Exploratory Workshop Scheme

Standing Committee for Life, Earth and Environmental Sciences (LESC)

Standing Committee for Social Sciences (SCSS)

ESF Exploratory Workshop on

Socio-economic and environmental implications of energy crop production in Europe – So little land so many services

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Convened by:

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SCIENTIFIC REPORT

1. Executive summary

1.1. Background

The workshop was held from 26th to 28th April (two half-days and one full day) in Trinity College Dublin, Ireland, and stimulated discussion among 22 scientists from 13 European countries working in the fields of biodiversity research, landscape change, risk assessment, lifecycle assessment, soil science, modelling of global change effects, socio-economics, agricultural production and rural economics[1]. The workshop was set against the background of increasing crop-based bioenergy production within Europe, forecast to continue in response to European Union targets for an average 20% share of renewable energy, and a minimum 10% market share of biofuels, by 2020. Signifcant areas of land will be required for the cultivation of energy crops, with implications for ecosystem services (ES) such as provision of biodiverse habitats, water and nutrient cycling, regulation of erosion, and socio-economic factors such as rural employment. In the context of a growing global population, and a shift toward more resource-intense diets, energy crop land use requirements are inevitably associated with global landuse consequences. Studies assessing the implications of increased energy crop production in Europe have so far been restricted with respect to the range of impacts, and the scale, considered. The primary purpose of this workshop was to discuss and assess the multiple (environmental and socio-economic) and multi-scale (from field to global) effects of bioenergy production in European landscapes, with particular emphasis on ES and the rural economy, from an interdisciplinary perspective. The main objectives of the workshop were to:

1. Produce plausible, spatially explicit scenarios of energy crop distribution in Europe over the coming decades
2. Understand how land use might change in response to increased energy crop production, and the associated ES impacts
3. Make recommendations for future strategic research and management
4. Stimulate future joint research

In relation to the above, consideration was given to different types of energy crops, the socio-economic and policy driving factors, the potential influence of changing climatic conditions, and the measurement of, and tradeoffs between, ecosystem services.

1.2. Invited presentations

Three keynote lectures provided an overview of the major workshop topics. Stefan Bringezu presented data showing that European bioenergy production is associated with a turnover of €23.4 billion and directly employs 277,000 persons, largely in rural areas. European bioenergy is currently dominated by heat and electricity generation, but biofuels and biogas are growing quickly in response to policy. Previous assessments of environmental impacts associated with bioenergy production in Europe have neglected global landuse consequences. Mark Rounsevelle observed that rural land-use changes have always occurred, in response to social, technological, economic, environmental, and policy governance drivers operating at multiple scales. Land-use change can be modelled reasonably well at global and continental scales, but less well at local and landscape scales owing to individual behaviour being poorly represented in current deterministic models. Dagmar Schröter presented six steps of scenario building, culminating in coherent scenarios that include: (i) a base year; (ii) a time horizon; (iii) a defined geographic scope; (iv) a description of stepwise changes; (v) driving forces or uncertainties; (vi) storylines relating key aspects within the scenarios. Modelling projections of European agricultural production suggest that there will be a considerable amount of land available for energy crop production in Europe by 2080. Further research on European bio-energy production should include

[1] Unfortnately, socio-economic expertise was notably under-represented amongst the final attendees owing to a few absences.

interaction with other land uses, ecosystem and human wellbeing effects, and a global context, and aim to identify the most beneficial feedstocks.

