calculate the values in this table with the exception of those identified by the (‡) is as described in Baseline Report 2008, Appendix C "Triangular trade". The value for Guatemala indicated with the (‡*)* has been calculated with a simplified methodology based on estimating the areas of sugarcane needed to produce the quantities of bioethanol imported from Guatemala using an average yield. For Tanzania, there is not data available.

'Unknown' in the transport column denotes difficult to assess as the impacts from transport are not specific to that crop and will depend on emissions from transport and distance to processing plants for which there is no data.

Remaining risks not covered by existing provisions

Within the EU, air quality is effectively regulated so that the risks from biofuel production are probably kept within tolerable limits. In non-EU regions that supply biofuels and feedstocks to the EU, however, there are air quality risks which may not be sufficiently addressed by regulatory and voluntary measures within the producing countries. The highest risks which are not sufficiently addressed are burning (of crop residues, of sugarcane pre-harvest, and for land clearings), agrochemical spray drift, and gaseous emissions from processing facilities.

Sugar beet, wheat, sunflower, and rye are largely supplied from within the EU (although sunflower import play certain role too). The main air quality risk associated with these crops in the EU is related to agrochemical spray drift. For row crops, wind erosion is another factor. However, EU regulations appear sufficiently stringent.

Rapeseed is primarily supplied from within the EU but also from Canada, Ukraine and Russia. The highest threat from rapeseed relates to gaseous emissions from processing facilities. Regulations to address this in the EU and Canada appear stringent. Through this research, the extent to which these emissions in Ukraine and Russia are controlled though was not determined; however, both countries were reported to have weak regulatory enforcement. Hence, this threat remains high.

Burning of soybean residues is the highest threat associated with that crop and the EU soybean supply for biofuels comes from Argentina, Brazil, United States, and Paraguay. Argentina has stopped residue burning and the United States has regulations which restrict when and where burning can occur to control the air pollution. In Brazil and Paraguay, no measures to reduce this threat were identified. In Argentina there was high reported impact associated with agrochemical spraying.

High risks from palm oil production are from burning for land preparation as well as gaseous emissions from processing facilities. The EU supply of palm oil comes from Malaysia and Indonesia. Both countries have plans to reduce burning, although Malaysia has begun to implement them and is a part of an international agreement to reduce haze.

The high risks from maize are agrochemical spray drift and some burning of residues. Maize is supplied from the US and EU, both of which have relatively effective regulations addressing these impacts.

Lastly, sugarcane has potentially high impacts associated with pre-harvest burning which occurs in all of the countries from which the EU sources it for biofuels: Brazil, Guatemala, and Tanzania. Some measures in Brazil begin to address this threat and no measures were found in Guatemala or Tanzania.

5.5 Conclusions

Preliminary results in key countries indicate that generally the greatest risks to air quality are associated with burning; there is burning of crop residues, of sugarcane pre-harvest, for clearing vegetation from land, or as a result of clearing lands. High risks are also associated with some applications of agrochemicals, areas highly vulnerable to wind erosion, and gaseous emissions from processing facilities. The results of the initial risk assessment show that soybean, palm oil, maize, and sugarcane have the highest overall potential risks, largely due to the presence of burning as part of their production. In the cultivation stage, all of the crops have high or medium risks associated with the volatilisation of nitrogen compounds from fertilisers, and in some countries air pollution from volatilisation of other agrochemicals raise the risks. Air pollution from the processing stages presents a medium to high threat in all countries where processing occurs.

The overall extent to which existing legislative and voluntary provisions successfully lower the overall threat associated with a specific practice or activity is unclear. In the EU, Canada, and Malaysia, and the United States, through consideration of the existing provisions and the potential to enforce legislation it was determined that the high and medium risks are likely lowered by the existing provisions. These countries have high potential enforcement, with the exception of Malaysia, which has medium.

However, the greatest threat from Malaysia relates to burning, which was noted to have high enforcement of bans. In Indonesia and Brazil (two of the countries with the highest risks to air pollutions), some of the risks are lowered to the extent that legislation is enforced and some remain the same. Both countries are considered to have 'medium' potential enforcement and burnings in both countries are not sufficiently addressed; Brazil does have several measures to address burning but none are fully in effect or having sufficient coverage at this point.

6 Analysis of the feasibility to introduce mandatory requirements in relation to air, soil or water protection

6.1 Introduction

This chapter explores the feasibility of introducing mandatory sustainability criteria related to water, air and/or soil in the RED. The first part of this report provides the data sources relevant to the key sustainability issues identified, which permits the development of appropriate substantive criteria in a robust form. The potential risk of negative impacts to soil, water and air from biofuel (and feedstock) production associated with EU mandates is assessed earlier in this report.

The introduction of mandatory criteria can only be considered if criteria are able to be defined robustly, if criteria are effective in mitigating the risks identified, and if the implementation of the criteria does not represent a disproportionate administrative burden.

Different actions are required by different actors and across different scales to avoid negative impacts. The appropriate scale and the most appropriate influencing actors should therefore be considered within an assessment of the feasibility of such sustainability criteria. In areas of water scarcity for instance, requiring an operator or site-scale approach (such as requiring a farmer to use less water) may not effectively mitigate the key water risks faced while placing an administrative burden on the supply chain. However, site-scale approaches to addressing soil erosion would likely be more cost-effective a solution for individual operators.

This analysis has been completed through the interviews of different experts in soil, water and air in the EU and the selected non-EU countries. The list of interviewees is presented in Annex 9.

6.2 Soil

Sections 3.3 and 3.4 describe the key soil-related risks identified. While there are some overarching messages and conclusions that can be made regarding soil risks, much of the actual risk will be determined at a highly localised level within agricultural systems. This will be based on small scale variation in natural risk (linked to soil type, slope, climatic conditions) but critically on management practices, given the important role of management techniques in mitigating or aggravating risks. Within this report attempts have been made to identify the key potential risks associated with given cropping systems. Many of these will be common, at least within the key classes of crops considered, i.e. annual, perennial, row crop or distributed. Recent research (e.g. Louwagie et al., 2009) at the EU level into controlling and limiting soil risks in agriculture have concluded that what is key is to have

farm-level nutrient and soil management plans for cultivation that take adequate account of soil conditions and adapt management practices to protect soil resources.

The risks to soils identified within the analysis vary significantly thus far. Within the EU the reliance on primarily annual crops means that risks relate largely to the on-going cycle of cultivation and management. For longer cycle crops, such as sugar cane and oil palm, much of the risk is associated with the initial establishment phase. This difference would need to be picked up within any approach to addressing the soil impacts of biofuel production, i.e. the impacts of on-going management versus newly established crop areas.

An important key message that was confirmed by talking to agricultural and agro-environmental experts is the critical role of management techniques. The high risks to soils require an adequate mix of measures for soil-water protection being put in place, with management approaches and actions tailored to locally specific conditions. While some of these management actions are available to mitigate the risks in theory, they are not systematically applied in risk zones in practice.

In the context of non-EU countries, the share of EU biofuel as a percentage of the total crop, from which the biofuel feedstock is taken, is insignificant (<2%). Therefore, the issues related to soil health and quality are related to general agro-ecological environments and prevalent agricultural practices.

As in EU countries, processes of soil degradation, which include soil erosion, loss of organic matter, low fertility, soil acidity/salinity, compaction, and loss of biodiversity, are all common across the non-EU countries. In addition, we are dealing with a wide range of agro-climatic conditions. Indonesia and Malaysia represent regions of high rainfall, where soils are highly weathered, with low fertility and acidity/Al^{+++} toxicity as a common feature of the soil environment. For such an environment, locally adapted tree crops are a natural choice. Risks of erosion are significant only during the early stages of crop development. However, use of plant protection chemicals and fertiliser applications, which continue through the crop's life, could have negative effects on the soil environment. The situation with sugarcane (Brazil, Guatemala, and Tanzania) is somewhat different. The crop occupies the land for 5 to 7 years, therefore the risk of erosion is limited to early stages of crop development. However, loss of fertility, acidity (where rainfall is significant, as in Brazilian Cerrados), and loss of organic matter are common problems, and aggressive application of inputs to overcome these problems could have negative consequences, especially if the inputs are chemical in nature, which seems to be the case everywhere. With respect to soybean and rapeseed (United States, Brazil, Argentina, Paraguay, Canada, Russia, and Ukraine) soil-related problems are very similar to those elsewhere, except that we are dealing with annual crops, with cultivation practices that are machine and chemical dependent. In some countries, regulatory measures (e.g., U.S. and Canada) designed for general environmental protection (e.g. protection of water systems) have had indirect beneficial effects on soils. No-till planting in soybean is popular in the United States, Argentina, and Brazil, and this has had beneficial effects on soil erosion and organic matter.

Except for the United States and Canada, many of the non-EU countries do not appear to have comprehensive programmes of scientific articulation of soils problems that may be comparable to those in EU countries. Therefore, a detailed analysis of soils issues, based on climatic conditions of the feedstock producing regions, inherent soil vulnerabilities, and known risk factors associated with agriculture practices is not possible for a majority of non-EU countries. We are dealing with numerous growing regions for a given crop, with variable soil characteristics, landscape settings, and climatic conditions. However, because agriculture in all of the producing regions is mechanised and chemical based, our assessments are heavily weighted by these two factors. Crude assessments indicate erosion, compaction, loss of organic matter, loss of biodiversity, and chemical diffuse pollution by agrochemical inputs as the outstanding issues. The magnitude of the risk being high, low or medium is conditioned by the climatic and agro-economic factors.

Legislative measures exist in many of the non-EU countries, but they appear to be designed for general environmental and natural resource protection, without directly addressing soil health issues. Setting standards for soil attributes may be thought of, but the scientific information base is not adequate in many of the third countries, exceptions being the United States and Canada. Enforcement and monitoring are other issues which require careful assessment. A pragmatic approach would be to promote *good agriculture* practices based on local conditions and local experience.

Given that ultimate impacts on soil from crop cultivation depend on management to a large extent, we deem it necessary that any new mandatory RED criteria on soil incentivise the use of appropriate management techniques.

6.2.1 Mandatory requirements for soil

We propose that a minimum basic pre-condition on compliance with relevant existing legislation is put in place for soil, air and water: Biofuel production is required to be in compliance with national, regional and local soil/air/water protection legislation.

In addition, we strongly recommend that the current reference in RED Article 17(6) to cross compliance and GAEC (good agricultural and environmental condition) standards remains in place and valid for any changes to cross compliance and GAEC standards that would be adopted as part of the CAP reform, as these set out a baseline for mitigating impacts on soil, air and water within the EU. However, it should be noted that the goal of the GAEC framework to ensure basic simple management, is only applicable to land managers choosing to receive payments under the CAP, and it is not sufficient to counter pressures from intensified energy crop production, where this occurs. Potential adoption of the EU Soils Framework Directive would be a welcome development, able to provide a level playing field for measures addressing the risks from productive agricultural sectors including the biofuel crops, while leaving sufficient flexibility to Member States to design appropriate measures and identify risk zones.

Beyond the basic pre-condition of legal compliance, setting quantitative criteria for soil would mean specifying quantitative values for selected soil properties that indicate the effectiveness of an attribute. Because soils vary in their capacity to function, the same criteria could not be set for all soils. For example, the water holding capacity of a sandy soil is naturally lower than that of a loam, therefore a given value cannot be a threshold for both the soils. To be meaningful, the selected property must be monitored from time to time to evaluate changes. This requires scientific methods involving laboratory procedures and trained personnel. For example, if organic matter at a level of 3.5% is the threshold for a given soil, it must be measured. Any approach to such quantitative soil criteria would therefore also have to consider questions such as: how many samples should be analysed for the result to be statistically valid, and at what time intervals would samples have to be taken.

This appears to be an unrealistic and impossible proposition, especially for non-EU countries. Even in scientifically advanced countries with little resource limitation (e.g. USA), data on soil condition are generated through voluntary efforts of research organisations - in controlled research plots, laboratories, or through general surveys. Results are generalised to indicate trends in the effects of management practices. Whether or not those practices can be accommodated within a producer's operational scheme is another matter. Most often it is the extension service that takes the useful research to the producer.

In the context of lesser developed non-EU countries, reliable data in adequate amounts may not be available to determine thresholds in respect of a selected soil property. Even if an arbitrary criterion is chosen, implementation and monitoring would be extremely difficult.

Further to such methodological considerations, the number of crops, variety of soils, and geographic locations would need to be considered in setting quantitative criteria.

The analysis on mitigating the key risks for soil in this report also concluded that impacts on soil from crop cultivation depend on management, so any new mandatory RED criteria ***should incentivise the use of appropriate management techniques***.

Mandating specific management techniques is not straightforward. There are issues related to the facts that 1) different management approaches to soil (and even water) risk mitigation are relevant for different crops and in different agronomic, environmental and climatic conditions, e.g. in regions with different dominant soil types, and that 2) it may be difficult to enforce a meaningful management approach to soil/water risk mitigation and to monitor this comprehensively by relatively inexpensive remote sensing or aerial photography. The first point implies that it is not feasible or at least not as part of this study to define concrete practices to be adhered to for all soil types in all areas.

What does seem feasible is to require soil management plans (see Box 2) to be in place on farms supplying to the EU biofuel market.

Management related criterion – Existence and implementation of a soil management plan: These plans would include lists of issues to consider, taking into account the local soil properties and climatic conditions as well as the type of crops grown. The goal is to avoid growing crops that pose excessive risks in certain areas; at the same time the soil management plans shall spell out appropriate techniques to effectively mitigate all risks arising from the cultivation of locally appropriate crops. This is a very soft form of approach and it will be of crucial importance who will check compliance and how.

As part of a previous study for DG ENER on assessing voluntary schemes against "non-mandatory criteria" (Ecofys and IEEP, 2011)[35], members of this consortium have screened voluntary scheme and sustainability initiatives for their criteria on soil, water and air. The following issues have been identified to be of key importance and are therefore suggested for inclusion in a soil management plan:

- Risk assessments of production areas (for the cultivation of biofuel and bioliquid feedstocks) to identify high-risk areas in relation to soil issues including erosion, SOM, compaction, pollution, salinisation and build up of pest and pathogen in soil;
- Land management activities and crop choice consider different soil types so as to avoid cultivation on particularly vulnerable soils (i.e. as established under the risk assessment);
- Identification of and adherence to geographically relevant practices for improving soil quality ('relevant' are deemed to be those practices for which there is sufficiently robust evidence that they improve soil quality/functionality, e.g. evidence contained in relevant guidance documents by national environmental authorities);
- Responsible soil management to identify soil erosion prone areas and have strategies and measures in place to mitigate risks;
- Tracing SOC development as a marker indicator of wider soil quality/functionality, including the definition of a SOC baseline and maintenance strategy;
- Consideration of the risks from the extraction of agricultural residues with regard to SOC and wider soil quality and the introduction of measures to mitigate these risks.

In addition to a soil management plan, a pesticide and nutrient management plan should be in place that deals with diffuse soil pollution as well as with risks to water quality from nutrient and pesticide run-off (see water section).

6.2.2 Feasibility of application (by crop): Soil

With regard to the proposed minimum basic pre-condition on compliance with relevant existing national, regional and local soil legislation, we recognise that different countries have different legislation in place. This results from the fact that national governments are in a good position to put in place legislation that is appropriate to the area, and where this is in place, requiring compliance

[35] Ecofys and IEEP (2012) Proposal for a methodology to assess voluntary schemes against 'non-mandatory' sustainability criteria, developed as part of framework contract Assessment of voluntary schemes used for sustainability claims of biofuels under Directive 2009/28/EC (ENER/C1/438-2010)

with it is sensible. Many voluntary schemes already require legal compliance as a basic pre-condition, as does other EU legislation, e.g. the EU Timber Regulation 995/2010 (see also Section 6.5).

The greatest feasibility challenge of requiring soil management plans is related to the enforceability of such a requirement. Independent auditors would have to be able to check compliance in order for new requirements to take any effect. Independent auditors could act on behalf of a voluntary scheme or directly for economic operators demonstrating compliance with criteria to Member State authorities by means of providing verified information about the sustainable origin of biofuels. In any case, independent auditors would need to carry out farm checks to verify the existence of appropriately drawn up management plans and the adherence to these plans. This requires the existence of detailed documentation systems by farmers.

Such documentation systems can be on farm level or can be field record systems. It should be noted that detailed farm record systems are in place in highly mechanised farming environments for economic reasons (optimising inputs). Therefore the technology and experience for such documentation systems exist. Simplified requirements might have to be considered for smallholders.

Some voluntary schemes (and other sustainability initiatives) already have requirements for soil management plans or certain practices in place. Some examples are included here:

- RSB: includes a mandatory soil erosion requirement: Soil erosion shall be minimised through the design of the feedstock production site and use of sustainable practices in order to enhance soil physical health on a watershed scale.
  We note that the effectiveness depends on the sustainable practices being defined by taking local soil characteristics into account.
- ISCC: contains, for example, the following mandatory criteria relevant to soil protection: SOM is preserved; Organic fertiliser is used according to nutritional requirements; Techniques have been used that improve or maintain soil structure. However participants within the EU that have implemented cross compliance requirements are not subject to audit against principle 2.
- Bonsucro: includes a mandatory requirement regarding residue use, that the use of co-products does not affect traditional uses (e.g. fodder, natural fertiliser, local fuel) or affect the soil nutrient balance or SOM.
- RTFO Meta-standard: suggests having in place soil management plans
- GBEP: includes extensive guidelines on tracing SOC as a marker indicator of wider soil quality/functionality (see GBEP, 2011, p39, methodology sheets, indicator 2 ‘soil quality’)

6.3 Water

Section 4.5 describes the key water-related risks identified. Bioenergy feedstocks have a water intensity that can be several orders of magnitude higher than that of other energy carriers. As such they present important risks to both the quality and quantity of water resources in the areas in which they are produced. The risk to water resources varies greatly, depending upon the feedstock employed and the location from which that feedstock is derived. These risks stand to increase as biofuel output increases and as agricultural systems are integrated or optimised to avoid the effects of indirect land use change. The goal of creating additional output from agricultural regions could lead to extensification of irrigated agriculture, intensification of existing production through addition of chemicals or irrigation, and the removal of biomass residues from the field. All of these activities have the potential to *increase* the water resource impacts of cultivation.

To be meaningful, any mandatory water-related criteria should take into account both water quality and water quantity.

6.3.1 Mandatory requirements for water

As for soil, we would propose that a minimum basic pre-condition of legal compliance is put in place for water, and that the current reference in RED Article 17(6) to cross compliance and GAEC tandards remains in place and valid for any changes to cross compliance and GAEC standards that would be adopted as part of the CAP reform.

The prior state of the water resource base is the single most critical factor in determining the sustainability of any activity impacting that resource. Knowing this, it would be advisable, if possible, for any mandatory criteria aimed at managing the water impacts of biofuels consumed in the EU to be based upon a quantitative evaluation of the water resource circumstance of the watershed[36] in which that fuel was produced.

It is important to stress that objectives for water in Europe are framed at the river basin level. The assessment of characteristics of water bodies, objective setting, understanding pressures and developing programmes of measures are all carried out within RBMPs under the 2000 Water Framework Directive. Currently the first RBMPs are being implemented (except for a few Member States which are late in implementation). A major assessment is underway at the moment to examine the assessment of different pressures and measures adopted in the plans and results from this assessment are being examined by the EC to be published in November 2012.

It has to be noted that under the Water Framework Directive, Member States have used the exemptions provided to postpone the most challenging decisions to subsequent river basin planning periods (2015-2021 and 2021-2027). However, at this stage pressures will need to be contained,

[36] These classifications should be done at the watershed (or even sub-basin) level, as that is the scale at which water stress is relatively uniform. The analysis presented in Task 3 of this report was conducted at the national level, because that is the scale at which cropping data are aggregated. This would not be an issue when evaluating individual operations.

including those from agriculture. The Directive is a legal obligation on Member States and, therefore, using its objectives as a basis for sustainability criteria for bioenergy crops (and other pressures) is the obvious starting point. Indeed, it is not clear if sustainability issues regarding agriculture and water in river basins that are compliant with the Directive would remain outstanding in 2027. Assuming compliance as the overall objective, additional criteria would not be needed as farmers would simply do what is required of them to meet the obligations of EU law. This is, however, not a general case at present. Therefore, the key criterion regarding water would be for bioenergy production to be compliant with whatever measures are adopted in the local RBMPs. Having said this, the current status of RBMPs (as noted above) would not necessarily result in a change of agricultural practice before 2020, the current timeframe of the RED (although the content of RBMPs for the period 2015-2021 is yet to be formulated). Thus, if RBMPs are relied upon to prevent water impacts in the EU, some bioenergy impacts on water objectives in the EU may not be addressed until 2027.

RED Article 17(6) requires that feedstock from EU Member States be grown in accordance with the best management practices (BMPs) laid out in the EC rule no. 73/2009. Appropriate management of water impacts could follow this precedent, setting out best practices mandatory only to EU producers.

On a global level, under such a system, watersheds would be placed into categories based on an objective, quantitative measure of water stress; this report suggests the Water Stress Indicator (Smakhtin, 2004) but there are others as well. The mandatory requirement imposed for a given fuel would then be based on these classifications. For example, operators in regions classified as low-stress would not be subject to a water intensity criterion. Those in regions classified as highly water stressed would be barred from producing fuels in any way that would increase total water consumption (e.g. through extensification of irrigated agriculture). Operators in intermediate watersheds could be allowed activities that only increase consumption by a set percentage, or could be required to implement improved management practices to mitigate future impacts.

Given implementation issues another route would be management-related criteria.