Three subsequent keynote lectures provided more indepth summaries of particular bioenergy assessment studies. Marc Londo emphasised the importance of biofuels within a sustainable European energy portfolio, but highlighted the obstacles presented by key uncertainties, primarily: (i) projections for future agricultural productivity growth, and the regional distribution of this growth; (ii) indirect land-use effects. Second generation feedstocks offer the possibility of using degraded or marginal lands. Angela Karp presented characteristics of two such feedstock crops – miscanthus and willow. These crops produce high yields from low inputs, and are associated with greater biodiversity than arable crops, but use more water and generate low economic returns to farmers. Public surveys indicated a public acceptance of potential visual landscape implications of these crops. Yield and suitability mapping, in which high food-production areas were excluded, indicated a high potential for miscanthus-based bionenergy production in the UK without displacing food production. Sustainability assessment indicated that small-scale biomass combined-heat-and-power production was a promising bioenergy landuse option. Ülla Roosmaa emphasised the central role of bioenergy within EU renewable energy targets, and that the value of such energy supplies goes beyond final energy costs to include energy security, human wellbeing and ecosystem functioning. These factors are valued differently across individuals and regions, but are always highly relevant with respect to public policy – nevertheless they are usually regarded as secondary and rarely accounted for. There is a clear need for development of social impact assessment methods, especially at the local scale, to inform appropriate regional and local policy formulation/implementation.

In the plenary discussion session following the keynote lectures, participants agreed that policy on bioenergy is running ahead of the science, and that the remainder of the workshop should focus on crop-based bioenergy. It was agreed that, in order to catch up with policy, scientists should attempt to achieve the following:

- Determine the spatial and economic niche for crop-related bioenergy in Europe, in particular considering
    - More accurate assessment of future agricultural production potential
    - Constraints for crop-related bioenergy within Europe
- Identify the interacting influences of scale and distribution (at field and regional scale) on the impact of energy crop production
- Improve understanding of farmer responses to external factors, including policy

1.3. Scenario building

The workshop was divided into two parallel working groups to discuss scenario building (this section) and ecosystem services assessment (section 1.4). The scenario working group developed new crop-based bioenergy storylines, based on the initial prerequisite of freeing up land for energy crop cultivation. Three potentially interacting scenarios of land provision within Europe were proposed: (i) Global Trade (food import); (ii) Technological (intensification of food production within Europe); (iii) Lifestyle (eating less meat). The Global Trade and Techno scenarios were divided into sustainable and non-sustainable variants, depening on how the imported food was produced and the methods of intensification applied – although the non-sustainable variants were seen as more realistic. These overarching scenarios will also determine the type of land made available for energy crop production: intensification of food production would exclude energy crops from more productive land, whilst global trade would allow energy crop production on productive agricultural land in Europe. In reality, a combination of these overarching scenarios is expected, and a novel task for further research identified by the working group would be to develop a modelling approach based on an "interaction triangle" in which the relative importance of each scenario could be varied in order to develop realistic scenarios and assess the implications of different policy / social choices. The scenarios developed could then act as filters, identifying constraints on land allocation, and could also relate European energy crop production with global landuse consequences. Further scenario development to generate more spatially explicit scenarios would require a multidisciplinary assessment of supply chains, land quality, locations of end-users, technology of energy production, and socio-economic factors. Optimised scenario development requires feedback from ES assessment, and ideally also modelling of individuals' behaviour (though there are currently no established methods for the latter).

1.4. Ecosystem services assessment

Complete assessment of energy crop impacts on ES first requires an accurate definition of reference land-use systems being displaced, at a local, regional and global scale. This requires input from scenario building, and may involve "chains" of displacement whereby a number of land uses are displaced stepwise until abandoned land in Europe (or natural habitats globally) are ultimately replaced. In such cases, full ES impact assessment requires the consideration of localised effects associated with changed land-use patterns in addition to the ultimate reference land use (abandoned land or natural habitat). It was postulated that low-input energy crops such as miscanthus grass and willow could have a positive impact on many ES within intensive agricultural landscapes, and so increase the productivity of agroecoystems – with consequences for scenario development. A major conclusion from the working group was that the typical characteristics of abanonded agricultural land vary considerably throughout Europe, and assessment of energy crop impacts on ES would be greatly assisted by a regional typology for such land.