Management related criterion – Existence of a water management plan: As part of a previous study for DG ENER on assessing voluntary schemes against "non-mandatory criteria" (Ecofys and IEEP, 2011)[37], members of this consortium have screened voluntary scheme and sustainability initiatives for their criteria on soil, water and air. The following issues have been identified to be of key importance and are therefore suggested for inclusion in a water management plan:

Water quantity:

- Consideration of the prevailing conditions in the watershed and of the anticipated impact of bioenergy crop production systems on wider water availability in the watershed;

[37] Ecofys and IEEP (2012) Proposal for a methodology to assess voluntary schemes against 'non-mandatory' sustainability criteria, developed as part of framework contract Assessment of voluntary schemes used for sustainability claims of biofuels under Directive 2009/28/EC (ENER/C1/438-2010)

- Water use for irrigation does not compromise water availability for ecosystem needs and for direct human consumption;
- Consideration is given to water quantity issues during the siting of crops;
- When using water from natural watercourses: it is demonstrated that this use does not modify the natural course or the physical, chemical and biological equilibrium the watercourse had before the beginning of operations;
- Where bioenergy crops are irrigated, farmers pay the appropriate local price for water;
- In the case of ground water use, customary as well as formal existing water rights are respected.

It is furthermore suggested to require that all farmers have water abstraction permits where water is abstracted for irrigation so as to avoid illegal abstraction.

Water quality:

- All point sources of pollution are registered (if required) with domestic authorities and must prove compliance with applicable regulations;
- Farmers have a nutrient and/or pesticide management plan consistent with the objectives of local policy and including consideration of run-off and safe storage of agro-chemicals;
- Control of effluents from processing plants is consistent with local treatment and control requirements;
- Waste water disposal is undertaken, consistent with local treatment and control requirements;
- Consideration of the prevailing conditions in the watershed;
- Consideration is given to water quality issues during the siting of crops.

6.3.2 Feasibility of application (by crop): Water

With regard to the proposed minimum basic pre-condition on compliance with relevant existing national, regional and local water legislation, we recognise that different countries have different legislation in place. This results from the fact that national governments are in a good position to put in place legislation that is appropriate to the area, and where this is in place, requiring compliance with it is sensible. Many voluntary schemes already require legal compliance as a basic pre-condition, as does other EU legislation, e.g. the EU Timber Regulation 995/2010 (see also Section 6.5).

We recognise that some of the criteria suggested above may not be feasible, not because operators would be unable to comply or the EC unable to ensure compliance, but for reasons of political economy and obligations under international trade structures.

In particular the proposed system of categorising watersheds by relative water scarcity is highly sensitive and could be seen as discriminatory under WTO rules, since it would explicitly raise a barrier to entry into the RED market for the biofuel products of certain countries. Despite noble intentions, it could be seen as penalising resource-poor nations *because* of their resource poverty. Nevertheless, it is important to consider this as compared to existing mandatory criteria which also effectively disallow biofuels from certain regions, for example because of the biodiversity that they have.

Water management plans may be more politically feasible. An example of existing legislation in the EU that includes water management plans includes:

- Some agri-environment measures (i.e. voluntary measures under CAP Pillar 2 with the purpose of improving the environmental management in agriculture through practices that go beyond the baseline requirements and to which farmers may subscribe and receive payments for) include the existence of farm record systems for measures such as integrated pest management and nutrient management plan.

Referring to the criteria proposed in the bullet list in section 6.3.1, logistically speaking, implementation of most of the criteria listed above would not be exceedingly difficult. The only point that could prove logistically infeasible is the maintenance of customary water rights. This is a critical issue, as access to water is necessary for human wellbeing, but customary rights are by definition informal, making this criterion difficult to adjudicate. As to the other criteria listed above, they should not prove more logistically challenging than the existing list. Regulators would need to require some supply chain traceability, some documentation from operators in that supply chain, and some knowledge of the land from which feedstocks were derived as well as the practices implemented on that land. The primary challenges to this are in creation of the infrastructure for tracing of materials and data along the supply chain and for auditing operations. Given that this infrastructure is already necessary for compliance with existing RED mandatory criteria, this should not pose a challenge in the addition of further criteria. As with existing criteria, the voluntary schemes recognised by the EC possess the capacity to ensure compliance with such criteria (although at present, not all include water-related criteria).

Other key challenges arise not from the feasibility of implementing the criteria in question, but from their efficacy in addressing all water resource issues of concern. Some issues that constrain the efficacy of overarching criteria are:

1. Water scarcity and pollution are emergent properties. While the impact of any individual project could be low, the cumulative effect might become problematic in regions undergoing rapid change.
2. Impact on key habitats such as aquifer-recharge zones, wetlands, and floodplains can have a large effect throughout a watershed.
3. Acute but localised ecological toxicity, eutrophication, or human health effects may result from even small pollution flows.
4. Water shortage for human uses does not necessarily derive from absolute scarcity, but can instead be due to social realities such as equity of access, barriers to entry, poor infrastructure, institutional failure, and other considerations that may be affected by bioenergy expansion.

These are complex issues that are difficult to address through a mandatory criterion, but they should be carefully considered nonetheless.

6.4 Air

Section 5.5 describes the key risks related to air quality. Within the EU, air quality is effectively regulated such that the risks from biofuel production are likely reduced. In other areas that supply biofuels and feedstocks to the EU, however, there are air quality risks which may not be sufficiently addressed by regulatory and voluntary measures within the producing countries. The highest risks which are not sufficiently addressed are burning (of crop residues, of sugarcane pre-harvest, and for land clearing), agrochemical spray drift, and gaseous emissions from processing facilities.

Sugar beet, wheat, sunflower, and rye are supplied mainly from within the EU. The main air quality threat associated with these crops in the EU is related to agrochemical spray drift and wind erosion as they are row crops. However, EU regulations address this to the extent that can be expected under the EU RED.

Rapeseed is primarily supplied from within the EU but also from Canada, Ukraine and Russia. The highest threat from rapeseed relates to gaseous emissions from processing facilities. Regulations to address this in the EU and Canada appear stringent. Through this research, the extent to which these emissions in Ukraine and Russia are controlled was not determined; however, both countries were reported to have weak regulatory enforcement. Hence, this threat remains high.

EU soybean supply for biofuels comes mainly from Argentina, Brazil, United States, and Paraguay. Burning of soybean residues is the highest threat associated with that crop. Argentina has stopped residue burning and the United States has regulations which restrict when and where burning can occur to control the air pollution. In Brazil and Paraguay, no measures to reduce this threat were identified. In Argentina there is also high reported impact associated with agrochemical spraying.

High risks from palm oil production are from burning for land preparation as well as gaseous emissions from processing facilities. The EU supply of palm oil comes from Malaysia and Indonesia. Both countries have plans to reduce burning, although Malaysia has begun to implement them and is a part of an international agreement to reduce haze.

The high risks from maize are agrochemical spray drift and some burning of residues. Maize is supplied from the US and EU, both of which have relatively effective regulations addressing these impacts.

Lastly, sugarcane has potentially high impacts associated with pre-harvest burning which occurs in all of the countries from which the EU sources it for biofuels: Brazil, Guatemala, and Tanzania. Some measures in Brazil begin to address this threat, but no measures were found in Guatemala or Tanzania.

6.4.1 Mandatory requirements for air

As for soil and water, we would propose a basic minimum pre-condition that legal compliance is put in place for air, and that the current reference in RED Article 17(6) to cross compliance and GAEC standards remains in place and valid for any changes to cross compliance and GAEC standards that would be adopted as part of the CAP reform.

For the EU RED to address air quality issues associated with biofuel production outside of the EU, it would need to add requirements primarily to address the practice of burning associated with biofuel crops. Additionally, it is suggested that the EU RED could address agro chemical spray drift and emissions from processing facilities where these impacts are not sufficiently addressed within the countries of production.

The criteria suggested may be selected from the following:

1. To reduce/eliminate risks from burning, biofuel operations shall avoid and, where possible, eliminate open-air burning of residues, wastes or by-products. Burning to clear the land shall be prevented. Reasons to permit burning should be clearly limited and justified, for example: if workers' health and safety is at stake, if no viable alternative is available or affordable in the local context, if burning may prevent natural fires, etc.
2. To reduce risks from processing facilities and from agrochemicals, air emissions limits shall be set for different production stages (e.g., at the farm, at the mill, at the processing facility, etc.). There shall be a monitoring system in place to assure the emissions limits are met.
3. To reduce risks from agrochemicals, best management practices for agrochemical application shall be implemented following international standards/agreements.

6.4.2 Feasibility of application (by crop): Air

With regard to the proposed minimum basic pre-condition on compliance with relevant existing national, regional and local air legislation, we recognise that different countries have different legislation in place. This results from the fact that national governments are in a good position to put in place legislation that is appropriate to the area, and where this is in place, requiring compliance with it is sensible. Many voluntary schemes already require legal compliance as a basic pre-condition, as does other EU legislation, e.g. the EU Timber Regulation 995/2010 (see also Section 6.5).

The feasibility of applying the criteria varies from country to country, depending on the voluntary interest, governance, and monitoring capacity. To successfully apply these criteria, a robust monitoring system would be needed to monitor for burning (e.g., through remote sensing technology and/or on the ground verification), for monitoring emissions at processing and milling facilities, and for verifying the presence of best management practices.

The challenges pertain to data availability and the time and cost associated with obtaining and verifying the data. The approach of compliance through regulations in compliance with EU air quality standards would likely garner pushback from countries not wanting to be told how to create their regulations. Furthermore, it would punish potentially well performing producers in countries with less stringent regulations. Lastly, it could be perceived as a violation of WTO agreements. The approach of compliance through the use of voluntary standards would require a new benchmarking exercise of standards wanting to comply and could also garner additional resistance from producers. The approach of reliance on voluntary standards presents the challenge that they do not all address all stages of the production chain.

However, some of these criteria are already being implemented through voluntary and regulatory measures. Some examples of criteria from voluntary standards which are used in some of the countries included in this analysis are:

- Bonsucro: Sets an SO_2 threshold of 5kg SO_2 per tonne of ethanol, covering agricultural, processing, and milling stages. Also has a non-mandatory criteria to "implement measures to mitigate adverse impacts where identified smoke, fallout from fires… drift from agrochemical spraying."
- ISCC: Restricts burning in feedstock production: "The burning of stubble or other crop residues is allowed only with the permission of competent authority. Burning as part of land clearance is not allowed."
- RSB: Mandatory criteria: "Biofuel operations shall avoid and, where possible, eliminate open-air burning of residues, wastes or by-products, or open air burning to clear the land within three years of certification." Some open air burning is allowed if "workers' health and safety is at stake or when no viable alternative is available or affordable in the local context, if burning may prevent natural fires, or if the cultivation of the crop periodically requires burning for viability in the long term without any equivalent alternatives."
- RTFO Meta-Standard: Non-mandatory criteria of no burning for land clearing or waste disposal.

There are examples of voluntary standards used in nearly all of the countries included in this project, primarily ISCC, RSPO, RTRS and SAN/RA. However, at this point in no country do those standards cover a significant portion of the biofuel feedstock produced.

There are also examples of such criteria in legislation in some of the studied countries. Some examples of criteria from legislation are:

- 2002 Sao Paulo State Law 11241 which aims to phase out sugarcane burning by 2021 in order to reduce air pollution. The phase out will be achieved by mechanising cane harvest. Where mechanisation is not possible, the target date is 2031.
- 1981 Brazil National Environmental Policy requires official authorisation for using fire for cropping.
- In the United States, states govern burning and there are a variety of approaches used. For example:

- California requires a permit for burning which can only happen on days specified by local air districts and residues must be shredded and piled if possible.
- Louisiana limits burning to during the daytime and certified burn managers must be present (McCarty, 2010).

- 1970 United States Clean Air Act requires that each state develops a State Implementation Plan to identify air pollution sources and determine what reductions are required to meet federal air quality standards. These Plans may address crop burning and set visibility standards. Locations classified as "nonattainment areas" may have more restrictions.
- 1998 Malaysia's 3rd Amendment to Environmental Quality Act completely bans open burning to clear vegetation for oil palm plantations. The penalty for open burning is a fine. Legislation in 2003 adds additional regulations for open burning including on restrictions on peatlands.

In some cases, the feasibility of implementing criteria may be limited if the criteria target biofuel feedstocks alone as the activities causing air pollution may not be biofuel feedstock specific and attribution is challenging. For example, burning for land clearing may have to be addressed beyond just a sectoral approach as the land clearing in some cases may not be connected to the subsequent feedstock production activities.

Another implementation challenge is considering broader trade-offs that may occur by addressing air pollution alone. For example, avoiding activities that create air pollution may result in negative impacts on livelihoods and employment (e.g., mechanisation in place of burning reduces harvesting jobs).

6.5 Overall conclusions

The main driver for increasing biofuel use in the EU is climate related. The RED sets a target of 10% renewable energy in transport in all EU Member States, which is specifically envisaged to stimulate an increase in biofuel production and use. The increase in feedstock production is expected to be both from within the EU and outside. As such it is appropriate for the RED to consider criteria to ensure that the feedstocks produced for biofuel do not cause negative environmental impacts.

The RED already contains mandatory sustainability criteria related to GHG emissions, biodiversity and carbon stock. This report has presented potential risks to the condition and quality of soil, water and air from the cultivation of a range of crops such as biofuel feedstocks. It has also identified risk factors (rated as high, medium, low) related to management practices. Considerable risks exist particularly to soil and water resources. Given this, introducing some form of environmental safeguard in the RED is necessary to avoid the continuation and potential aggravation of adverse impacts to extremely precious and non-renewable natural resources. It is evident that the risks to soil, water and air from feedstock cultivation for biofuels are on the whole the same risks associated with the management of agricultural land more generally. However, the study found that in many situations, biofuel markets bring additional pressure on the areas under existing agricultural use and have acted as a major driver in the intensification and the expansion of intensive agriculture into areas with challenging soil conditions. Therefore, mitigating the risks to soil, water and air from the crops that potentially supply biofuel markets is a critical priority. Promoting good agricultural practices for the feedstocks used for biofuels, both within and outside the EU, through the RED is likely to contribute to the mitigation of the risks identified. Introducing some form of safeguards under the RED appears much more promising than expecting the risks to be mitigated by maintaining the status quo.

As has been described in this report, good agricultural practice depends on the type of crop and the prevailing bio-physical, environmental, and climatic conditions in diverse farming systems and has to be carefully targeted to these conditions. Applying mandatory quantitative criteria under the RED for protection of soils, water and air is therefore not feasible. This study recommends that greater emphasis be placed on targeted management practices to mitigate potential impacts on soils, water and air. We present in the following our key recommendations for soil, water and air. Apart from the specific recommendations, we propose that a minimum basic pre-condition on compliance with relevant existing legislation is put in place for soil, air and water: **Biofuel production is required to be in compliance with national, regional and local soil/air/water protection legislation**. The practicability of such a basic compliance criterion is demonstrated by its inclusion in many existing voluntary schemes. Compliance with national, regional and local legislation is also an element of the EU No 995/2010 Timber Regulation. This regulation which will come into force in March 2013 lays obligations on the operators who place timber or timber products in the EU market. Part of these obligations are to produce a due diligence report, keep records of suppliers and customers and to prohibit placing illegally harvested timber products on the EU market[38]. The Timber Regulation due

[38] EU Timber Regulation http://ec.europa.eu/environment/forests/timber_regulation.htm

diligence system seeks to minimise the risk of placing illegally harvested timber in the EU. As mentioned above, a similar system such as this could be used for minimum compliance with legislation on air, soil and water, especially for legislation outside the EU.

A mandatory criterion requiring the existence of **management plans (see Box 2) at farm level is proposed as a feasible way forward for soil and water management**. In these plans, the farmer takes responsibility of identifying risks and designing management schemes which appropriately address the specific risks. It is recognised that management plans are not currently common practice in all countries, not even in the EU, and issues of effectiveness and enforceability must be addressed. However, management plans are already used in many countries and for many crops. Voluntary schemes, for example, already use the management plan requirement and report having achieved positive actual outcomes. Similarly, the EU Nitrates Directive requires nutrient management plans for farms in nitrate vulnerable zones. Consequently, this appears to be a feasible approach that provides a mandatory framework for improving management in specific farming systems involved in feedstock production whilst it gives sufficient flexibility to farmers to make choices about management practices that are adapted to their agronomic environmental, climatic and other bio-physical conditions.

To take explicit account of risks to water availability from biofuel feedstock cultivation in **sustainability criteria for water scarce regions** is not straightforward. It may be hampered by political sensitivities and the fact that mitigation requires large scale approaches. However, there are some feasible solutions. For example, the EU Water Framework Directive contains the concept of RBMPs, which identify regions at risk. Within those, farmers are being informed of effects of agricultural management on water in the region. The recently published EU Water Blueprint refines the understanding of priority actions to be taken in these regions and offers further opportunity for specifying sustainability criteria on the efficient use of water in agriculture for these regions. Water stress index maps are produced for regions outside the EU, which could serve as a basis for developing appropriate sustainability criteria for the imported feedstocks.

Regarding **air quality**, three key recommendations are made to reduce risks from biofuel crops cultivation. Firstly, it is recommended to eliminate (where possible) open air burning. This entails avoiding or eliminating open-air burning of residues, wastes or by-products, and burning to clear the land. Permission to allow burning should be clearly limited and justified, for example: if workers' health and safety is at stake, or no viable alternative is available or affordable in the local context, or if burning is meant to prevent natural fires. The second recommendation on air is to reduce risks from processing facilities and from agrochemicals, and air emissions limits can be set for different production stages (e.g. at the farm, at the mill, at the processing facility) at national level. Monitoring systems must be put in place to ensure the emissions limits are met. The final recommendation is to reduce risks from agrochemicals by implementing management plans for agrochemical application following international standards and agreements.

We also note that for the EU Member States, the existing mandatory RED criterion in Article 17(6) requires adherence to cross compliance requirements under the CAP. We recommend clarifying that this provision of the RED will continue to apply to the revised cross compliance provisions given the forthcoming reform of the CAP.

Finally, we note the important role **voluntary schemes** can play in advancing and implementing standards on soil, water and air. The voluntary schemes recognised by the EC allow certifiers to check an operator's compliance with the existing mandatory RED criteria. The advantage of this approach is that many of the existing voluntary certification schemes reach much further than the EC currently does in defining and certifying broad-based sustainability for bioenergy. Furthermore, some schemes are targeted to a particular feedstock and/or regional conditions and therefore have the local expertise needed to define management requirements targeted at local conditions.

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8 Annexes

Annex 1: Data on biofuel feedstocks and their cultivation areas in the EU

Table 26: Land use in 1000 ha in 14 EU countries (including the 10 case study countries of this report) for 2010

		Total (kha)	To EU biofuels (kha)	% for biofuels			Total (kha)	To EU biofuels (kha)	% for biofuels
France	Total land	54,766			**Belgium**	Total land	3,028		
	Total cropland	19,396				Total cropland	862		11%
	Rapeseed	1,465	619	42%		Wheat	210	23	15%
	Sunflower seed	695	314	45%		Rapeseed	11	2	
	Sugar beet	383	60	16%	**Sweden**	Total land	41,034		
	Wheat	5,426	101	2%		Total cropland	2,643		
	Maize	1,571	28	2%		Wheat	404	56	14%
	Soybean	51	18	35%		Rapeseed	109	64	59%
	Barley	1,582	5	0.3%		Barley	309	1	0.4%
Germany	Total land	34,861			**Spain**	Total land	49,880		
	Total cropland	12,145				Total cropland	17,216		
	Rapeseed	1,461	595	41%		Maize	320	8	3%
	Sugar beet	367	21	6%		Wheat	1,907	27	1%
	Wheat	3,298	30	1%		Sunflower seed	698	32	5%
	Maize	464	9	2%		Barley	2,877	23	1%
	Barley	1,653	12	1%		Rapeseed	20	11	57%
UK	Total land	24,193			**Slovakia**	Total land	4,809		
	Total cropland	6,092				Total cropland	1,406		
	Sugar beet	92	44	48%		Rapeseed	164	147	89%
	Rapeseed	653	81	12%		Maize	174	26	15%
	Wheat	1,937	3	0.2%		Wheat	350	2	1%
Poland	Total land	30,420			**Austria**	Total land	8,244		
	Total cropland	12,939				Total cropland	1,437		
	Rapeseed	769	176	23%		Rapeseed	54	30	56%
	Maize	299	22	7%		Wheat	303	18	6%
	Wheat	2,406	22	1%		Maize	180	4	2%
Czech Republic	Total land	7,725				Sugar beet	45	1	2%
	Total cropland	3,256				Barley	350	3	1%
	Rapeseed	369	176	48%	**Italy**	Total land	29,414		
	Sugar beet	56	9	16%		Total cropland	9,485		
	Wheat	834	17	2%		Soybean	160	28	18%

		Total (kha)	To EU biofuels (kha)	% for biofuels			Total (kha)	To EU biofuels (kha)	% for biofuels
	Maize	105	2	2%		Sugar beet	63	7	12%
Hungary	Total land	9,053				Rapeseed	20	12	60%
	Total cropland	4,779				Sunflower seed	101	2	2%
	Rapeseed	259	159	61%	**Romania**	Total land	23,006		
	Maize	1,061	23	2%		Total cropland	9,151		
	Sugar beet	14	5	38%		Rapeseed	527	134	25%
	Wheat	1,011	2	0.2%		Maize	2,094	3	0.1%
Netherlands	Total land	3,373				Wheat	2,153	4	0.2%
	Total cropland	1,090				Soybean	63	2	3%
	Rapeseed	3	3	121%					

Source: Ecofys et al., 2012

Table 27: Ultimate origin of feedstock for bioethanol consumed in the EU in 2010 expressed in volume of bioethanol (ktoe)

	Wheat	Maize	Barley	Rye	Triticale	Sugar beet	Wine	Sugar cane	Other	Total
EU	581	344	58	81	20	733	101		33	1,951
Brazil		8						234		242
USA	2	122								124
Peru								26		26
Switzerland	25									25
Bolivia								20		20
Ukraine	6	7				2				15
Egypt								15		15
Guatemala								14		14
Argentina		2						5		7
Cuba								6		6
Other	10	7						16	2	34
Total	623	490	58	81	20	735	101	336	35	**2,480**

Source: Ecofys et al., 2012

Table 28 Ultimate origin of feedstock for biodiesel consumed in the EU in 2010 expressed in volume of biodiesel (ktoe)

	Rapeseed	Soybean	Palm oil	Sunflower seed	Tallow	RVO	Other	Total
EU	4,098	87	5	444	159	1,182	3	5,977
Argentina		1,191						1,191
Indonesia			814					814
Brazil		417			1			419
Canada	212	44			13	22		292
Ukraine	252	14						266
USA	7	221			12	5		245
Malaysia			212					212
Paraguay	3	185						188
Russia	80	45						124
China		1				67		67
Other	99	14	13			1		126
Total	4,751	2,220	1,043	444	184	1,276	3	**9,922**

Source: Ecofys et al., 2012

Table 29: Biodiesel EU (i.e. the EU originating feedstocks for EU consumed biodiesel) in 2010 expressed as ktoe of biodiesel

	Rapeseed	Soybean	Palm oil	Sunflower seed	Tallow	RVO	Other	Total
Austria	54	1	0	0	0	90		145
Belgium	4	1	1	0	0	228		234
Bulgaria	52	0	0	3	0	0		55
Cyprus	0	0	0	4	0	4		7
Czech Republic	279	0	0	0	0	0		279
Denmark	57	0	0	0	16	0		73
Estonia	5	0	0	0	0	0		5
Finland	0	0	0	0	0	0		0
France	1,143	23	0	413	0	162		1,741
Germany	1,305	1	0	0	0	126		1,433
Greece	8	1	0	0	0	37		45
Hungary	183	1	0	0	0	56		239
Ireland	30	0	0	0	15	15		61
Italy	17	46	0	2	5	0		70
Latvia	31	0	0	0	0	0		31
Lithuania	86	0	0	0	0	0		86
Luxembourg	4	0	0	0	0	0		4
Malta	0	0	0	0	0	0		0
Netherlands	8	11	3	0	13	202		237
Poland	268	0	0	0	0	98		366
Portugal	0	0	0	0	0	0		0
Romania	135	2	0	0	0	0		137
Slovakia	162	0	0	0	0	0		162
Slovenia	8	1	0	0	0	0		9
Spain	11	0	0	23	54	54		142
Sweden	92	0	0	0	0	0		92
United Kingdom	156	0	0	0	55	110		321
Total	4,098	87	5	444	159	1,182	0	5,974

Source: Ecofys et al., 2012

Table 30: Bioethanol global (i.e. the globally used feedstocks for EU consumed bioethanol) in 2010 expressed as ktoe of biodiesel

	Wheat	Maize	Barley	Rye	Triticale	Sugar beet	Wine	Sugar cane	Other	Total
Austria	28	19	2	0	0	5	0	0	0	54
Belgium	63	0	0	0	0	0	0	0	0	63
Bulgaria	2	1	0	0	0	0	0	0	0	3
Cyprus	0	0	0	0	0	0	0	0	0	0
Czech Republic	26	4	0	0	0	33	0	0	0	63
Denmark	6	0	0	0	0	0	0	0	0	6
Estonia	0	0	0	0	0	0	0	0	0	0
Finland	0	0	0	0	0	0	0	0	17	17
France	219	94	11	0	0	340	10	0	0	673
Germany	68	31	23	48	12	92	0	0	8	282
Greece	0	0	0	0	0	0	0	0	0	0
Hungary	3	58	0	0	0	22	0	0	0	82
Ireland	0	0	0	0	0	0	0	0	0	0
Italy	0	0	0	0	0	29	50	0	0	79
Latvia	6	0	0	0	0	0	0	0	0	6
Lithuania	2	0	0	8	8	0	0	0	0	18
Luxembourg	0	0	0	0	0	0	0	0	0	0
Malta	0	0	0	0	0	0	0	0	0	0
Netherlands	0	0	0	0	0	0	0	0	0	0
Poland	26	48	0	25	0	0	0	0	0	99
Portugal	0	0	0	0	0	0	0	0	0	0
Romania	3	4	0	0	0	0	0	0	0	8
Slovakia	2	54	0	0	0	0	0	0	0	56
Slovenia	0	0	0	0	0	0	0	0	0	0
Spain	24	31	20	0	0	0	4	0	0	79
Sweden	94	0	2	0	0	0	38	0	8	141
United Kingdom	7	0	0	0	0	214	0	0	0	221
Total	581	344	58	81	20	733	101	0	33	1,951

Source: Ecofys et al., 2012

Annex 2: Crop data for the EU-27

Detailed data on production and areas of cultivation including regional breakdown – rapeseed
In 2007, 18.1 million tonnes of rapeseed were produced in the EU, a 13% increase on the 2006 figure. Rapeseed is used in the manufacture of oil (mainly non-edible oil, such as biodiesel, but also edible oil) and animal feed (rapeseed cake from the crushing of rapeseed grain).

Rapeseed is best suited to a temperate climate. Four countries in the south of the EU — Portugal, Greece, Cyprus and Malta — do not produce rapeseed; southern regions (in Spain, Italy and Bulgaria) account for less than 10% of EU production. The 13 regions (including Denmark) that produce the most rapeseed account for at least 50% of total production in the EU. This EU production total was calculated without figures for the Czech Republic and the United Kingdom for which regional data are not available.

Of the regions with the highest production, eight are in Germany, the biggest rapeseed-producing country, with 5.3 million tonnes (starting with the highest producing region): Mecklenburg-Vorpommern (5.8% of EU production), Bayern, Sachsen-Anhalt, Niedersachsen, Schleswig-Holstein, Sachsen, Thüringen and Brandenburg. Four are in France, the second biggest producer of rapeseed, with 4.6 million tonnes (starting with the highest producing region): Centre (6% of EU production), Champagne-Ardenne, Bourgogne and Lorraine. Denmark contributes 3.9% of EU production.

The next 34 regions account for 40% of the EU's total production. Poland, with 2.1 million tonnes, is the third biggest producer of rapeseed in the EU. Ten Polish regions are in this group: Wielkopolskie (2.1% of EU production), Kujawskopomorskie, Zachononiopomorskie, Dolnośląskie, Opolskie, Pomorskie, Warminsko-mazurskie, Lubelskie, Mazowieckie and Lubuskie. Two Baltic countries, Estonia and Lithuania, also feature in this group. The table and figure below show rapeseed production and areas for all Member State and production broken down on NUTS 2 level, respectively.

Table 31: 2010 rapeseed production in the EU-27 (Source: FAOSTAT)

Member State	Area (ha)	Production (t)
France	1,465,230	4,815,520
Germany	1,461,200	5,697,600
Poland	769,331	2,077,630
United Kingdom	653,000	2,230,000
Romania	527,175	943,03
Czech Republic	368,824	1,042,400
Lithuania	260,400	415,200
Hungary	259,303	530,619
Bulgaria	212,000	544,800
Denmark	166,500	579,800
Slovakia	163,989	322,452
Finland	157,700	178,500
Latvia	110,600	226,300
Sweden	109,100	278,600
Estonia	98,188	131,022
Austria	53,804	170,584
Italy	20,400	50,300
Spain	19,600	35,500
Belgium	11,300	41,669
Ireland	7,900	23,800
Slovenia	5,303	15,522
Luxembourg	4,715	15,895
Greece	4,000	6,000
Netherlands	2,632	11,521

Detailed data on production and areas of cultivation including regional breakdown – sunflower

With the exception of Romania in 2007, there has been a steady incline in sunflower seed production from 6.3 million tonnes in 2003 to 8.3 million tonnes in 2011. The five largest producing Member States are France, Romania, Bulgaria, Hungary and Spain: output ranges from 1.89 million tonnes to 1.08 million tonnes (see Figure 6). The two Member States with the highest production levels, France and Romania, are looked at in more detail. In France, the South West (Aquitaine, Midi-Pyrenees and Limousin) has the highest production level, accounting for ~35% of French sunflower seed production, followed closely by the West (~33%) (Pays de la Loire, Bretagne and Poitou-Charentes). In Romania, the South East and South produce the greatest amount of sunflower seed (~32% of Romanian production each). The area of land used for the production of sunflower seeds has risen gradually since 2003 from 3,622 thousand hectares in 2003 to 4,218 thousand hectares in 2011. In 2011, this area was split 60:40 between New Member States and old Member States. The area of sunflower seed production does not reflect the quantity of production. Although France has the highest production, Romania, Spain and Bulgaria have a greater area. The South East and South of Romania have the greatest share of land producing sunflower seeds and in Spain, the centre (namely Castilla y Leon and Castilla-la Mancha) and south do (56% and 40% respectively). The table and figure below show sunflower production and areas for all Member States and production broken down on NUTS 2 level, respectively.

Table 32: 2010 Sunflower seed production in the EU-27 (Source: FAOSTAT)

Member State	Area (ha)	Production (t)
Austria	25,411	66,500
Bulgaria	700,000	1,596,100
Czech Republic	27,172	57,358
France	694,811	1,633,110
Germany	24,973	47,240
Greece	23,500	16,080
Hungary	501,507	969,718
Italy	100,500	212,900
Poland	2,100	3,178
Portugal	14,000	7,600
Romania	786,058	1,262,930
Slovakia	82,866	150,326
Slovenia	203	476
Spain	697,900	887,000

Detailed data on production and areas of cultivation including regional breakdown – Sugar beet
In 2011, the area of production for sugar beet was 1.6 million hectares. This marks a drop in area of production from 1.7 million hectares in 2007 but an incline since 2008 when the area was 1.4 million hectares. This decline, both in area and production of sugar beet is explained by the 2006 CMO reform which restructured the EU sugar sector to remove the sugar quota with the intention of making it more competitive. At the EU-27 level, there was a 19 per cent decline in average production levels from before (2003-2005) and after the reform (2008-2010). [39]

In 2011 the total EU-27 sugar beet production was ~113 million tonnes, of which 80% is produced in the old Member States and only 20% in the New Member States. There has been a steady incline since the sudden drop in production levels from ~136 million tonnes in 2005 to ~111 million tonnes in 2006. France and Germany also have the highest production levels, again higher than the new Member States collective output. In 2010, Germany produced ~23 million tonnes of sugar beet, of which ~6 million tonnes was produced in Niedersachsen and ~4 million tonnes was produced in Bayern. The remaining sugar beet was produced in an additional ten German regions, but predominantly Nordrhein-Westfalen, Sachsen-Anhalt, Mecklenburg-Vorpommern, Rheinland-Pfalz, Baden-Württemberg. In France, the most recent information on sugar beet production at a NUTS 2 level is from 2007 when total production was ~33 million tonnes, of which 72.5% of French sugar beet production is in Bassin Parisien (Île-de-France, Champagne Ardenne, Picardie and Haute-Normandie) (note that production levels have since risen to ~35 million tonnes in 2011). Poland has the third highest production levels, followed by the UK, the Netherlands, and Belgium, as depicted in Figure 5.

The old Member States have significantly more land under sugar beet production compared to the New Member States (1.3 million hectares compared to 330 thousand hectares, respectively). France and Germany alone have a greater area under production than the new Member States collectively. Only two new Member States rank in the top ten, Poland and the Czech Republic. In 2010, at a NUTS 2 level, the regions in Germany with the greatest area producing sugar beet are Niedersachsen (27%), Bayern (16%), Nordrhein-Westfalen (15%) and Sachsen-Anhalt (12%). In 2007, at a NUTS 2 level, the regions in France with the greatest area producing sugar beet were Picardie (35%) and Champagne-Ardenne (22%). The table and figure below show sugar beet production and areas for all Member States and production broken down on NUTS 2 level, respectively.

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[39] Agrosynergie (2011) *Evaluation of Common Agricultural Policy measures applied to the sugar sector.* [Chapter 4: Theme 1: Impacts on the sugar beet sector] http://ec.europa.eu/agriculture/eval/reports/sugar-2011/chapter4_en.pdf

Table 33: 2010 Sugar beet production in the EU-27 (Source: FAOSTAT)

Member State	Area (ha)	Production (t)
Austria	44,841	3,131,670
Belgium	59,303	4,464,780
Czech Republic	56,400	3,065,000
Denmark	39,200	2,356,000
Finland	14,600	542,100
France	383,479	31,910,400
Germany	367,000	23,858,400
Greece	13,200	761,500
Hungary	13,859	818,941
Italy	62,700	3,550,100
Lithuania	15,500	722,500
Netherlands	70,560	5,280,430
Poland	199,900	9,822,900
Portugal	1,600	137,000
Romania	21,627	837,895
Slovakia	17,932	977,694
Spain	44,300	3,399,400
Sweden	37,900	1,973,700
United Kingdom	92,000	6,484,000

Detailed data on production and areas of cultivation including regional breakdown – Maize

In 2007, 47.5 million tonnes of grain maize were produced in the EU, which amounts to 18% of all cereal production (Figure 2). Grain maize is mainly intended for animal feed but it is also used for industrial products, such as starch and glue. Given its physiological needs, this crop covers a smaller geographical range of EU regions. The most northerly Member States (Ireland, the United Kingdom, Denmark, Estonia, Latvia, Finland and Sweden) produce little or no grain maize.

The 14 regions producing the most grain maize are responsible for over 50% of total grain maize production. This total EU production was calculated without production figures for the Czech Republic and Greece, as regional data for those countries are not available. Of those 14 regions, seven are in France, as follows (starting with the highest-producing region): Aquitaine (which accounts for 6.3%

of EU production), Poitou-Charentes, Midi-Pyrénées, Alsace, Pays de la Loire, Rhône-Alpes and Centre. Four are in the north of Italy (starting with the highest-producing region): Veneto, Lombardia, which accounts for 6.2% of EU production, Piemonte and Friuli-Venezia Giulia. There is one such region in Hungary (Dél-Dunantul, which accounts for 2.3 % of EU production), one in Spain (Castilla y Leon, 2.2 % of EU production) and one in Germany (Bayern, 2.1% of EU production).

The next 40 regions account for 40% of the EU's total production. Romania, with 3.9 million tonnes, is the fourth biggest producer of grain maize in the EU (after France, with 14 million tonnes, Italy, 9.9 million tonnes, and Hungary, 4 million tonnes). All regions of Romania except Bucureşti-Ilfov are in this group. Romania specialises in grain maize cultivation (2.5 million hectares, i.e. the largest surface area dedicated to this crop in the EU), but its yields are not as high as those in the older Member States. The tables and figure below show maize production and areas for all Member States and production broken down on NUTS 2 level, respectively.

Detailed data on production and areas of cultivation including regional breakdown – Wheat

Some 21 regions account for over half the wheat production in the EU[40] Of those 21 regions, 10 are in France, as follows (ranging from the highest production to the lowest): Centre (which accounts for 4.5% of EU wheat production), Picardie, Champagne-Ardenne, Poitou-Charentes, Pays de la Loire, Nord — Pas-de-Calais, Bourgogne, Haute-Normandie, Île-de-France and Bretagne. This makes France the biggest wheat producer in the EU. France harvested almost 33 million tonnes of cereal in 2007. Germany, with 20.9 million tonnes, is the second biggest producer. It has eight of the 21 most productive regions, and they are as follows (from the largest producers to the lowest): Bayern (which accounts for 3.6% of wheat production in the EU), Niedersachsen, Sachsen-Anhalt, Nordrhein-Westfalen, Mecklenburg-Vorpommern, Baden-Württemberg, Thüringen and Schleswig-Holstein. It can, therefore, be said that the EU's wheat 'granary' is located in the northern half of France and Germany. The next 63 regions contribute 40% of the EU's total production. These include all but three regions of Poland, which is the fourth biggest producer of wheat, after the United Kingdom (8.3 million tonnes). The table and figure below show wheat production and areas for all Member States and production broken down on NUTS 2 level, respectively.

[40] Calculated without the figures for production in the Czech Republic, Greece and the United Kingdom, for which regional data are not available

Table 34: 2010 Wheat production in the EU-27 (Source: FAOSTAT)

Member State	Area (ha)	Production (t)
Austria	302,852	1,517,810
Belgium	209,532	1,849,580
Bulgaria	1,108,700	3,994,900
Cyprus	7,438	14,843
Czech Republic	833,600	4,161,600
Denmark	763,600	5,059,900
Estonia	119,700	324,400
Finland	211,200	724,400
France	5,426,000	38,207,000
Germany	3,297,700	24,106,700
Greece	510,000	1,600,000
Hungary	1,011,180	3,763,680
Ireland	77,800	669,000
Italy	1,865,000	6,900,000
Latvia	307,600	973,000
Lithuania	525,500	1,708,200
Luxembourg	14,009	83,474
Malta	2,700	13,100
Netherlands	153,723	1,369,550
Poland	2,406,100	9,487,800
Portugal	60,400	111,700
Romania	2,152,520	5,811,810
Slovakia	350,300	1,227,800
Slovenia	31,946	153,481
Spain	1,907,300	5,610,700
Sweden	404,300	2,184,400
United Kingdom	1,937,000	14,878,000

Detailed data on production and areas of cultivation including regional breakdown – Rye

In 2009, 9.8 million tonnes of rye was harvested in the EU-27. Germany and Poland are responsible for 81% of this rye production (43 and 38% respectively). Rye accounts for 62 and 43% of their overall cereal production, whilst in the remaining 25 Member States rye production accounts for no more than 30% of Member State cereal production and averages 8% (see Table 2).

In Germany, Brandenburg and Niedersachsen produce just under 50% of rye; the former is the largest producing region, harvesting 25.8% of total German production in 2009 (1.1 million tonnes), whilst Niedersachsen produced 22.4%. The remaining rye production is mainly in the regions of Sachsen-Anhalt and Mecklenburg-Vorpommern (~10% each) with nine other regions making up the rest. In Poland there are also two main rye producing regions, the Region Pólnocno-Zachodni (31%) and the Region Centralny (30%). The table and figure below show rye production and areas for all Member States and production broken down on NUTS 2 level, respectively.

Table 35: 2010 Rye production in the EU-27 (Source: FAOSTAT)

Member State	Area (ha)	Yield (t)
Austria	45,699	163,600
Belgium	459	1,969
Belgium-Luxembourg	-	-
Bulgaria	10,900	17,500
Cyprus	-	-
Czech Republic	30,200	118,200
Denmark	52,100	254,700
Estonia	12,600	25,100
Finland	25,200	68,500
France	24,700	121,700
Germany	627,100	2,903,470
Greece	15,600	34,500
Hungary	35,900	79,400
Ireland	180	420
Italy	4,500	12,800
Latvia	34,600	69,400
Lithuania	51,300	86,700
Luxembourg	896	5,116
Malta	-	-
Netherlands	2,252	11,242
Poland	1,395,600	3,270,300
Portugal	20,400	17,600
Romania	14,439	34,281
Slovakia	17,000	37,600
Slovenia	796	2,676
Spain	133,300	251,800
Sweden	25,400	123,400
United Kingdom	3,400	21,420

Annex 3: Soil risks within the EU

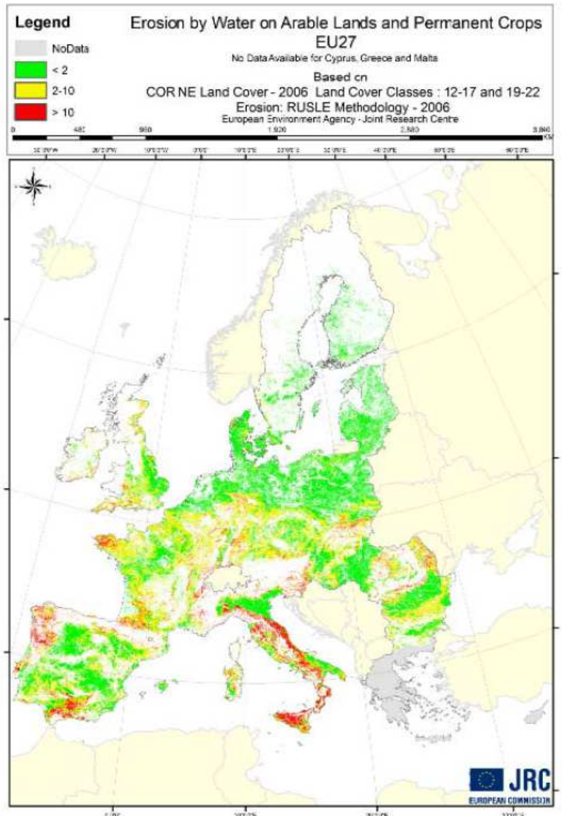

Figure 12: Risk of water erosion on areas of arable and permanent crops in the EU-27

Source: Jones et al., 2012

Note: Calculations based on the RUSLE model (1 km grid cells and Corine 2006 Land Cover database. White areas are not considered as cultivated land in the Corine classification system).