The working group took the 28 ES definitions contained in the Millenium Ecosystem Assessment Report (MEAR), according to five categories (Provisioning, Regulatory, Supporting, Socio-economic, Cultural), and proposed important scales and factors for each one in relation to energy crop impact assessment. Findings from this exercise included: (i) climate (bioclimatic region) provides an important overarching context for all ES impact assessments; (ii) specific management (farming) practices are very important; (iii) the field pattern of energy crops will be critical for some ES impacts - particularly for regulatory ES such as invasion resistance and pest/disease regulation. It was concluded that assessing / modelling the impact of energy crop production on certain ES will require high resolution information on spatial distribution. Traditional techniques for assessing the environmental impacts of energy crops, such as lifecycle assessment, omit or poorly quantify many of the ES identified. Workshop participants thought that the list of socio-economic services defined in the MEAR list should be expanded, and that socio-economic assessment of energy crops has hitherto been resticted in scope to traditional economic comparisons of energy costs and field gross margins – overlooking wider economic gross-value-added, balance of trade and employment effects that would be expected to be positive at both regional-rural and European scales when entire energy supply chains are considered. The working group made a rapid initial assessment of ES impacts for two simplified scenarios, in which either miscanthus or oil-seed-rape were grown on abandoned tillage land. This exercise emphasised that some form of weighting or mulit-criteria analysis will be required to compare and aggregate results for the range of ES. The valuation (weighting) of different ES is likely to vary considerably across Europe depending on factors such as prevailing climate, water availability, soil conditions, dominant landuses etc. Whilst both miscanthus and oil-seed-rape offer additional provisioning services (i.e. fuel), miscanthus (and other perennial, low input energy crops) is more likely to have positive impacts across more ecosystem services.

1.5. Conclusions and Recommendations

- Global Trade, Technological, and Lifestyle factors outlined in this workshop provide a useful basis for identifying land constraints in Europe for energy crop production. Modelling interaction among these factors would be a valid and novel starting point for developing European energy crop production scenarios

- Full scenario development will require multidisciplinary consideration of many factors, including demand side factors such as technological and economic aspects of energy generation, and should ideally account for individuals' behaviour (response to market and policy forces)

- ES impacts may feed back into agricultural productivity, and will depend on spatial patterns of energy crop cultivation. Scenario development and ES impact assessment should be interacting, iterative processes

- Energy crop cultivation scenarios are associated with consequential "chains" of landuse change - at the local, regional, European and global scales. These must be fully considered in ES assessment in order to generate valid and complete results

- The region and landscape context affects both the impact on, and relative importance of, specific ES. Assessment or modelling of impacts on these services therefore requires high resolution information on spatial distributions

- Characteristics of abandoned land vary considerably across European regions. Development of a regional typology of such land would greatly assist the assessment of ES impacts associated with landuse change in Europe

- Current policy stimulating biofuel production from first generation crops is running ahead of the science. The supply side should also be considered in bioenergy policy, preferably in a spatially-explicit manner (e.g. using the single farm payment to influence farmers)

- Potential components of an optimised energy crop production stragey include: (i) low-input energy crops established on abandoned (marginal) agricultural land; (ii) low-input energy crops interspersed throughout agricultural landscapes as "break crops"

1.6. Outreach

It is planned to draft two scientific papers, one methodological paper on the scenario approach and one opinion paper on the ES impact assessment. Concrete follow-on actions decided by the research network founded during the workshop are (i) applying for a COST-action and (ii) identifying a call within the EU Framework programme that could host the research network. A strong emphasis of the planned action will be on socio-economic research