Table 36: Areas of agricultural land at risk of soil erosion by water

Indicator	Objective 22 - Soil: areas at risk of soil erosion					
Measurement	Estimated agricultural area affected by moderate to sever water erosion (>11 t/ha/yr)			Share of estimated agricultural area affected by moderate to sever water erosion (>11 t/ha/yr)		
Source	JRC (RUSLE Model)			JRC (RUSLE Model)		
Year	"2006-2007"			"2006-2007"		
Unit	1000ha			%		
Subdivisions	Total agricultural area	Arable and permanent crop area	Permanent meadows and pasture	Total agricultural area	Arable and permanent crop area	Permanent meadows and pasture
Country						
Belgium	16.3	15.7	0.6	0.9	1.1	0.2
Bulgaria	69.0	63.7	5.3	1.1	1.2	0.7
Czech Republic	8.4	8.3	0.1	0.2	0.2	0.0
Denmark	0.0	0.0	0.0	0.0	0.0	0.0
Germany	569.7	554.7	15.0	2.7	3.3	0.3
Estonia	0.0	0.0	0.0	0.0	0.0	0.0
Ireland	115.8	90.1	25.7	2.4	8.0	0.7
Greece	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Spain	2 071.2	1 994.9	76.3	7.4	8.1	2.3
France	1 749.3	1 537.7	211.6	5.1	6.4	2.1
Italy	4 782.5	4 602.1	180.4	27.8	30.1	9.6
Cyprus	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Latvia	0.0	0.0	0.0	0.0	0.0	0.0
Lithuania	0.0	0.0	0.0	0.0	0.0	0.0
Luxembourg	5.4	5.4	0.0	3.8	5.1	0.0
Hungary	62.9	61.9	1.0	1.0	1.1	0.1
Malta	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Netherlands	5.2	5.2	0.0	0.2	0.4	0.0
Austria	329.1	224.7	104.4	10.0	11.4	7.8
Poland	223.7	220.4	3.3	1.1	1.3	0.1
Portugal	811.5	789.9	21.6	18.6	19.0	10.2
Romania	769.4	730.5	38.9	5.6	6.7	1.3
Slovenia	269.9	256.5	13.4	37.1	43.3	9.9
Slovakia	67.0	64.8	2.2	2.8	3.1	0.7
Finland	0.1	0.0	0.1	0.0	0.0	1.3
Sweden	24.9	0.6	24.3	0.6	0.0	5.3
United Kingdom	491.5	314.3	177.2	3.1	4.5	2.0
EU-27	12 442.8	11 541.4	901.4	6.0	7.2	2.0
EU-15	10 972.5	10 135.3	837.2	7.6	9.4	2.3
EU-N12	1 470.3	1 406.1	64.2	2.4	2.7	0.6

Source: European Commission, 2012, based on Agri-environmental indicator draft factsheet – Soil water erosion (AEI 21) and calculations of the average annual rate of erosion by the RUSLE model.

Note: EU totals exclude Cyprus, Malta and Greece.

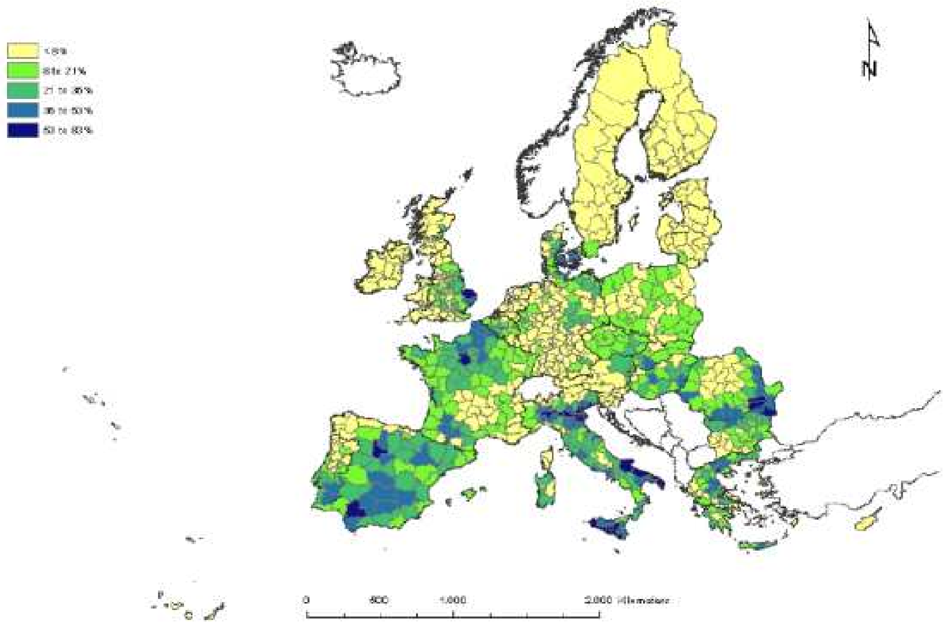

Figure 13: Share of agriculturally used soils with low organic carbon content per FARO region
Source: Nowicki et al., 2009

Note: 2% SOC was used as threshold for low organic carbon content. However, this threshold has been disputed in the literature.

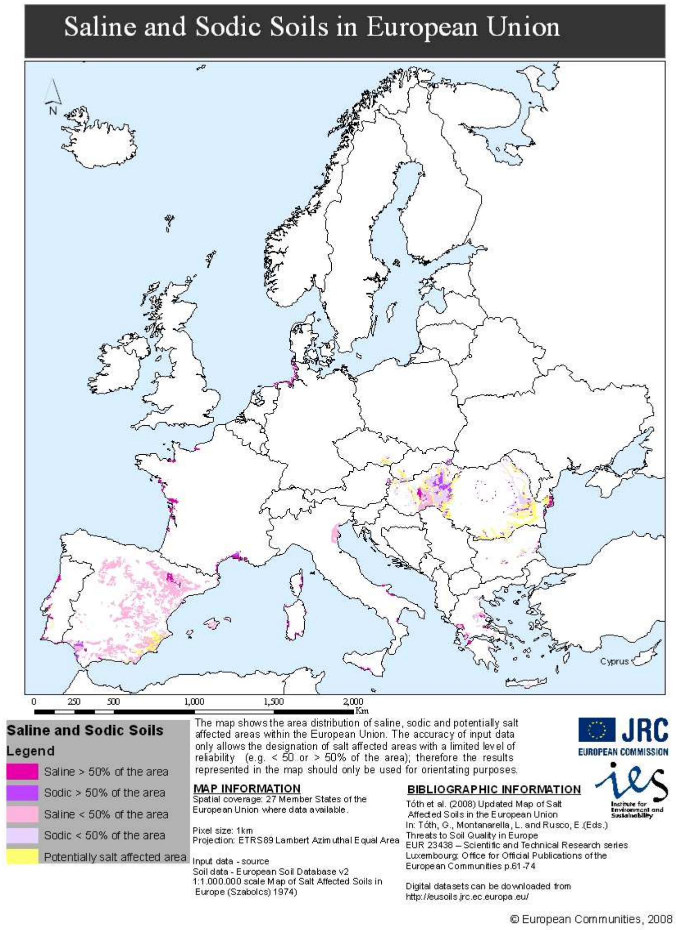

Figure 14: Saline and sodic soils in the EU-27

Source: Tóth et al., 2008

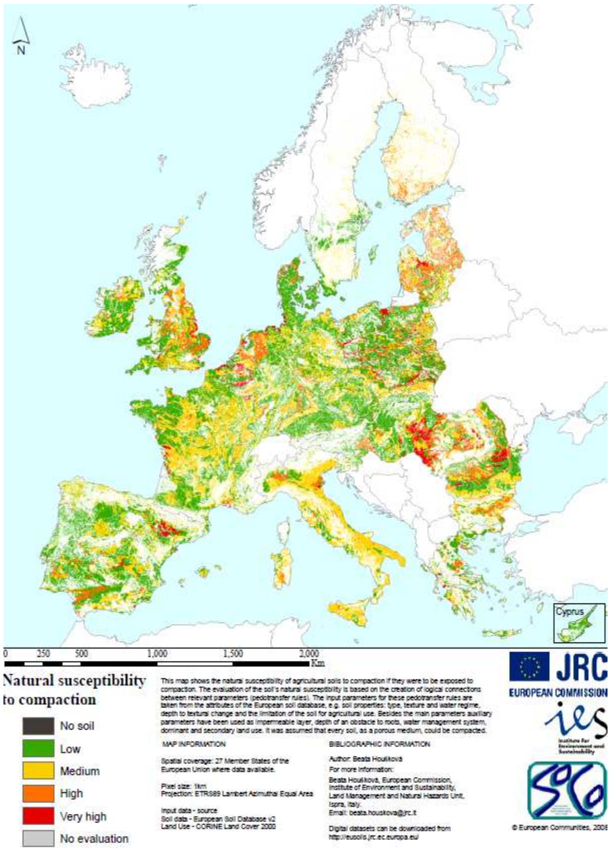

Figure 15: Soils susceptible to compaction in the EU-27
Source: Van Liedekerke and Panagos, 2008

Annex 4: Soil risks per Member State

Czech Republic

*T*he most important risks to soils in the Czech Republic from agricultural land use relate to soil erosion and loss of soil organic matter. Although Czech soils are at a moderate risk of water erosion in cross country comparison, with prevailing stable trends between 2000 and 2006 (European Commission, 2011), currently more than half of soils are at risk of soil erosion. The on-going intensification of crop production, in which the types of crops that are particularly high erosion risk – *rape, sugar beet and maize* – play a very important role, exacerbates the state of soils. There are significant cumulative negative impacts on soil erosion and soil organic matter resulting from the co-existence of croppings based on maize varieties going into biogas sector and cropping for biofuel sector. There is a concomitant growing tendency to the concentration of fields, the expansion of cropping into more steeply sloping terrains, highly reduced diversity of crops in areas under these crops and frequent adoption of continuous cropping systems. Management practices are typically motivated by short term economic objectives (for example ploughing up and down the slope, lack of cover crops in maize systems, land levelling). There are increasing concerns about the unsuitability of such land consolidation and intensification trends in combination with crops of high erosion risk. It has been highlighted that extension of areas under these crops has often taken place at the account of fodder crops which were beneficial in countering soil erosion. On-site and off-site damage to public goods through soil erosion prompted these changes in land structure and land management is high (Janecek et al., 2012; Dumbrovský M., pers.comm). In addition, soil erosion processes are inextricably linked with decline in SOM. Although the share of agriculturally used soils in the Czech Republic with low soil organic matter is relatively low compared to EU-12 Member States (between 8 and 21%, with hotspots between 21 and 36%, Nowicki et al*.,* 2009), the current erosion trends involve decline in valuable topsoil occurring at landscape scales, often combined with anthropogenic soil degradation through land levelling and through the dilution of remaining topsoil by deep ploughing (Dumbrovský M., pers.comm).

The expansion of bioenergy sectors over the past years has been associated with the dominant use of the domestic rape outputs as the key biodiesel feedstock. In terms of the relative share of rape in the total arable area, the Czech Republic is together with Germany, UK and Slovakia among the leading EU rape producers. Sugar beet is used as key bioethanol feedstock, and silage maize is highly popular as feedstock for the biogas sector (for heat/electricity). Grain maize (and winter wheat) is used in a limited amount for the bioethanol production (see Table 2 and Annex 1). This expansion brought along considerable extension of cropping areas under rape, sugar beet and maize. The scaling up was made possible due to declining number of cattle heads and hence less feed requirements, due to re-distribution of agricultural output going to food, feed and energy, and due to intensification of agricultural management (Dumbrovský M., pers.comm).

Currently applied GAEC standards include a ban on burning stubble; permanent soil cover on slopes above 7°; a ban on the cultivation of row crops such as maize, sugar beet and sunflower in areas critically threatened by soil erosion; and a restriction of the cultivation on cereals including rape in areas prone to erosion unless appropriate protection measures have been taken, for example, farmers must use cover crops.

France

The main soil degradation problems linked to agriculture in France are the decline of soil organic matter and erosion. Soils in France generally have a low organic carbon content[41] (between 2 and 5%) and a very low content in southern regions (between 1 and 2%), affecting the soil's capacity to cope with erosion. The share of agricultural soils with a low carbon organic content (ranging from 40 to 50 tonnes/ha) is particularly high in the North of France and South West (36-53%). There is a slightly higher organic carbon content in central southern and eastern France (between 5-10%). Although France has only limited peat soils under agricultural use, 1,500 ha of which 1,200 ha is cropland, there are high levels of carbon in these areas and those of mountainous and forested regions (Joosten and Clarke, 2002; Byrne et al., 2004; Gobin et al., 2011). Agricultural management poses less of an issue in these areas also because only a low share of land is used for agriculture (Nowicki et al., 2009).

In terms of erosion, 5.6 million hectares (12% of UAA) of French agricultural land is under high or very high risk of erosion (Pointereau et al., 2008). The main form of erosion in France is caused by water, impacting approximately 5 million hectares of UAA, whereas wind erosion affects only 0.5 million hectares (Montanarella, 1999). The areas with loamy soils that are naturally sensitive to erosion are found in Ile-de-France, Aquitaine, Haute Normandie, Basse Normandie, and Midi Pyrenees. For example, in the Paris basin, moderate rainfall can result in severe erosion due to the low structural stability of such loamy soils that reduces soil capacity to absorb water thus increasing sediment runoff; this occurs even more so where there is a lack of soil cover (Pointereau et al., 2008). It is becoming increasingly apparent that on agricultural land the risk of erosion is linked to intensive production and run-off, irrespective of the slope gradient and soil type. This erosion is largely associated with the cultivation of spring crops (potatoes, sugar beet, maize and sunflower) and vineyards which are situated in the North West, the South West and Mediterranean regions of France.

Soil degradation can be linked to the cultivation of biofuel feedstocks, particularly the cultivation of maize. However, the French agricultural land used for the production of biofuel crops of 1.7 million hectares in 2010 represents a marginal share of French agriculture (6%) (Cour des Comptes, 2012).
The main biofuel feedstock in France is rapeseed, followed by sunflower, sugar beet, wheat and maize. Significant shares of total area of production of rapeseed, sunflower and sugar beet are devoted to biofuels, 42%, 45% and 16%, respectively. In the past, biofuel crops were concentrated on former set-aside land; rapeseed took over about half of the former compulsory fallows (and has replaced leguminous crops elsewhere). Since then, the use of feedstocks for biofuels depends on market conditions which determine the shares of crop output going to the food, feed and energy markets. Furthermore, some of the documented decrease in permanent grassland is associated with expanding agricultural cropping. Sunflowers tend to be cultivated on lowest yield lands. Overall,

[41] //eusoils.jrc.ec.europa.eu/projects/soil_atlas/download/Atlas.pdf

production of biofuel feedstocks contributes to maintaining or extending the area of arable land in France. Negative impacts are noted due to the conversion that has taken place, because compared to fallows and grassland, arable land has detrimental effects on soil conservation, nitrogen and carbon storage and pesticide/herbicide use. On the other hand, there are some positive impacts (of unknown scale) as well due to the introduction of rapeseed into formerly simple crop rotations. In the case of sugar beets, biofuel production represents a diversification of sugar production and is not believed to expand areas of production. However, substantial sugar beet yield increases are observed with highly intensive farming practices and associated adverse environmental effects from increased pesticide and fertiliser use. Again, the maintenance of sugar beets in crop rotation may have positive agronomical and environmental effects for succeeding cereals (Dupraz P., pers.comm).

With regard to management practices and their impact on soil risks, a key cultivation practice thought to exacerbate erosion is tillage, particularly where practiced on sloped arable land in the South West of France (Romero, 2001). In France there are no direct payments to address soil conservation (priorities are biodiversity and water quality). The key measures that deliver benefits for soil are soil cover and buffer zones (Pointereau et al., 2008). Another practice linked to arable cultivation is the removal of vegetation resulting in bare soils which heighten the risk of erosion, a risk that is further increased where tillage is carried out on bare soils, usually following spring sown crops (such as maize and sugar beet); particularly a problem in Alsace and Brittany (North France) and regions in the South West (Pointereau et al., 2008). Furthermore, a significant pressure on soils from agricultural land use in France is the replacement of rotated systems by continuous cropping systems, with the concomitant effects of declining organic carbon content and increasing areas of bare land after harvest, which are prone to wind and water erosion.

This high risk of water erosion in France, resulting in rapid run off and rill and ephemeral gully erosion, can be alleviated by certain agricultural practices, as outlined in national farming restrictions. In order to mitigate water erosion, farmers must maintain riparian buffer strips with soil cover all year round (GAEC 5 – minimum soil cover). In order to protect organic matter levels farmers cultivating cereal crops, oilseeds and protein crops are prohibited from burning stubble (GAEC 7 – Arable stubble management). To avoid bare land, farmers with a single crop arable land must have winter cover (GAEC 5 – minimum soil cover). Furthermore, farmers are obliged to cultivate at least three crops covering 5% of the holding; or cultivate 10% with only two crops if one is a legume; or maintain winter cover by mulching (GAEC 6 – crop rotations).

Germany

Levels of soil organic matter in German soils varies greatly. Large parts of Germany have low levels between 1-6% with very low levels between 1-2% prevailing in Eastern parts of Germany. High levels (up to 30%) are found along the North Sea coast and in some other places in Northern Germany. Some of the medium mountain ranges and the foothills of the Alps level shows levels of around 5-10% (see Umweltbundesamt, 2011). Intensive agricultural management on soils with very low levels of SOM is risking irreversible degradation of soils. Agricultural management on soils with very high levels of SOM often involves peat soils. Northern Germany hosts large areas of peat soils, totalling

16,520 ha of which 12,000 ha is drained and under agricultural management in grassland and cropland sectors (Joosten and Clarke, 2002; Byrne et al*.,* 2004; Gobin et al*.,* 2011). Together with regions in Northern Poland, these areas represent an important share of EU peat soils and the most extensive peatlands under agricultural use in the EU. In the natural state peat soils are very important soil carbon sink with very high levels of soil organic matter. Drainage and agricultural management greatly reduces SOC levels, and the loss of soil carbon content associated with mineralisation of peat soils continues to occur for decades. Peat soils are also at high risk of soil compaction (see Figure 15).

The potential erosion risk in Germany increases from north to south. The distribution of actual erosion risks taking into account cover and management practices (C-factor) shows that the highest risk areas are found in Central Germany (parts of Lower Saxony, North Rhine-Westphalia, Saxony and Hesse) as well as northern parts of Baden-Württemberg and parts of Bavaria in hilly areas along the rivers Danube, Isar and Inn (see Wurbs and Steininger, 2011). Northern Germany is subject to strong winds and is located in the European sand belt, making it one of the regions with the highest number of erosive days on bare soils in Europe (EEA, 2003).

The expansion of the market demand for energy crops has brought along certain extension of cropping areas under rape, sugar beet and maize in Germany, but not on significant scales. The scaling up of crop production destined for biofuels was possible due to declining number of cattle heads and hence less feed requirements, due to re-distribution of agricultural output going to food, feed and energy and due to cultivation of former set-aside land. Given the high intensity of the existing agricultural management reaching optimum levels, the energy crops did not cause increase in intensification, or higher use of agrochemical inputs (Gödeke K., pers.comm[42]). Rapeseed for biodiesel is by far the most important biofuel crops, both in absolute terms and relative to its total cultivation area, with around 40% of this area used for biofuel production. For sugar beet, grain maize and wheat, 6, 2, and 1% of total cultivation area are for biofuels, respectively (see Annex 1). While most silage maize used for energy purposes yields biogas for heat and electricity generation, a small but growing share is used in transport in the form of biomethane (Thrän D., pers.comm). While rapeseed is typically grown in rotated systems, continuous maize cultivation is found in certain regions, most importantly Lower Saxony and Bavaria (Gödeke K., pers.comm).

The maintenance of soil organic matter is an important priority under GAEC cross compliance. Farmers are obliged to show proof of their annual humus balance or ensure a three-crop crop rotation on at least 15% of their plot (GAEC 6 – crop rotations). Furthermore, farmers are prohibited from burning stubble (GAEC 7 – Arable stubble management). In order to address soil erosion risk, farmers are restricted to manage their arable land in between certain dates to avoid disturbing the soil structure when the risk of water and wind erosion is highest, observe strict requirements for cultivation on slopes, requirements for catch crops and cover crops, and contour ploughing (GAEC 5 – minimum soil cover). Grass strips and flowering strips are often used as a protection measure in

[42] Thüringer Landesanstalt für Landwirtschaft

continuous crop systems. They may be used as erosion control in lieu of GAEC cross compliance (in CC Water 1 and 2 areas).

Hungary

The most significant risks identified from agricultural crop including biofuel crop production in Hungary are water erosion and acidification of soils with low pH. Soil compaction and the continuous reduction of topsoil thickness are also considered significant problems (Institute for Soil Science and Agricultural Chemistry[43]). There is particularly high risk of soil compaction in the South East of Hungary (seeFigure 15). According to Kertész, '25% of the total area of Hungary (more than one-third of agricultural land) is affected by water erosion (on agricultural land 13.2% slightly, 13.6% moderately and 8.5% severely eroded) and 16% is affected by wind erosion' (2009, p83). The reasons for severe water erosion problems are mainly due to historically large fields and bare soils during extended critical period with many areas being harvested by the beginning of July (Kertész, 2009). The organic carbon content in soils in Hungary ranges between 2 and 10%. A significant share of soils with low organic carbon content in Hungary is used for agricultural purposes, between 21 and 36% and even as much as 36 to 53% in some of the more central regions (Nowicki et al*.,* 2009).

The main biofuel crops are rapeseed and maize. Rapeseed is most important in absolute terms as well as in relative terms: 61% of rapeseed area of cultivation is destined for the biofuel sector in 2010 (see Annex 1). Given the large maize cropping area (close to one fourth of total cropland), the share of maize area of cultivation devoted to biofuels is relatively small with 2% in 2010. A much higher share – though small in absolute terms – of sugar beet area of cultivation (38%) is devoted to biofuels. The expansion of Hungarian biofuel production relies exclusively of the use of domestic biomass. According to the Hungarian Institute for Soil Science and Agricultural Chemistry, this is facilitated by large surpluses of domestic crop production, most notably maize, which is projected to become the dominant biofuel feedstock in 2020 (reaching a level close to three times as much as rapeseed use for biofuels in 2020). Production surpluses in the maize sector amounted to 2.5 to 5 million tonnes/year over the years 2005-2010 and therefore intensification or conversion of new areas for biofuel cropping are neither observed nor anticipated; at the same time, it is stated that neither maize nor rapeseed area can be increased without adverse effects. Increases in harvested acreage would necessarily imply the abandonment of current crop rotation practices resulting in biodiversity decline, the depletion of available soil nutrients, increased use of agro-chemicals and pollution of surface and ground waters from fertiliser use. Continuous crop systems would furthermore require more intensive pest management and higher pesticide inputs (Institute for Soil Science and Agricultural Chemistry).

To allow the soils to recover some of the organic carbon content, farmers are restricted from growing certain crops for more than two (such as rye and wheat) or three (such as maize) consecutive years (GAEC 6 – crop rotations). In addition to this, farmers are prohibited from burning stubble, reed, crop residue and grassland (GAEC 7 – Arable stubble management). On arable land with slopes that are

[43] Part of the Centre for Agricultural Research, Hungarian Academy of Sciences. The Hungarian (written) response was prepared in contribution with the Green Economy Development Department (Ministry of National Development)

steeper than 12%, farmers must have autumn-winter soil cover and they are prohibited from cultivating certain crops including sugar beet (GAEC 5 – minimum soil cover). There is a restriction on any overgrazing and heavy machinery (GAEC 8 - Minimum livestock stocking rates or/and appropriate regimes).

Italy

The organic carbon content in Italian soils is consistently the lowest across all regions in the EU-27; particularly in the southern and coastal regions. Furthermore, these areas are largely used for agricultural purposes (Nowicki et al., 2009). Loss of organic matter due to intensive arable crop production is the major threat to soil quality, especially in the Po valley, the area of most intensive agriculture in Italy and of importance for energy crop production (Povellato A., pers.comm[44]). Italian soils are also under considerable pressure from water erosion (European Commission, 2011). Soil erosion from agriculture is mainly an issue of concern in hilly areas in Central Italy (and to a lesser extent in the South), cultivation areas of e.g. sunflower, wheat, maize (where irrigation is available), sorghum etc. Pieri et al. (2007) point out in particular clay areas of the North Apennines mountain range in Italy as being increasingly subject to erosion, mostly due to intensive agricultural practices in the area. A dominant threat also in these parts of the country is the loss of organic matter, however (Povellato A., pers.comm).

Cultivation of energy crops is not widespread in Italy as Italian feedstocks are hardly compatible with imported feedstock. Most of the cultivation of energy crops was concentrated in Northern regions (84%) and only negligible share in Southern Italy (2%), according to the 2010 Census of Agriculture[45]. The Italian biofuel market is dominated by biodiesel, making up 95% of biofuel use (Energy & Strategy Group, 2011). Around 10-20,000 ha of land is used for biofuel feedstock cultivation (mostly rapeseed, sunflower), with the main cultivation region being the Po valley. Maize is mostly used for the production of biogas (grown on 50 - 100,000 ha), while the scale of ethanol production is negligible[46]. Since the Po valley is the most intensive agricultural area in Italy (hosting 70% of the country's livestock production), competition between growing energy versus feed crops can be observed. However this competition is mostly triggered by maize cultivation for biogas production, and to lesser extent by biofuel production (Povellato A., pers.comm).

In order to moderate the low level of organic carbon content, farmers are restricted from growing more than one crop on the same parcel for more than five years, unless a farmer can demonstrate with a soil analysis sample that 'no significant variation of soil organic matter levels occurred during the monocultivation period' (GAEC 6 – crop rotations). Although farmers are prohibited from burning stubble and grassland, certain regions are permitted to carry out this practice due to the compactness of their soil and low nutrient level (GAEC 7 – Arable stubble management). To mitigate the risk of water erosion, where there is evidence of water erosion, farmers are required to maintain

[44] Director of research at INEA (National Institute of Agricultural Economics, Italy).
[45] http://www.istat.it/it/archivio/66591
[46] We note that there is an inconsistency between the data and expert opinion on biofuel use and types gathered for this report, suggesting a biodiesel market based on rapeseed and sunflower, and the data reported in Annex 2, suggesting a more balanced market between ethanol and biodiesel and use of sugar beet, wine and soy as domestic feedstock. This could not be confirmed by information gathered here.

soil cover all year round on uncultivated land and during the winter months on cultivated land (GAEC 5 – minimum soil cover). In addition to this, drainage systems must be properly maintained and the appropriate authorisation must be obtained before any soil levelling is carried out.

Poland

Soils in Poland generally have an organic carbon content of between 5-10%; there are two regions outside of this norm, central Poland, where the organic carbon content is lower (between 2-5%) and the far east of the country, where the organic carbon content is higher (10-25%). The share of these soils with low organic carbon content that are used for agricultural purposes varies from less than 8% to between 8 and 21% (Nowicki *et al.,* 2009). It should be noted that Poland has 12,500 ha of peat soils of which 7,565 ha are used as grassland (Joosten and Clarke, 2002; Byrne et al*.,* 2004; Gobin et al*.,* 2011).

Wawer, Nowocień and Podolski (2010) have produced maps of water erosion in Poland and find that 7% of the Polish area is at risk of actual erosion of devastating form ('average' to 'very strong'), mostly found in uplands, mountain areas and lake districts. On these areas, among them agricultural areas with slopes exceeding 10%, anti-erosion measures such as permanent crop cover are needed. They furthermore confirm what had been noted in an earlier study, that their results 'show far higher actual water erosion risk in Poland than those obtained by European erosion risk assessments' due to differences in methodologies and data quality (e.g. higher resolution data used in Polish studies) (Wawer and Nowocień, 2007, p766).

In addition to this, South Eastern Europe has the most extensive and severe wind erosion and Poland is located in the European sand belt and is one of the Member States with the highest number of erosive days on bare soils in Europe (EEA, 2003). Wind erosion, occurring especially in the early stages of crop growth, is considered a problem both for the most important biofuel crops rapeseed and maize. In general, risks for soils from the agricultural sector in general are mainly related to the intensity of production and adoption of inappropriate practices.

Rapeseed is by far the most important biofuel crop (accounting for roughly three third of Polish biofuel production) and with the most significant share of total area of production devoted to biofuels (23%). Maize and, to a more limited extent, wheat are used for ethanol production, with 7 and 1%, respectively, of total area of production destined for the biofuels market. Furthermore rye is used to produce ethanol, in similar absolute quantities as wheat (see Annex 1). According to a Polish expert, biofuel production has not led to a notable increase scale of area of rapeseed and maize production. Rapeseed production is particularly sensitive to weather conditions, which leads to fluctuations in supply of domestically produced rapeseed. Poland also imports rapeseed and the availability of domestic supply, its quality and ultimately market prices determine whether processors purchase domestic or imported rapeseed (Maciejczak M., pers.comm[47]).

[47] Scientist at Warsaw University of Life Sciences

Mitigating practices are confined to the minimum requirements resulting from GAEC standards. Farmers are prohibited from burning stubble in order to protect the organic carbon content of their soils (GAEC 7 – Arable stubble management) and there are restrictions on the cultivation of the same crop for more than three consecutive years, including wheat and rye (GAEC 6 – crop rotations). To mitigate this water erosion, farmers with arable land in areas prone to water erosion are required to maintain at least 40 per cent of arable land under cover during the winter months (GAEC 5 – minimum soil cover). Where the arable land is located on a slope with a gradient greater than 20 degrees, farmers are restricted from cultivating crops that might require a ridge (GAEC 5 – minimum soil cover).

Romania

Soils in Romania are at some risk of erosion; however, there is a lack of comprehensive data for the risk to Romanian soils of water erosion. The available data is for regions on the boarders and central Romania and shows that the risk is greatest in the eastern and southern parts of the country. There is also a high risk of wind erosion in Romania as South Eastern Europe has the most extensive and severe wind erosion (European Commission, 2011). In order to mitigate these risks, farmers are required to have a minimum 20% winter soil cover and where row crops are being cultivated on a slope with a gradient steeper than 12%, the crop must be planted perpendicular to the slope (GAEC 5 – minimum soil cover).

Romanian soils generally have low organic carbon content (2-5%); however, central Romania has a slightly higher level, 5-10%. In terms of soils used for agriculture, there is a significantly high share in the south and south east of Romania (Nowicki et al*.,* 2009). In order to protect organic carbon content farmers are prohibited from burning stubble (GAEC 7 – Arable stubble management). In addition to this, farmers cultivating sunflower seeds are prohibited from doing so on the same plot for more than two consecutive years (GAEC 6 – crop rotations).

Soils in North West Romania have a very high natural susceptibility to compaction (see Figure 15).

The most important feedstock for biofuel production in Romania is rapeseed, both in absolute and relative terms, with 25% of rapeseed area of production being used for biofuels (Annex 1).

Slovakia

The organic carbon content of soils in Slovakia ranges between 2 and 10% and between 8 and 21% of this soil is under agricultural management (Nowicki et al*.,* 2009). Bielek et al. (2005) note that soil organic matter has decreased since 1993 on cultivated and arable soils. In line with the observed decline in soil organic matter, soil erosion is considered a ‘very serious problem’. Medium degrees of water erosion affect 21% of farming land while another 3% are affected by strong or extremely strong erosion from water (Bielek et al., 2005). Greatest risk areas are found in the region bordering with Poland (European Commission, 2011). Wind erosion furthermore affects soils, with 5% of agricultural land suffering from medium erosion and 2% from strong forms of wind erosion. Bielek et al. (2005) further note a worsening of soil compaction parameters.

Biofuel production in Slovakia is dominated by rapeseed and to more limited extent based on maize, both medium to high risk crops with regard to erosion. 89% of all rapeseed area goes into biofuel production and a still significant 15% of all maize cultivation area is destined for biofuel production. Wheat is a more marginal biofuel feedstock.

In order to protect organic carbon content farmers cultivating cereal crops, oilseeds and protein crops are prohibited from burning stubble (GAEC 7 – Arable stubble management). Furthermore, farmers cultivating root crops (such as sugar beet) cannot cultivate the same crop on the same plot for more than two consecutive years (GAEC 6 – crop rotations). In order to mitigate erosion risks, arable land on a slope with a gradient greater than 12 degrees must have a minimum 40% soil cover during the winter months. In addition to this, where row crops are cultivated, the farmer must prevent a ridge from exceeding 20 centimetres (GAEC 5 – minimum soil cover).

Spain

Soil erosion and desertification are key risks to soil in Spain. Drought, forest fires, low organic carbon content and salinisation also pose a threat but are classified as lower risk (Calatrava et al*.,* 2008). Although there are data gaps for some of the central regions (Castille-Leon, Castille la Mancha and Aragon), maps compiled by the Spanish government[48] show that the potential for soil erosion is greatest along the southern coast (Andalucía and Murcia), the North West (Asturias, Cantabria and Galicia) and North East (Catalonia). The greatest risk of erosion posed to these areas is from water courses and possible landslides. Additional risks that have been noted are sheet erosion (of varying degree across the country, see Calatrava et al., 2008, for details) and wind erosion. The latter, however, in mainly concentrated in central Navarra, South West Andalucía and the Balearic Islands; soils in other regions are generally at a very low risk of wind erosion. In addition to these regional variations, the risk of soil erosion varies according to the land management. Soil erosion is typically associated with rainfed agricultural systems and marginal areas at risk of abandonment. Some of the key risks from land management, as identified in a case study for Murcia, are hill slope cultivation, excessive cultivation, irrigation with saline water, removal of vegetative cover, land abandonment and burning of stubble (Calatrava et al., 2008).

The organic carbon content in Spain is particularly low, ranging from 1-2% in most southern regions, with slightly higher levels in the North of Spain and particularly in the North West (Galicia), with levels of 5-10%. The threat of salinisation to soils is naturally low in Spain. In terms of soil compaction, Spanish soils are generally at low risk, with the exception of Aragon and parts of Extremadura (CARM, 2007; Eckelmann et al., 2006).

[48] Inventory by region of the different types of soil erosion and the potential risk to soils; regional profiles can be viewed here: http://www.magrama.gob.es/es/biodiversidad/temas/inventarios-nacionales/inventario-nacional-de-erosion-de-suelos/resumen_resultados.aspx. Interactive map: Sistema de Información del Banco de Datos de la Naturaleza (BDN): http://sig.magrama.es/bdn/

Given the climatic conditions, biofuel crop production is very limited in Spain. Sunflower, wheat and maize are among the most important biofuel crops (Annex 1; also Garrido A., pers.comm[49]). Irrigation needs for crops such as maize make cultivation unprofitable and it was mentioned that often crops sold to the biofuel sector are surplus harvest once food and feed sectors have been supplied. Therefore, no particular increases in the risks to soils reported above stemming from biofuel crop production have been identified, rather general issues in relation to soil from the agricultural sector as a whole prevail (Fernández López C., pers.comm).

In order to mediate risks of erosion, farmers are required to maintain a winter cover crop (GAEC for minimum soil cover, further information in Annex 6). With regard to protection of soil organic matter, although farmers are prohibited from burning stubble and cuttings, exceptions are permitted where burning is needed as a fire prevention measure (see GAEC for arable stubble management in Annex 5).

United Kingdom

Scotland, Wales, Northern Ireland, North and South West of England have relatively high levels of organic carbon content in their soils; however, these areas are mainly used to graze animals or for recreational activities. Areas of peat soils that are highly productive and subject in most cases to intensive agricultural practices are found in the drained fenlands of the East of England. The remaining regions in England have a low level of organic carbon matter (2-5%). The UK has the third largest area of peat soils in the EU-27. Large areas are under some form of agricultural management; according to JNCC (2011), in England alone 162 thousand ha are under cultivated cropland and temporary grassland.

The three main risks to soils in the UK are erosion from wind and water, compaction and loss of soil organic matter. Soil erosion from water has seen an increase in the UK (European Commission, 2011) particularly so in the north and west of the country. There is generally moderate wind erosion in the UK; however, coastal areas, England and Northern UK are areas subject to strong winds. They are located in the European sand belt and are areas with the highest number of erosive days on bare soils in Europe (EEA, 2003).

Crops used for biofuels in the UK are rapeseed, sugar beet and wheat. The shares of area of cultivation of these crops going to biofuels are 12%, 48% and a marginal 0.2%, respectively (see Annex 1). Maize cultivation is increasingly important for biogas production. The increase in the use of these crops for biofuel purposes was facilitated by a combination of intensification and cropping on marginal land and grassland as well as changes in end uses. All of these resulted from overall demand and supply dynamics in the agricultural market and cannot be pinned down to biofuels. An exception is the conversion of marginal land and grassland for maize cultivation. Also, biofuel crops were one of the few crops eligible to be grown on set-aside land before the policy was abolished. The most important risks to soils and water from biofuel crops are the relatively high nitrate losses and

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pesticide use in the case of rapeseed and intensive wheat cultivation as well as soil compaction and erosion risks from sugar beet cultivation. The greatest threat to soil erosion is maize cultivation, however (Letts J., pers.comm[50]).

In keeping with the Crop Residue (Burning) Regulations 1993, UK farmers are prohibited from burning stubble on arable land. Stubble management also requires additional actions, for example in Scotland farmers must incorporate livestock manure on their stubbles (except for on wind erosion prone land) (GAEC 8). To mitigate the risk of erosion on soils farmers are required to maintain varying degrees of soil cover across the UK, for example, in Scotland, spring soil cover is required to mitigate this risk (GAEC 2 – wind erosion). In England, waterlogged areas are carefully monitored by farmers in a Soil Protection Review and in Northern Ireland and Wales any cultivation is prohibited on such areas (GAEC 1). Additionally, Northern Irish and Welsh farmers are required to avoid severely trampling and poaching the land to avoid soil compaction (GAEC on Minimum soil cover). This requirement is also outlined under site-specific conditions in England particularly with the aim of avoiding making ruts.

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Annex 5: Provisions for soil protection within standards for Good Agricultural and Environmental Condition (GAEC) in ten EU countries

GAEC relating to minimum soil cover	
Germany	• Restrictions on ploughing during winter season: o No ploughing on 40% of the arable land between the harvest of the previous crop and 15 February of the following year, unless the ploughed land is sown before 1 December. No ploughing on land that falls within the water erosion hazard category, CCWater1 and CCWater2, and land that is not covered by a special erosion protection funding scheme. o Ploughing after the previous crop has been harvested shall only be permitted where sowing takes place before 1 December. Ploughing between 16 February and 30 November shall only be permitted where sowing follows immediately.
Spain	• On dry plots seeded with herbaceous winter crops, the soil is not ploughed between the date of the previous harvest collection and 1 September, except in the case of secondary crops. • Sloped land with olive groves with a gradient equal to or greater than 10% (except when the slope is compensated through terraced or benched farming) should have a minimum 1 metre green cover across the widest width of the slope or in parallel to this when the plots design or the irrigation system impedes their establishment in the other direction. • Must not remove woody crops trunks from sloped land with woody crops with a gradient equal to or greater than 15% (except when the real slope of the area is compensated through terraced or benched farming). In exceptional cases when the replacement of these woody crops is authorised by the competent authority, traditional crop varieties must be used for the replacement. Must ensure that native crops are maintained on set-aside plots or fallow land. Maintenance includes: minimum labour and adequate green cover, whether spontaneous or through the seeding of ameliorative species.
Italy	• On arable land which is no longer used for production purposes and shows marks of erosion (run-off rivulet, small channels), the farmer shall ensure a minimum soil cover all year long. • On all land where there are marks of erosion (run-off rivulet, small channels), the farmer shall ensure a minimum soil cover for at least 90 days between 15 September and 15 May of the following year. In case the Regional Authority does not set the period of 90 days, the farmer shall ensure a minimum soil cover from 15 November up to 15 February of the following year.
Poland	• On arable land - the land must be cultivated or kept as a fallow land. Where land is fallow, it should be mown/ managed at least once a year, by 31 July, to prevent the occurrence and spread of weeds. • On arable land prone to water erosion and constituting a part of an agricultural holdings, at least 40% must be kept under plant cover at least from 1 December to 15 February.
Czech Republic	• Until 30 November, sloped arable land with a gradient steeper than 7% must have either soil cover (stubble) on all or part of the plot, or ensure the soil is ploughed or tilled in order to allow water absorption.
France	• On cultivated land, including grassland: land density must comply with local practices to allow uniform coverage and covering, and be maintained in such a way that it allows for flowering. These rules may be complemented at local level. • On uncultivated land: there must be soil cover between 1 May and 31 August. • On single-crop farming undertaking (where the same crop covers 95% of the plot): there must be winter cover between 1 November and 1 March. • There must be buffer strips with soil cover all year round by watersheds.
Hungary	• On arable land with a gradient steeper than 12%, the cultivation of the following crops is prohibited: tobacco, sugar beet, fodder beet, potato, and Jerusalem artichoke. • On arable land with a gradient steeper than 12%, there must be soil cover after the summer harvest and after the autumn harvest. Soil cover cane be: a) sowing autumn crops, or b) maintaining the stubble until 30 October - low stubble cleaning is allowed provided the stubble is kept weeded, or

	c) applying a secondary planted cover crop.
Romania	• During winter, at least 20% of arable land shall be covered with winter crops and/or shall be left un-worked after harvesting.
Slovakia	• On land with a gradient steeper than 12 degrees, must ensure a minimum 40% green cover from 15 October until 1 March. Green cover can be winter cereal crops, perennial fodder crop, intercrop or stubble.
United Kingdom	**England** GAEC 1 in England regulations: • A revised 2010 SPR form has been provided to all farmers which includes assessment of risk for access to waterlogged soils (including recording access and remediation measures), post-harvest management options and requiring farmers to abide by the Crop Residues (Burning) Regulations 1993 • Farmers must implement measures previously identified on their Soil Protection Review (SPR). • Update their SPR at least once a year. • Update their SPR as soon as practicable when it becomes clear the measures they are implementing are not working or if new measures are adopted. • Update their SPR as soon as practicable when land is transferred in, or where management systems or cropping practices change. • Have regard to any specific guidance or comply with any written directions that the Secretary of State may give them regarding the management of their soils. • Where land has been under specific crops, implement one of the listed measures for postharvest management. • Where land is waterlogged and access is needed, record any such access on the SPR along with remediation action to be taken within 12 months of the access. • Comply with the Crop Residues (Burning) Regulations 1993 **Northern Ireland** • The protection of soils from erosion and maintenance of soil structure by preventing land from being severely trampled or poached. • All cultivated land must have either crop cover, stubble cover, grass cover or be ploughed or disced over the following winter. Finely tilled seedbeds are not permitted over the winter. • No cultivations are permitted if water is standing on the surface, or if the soil is waterlogged *Exceptions include gateways, drainage operations, welfare, harvesting vegetables to meet contractual deadlines or where DARD has granted a temporary exemption because of poor weather.* **Scotland** ● Winter soil cover and final seedbeds: I. Subject to sub-paragraph (2), where land has been cropped with any crop which has been harvested a farmer must ensure that throughout the winter following that harvest such land: (a) is covered by the stubble of the harvested crop, by another crop or by grass; or (b) has a surface which is ploughed, or roughly cultivated (by the use of discs or tines or otherwise). II. Sub-paragraph (1) does not apply to the extent that the prevailing agronomic or weather conditions and the condition of the composition of the soil of that land: (a) after harvest are such that compliance with that sub-paragraph would be detrimental to the use of the land for agricultural production; or (b) are such that they would indicate the planting of the following year's crop before the end of winter. III. Final seedbeds must only be created as shortly before the next crop is planted as possible to avoid significant evident erosion of the soil, taking account of prevailing weather conditions. **Wales** • Post-harvest management of soils (from harvest to 1 March). To combat erosion, we identified the largest risk as bare arable soils. We developed the standard that ensures that following harvest the soil is left with a vegetative cover or a rough cultivated surface so that rainfall can infiltrate to the soil and not run off the land carrying soil particles with it. • Burning of crop residues to combat organic matter decline, we identified the removal of cereal stubbles as the significant risk. We utilised an existing regulation, that of the Crop Residue (Burning) Regulations 1993, to ensure that arable stubbles return organic matter to the soil. • Waterlogged soils to combat structural degradation, we identified the use of