2. Scientific content of the event

2.1. Introduction

The European Union and its Member States are committed to increasing the use of renewable energy sources with the aim of reducing greenhouse gas emissions and dependence on fossil fuels. The European Commission put forth a directive on the promotion of the use of renewables, setting an overall binding target for the European Union of 20% renewable energy by 2020 and a 10% minimum target for the market share of biofuels used in road transport by 2020 (EC, 2009). Among the renewable energies, bioenergy has been identified as an important source. Bioenergy can be derived from a wide range of products and by-products from agriculture and forestry as well as municipal and industrial wastes. Bioenergy from agricultural cropping represents a relatively small share within the total renewable energy sector but its production is increasing constantly, and this is projected to continue – partly in response to specific EU targets set for biofuels (EC, 2007). Achieving the current binding targets will require a substantial increase in land use for bioenergy production and will have implications for related natural resources and ecosystem services such as water, soil nutrients, biodiversity. As it is anticipated that land requirements for projected EU food and non-food demand will exceed domestic land availability, the EU will require a considerable amount of imports (Ribeiro et al., 2008). Consequently, EU policy will not only influence bioenergy industry development in Europe, but will also result in potentially negative environmental and socio-economic outcomes at the global level (Ribeiro et al., 2008; Bringezu et al., 2009; Reinhard & Zah, 2009). So far, only few quantitative assessments of the potential impact of increased bioenergy production on European environment, biodiversity, ecosystem services and socio-economy have been made (Dauber et al., in press; Rowe et al., 2009). Additionally, many assessments are limited to an analysis of land use directly replaced by bioenergy cultivation and indirect effects through relocation of food and feed production have thus been ignored (Hellmann & Verburg 2010).

While at a local scale bioenergy may provide positive prospects for the environment and for local and rural development, there is concern about the current development of large-scale bioenergy production (Florin & Bunting, 2009). One matter of particular concern is land-use change, but there are large uncertainties associated with this effect. Uncertainties occur from large ranges of bioenergy potentials reported, due to differences in methodologies, varying assumptions on crop yields and available land, and from the diversity of scenarios considered in the respective analyses (Dornburg et al., 2010). Further factors creating uncertainty are issues generally not considered in sufficient detail such as: (i) whether—and which—degraded and/or marginal land areas can be used for bioenergy production; (ii) competition of energy crops with other sectors for water resources; (iii) human dietary trends; (iv) development of alternative protein chains and alternative animal production systems; (v) the impact of large-scale biomass production on land use, agricultural commodity prices and agricultural productivity; and (vi) the incorporation of specific biodiversity and ecosysytem service objectives (Dornburg et al., 2010). Awareness of the existence of risks is emerging faster than scientific knowledge of them, and it appears that policies are often being decided before sound scientific knowledge about the risks has been considered (Florin & Bunting, 2009). The difficulties for science in catching up with policy might stem from the limited progress in integrating the various scientific fields pertinent to the risks and prospects of energy crop production. One reason for this lack of integration might be that the relationships between the issues are manifold and complex (Dornburg et al., 2010).

This exploratory workshop, which focused on bioenergy production from agricultural cropping, brought together 22 scientists working in the fields of biodiversity research, landscape change, risk assessment, life-cycle analysis, soil science, modelling of global change effects, vulnerability, socio-economy, agricultural production and rural economy. This interdisciplinary panel approach was chosen to reduce the beforementioned uncertainties by stimulating integration of the research fields via discussion and assessment of the multilevel (i.e. socio-economic and environmental) effects of bioenergy production in

European landscapes and their effects on biodiversity, ecosystem services and rural economy. The set objectives of the workshop were to:

- Produce plausible, spatially explicit scenarios of energy crop distribution in Europe over the coming decades, based on
    - An understanding of the best energy crop types
    - An understanding of the best energy crop types
    - An understanding of the socio-economic and policy factors affecting farmers' decision making
    - An understanding of changing climatic conditions and potential agricultural responses to these
    - An understanding of trade-offs between the ecosystem service of energy crop production and other services, including biodiversity
- Understand how land use might change in the light of increased energy crop production
- Stimulate future joint research in order to inform European and national policy decisions
- Make recommendations for future strategic research and management

2.2. Summaries of keynote lectures

Six keynote lectures (see section 4) were invited to present an overview of the major workshop topics and to direct and stimulate the discussions within the working group sessions. This section comprises the summaries of those presentations as well as comments made and consent or dissent expressed by the participants during the plenary discussions. The **first set of three lectures** aimed at: (i) providing an overview of the trends, sectoral patterns and environmental and socioeconomic impacts of energy crop production in Europe, including the global scale implications of the developments; (ii) demonstrating the impacts policy decisions can have on land-use change and the associated environmental impacts; and finally (iii) introducing scenarios as tool for projecting and assessing impacts of energy crop production.