	machinery on waterlogged soils as the largest risk. We developed a standard that prevents harvest, cultivation and all vehicular activity on waterlogged soil, except under certain economically and environmentally justified circumstances.
GAEC relating to minimum land management reflecting site-specific conditions	
Germany	Same as minimum soil cover. *Following Exceptions can be approved by authority:* • *Farmers may plough land which falls within wind erosion hazard category CCWind within the meaning of Annex 2 and which is not covered by a special erosion protection funding scheme only where sowing takes place before 1 March.* • *With the exception of row crops, ploughing shall be permitted from 1 March only where sowing follows immediately. The ban on ploughing in the case of row crops shall not apply provided that green strips are sown at a maximum distance of 100 metres apart and with a width of at least 2.5 metres at right angles to the prevailing wind direction before 1 December or, in the case of potato cultivation, provided that the potato ridges are laid out at right angles to the prevailing wind direction and when weather conditions are not met.*
Spain	• For herbaceous crops: no ploughing in the direction of the slope on land with a gradient greater than 10% (except for terraced or benched farming). • For vineyards, olive groves and nut crops: no ploughing in the direction of the slope on land with a gradient greater than 15% (except for terraced or benched farming with labour for conservation or maintenance of a total vegetation coverage for the soil). • On terraced plots: avoid any kind of work which could affect the structure of the existing slopes and banks. The restrictions by the competent Administration to avoid degradation and loss of soil must be respected in areas with high risk of erosion.
Italy	• Annual realisation of run-off furrows for the collection of runoff water from sloping cultivated land, so that rainwater may cause as little damage as possible to soil surface. These furrows should be deeper than the normal ploughing depth. Alternatively, wherever soil characteristics may hamper the execution of the above mentioned furrows, because of instability problems for machinery operators, farmers should prevent soil erosion by leaving untilled ground streaks transversal to the maximum slope direction. • The land drainage system must be efficiently maintained. • Relevant soil-levelling operations must undergo an authorisation.
Poland	• In the case of arable land located on slopes with a gradient exceeding 20°, the land is not used for cultivation of plants which require maintaining ridges along the slope or the land is not maintained as bare fallow. • In the case of perennial plants plantations located on slopes with a gradient exceeding 20°, it is recommended to retain the plant cover or to mulch in inter-rows, or to cultivate on the basis of terraces.
Czech Republic	• Restriction on growing wide-row crops of maize, potatoes, beet, sown beans, soy and sunflower on land seriously endangered by erosion. • Cereals and rapeseed crops are to be planted on such areas using soil protective technologies, especially sowing into mulch or sowing without tillage.
France	• The requirements of this standard have been included in the GAEC 'buffer strips along water courses' falling within the compulsory standard 'Establishment of • buffer strips along water courses'. The standard 'minimum land management reflecting site-specific conditions' has been implemented at local level by prefectural decree by means of the GAEC 'Minimum land maintenance', 'Buffer strips along water courses' and 'Retention of landscape features'. • National standards: • Buffer strip obligation by water courses • All agricultural land and grassland should conform with density coherent to local tradition and a uniform soil cover that permits a good flowering. • Specific regulations for wine, olives, tomato plantations and fruit trees.
Hungary	• Same standards as with minimum soil cover • On arable land with a gradient steeper than 12%, the cultivation of the following crops is prohibited: tobacco, sugar beet, fodder beet, potato, and Jerusalem artichoke. • On arable land with a gradient steeper than 12%, there must be soil cover after the summer harvest and after the autumn harvest. Soil cover cane be: o sowing autumn crops, or

	o maintaining the stubble until 30 October - low stubble cleaning is allowed provided the stubble is kept weeded, or o applying a secondary planted cover crop.
Romania	• On arable land with row-plants and a gradient greater than 12% cultivation shall be along the level curves.
Slovakia	• Use suitable measures to prevent arable land from gully rill erosion with erosion gully rill exceeding 20 cm.
United Kingdom	**England** Same obligations as with as minimum soil cover apply here • In addition: Farmers must not overgraze (or allow to be overgrazed) the natural and semi-natural vegetation on their holding. They must also not carry out any unsuitable supplementary feeding practices which adversely affect the quality or diversity of natural or semi-natural vegetation through trampling or poaching of land by livestock, or ruts caused by vehicle used to transport feed **Northern Ireland** • (GAEC 2) Supplementary feeding on semi-natural habitats, archaeological sites, or within 10 meters from waterways, or 50 meters from a borehole or well, or 250 meters from any borehole used for a public water supply. • Supplementary feeding sites should be rotated and managed to prevent excessive trampling, poaching or vehicle rutting. • (GAEC 3) Damage to the growth quality or species composition of vegetation to any significant degree (that is where there is no vegetative cover and or there is evidence of run-off or standing water). **Scotland** Scottish GAEC 2: Wind erosion • In relation to an area of land prone to wind erosion of the soil, a farmer must reduce the risk of soil loss during the spring by planting and maintaining on or in relation to that field, until a crop is established in that area, (this can be: crop cover by another crop; coarse seedbeds; shelter belts; or nurse crops to protect other crops grown on the land, or taking other measures with equivalent effect to the establishment of one of those features. Scottish GAEC 3: Capping • In any field which is prone to capping, or where there is capping, a farmer must form a coarse seedbed or ensure that the farmer breaks any cap which forms so as not to cause erosion. • In this paragraph, "capping" means soil particles which run together when wet and dry so as to form a crust on the surface of the soil; and "cap" shall be construed accordingly. Scottish GAEC 4: Watercourses, watering points and feeding areas • A farmer must prevent the erosion of the banks of watercourses, at watering points or feeding areas from overgrazing or heavy poaching by livestock except: o within 10m of a gateway; or o within 3m of a farm track necessarily used during wet-periods, by reducing the livestock numbers on that land so as to cause the land to recover to the extent that the erosion is no longer significant by any time during the growing season in the calendar year following the date when that erosion first occurred. Scottish GAEC 5: Field drains • (1) Subject to sub-paragraph; • (2) a farmer must maintain any functional field drainage systems on the land in a working state (whether by clearing ditches or otherwise). Exceptions • (2) Sub-paragraph (1) shall not apply where an environmental gain would be achieved by not maintaining the field drainage systems provided the farmer has, prior to that system ceasing to function, declared the environmental gain to be achieved- o in the farmer's aid application under Article 22 of the Council Regulation; or o in any other prior application for a direct payment. Scottish GAEC 6: Muirburning • A farmer must comply with the requirements of the Muirburn Code (The code describes best practice and legal requirements when burning on moorland). **Wales** • Complete a soil assessment record annually and update regularly

	• Post harvest management of soils (from harvest to 1 March) • To combat erosion, we identified the largest risk as bare arable soils. We developed the standard that ensures that following harvest the soil is left with a vegetative cover or a rough cultivated surface so that rainfall can infiltrate to the soil and not run off the land carrying soil particles with it. • Burning of crop residues to combat organic matter decline, we identified the removal of cereal stubbles as the significant risk. We utilised an existing regulation, that of the crop residue (burning) Regulations 1993, to ensure that arable stubbles return organic matter to the soil. • Waterlogged soils to combat structural degradation, we identified the use of machinery on waterlogged soils as the largest risk. We developed a standard that prevents harvest, cultivation and all vehicular activity on waterlogged soil, except under certain economically and environmentally justified circumstances. • Overgrazing only applies to natural and semi-natural vegetation and continues an existing regime attached to previous livestock regimes. Tackles overgrazing that can result in soil erosion, soil compaction and contributes to increase risk of flooding. Overgrazing has been for many years the key reason why many upland Sights of Special Scientific Interests (including Natura 2000) have not been in favourable condition. • Supplementary feeding applies to natural and semi-natural vegetation and continues an existing regime attached to previous livestock regimes. It also covers feeding away from watercourses.
GAEC relating to crop rotations	
Germany	• Farmers must maintain soil organic matter. Farmers must show proof of an annual humus balance. If the humus level is below the reference level the requirements is still seen as met if the mean over three years is above the reference level. *OR* • Where the annual crop ratio on arable land comprises at least three crops, whereby set aside and uncultivated arable land count as one crop. Each crop shall cover at least 15% of the arable land. Where a farm has more than three crops, the minimum area share of 15% may also be attained by combining several crops. In doing so, the crops with an area share of less than 15% each may be divided up among other crops or where farmers who cultivate less than three crops and exchange their entire arable land with other farms each year prove that other crops were grown on the land currently being farmed by them in that year and in each of the two previous years.
Spain	No data
Italy	• The repeated cultivation of the same cereal (i.e. mono-cultivation) on a particular land parcel shall not last more than five years. • The turnover between two or more of the above mentioned crops is considered as a repetition of the same crop. Second-harvest crops (i.e. short-cycle tomato after barley then followed by barley again or any other cereal) are not considered as crop turnovers. In their implementing acts, Regions and Autonomous Provinces may require stricter terms for crop turnover, ranging from 2 to maximum 4 years. Exception • *Derogations are admitted only when a farmer may demonstrate, by means of official soil analysis results that no significant variation of soil organic matter levels occurred during the mono-cultivation period.*
Poland	• In the case of wheat, rye, barley and oat, the same plant species cannot be cultivated on the same area on the holding for more than 3 years *Exceptions can be authorised for 4th and 5th year (see comment).*
Czech Republic	• Restriction on growing wide-row crops of maize, potatoes, beet, sown beans, soy and sunflower on land seriously endangered by erosion. • Cereals and rapeseed crops are to be planted on such areas using soil protective technologies, especially sowing into mulch or sowing without tillage. • On at least 20% of arable land, must apply solid farm fertilisers or solid organic fertilisers to a minimum dose of 25 tonnes per hectare, with the exception of solid fertiliser from poultry farming, when the minimum dose is 4 tonnes per hectare. For the ploughing in of waste products from growing plants (e.g. straw) a minimum dose is not set. Or cover this area or a corresponding part from 31 May to 31 July of

	the relevant calendar year with legumes. Crops may be sown as an under-sow into the covering crop or mixed with grasses under the condition that the proportion of grasses does not exceed 50%.
France	• Obligation to plant at least three crops, each of which covering 5% or more of the cultivated soil. It is accepted that the smallest of the three crops (in terms of area) will only account for 3% at least of the soil cultivated. This 3% ceiling may be reached by adding the third crop and all the other crops whose area is less. • Farmers who plant at least 10% with leguminous vegetables or temporary grassland must plant two crops, one of which is a leguminous vegetable accounting for at least 10% of the soil cultivated OR two crops, one of which is temporary grassland accounting for at least 10% of the soil cultivated. If one leguminous vegetable or temporary grassland is the biggest crop, the lower limit is 3% for the second crop including the possibility of accumulating several diversification crops. OR • Maintain a winter cover or to manage the crop residues by grinding.
Hungary	• Rye, wheat, triticale, barley can be cultivated in 2 consecutive years; Maize and tobacco can be cultivated in 3 consecutive years; • The following crops can be cultivated for several consecutive years: multiannual horticultural crops, fodder crops, grass seed, apiculture crops, multiannual energy crops and rice; • All other crops can be cultivated only besides crop rotation. Exceptions: crop rotations where applicable
Romania	• The cultivation of sunflower on the same area for more than 2 consecutive years is forbidden.
Slovakia	• Must not cultivate the identical root crop in the same place two years consecutive.
United Kingdom	**England** • Requirements that farmers assess risks to their soils, record those risks and make arrangements to rectify any damage caused. A revised 2010 SPR form has been provided to all farmers which includes assessment of risk for access to waterlogged soils. Same measures as under Minimum soil cover. **Northern Ireland** • (GAEC 1) All cultivated land must have either crop cover, stubble cover, grass cover or be ploughed or disced over the following winter. Finely tilled seedbeds are not permitted over the winter. • Residues of Crops harvested late (after 1st November), such as maize and potatoes, must be left undisturbed until just before sowing the following spring. **Scotland** • Scottish GAEC 7: Arable break crops or the application of organic materials • On arable land cultivated for crop production, a farmer must either- o use suitable break crops to maintain organic matter in the soil in an arable rotation; or o optimise the application of organic materials to land by applying rates of application of the material calculated by reference to the requirements of the soil and crops grown. • Where a farmer uses the option specified at sub-paragraph (1)(b), the farmer must make and keep for 5 years a written record of the organic materials, and the quantities of those materials, applied to the land. **Wales** • Complete a soil assessment record annually and update regularly. The soil assessment record ensure that farmers assess the soil issue/damages on their farm annually and identify what action they will take to rectify the issue/damage.
GAEC relating to arable stubble management	
Germany	• The burning of stubble fields is prohibited. *Exceptions: When burnt for plant protection reasons and when the plant protection act requires and there is no risk of harmful effects on the natural balance (must be authorised by competent authority).*
Spain	• Must not burn stubble and cuttings. In the event that they are, due to phytosanitary reasons, this burning may be authorised by the competent authority, the rules established concerning fire prevention are complied with, and particularly, those relating to the minimum width of a perimeter border when the land plots are

	adjoining forest areas. • That when the remains of the harvest (herbaceous crops) and prunings (woody crops) are eliminated, this is done pursuant to established regulations
Italy	• Stubble burning is forbidden in arable crops, grassland and pastures. *Exceptions: In arable land, a derogation is recognised in regions having their own Acts regulating the periods and ways admitted for stubble burning, according to the local usage. The burning of stubble or other remains of annual crops is an old agronomical practice in some areas of southern Italy, where the combination of soil hardness and poverty in mineral nutrients justifies this operation, if appropriately done.*
Poland	• Burning of agricultural land is forbidden.
Czech Republic	• Prohibited to burn stubble
France	• Farmers with areas sown in cereals, oilseeds and protein crops must not burn arable stubble. Under a national derogation, areas sown in rice are excluded from this measure.
Hungary	• The burning of stubble, reed, crop residue and grassland is prohibited.
Romania	• Burning of stubble and plant remains Is not allowed on arable land
Slovakia	• It is prohibited to burn out harvest fields and to burn plant remainders after harvest of grain, legume and oily crops.
United Kingdom	**England** • Requirements that farmers assess risks to their soils, record those risks, record and make arrangements to rectify any damage caused. A revised 2010 SPR form has been provided to all farmers which includes assessment of risk for access to waterlogged soils. Same requirements as under Minimum soil cover. **Northern Ireland** • (GAEC 1) All cultivated land must have either crop cover, stubble cover, grass cover or be ploughed or disced over the following winter. Finely tilled seedbeds are not permitted over the winter. • Residues of Crops harvested late (after 1st November), such as maize and potatoes, must be left undisturbed until just before sowing the following spring. **Scotland** GAEC 8: Incorporation of livestock manures • Obligation to incorporate livestock manures spread on stubble into the soil within a period of 2 weeks after the date of spreading on a particular area of stubble. Exception: On wind erosion prone land **Wales** • Removal of cereal stubbles identified as a significant risk. • Existing regulation, the Crop Residue (Burning) Regulations 1993 is used to ensure that arable stubbles return organic matter to the soil.

Annex 6: Provisions for soil protection in non-EU countries

Country	Year	Legislative provision	Voluntary provision	Function	Relevance to soil
USA	1972	Clean Water Act		Setting quality standards for surface water	Indirect or none
	2008	Food conservation and Energy Act/U.S. Farm Bill		Addresses environmental impacts through land retirement for conservation, land and water stewardship, and farmland protection	Direct
	Various	State legislation and regulation, including State Department of Environmental quality Regulations and Permits		Environmental legislation – vehicle emission, crop residue burning regulations, permits requirements, record keeping, and reporting	Indirect
			Federal Conservation Programs	Contributed to reducing soil erosion, no-till planting, moisture conservation	Direct
			EQIP	Reduce nonpoint source pollution, conserve ground and surface water, reduce erosion and sedimentation, protect at risk-species habitat	Indirect
Canada	1985	Water Act (RSC, C-11)		Management of water resources, prevention of water pollution	Indirect (maybe)
	1985	Fertiliser Act		Regulates agricultural fertilisers	Direct
	1999	Canadian Environmental Protection Act		Pollution prevention, including nutrient pollution	Indirect (maybe)

Country	Year	Legislative provision	Voluntary provision	Function	Relevance to soil
	2008	Biofuels Act (Bill C-33)		Regulates blending of fuels and negative effects of biofuels	None
Russia	2001	Russian Land Code		Regulates use of land	Indirect
	2002	Federal Law on Agricultural Land Turnover (# 101-F2)		Regulates possession, use, and disposal of agricultural land parcels, environmental provision, including pollution	Indirect
	2006	Water Code of the Russian Federation (#74-FZ)		Addresses use and protection of water sources	Indirect or none
Ukraine	1991	Law on environmental Protection		Basic provisions for environmental protection, rational use of natural resources	Indirect (maybe)
	1995	Law on Pesticides and Agrochemicals		Regulates use of pesticides and fertilisers, requires restriction on these chemicals.	Indirect
	1998	Land code of Ukraine, 25.10.2001 # 2768-III		Provides for land ownership and use, including agricultural use	Indirect (maybe)
Brazil	1988 2005	Sao Paulo State Law 6171, Updated Law 11970		Soil conservation in agriculture	Direct
	1989	Law No. 7802 on Agricultural Chemicals and Like-Substances		Substances must be registered with relevant federal agency and use must follow specific directives and requirements for health, environment, and agriculture	Indirect
	2002	Sao Paulo State Law 11241		Phase out sugarcane burning by 2021	Indirect
	2008	Sao Paulo State Law SMA-SAA		Agro-ecological zoning for sugarcane	Indirect

Country	Year	Legislative provision	Voluntary provision	Function	Relevance to soil
	2009	Presidential Decree 6961(2009)		Agro-ecological zoning for sugarcane and ethanol mills	Indirect
			Green Certificate Program	Certifies plantations and ethanol plants that do not burn sugarcane fields	Indirect
			About 140 mills associated with Brazilian Sugarcane Industry Association (UNICA)	Awarding good practices in sugarcane sector	Indirect (maybe)
Argentina	1992	Hazardous Waste Law 24.051 (Decree 831/93), (Decree 776/92): Water Preservation and control of Pollution		Regulation of generation, handling, transport, and treatment of a wide range of substances detrimental to living beings, and pollute the soil, water, air, or the environment	Indirect (maybe)
	1994	Reformed Argentine Constitution		Provides for protection of the environment, sustainable development, sustainable use of resources, environmental education and information, protection of biodiversity,	Indirect (maybe)
	2000	Provincial Law 7070		Provincial environmental law requiring permits and environmental assessments for land clearing and agriculture	Indirect

Country	Year	Legislative provision	Voluntary provision	Function	Relevance to soil
			AARESID, No-Till Farmers Association	Soil conservation by adopting no-till farming system, increasing carbon sequestration.	Direct
Paraguay	1993	Law on Environmental Impact Assessment (Law 294)		Outlines process and conditions for conducting environmental impact assessment	Indirect (maybe)
	2000	Law 1561, Creating the National Environmental System, National Environmental Council, and Office of the Secretary of the Environment		Provides for basic environmental principles and oversight	Indirect (maybe)
	2004	Decree Regulating the Use and Management of Pesticides for Agricultural Use		Regulates use and management of agricultural chemicals	Indirect
Indonesia	1992	Law 12/1992 on Cultivation of Plants		General provisions for sustainability, including water us (Art.19), pesticides (Art. 38), and spatial planning (Art. 45-46)	Indirect (maybe)
	2004	Law 18/2004 on Plantations		Regulates land utilisation (Art. 9-12), and requires environmental impact assessment for plantation activities (Art. 25)	Indirect

Country	Year	Legislative provision	Voluntary provision	Function	Relevance to soil
	2009	Ministerial Decree on Agriculture (14/Permentan/PL110/2/2009) Guidance on Oil Palm Plantation on Peatland		Allows planting of oil palm on peatland if (a) on community land, (b) peatland that has a depth of 3 meters, (c) the subsoil under the peatland is not silica sand or acid sulfate soil, (d) the maturity of soil is sapric and (e) peatland is eutropic	Direct for peatlands
Malaysia	1960	Environmental Land Conservation Act 1960 (revised in 1989 – Act 73)		Conserve hill lands to prevent soil erosion	Direct
	1987	Environmental Quality (environmental Impact Assessment) order		Establishes process for environmental impact assessment, determining site suitability. An EIA is required when new land covering 50 ha or more is converted to oil palm	Indirect
	1996	Conservation of Environment Enactment (No. 14 of 1996)		Provides for conservation of or prevention of injury to the natural resources. Relates to conservation areas, control of cultivation, and protection of water and other resources.	Indirect (maybe)
	1998	Third Amendment to Environmental Quality Act		Complete ban on open burning to clear vegetation for oil palm plantations	Indirect

Country	Year	Legislative provision	Voluntary provision	Function	Relevance to soil
	2002	National Policy on the Environment		Includes principles of environmental stewardship, conservation, and sustainable use of natural resources	Indirect
Tanzania	1994	National Environmental Action plan		Reducing land degradation and deforestation, access to quality water, reducing pollution and loss of wildlife habitat and biodiversity, and reduction of the deterioration of marine and fresh water systems	Indirect
	1997	National Environmental Policy		Reducing agricultural runoff, water management and forestry, environmental impact assessments, prevention and control of land degradation, water, vegetation and air.	Indirect
	1997	Agriculture and livestock policy		General policy for managing agriculture, including effects of agrochemicals and land use	Indirect
	2000	National Biodiversity Strategy and Action Plan		Strategy for agro-biodiversity and priority action.	Indirect

Source: information from Winrock International

Annex 7: Water risks in the EU

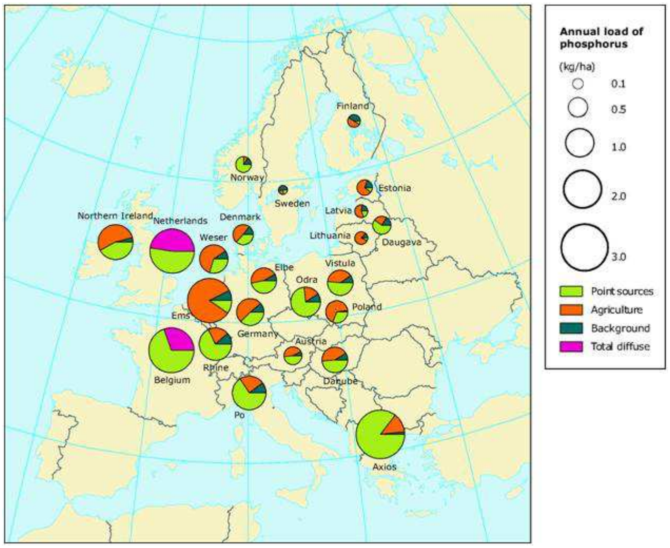

Figure 16: Annual phosphorus discharges by source

Source: EEA, 2005

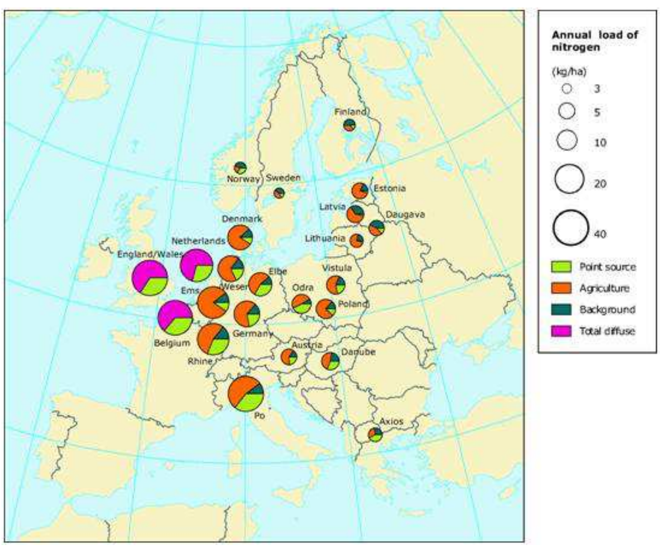

Figure 17. Annual nitrogen discharges by source

Source: EEA, 2005

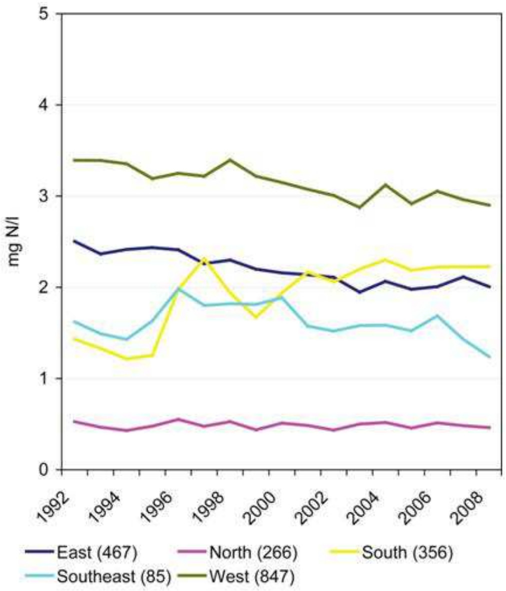

Figure 18: Nitrate concentrations in rivers between 1992 and 2008 in different geographical regions of Europe

Source: EEA,2010

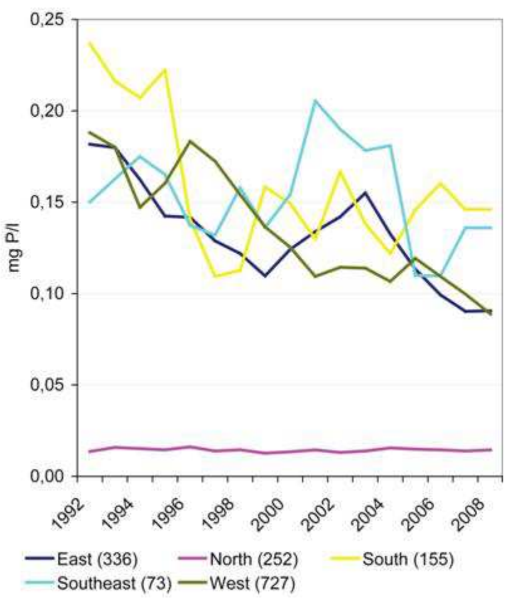

Figure 19: Phosphorus concentrations in rivers (orthophosphate) between 1992 and 2008 in different geographical regions of Europe

Source: EEA, 2010

Annex 8: Air quality impacts from biofuel crop production

Detailed assessment by crop and region:

Rapeseed (for 4,530kTOE EU biodiesel, primarily from the EU, Ukraine, Canada, and Russia)

Rapeseed production may produce air pollution such as dust from land preparation and erosion of post-harvest, uncovered soils. Rapeseed protection is based on chemical weed, pest and disease control and rapeseed has high nutrient requirements. There are therefore potential risks associated with the volatilisation of these compounds depending on the nature of application processes. At the processing facility, air emissions may come from sorting and processing seeds and VOCs from product storage.

Rapeseed is widely grown throughout the EU (in all but three Member States) covering more than 60% of the area covered by oil crops. Rapeseed has relatively high nutrient requirements with winter rapeseed having one of the highest demands for nitrogen fertiliser. As a consequence, there is a high potential of nitrogen emissions associated with production, depending upon the effectiveness/efficiency of fertiliser application.

In Ukraine and Russia, due to the state of agriculture, there is less modern and less efficient technology used for farming compared to much of the EU. Industrial infrastructure is aging and energy inefficient (UN, 2007) and since the 1990s, fertiliser and agrochemical use decreased significantly. In Ukraine, between 2003 and 2008 there was a sharp increase in area used to grow rapeseed (from 54,000 ha planted in 2003 to 1.2 million in 2008) (European Communities, 2009). However, it is a risky crop to grow in Ukraine and planted area has again decreased.

Canada's rapeseed (Canola) is grown in the Western Prairie regions. Agriculture in Canada has become increasingly more resource efficient, resulting in relatively low fertiliser emissions.

To the extent possible, these risks for each region are categorised as high, medium, and low in the following table.

Table 37: Potential risks from rape cultivation

		Key risk factors linked to practices and processes				
	Planted area used for EU biodiesel supply 2010	**Land Preparation and Post-harvest**	**Cultivation**	**Harvest**	**Transport.**	**Processing**
EU 27		Risk associated with emissions primarily of particulates during ploughing and establishment Will depend on the nature of the soil and climatic conditions and potential adoption of low till systems	High risk associated with emission of nitrogen compounds and volalilisation of chemicals if not appropriately applied or stored	Potential emissions of particulates depending on approach to harvest and treatment of residues	Difficult to assess as it is not specific to rapeseed impacts. Will depend on emissions from transport and distance to processing plant for which there is no data.	Handling, storage, and processing emissions
France	618,732ha 3.2% of cropland 42.2% of rapeseed planted area					
Germany	595,438ha 5% of cropland 41% of rapeseed planted area					
Poland	176,393ha 1.3% of cropland 23% of rapeseed planted area					
Czech Republic	175,566ha 5.4% of cropland 47.6% of rapeseed plantings area					
UK	80,998 ha 1.3% of cropland 12.4% of rapeseed planted area					
Ukraine	262,779ha 0.8% of cropland 30.5% of rapeseed planted area	Risk associated with emissions primarily of particulates during ploughing and establishment Will depend on the nature of the soil and climatic conditions and potential adoption of low till systems.	Within the feedstock production, most air pollution associated with fertilisers. Fertiliser and agrochemical use is low. Tillage practices unknown	Machinery used is old and inefficient.	Difficult to assess as it is not specific to rapeseed impacts. Will depend on emissions from transport and distance to processing plant for which there is no data.	Energy inefficient industries that use aging equipment.
Forest Steppe						
Steppe						

	Planted area used for EU biodiesel supply 2010	Key risk factors linked to practices and processes				
		Land Preparation and Post-harvest	**Cultivation**	**Harvest**	**Transport.**	**Processing**
		Likely to replace other crops.				
Canada *Saskatchewan (42%)* *Manitoba (21%)* *Alberta (36%)*	207,393 ha 0.4% of cropland 3.2% of rapeseed planted area	Some areas of PM concentrations associated with land preparation.	Low fertiliser emissions in rapeseed growing regions. Increasingly using more efficient fertiliser application and production methods. Some areas have med-high PM from wind erosion. High prevalence of no-till and conservation tillage.	Some areas of med-high PM associated with harvest practices.	Difficult to assess as it is not specific to rapeseed impacts. Will depend on emissions from transport and distance to processing plant for which there is no data.	Handling, storage, and processing emissions
Russia *Orel Region* *Krasnodar Region* *Rostov Region (13%)*	128,662ha 0.1% of cropland 21.2% of rapeseed planted area	Unknown	Conventional cultivation equipment used, which is in poor condition. Agrochemical usage unknown	Conventional harvest equipment is used which is in poor condition (FAS, 2005).	Difficult to assess as it is not specific to rapeseed impacts. Will depend on emissions from transport and distance to processing plant for which there is no data.	Handling, storage, and processing emissions

Soybean (for 2,216kTOE EU biodiesel, primarily from Argentina, Brazil, United States, Paraguay)

In many countries, soybean residues are burned post-harvest, which is a high level threat for air quality because of the smoke and particulate matter which may lead to respiratory problems and cause haze. There is no burning in Argentina, but there is some in Brazil, the United States, and Paraguay. Dust may also be generated from removal of vegetation to clear lands for initial crop production, from tillage, from vehicle or machine exhaust in cultivation and harvest, from transport on dry roads, and from handling soybeans and mechanical extraction of the oil at the soybean oil processing stage. Other air pollutants come from machine and vehicle exhaust, fertiliser production and application, and soybean storage.

The risk to air quality depends on how many of these practices are employed, especially whether residues are burnt. This may be mitigated through burning alternatives and regulations controlling the timing when burning takes place. Pesticide spraying near communities can also have significant health impacts to those exposed, which is concern in some parts of Argentina (Tomei, 2009).

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Table 38: Potential risks from soybean cultivation

		Key risk factors linked to practices and processes				
	Planted area used for EU biodiesel supply 2010	**Land Preparation and Post-harvest**	**Cultivation**	**Harvest**	**Transport.**	**Processing**
Argentina *Pampas*	867,795ha 2.7% of cropland 4.8% of soybean planted area	No burning.	Highly mechanised. 85% no till. Pesticide spraying. Mineral fertiliser applied to 30% of area.[51]	Highly mechanised	Unknown	Handling, storage, and processing emissions
Brazil *South-Central* *Centre-West*	300,353ha 0.4% cropland 1.3% soybean planted area	Burning is practiced, although decreasing.	Mineral fertiliser used.[52] More than half grown under no-till.	Mechanisation	Unknown	Handling, storage, and processing emissions
USA *Midwest* *Central Atlantic* *Delta*	160,127ha 0.1% of cropland 0.5% of soybean planted area	Some burning.	Use of machinery, but generally reduced tillage. Mineral fertiliser used.[53]	Mechanised harvest.	Unknown	Processing soybean oil.
Paraguay *Alto Parana (30%)* *Canindeyu (22%)* *Itapua (20%)* *Caaguazu (12%)*	140,376ha 3.5% of cropland 5.3% of soybean planted area	Rapid expansion, some into forest, including through slash and burn of forest (until 2004). Burning unknown	Fumigation of plantations reported health concerns. Mineral fertiliser use 80% produced under no-till.	Practices unknown	High fossil fuel requirements for transportation and for exporting.	Paraguayan soybeans are exported as beans and not processed in country.

[51] In 2002/3, the average fertiliser application where applied, according to FAO, was 2kg/ha N, 6kg/ha P, and no K.

[52] In 2002, according to the FAO, the average fertiliser application for soybeans in Brazil was 8kg/ha N, 66kg/ha P, and 62kg/ha K.

[53] 70% of area used fertiliser in 1998. Those areas applied 30kg/ha N, 60kg/ha P, and 95kg/ha K. *Reference: Fertistat.*

Palm oil (for 976kTOE EU biodiesel, primarily from Indonesia and Malaysia)
In 2010, the EU increased its use of biodiesel from palm oil grown in Indonesia and Malaysia. The most significant potential air quality risks associated with this production have to do with burning (to clear lands and unintentional burns resulting from peatland drainage and deforestation), resulting in haze and health hazards. Burns in Indonesia cause severe haze in nearby countries that have partially motivated international response. Other serious air impacts may occur from agrochemical application, especially for workers applying the chemicals, and palm oil processing emissions (ash from nut/fibre separation, smoke and soot and other pollutants from the flue boiler, smoke from burning EFBs, and effluent emissions). Processing occurs relatively near to the oil palm trees so the transportation emissions are relatively low.

Table 39: Potential risks from oil palm cultivation

		Key risk factors linked to practices and processes				
	Planted area used for EU biodiesel supply 2010	**Land Preparation and Post-harvest**	**Cultivation**	**Harvest**	**Transport**	**Processing**
Indonesia	56,672ha 0.1% of cropland 1.1% of oil palm planted area	Planned and unintentional burnings. Replanting to replace forest or old rubber or oil palm stands traditionally involves felling and burning (Crop Life International, 2005). Mechanisation of land clearing. Plantings may replace forest.	Agrochemical application.	Manual	Short distances	Ash, smoke, soot, effluents, etc.
Sumatra	*80% of total plantings*					
Kalimantan	*17%*					
Malaysia	11,954ha 0.2% of cropland 0.3% of oil palm planted area	Planned and unintentional burnings. Replanting to replace forest or old rubber or oil palm stands traditionally involves felling and burning. Zero-burning replanting techniques becoming more prevalent (Crop Life International, 2005). Some mechanisation of land clearing. Plantings may replace forest.	Agrochemical application, although on average, more efficient application compared with Indonesia.	Manual	Short distances	Ash, smoke, soot, effluents, etc.
Peninsular Malaysia	*56% of total plantings*					
Sabah	*35%*					
Sarawak	*9%*					

Sugar beet (for 735kTOE EU bioethanol, primarily from the EU)

Sugar beet is produced in commercial quantities in 19 of the EU-27 Member States. The greatest areas under beet production are found in Germany and France, with the greatest planted area found in Germany. Sugar beet is a root crop, meaning that it requires significant disturbance to extract it from the soil during harvest, hence the potential risks associated with wind erosion. This may also be exacerbated by its tendency to prefer relatively light/medium soils.

In terms of fertiliser requirements, sugar beet is highly demanding depending on soil and preceding crop type. Herbicides and fungicides are used to control weeds and disease during early stages of development.

Table 40: Potential risks from sugar beet cultivation

		Key risk factors linked to practices and processes				
	Planted area used for EU biodiesel supply 2010	**Land Preparation and Post harvest**	**Cultivation**	**Harvest**	**Transportation**	**Processing**
EU 27		Dust from establishment of crops due to wind erosion of soils esp given sugar beet's preference for light soils	Herbicide and fungicide application esp at early growth stages Potentially intensive fertiliser demands depending on previous rotation and soil fertility, hence risk of nitrogen compound emissions.	Emissions from harvest machinery. Particulate emissions due to the need to harvest a root crop (hence soil particulates and potential for wind erosion) and practice of ploughing back in top portions of the crop	Difficult to assess, not specific to sugar beet, impact will depend on emissions from transport and distance to processing plant for which there is no data	
France	59,516ha 0.3% of cropland 15.5% of sugar beet planted area					
Germany	20,525ha 0.2% cropland area 5.6% of sugar beet planted area					
Italy	7,357ha 0.1% of cropland 11.7% of sugar beet planted area					
UK	1,037ha 0.0% of cropland 0.2% of sugar beet planted area					

Wheat (for 623kTOE EU bioethanol, primarily from the EU)

Wheat[54] is widely grown across the EU in all 27 Member States with the largest areas under cultivation in France, Germany, Poland, Romania and the United Kingdom.

Wheat is highly susceptible to pests and diseases, particularly during the early growing phases. Seed treatment can be an effective means of preventing diseases during early stages but the application of pesticides and herbicides are required throughout the early growing season.

In general terms winter wheat requires more nitrogen fertiliser than summer wheat. Winter wheat grown for good quality grain production has greater nitrogen requirements than winter wheat grown for other purposes.

Table 41: Potential risks from wheat cultivation

		Key risk factors linked to practices and processes				
	Planted area used for EU biodiesel supply 2010	Land Preparation and Post-harvest	Cultivation	Harvest	Transportation	Processing
EU 27		Dust during ploughing of land for crop establishment	Application of fertilisers leading to emission of nitrogen based compounds – particularly high for winter wheat Application of pesticides and herbicides particularly early in the season	Wind erosion and production of particulates during harvest esp if ground left uncovered/ stubble removed Burning of straw/stubble	Difficult to assess, not specific to wheat, impact will depend on emissions from transport and distance to processing plant for which there is no data	
France	101,748ha 0.5% of cropland 1.9% of wheat planted area					
Spain	26,812ha 0.2% of cropland 1.4% of wheat planted area					
Poland	22,618ha 0.2% of cropland 0.9% of wheat planted area					
Czech Republic	17,164ha 0.5% of cropland 2.1% of wheat planted area					

[54] A large variety of wheat is grown in the EU however the two most important varieties are common wheat (Triticum vulgare) and hard wheat (Triticum durum).

Maize (for 490kTOE EU bioethanol, primarily from the EU and US)

Being a photophilic (light demanding) crop it is important to ensure that maize plants are grown sufficiently far apart in order to allow light to reach each plant equally. This results in relatively wide row widths, which have implications for exposed soils at risk of erosion.

Weed reduction in maize is carried out by both mechanical and chemical means. Disease control is recommended through the use of rotations and effective crop management, but may also be dealt with using chemical products.

In some locations, the stubble remaining after corn harvest is burned.

Maize is grown in significant quantities in only 18 of the 27 EU Member States with Romania, France and Hungary having the most planted area. Maize is the main source of bioethanol produced in the United States, of which the EU imported significant quantities in 2010. In terms of fertiliser requirements, maize requires half of the total amount of its nitrogen demand in the period from flowering to full maturity. However, the application of fertilisers depends on soil fertility, nutrient content, moisture content, the aim of production and the expected level of yield. For example nitrogen collection depends on the temperature.

Table 42: Potential risks from maize cultivation

		Key risk factors linked to practices and processes				
	Planted area used for EU biodiesel supply 2010	**Land Preparation and Post-harvest**	**Cultivation**	**Harvest**	**Transportation**	**Processing**
EU 27		Dust during ploughing of land for crop establishment. Residue burning.	Row crop – therefore potential for wind erosion, especially given its preferred habit i.e. relatively high temperatures, hence particulates Emissions of nitrogen compounds linked to fertilisation Agro chemical application Potential particulates due to need for ploughing and harrowing during	Wind erosion leading to particulates if land is left uncovered i.e. stubble removed and no cover crop Emissions from machinery harvesting the crop	Difficult to assess, not specific to maize, impact will depend on emissions from transport and distance to processing plant for which there is no data	
France	27,658ha 0.1% of cropland 1.8% of maize planted area					
Poland	21,881ha 0.2% of cropland 7.3% of maize planted area					
Spain	8,111ha 0.0% of cropland 2.5% of maize planted area					

		Key risk factors linked to practices and processes				
	Planted area used for EU biodiesel supply 2010	Land Preparation and Post-harvest	Cultivation	Harvest	Transportation	Processing
			establishment stages leading to bare soils.			
United States *Midwest (62%)* *South* *- Northeast*	33,342ha 0.0% of cropland 0.1% of maize planted area	Dust during ploughing of land for crop establishment and other machinery for land preparation. Some residue burning	Wind erosion of exposed soils between rows. Seeding machines make insecticides airborne and threaten bees. Emissions of nitrogen compounds linked to fertilisation Agro chemical application Potential particulates due to need for ploughing and harrowing during establishment stages leading to bare soils.	Mechanised harvest. Wind erosion from uncovered lands	Difficult to assess, not specific to maize, impact will depend on emissions from transport and distance to processing plant for which there is no data	Chemicals and particulate matter from the processing facility.

Sunflower (for 438kTOE EU biodiesel, from the EU)

Fourteen Member States in the EU grow sunflowers in significant quantities with the main areas of production largely confined to southern and Mediterranean Member States. However, there are significant areas of production in the Czech Republic and Romania as well. As a row crop, sunflowers present a greater risk of erosion during establishment and growth, assuming cover crops or other soil management techniques are not applied.

Sunflowers are nutrient demanding, and in comparison to rapeseed require almost twice as much nitrogen and potassium which increases the potential for N2O release.