The first presentation by **Stefan Bringezu** encompassed the following six major topics:

- Bioenergy trends and socio-economic impacts in the EU
- Global trends determining land use
- Environmental impacts of biofuels
- Options for more efficient and sustainable resource use
- Growing competition for ligno-cellulosis
- Future vision and recommendations

A survey of the socio-economic impacts of bioenergy (solid biomass, transport fuels, biogas) in 14 EU countries in 2008 reported a turnover of 23.4 billion Euro and direct employment of 277,000 persons in the sector. However, bioenergy was often associated with higher production costs which lead to direct or indirect subsidization, reduced available income for purchasing other goods and a negligible net employment effect economy-wide. Nevertheless, a redistribution of employment towards rural areas could be discerned. Currently, estimates of future bioenergy potentials in Europe are focussing on intra-European developments (see EEA, 2006; EEA, 2007). For example the EEA (2006) assessed that 15% of the European energy demand in 2030 could be produced "without harming the environment". These assessments were falling short of showing the whole picture because the external dimension of Europe was not taken into consideration. Imports/exports were regarded as constant, the EU was assumed to be (net) self-sufficient for food, neither global yield dynamics of food crops nor development of food demand outside the EU were considered. The interim conclusions on the socio-economic impacts were that bioenergy in the EU is mainly used as solid biomass for heating/electricity but that biofuels and biogas are growing more rapidly; that turnover and employment are induced by the bioenergy sector but that the latter is rather distributed over the economy as a whole; and that potentials for increased use and production of bioenergy within the EU have been determined, but some key factors are not yet considered appropriately, which leads to a high risk of problem shifting.

Global trends of land use in the context of bioenergy production were identified, with built-up land expanding at the expense of agricultural land; European forests growing whereas global forest area is in decline; global cropland expanding to feed the world human population and an additional demand for non-food biomass adding on top of this. A summary of the environmental impacts of these global trends by Bringezu stated that an expansion of global cropland for fuel crops may lead to increased net GHG emissions over the next 30 years as well as losses of biodiversity. This could not be avoided by production standards and product certification as long as the demand for biomass is growing globally (indirect land-use changes). In this context, it has to be kept in mind that the EU is already a net importer of agricultural land.

Bringezu listed various options for a more sustainable use of resources:

- Optimize agricultural production
- Restore degraded land
- Stationary use of biofuels
- Use of waste and residues
- Cascading use of biomass
- Mineral based solar systems
- Increased material and energy efficiency in transport, industry and households.

He concluded that using biomass for capturing solar energy is rather inefficient and biomass would better be used for material purposes. Energy should instead be recovered from waste and residues, and cascading use of biomass should be further explored and developed. Overall, enhancing an efficient use of biomass and minerals may be more rewarding than increasing the supply. There is a growing concern about 2nd generation biomass feedstocks regarding trade-offs and competition. As domestic production of biomass is not sufficient in covering the demand, biomass will have to be bought from the global market. This could be a problem as policy targets for biomass use rely on uncertain environmental and economic performances. There is growing competition for use of biomass between material and energy use and between power/heat vs. transport fuel use. Also hydrocarbon/cellulosic BF need lignocellulosis. This could put further pressure on forests (deforestation, conversion to plantations).

Bringezu issued the following recommendations:

- Production standards and product certification of biomass may be helpful but are insufficient
- Overall consumption of biomass & energy demand must not exceed sustainable levels
- Current policy mandates, targets, quota need to be reconsidered (bias towards energy use of biomass – risk of triggering undue demand)
- EU, national and regional resource management programmes need to be developed
- Integration of climate and biodiversity protection, security of supply (food, materials, energy)
- Consideration of global land and biomass/minerals use for domestic consumption (limit burden shifting).