Table 43: Potential risks from sunflower cultivation

		Key risk factors linked to practices and processes				
	Planted area used for EU biodiesel supply 2010	**Land Preparation and Post-harvest**	**Cultivation**	**Harvest**	**Transportation**	**Processing**
EU 27		Dust during ploughing of land for crop establishment – although on-going risk will depend on whether annual or perennial crops are grown	Row crop – therefore potential for wind erosion, hence particulates Harrowing during early establishment potentially leading to soil disturbance and wind erosion Emissions of nitrogen compounds linked to fertilisation Agro chemical application esp at early stages of production	Application of chemicals for artificial desiccation process to allow drying ahead of on phase harvesting Particulates from wind erosion if soil left uncovered Emissions from harvest machinery	Difficult to assess, not specific to sunflower, impact will depend on emissions from transport and distance to processing plant for which there is no data	
France	314,219ha 1.6% of cropland 45.2% of sunflower planted area					
Spain	32,392ha 0.2% of cropland 4.6% of sunflower planted area					

Sugarcane (for 336kTOE EU bioethanol, primarily from Brazil)

Despite significant changes to harvesting green cane, in many sugar cane growing regions burning pre-harvest is the dominant source of air pollution. Other air pollution may come from agricultural activities, such as dust generated from removal of vegetation or tillage, fertiliser emissions, and exhaust from vehicles and machinery. Additionally, sugar mills and ethanol refineries using bagasse boilers emit particulate matter and NOx with the amount dependent on their technology (older plants tend to be worse than newer plants).

Whether pre-harvest burning is practiced is the main factor in determining air quality risk, which may cause health problem due to the particulate matter. Tsao (2012) carried out a lifecycle analysis of sugarcane ethanol air emissions in Brazil, producing calculations of the amount of air emissions from key life cycle activities. The results are shown in the following figure and indicate burning is the dominate source of most air pollutants.

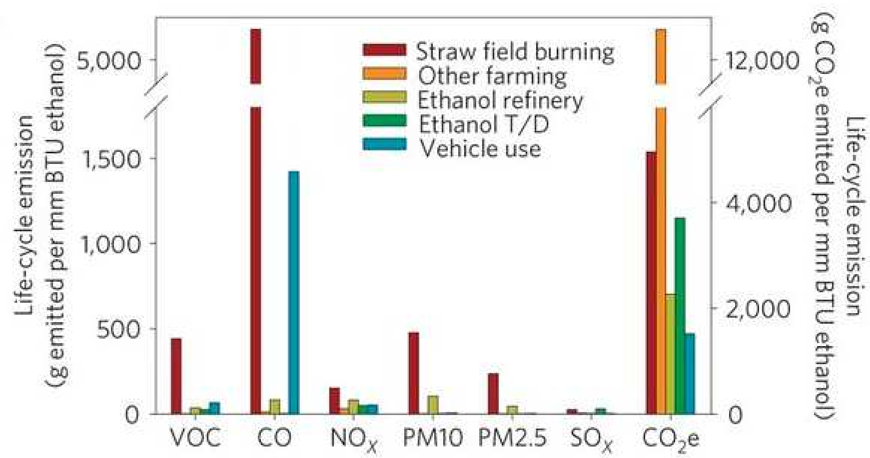

Figure 20: Lifecycle air emissions from sugarcane ethanol in Brazil (Tsao, 2012)

Table 44: Potential risks from sugarcane cultivation

		Key risk factors linked to practices and processes				
	Planted area used for EU biodiesel supply 2010	Land Preparation and Post-harvest	Cultivation	Harvest	Transportation	Processing
Brazil	73,959ha 0.1% of cropland 0.8% of sugarcane planted area	Unknown	Conventional Tillage dominant. Mineral fertiliser applied.[55]	In 2007, 40% no burn harvest in the State of Sao Paulo. This was forecast to reach 50% in 2010 (Goldemberg, 2008). Some mechanised harvest	Short transportation distances from field to processing.	
South-Central	90% of sugarcane produced					
Northeast	10%					
Guatemala	44,000ha 20.7% of sugarcane	Unknown	Some mechanisation. Tillage, fertiliser, and pesticide practices unknown, but assumed present.	Burning is a common pre-harvest practice.	Short transportation distances from field to processing.	12 mills close to the main port
Tanzania	Unknown	Unknown	Low fertiliser use. Tillage, pesticide, and other cultivation practices unknown.	Burning is a common pre-harvest practice.	Short transportation distances from field to processing.	
Central						
Northwest						

[55] In 2002, according to the FAO, the average fertiliser application for sugarcane in Brazil was 55kg/ha N, 51kg/ha P, and 110kg/ha K.

Rye (for 81kTOE EU bioethanol, primarily from the EU)

Rye for EU biofuels is grown mostly in northern EU Member States, with Germany, Poland and Denmark producing the greatest annual quantity. However the greatest areas sown to Rye crops are from Germany, Poland and Spain.

Rye can suffer from a large number of diseases during the growing phase and as such requires the application of disease prevention chemicals prior to sowing. Fertiliser requirements for Rye depend on a range of factors such as soil quality, weather conditions, the production technology and the expected or desired yield.

Table 45: Potential risks from rye cultivation

		Key risk factors linked to practices and processes				
	Planted area used for EU biodiesel supply 2010ǂ	**Land Preparation and Post-harvest**	**Cultivation**	**Harvest**	**Transportation**	**Processing**
EU 27		Dust during ploughing of land for crop establishment	Fertiliser application hence nitrogen compounds, however more adaptable than other cereal varieties to different conditions. Application of agro chemicals	Emissions associated with harvest machinery Particulates from exposed soil due to wind erosion	Difficult to assess, not specific to rye, impact will depend on emissions from transport and distance to processing plant for which there is no data	
Poland	1,395,600ha 3.9% of rye planted area					
Germany	52,670ha 8.4% of planted rye area					

ǂ The method used to calculate the areas used for biofuels in the EU are calculated different from the other crop tables. In this table, the values have been calculated with a simplified methodology based on estimating the areas of rye needed to produce the quantities of biodiesel imported from Poland and Germany using an average yield.

Detailed provisions for air quality risks in the EU

In step 2, the risks to air considered to be medium to high in the EU were primarily emissions from nitrogen compounds and facilities for processing oil and biofuels, as well as some potential burning.

Within the EU agricultural production is considered to be a significant source of PM10 emissions (accounting for approximately 300Gg/year in 2008 (EEA, 2011)) and of ammonia emissions (according to EEA figures, accounting for 94% of EU emissions in 2009). PM10 rural baselines contribute significantly to overall EU peaks in PM10 concentrations. In terms of crop production, this could be linked to wind erosion and the generation of particulates due to the exposure of high risk soils (i.e., light soils, with relatively low organic matter content). Additionally, for certain crops there were air risks related to the harvesting of root crops (sugar beet), early application of pesticides and herbicides (wheat), wind erosion from exposed soils for row crops, residue burning (maize) and chemical application for pre-harvest drying (sunflower).

To limit overall emissions of key air pollutants, the National Emission Ceilings Directive (Directive 2001/81/EC) was adopted, which set ceilings which Member States were to comply with by 2010. Compliance with the 2010 deadlines was mixed. Nitrogen oxides were the pollutant for which most exceedances of national ceilings were found, with eleven Member States failing to respect the ceilings: Austria, Belgium, Denmark, France, Germany, Ireland, Luxembourg, Malta, Netherlands, Spain and Sweden. Concerning NMVOCs, Spain and Germany failed to meet their specific ceilings. For ammonia, Spain and Finland exceeded the limits. Once the ammonia ceilings are complied with, there is no air quality objective (see below) for this pollutant and, beyond specific concerns for biodiversity protection, no further immediate policy driver to reduce ammonia. However, the Commission is to review air protection policy in 2013 and this will include the National Emission Ceilings Directive (although agreement on a revision to the Directive has been impossible to achieve through repeated attempts since 2005).

Regulation of air emissions from crop production:
Within the EU support for agricultural activities is calculated according to the area of land farmed, irrespective of the type of production, through a Single Farm Payment. In order to ensure a minimum level of protection for the environment, the system of cross-compliance requirements was introduced where by farmers receiving the SFP must comply with certain requirements or face a reduction/complete loss of payments. Cross-compliance requirements comprise two distinct elements. Firstly, a suite of Statutory Management Requirements (SMRs), which are based on selected articles from 19 pieces of pre-existing items of EU legislation, such as the Birds Directive (79/409/EEC; IEEP, 2012a) and the Nitrates Directive (91/676/EEC; IEEP, 2012b), whose implementation is required in all 27 Member States. Secondly, a set of standards of Good Agricultural and Environmental Condition (GAEC), which are additional requirements relating to soil erosion, soil structure, soil organic matter and the minimum maintenance of habitats but which are determined at the country level.

In terms of the protection of air quality during cultivation cross compliance provides the primary regulatory mechanisms for the protection of air. In the context of this analysis this would need to consider the core areas of concern in terms of production set out above i.e. emissions linked to application of agro-chemicals, protection of soils from wind erosion and prevention of emissions to air of nitrogen based compounds.

Importantly, cross compliance requires compliance with specific Articles of the Nitrates Directive. Although intended for the protection of watercourses, this actually offers one of the key mechanisms for controlling the application of nitrogen based material to land, hence overall quantities of nitrogen compounds applied. However, it should be noted that controls focus on nitrate vulnerable zones based on the assessment of water risk. The effectiveness of this measure in controlling emissions from manure and fertilisers to air is therefore limited to where this overlaps with water concerns.

More generally, GAEC requirements do consider soil management including management of crops to minimise exposure of soils and wind erosion and stubble management (including prohibition of burning) (European Commission, 2007). However, GAEC is determined at the national level meaning that the management requirements relating to air emissions vary.

Regulation of air emissions from industrial plants: The protection of air quality is highly regulated at the EU level, in particular that from industrial plant given the potential impact upon the internal market of different Member States operating to different standards of environmental protection. Large scale EU biorefineries in the EU would be covered by the requirements of the Industrial Pollution Prevention and Control Directive (EC, 2008a), to be replaced by the Industrial Emissions Directive (EC, 2010) as of January 2014. Biorefineries are covered under the following category of industrial plant within the relevant Directives (i.e., Annex 1, 1.4 Gasification or liquefaction of: (a) coal; (b) other fuels in installations with a total rated thermal output of 20 MW or more). Under the auspices of the Directives such installations would receive an environmental permit from the relevant Member State controlling their emissions to air (water and land).

For smaller scale plants (<50MW thermal output), the EU does not set direct regulatory requirements (although the DG ENV is currently examining possible future regulatory frameworks for combustion plants below 50MW). However, air quality limit values established under the Air Quality Framework Directive (EC, 2008b) have to be complied with by Member States. If emissions from installations threaten to exceed air limit values (whether covered by IPPC/IED or not), then Member States would need to take appropriate control measures. To date, a number of Member States have had problems complying with PM10 and NO2 limit values. However, much of this compliance problem is driven by transport emissions rather than from stationary installations. The Commission is currently taking enforcement action against a number of Member States on this issue.

For small plants dealing with waste processing, additional requirements will apply requiring the management of emissions from processing and storage. At the EU level the overarching principles of permitting and control are set out in the Waste Framework Directive (EC, 2008c). However, specific approaches to the application of environmental permits would be left up to the Member State based on an assessment of risk. In the UK, as an example, Waste Management Licensing Regulations (EP Regulations) would be applicable, whereby small-scale plants (<5,000 litres of waste cooking oil) are deemed low-risk and hence exempted (Defra, 2008).

Detailed provisions for air quality risks outside of the EU

The highest risks in the non-EU countries in this study are related to burning: burning to clear and prepare land, burning of residues, pre-harvest burning of sugarcane, and accidental burns resulting from land clearing. Burning is associated with soybeans, palm oil, maize, and sugarcane. Additional high risks are pesticide and agrochemical spraying; wind erosion, especially in row crops; feedstock processing, especially where industry is inefficient, equipment is aging, and environmental controls of the plants may be absent; intensive use of cultivation and harvest machinery, especially where the machinery may be aging and inefficient; nitrogen compounds and other emissions associated with fertiliser; and areas where the crops are produced on land that was converted from forests or high vegetation land cover.

The table below shows each of the non-EU countries' medium and high risks and which legislative measures may address them along with the potential to enforce that. Potential to enforce is based on Transparency International's Corruption Perception Index, the Global Integrity Report's Global Integrity Index, the Economist Intelligence Unit's Democracy Index, and the World Justice Department's Rule of Law Index's Regulation Enforcement score. The ranking of 'low' is given if two or more of the indicators are below 50% the score, 'high' is two or more above 80% of the score, and 'medium' is everything else. See the section on existing provisions for a more in depth explanation of the provisions.

Table 46: Non-EU countries' medium and high risks and legislative measures

Region	Threat	Existing provisions addressing threat	Potential to enforce	Effect on overall threat level
Argentina (1,198kTOE)	Highly mechanised cultivation and harvest of soybeans and aerial spraying of agrochemicals	-General Environmental Law -Roundtable on Responsible Soy (voluntary sustainability certification) -SAN/RA (voluntary sustainability certification) -AAPRESID (national voluntary sustainability certification)	Medium	**Remains the same** (for production covered by voluntary certifications, threat is reduced, but this is a small fraction)
	Soybean oil processing facilities	-General Environmental Law		**Remains the same**
Indonesia (774kTOE)	Planned and unintentional burnings.	-Ministry of Forestry and Plantation Revolved Letter No.603/Menhutbun-VIII/2000 joint MoF Letter No. 1712/Menhut-VII/2001 -ISCC, SAN/RA, and RSPO (voluntary sustainability certifications)	Medium	**Remains the same**
	Agrochemical application	-1992 Law on Cultivation of Plants -2004 Law 18/2004 on Plantations -Law 32 of 2009 on Environmental Protection and Management -ISCC, SAN/RA, and RSPO (voluntary sustainability certifications)		**Lowers** to the extent enforced (limited enforcement) and depending on coverage of voluntary provisions
	Processing soot, smoke, ash, etc.	-Law 32 of 2009 on Environmental Protection and Management -ISCC, SAN/RA, and RSPO (voluntary sustainability certifications)		**Potentially will lower** to the extent enforced and depending on coverage of voluntary provisions
Brazil (660kTOE)	Preharvest sugarcane and soybean residue burning	-Sao Paulo State Law (phase out burning) - Minas Gerais Union of Ethanol Manufacturers protocol to eliminate sugarcane burning -Numerous voluntary sustainability certifications	Medium	**Will lower** once enacted/phase out period occurs
	Fertiliser and agrochemical emissions and tillage	-Sao Paulo State Environmental Laws -Law No. 7802 on agricultural chemicals and like-substances. -Numerous voluntary sustainability certifications		**Lowers** to the extent enforced
	Wastes and emissions from soybean oil processing facilities and ethanol distilleries	-Sao Paulo State Environmental Laws -National Environmental Policy -Ordinance No. 323 (Vinasse) -Resolutions No. 0002 (1984) and 0001 (1986) -Numerous voluntary sustainability		**Lowers** to the extent enforced

Region	Threat	Existing provisions addressing threat	Potential to enforce	Effect on overall threat level
		certifications		
United States (369kTOE)	Residue burning	-State legislation on burning -ISCC (voluntary sustainability certification)	High	**Lowers**
	On farm vehicles and machinery and dust from land preparation. Wind erosion from exposed soil of row crops.	-State legislation on machinery and vehicle emissions -1970 Clean Air Act -ISCC (voluntary sustainability certification)		**Lowers**
	Fertiliser and agrochemical emissions, including airborne pesticides from seeding operations.	-1972 Federal Insecticide, Fungicide, and Rodenticide Act -ISCC -EQIP (voluntary program)		**Lowers**
	Soybean oil and ethanol processing facilities	-1970 Clean Air Act -National Environmental Policy Act -ISCC (voluntary sustainability certification)		**Lowers**
Ukraine (280kTOE)	Fertiliser Use	-1992, 2001 Law on Ambient Air Quality -1995 Law on Pesticides and Agrochemicals -ISCC (voluntary sustainability certification)	Medium	**Remains the same**
	High polluting industrial equipment	-1992, 2001 Law on Ambient Air Quality -ISCC (voluntary sustainability certification)		**Remains the same**
Canada (292kTOE)	PM, VOCs, etc., from soybean handling, storage, and oil processing	-Environmental Assessment Act -Environmental Protection Act -ISCC (voluntary sustainability certification)	High	**Lowers**
Malaysia (189kTOE)	Planned and unintentional burnings.	-Environmental Quality Act (1985, 1996, 1998) -1974 Air Quality Act (original burning ban) -1978 Environmental Quality (Clean Air) Regulation -1998 3rd Amendment to Environmental Quality Act (complete ban on open burning to clear land for oil palm) -2003 Environmental Quality (Declared Activities) (Open Burning) Order PU(A) 460/2003 – additional regulations on open fires.	Medium	**Lowers** (high enforcement)

Region	Threat	Existing provisions addressing threat	Potential to enforce	Effect on overall threat level
		-RSPO and ISCC (voluntary sustainability certifications)		
	Agrochemical application	-Environmental Quality Act (1985, 1996, 1998) -Pesticides Act (1974, 1988, 2004) -1978 Environmental Quality (Clean Air) Regulation -RSPO and ISCC (voluntary sustainability certifications)		**Lowers**
	Processing soot, smoke, ash, etc.	-Environmental Quality Act (1985, 1996, 1998) - Environmental Quality Order and Regulations (1977, 1982) regulates effluent discharge from palm oil mills. -1978 Environmental Quality (Clean Air) Regulation -1979 Environmental Quality (Sewage and Industrial Effluents) Regulations -1989 Scheduled Wastes Treatment and Disposal Order -2006 Environmental Quality (Prescribed Premises) (Scheduled Wastes Treatment and Disposal Facilities) Regulations -2009 Environmental Quality (Industrial Effluents) Regulations -RSPO and ISCC (voluntary sustainability certifications)		**Lowers**
Paraguay (188kTOE)	Land preparation through slash and burn of forests. Possible soybean residue burning	-2000 Law 1561 Creating the National Environment System, National Environment Council & Secretary of the Environment (basic environmental oversight) -RTRS (voluntary sustainability certification)	Low-Med (only 2 indicators available)	**Unknown**
	Fertiliser, agrochemicals, and fumigation used	-2000 Law 1561 Creating the National Environment System, National Environment Council & Secretary of the Environment (basic environmental oversight) -2004 Decree Regulating the Use & Management of Pesticides for Agricultural Use -RTRS (voluntary sustainability certification)		**Unknown**
	High fossil fuel requirements for transportation	-2000 Law 1561 Creating the National Environment System, National Environment Council & Secretary of the Environment (basic environmental oversight)		**Unknown**

Region	Threat	Existing provisions addressing threat	Potential to enforce	Effect on overall threat level
Russia (124kTOE)	High polluting cultivation and harvest equipment	-1999 Law on atmospheric air protection" (#96-FZ) -ISCC (Voluntary sustainability certification)	Low	**Unknown**
	Unknown threat of processing facilities	-1999 Law on atmospheric air protec-tion" (#96-FZ)		**Unknown**
Guatemala	Some mechanisation. Tillage, fertiliser, and pesticide practices unknown but assumed to be present.	-1986 Environmental Protection Law -1974 Decree No. 43-74 on pesticides -1993 Ministerial Decision No.152-93 on agrochemicals -2007 Law for evaluation, control, and monitoring of the environment. -ISCC voluntary certification	Medium	**Remains the same (lack of coherent management and enforcement of laws, lack of legal framework to coordinate them).**
	Preharvest burning for sugarcane	-2007 Law for evaluation, control, and monitoring of the environment. -ISCC voluntary certification		
	Processing emissions from 12 mills in close proximity	-1986 Environmental Protection Law -2007 Law for evaluation, control, and monitoring of the environment. -ISCC voluntary certification		
Tanzania	Cultivation emission	-1997 National Environmental Policy -1997 Agriculture and Livestock Policy -2005 National EIA Audit Regulation	Low-Med (only 2 indicators available)	**Remains the same**
	Preharvest burning for sugarcane			
	Emissions from processing facilities	-1997 National Environmental Policy -2005 National EIA Audit Regulation		

Annex 9: List of interviewees

EU interviewees

Member State	Name	Affiliation
Czech Republic	Milan Dumbrovsky	University of Technology, Brno, Czech Republic
France	Pierre Dupraz	Researcher
Germany	Frank Glante	German Federal Environment Agency, Head of the Soil Protection Commission
	Katja Gödeke	Thüringer Landesanstalt für Landwirtschaft
	Daniela Thrän	German Biomass Research Centre (DBFZ)
Hungary	Anonymous	Institute for Soil Science and Agricultural Chemistry (Centre for Agricultural Research, Hungarian Academy of Sciences) The Hungarian response was prepared with contribution from the Green Economy Development Department (Ministry of National Development)
Italy	Andrea Povellato	Director of research at INEA (National Institute of Agricultural Economics)
Poland	Mariusz Maciejczak	Scientist at Warsaw University of Life Sciences
Spain	Carlos Alberto Fernández López	
	Alberto Garrido	Director of Research Centre for the Management of Agricultural and Environmental Risks (CEIGRAM), Technical University of Madrid
United Kingdom	James Letts	Environment and Business Advisor, Environment Agency England (for England and Wales)
EU level	Vincenzo Angileri	Joint Research Centre, European Commission
	Luca Montanarella	Joint Research Centre, European Commission
	Jan-Erik Petersen	European Environment Agency

NON-EU Country interviewees

Country	Name	Affiliation
Argentina	Jorge Hilbert	INTA (National Institute on Agricultural technology)
Argentina	Jimena Frojan	Roundtable on Sustainable Soy
Brazil	Arnaldo Walter	Brazilian Bioethanol Science and Technology Laboratory.
Canada	Dennis Rogoza	Advisor, Sustainability, Canola Council of Canada
Indonesia	Dwi Rahmad Muhtaman and Cecep Saepulloh	ReMarkasia
Malaysia	Jin Hooi Chan	University of Cambridge
Switzerland	Sebastien Haye	Roundtable for Sustainable Biofuels

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