And he identified the following research needs:

- Development of integrated scenarios of food, material and energy uses of biomass in Europe while considering global developments (agric. + forestry)
- Further develop modelling EU+extra-EU land use by domestic consumption activities
- Work out acceptable attribution rules of globally fair use of net consumption area
- Agriculture: How to optimize combined food and non-food production? How much residues can be drawn from the fields sustainably?
- Forestry: globally: how much area shall be devoted to plantations, managed and natural forests?
- Europe: how to make use of unused potentials (different uses, activation of small holder plots)

In the second presentation, **Mark Rounsevell** gave an overview of the effects of environmental and policy change on land-use systems. He showed that rural land-use change is not something new that relates only to biomass production or climate change. Rural land-use change has always occurred and the drivers are well known: Social, Technological, Economic, Environmental, Policy governance (STEEP). Different drivers however play out at different scale levels, e.g. macroeconomics versus individual behaviour. Different drivers are also relatively more or less important at different times and in different places. With respect to the EU bioenergy directive, it is questionable how important policy is in driving land-use change. Arguably it is often less important than commonly thought, with policy tending to be more reactive (responsive) than driving. There are clear examples of where policy makes a difference, but policy is often a barrier or brake on change rather than a cause (e.g. CAP). Pathways of how policy affects landuse change are (i) regulation (mandatory; e.g. NVZs, ESAs, quotas), (ii) incentives (subsidy; e.g. area payments, Less Favoured Area payment, rural development) and (iii) other support (optional; e.g. agri-environment schemes). An example of a subsidy effect is the change in oilseed rape areas in Europe where a US soyabean shortage led to a European oilseed subsidy in the early 80s, resulting in an increased use of OSR as a break crop. Rounsevell demonstrated that the accuracy of modelling of future landuse change is scale dependent. There are many models of LU change at different spatial scales and we are probably quite good at modelling LU change at global and continental scales as much as these models are able to represent processes appropriately at these scale levels. However, we are less well equipped to model local/landscape level change, especially as this requires an understanding of the behaviour of individuals.

Rounsevell presented various examples of scenario based models of cropland changes in Europe. He suggested moving from top-down to bottom-up approaches. ‘Macro’ land use models and downscaling methods provide graphical representations of landscapes, but there is no new process information at the landscape scale. Therefore, there is a need to think about individual decision making processes, social structure and interactions. People have to be put into land use models with new modelling paradigms that reflect the behaviour of individuals (e.g. Agent-Based Models). This is particularly important for rural landscape change as farmers are good at adapting to changing circumstances and making decisions under uncertainty. They have different goals and means of achieving these goals and behave differently according to their experiences and social attributes. Rounsevell concluded that we need to improve our understanding of the policy levers of landuse change as the complex interactions between different policy instruments across sectors affect landuse decision making in ways that are difficult to predict in practice. There is a need for multi-scalar approaches, for better representation of human decision making processes with respect to land use and for probabilistic thinking instead of deterministic scenarios.

Dagmar Schröter introduced scenario building as a tool for projecting and assessing impacts of energy crop production. The outline of her presentation was:

- What are scenarios?
- Scenario development – six steps.
- Some snapshots of scenarios from ecosystem service oriented European Vulnerability Study ATEAM.
- Land use and ecosystem services.
- Land efficiency of biofuels vs. solar.

Schröter highlighted that scenarios are neither predictions nor forecasts. Following the definition given by the Millennium Ecosystem Assessment (Carpenter et al., 2005), scenarios are plausible and often simplified descriptions of how the future may develop, based on a coherent and internally consistent set of assumptions about key driving forces and relationships. The main objectives of scenario analysis are to imagine/estimate the future states of the environment and society and to test strategies of sustainable development (“wind tunnel“). Scenario development is a transdisciplinary, long-term, iterative process involving the following steps:

1. Select objectives and boundary conditions
2. Select themes
3. Select actors and factors
4. Develop mini-scenarios for each theme
5. Reduce number of mini-scenarios
6. Write full scenarios – storylines

This is what is required for each of the steps:
Step 1: Objectives and boundary conditions have to be defined. For the objectives we have to devise what our scenarios should accomplish (e.g. Examine if bioenergy is an effective mitigation tool. Examine the implications of bioenergy production for the environment (does it compromise other ecosystem services, biodiversity or traditional landscapes?). Examine the socioeconomic implications of bioenergy production.). Setting the boundary conditions requires deciding on a base year, the time horizon, the time steps (e.g. 5 to 10 year steps) and the geographic coverage (e.g. EU, but in global context).
Step 2: Each scenario should have a main theme or message. Those themes are based on main uncertainties or questions about the future (cp. SRES, Special Report on Emissions Scenarios, themes global vs. regional, economic vs. environmental focus).
Step 3: Actors and factors relevant for the scenarios have to be selected. Main actors are people and institutions that will play an important role (e.g. farmers, energy producers, financial institutions, governments, nature conservationists, citizens). Accordingly main factors are main variables that will play an important role (e.g. global market, land availability, technological development (also of competing renewables), financial incentives, EU targets, the diversity of values of the main actors, their communication, power structure between them).
Step 4: For each theme, an outline or “mini-scenario” should be constructed as a narrative or in tabular form. These outlines should describe step-wise changes – events between the base year and the time horizon which explains how the future situation evolved from the present. Among other things they contain the driving forces or uncertainties of the scenario. In this process it is important to maintain internal consistency and to include main actors and factors.
Step 5: The total number of mini-scenarios should be reduced to a manageable number. Implausible mini-scenarios should be eliminated and similar mini-scenarios combined. While the target number of scenarios depends on the goals of each individual study, two to four scenarios are recommended for strategic studies.
Step 6: In the final step full scenarios and storylines will be written by elaborating the mini-scenarios, step-by-step. Influence diagrams can be used, boxes added to communicate important or additional information. Anecdotes/stories illustrate the main messages.
When all steps have been followed diligently, the resulting elements of the emerging scenarios will be: a base year, including a description of the state of things in this year; a time horizon and time steps; a geographic coverage; a description of stepwise change, explaining how the future situation occurred from the present; driving forces or uncertainties; and storylines, i.e. detailed narratives presenting important aspects of each scenario, including the relationship between driving forces and events of the scenario.

Schröter then presented how a set of internally consistent socio-economic, climate and land use change scenarios were used to drive a European vulnerability study focussing on future trends in ecosystem service supply (ATEAM). This study was based on multiple environmental models and an embedded stakeholder dialogue. She illustrated how socio-economic storylines were the starting point of developing spatially explicit scenarios, using a sequence of models and methods; i.e. the integrated assessment model IMAGE to quantify socio-economic variables and atmospheric greenhouse gas concentration pathways from the SRES storylines, four different global circulation models (i.e. climate models), to arrive at a set of 16 climate scenarios based on the socio-economics, and finally – using the storylines and all previous quantifications – a set of land-use change scenarios that was consistent with the development of relevant variables in the climate and socio-economic scenarios. Schröter showed how a set of seven priority scenarios needed to be chosen from the original set of 16 scenarios, for the further analysis of consequences for ecosystem service supply. She explained how the priority scenarios were designed to represent a large range of socioeconomic choices, as well as climatic uncertainty.

Because of its particular relevance to the workshop, Schröter then went into further detail about the actual development of land-use change scenarios for Europe. She showed how a three step approach was used, first, quantifying the total area requirement for each land use (urban, cropland, grassland, bio-energy, forest, protected areas), second allocating the land using scenario-specific rules, and third post-processing the resulting scenarios to maintain designated areas (such as nature reserves and the like). Schröter further illustrated the particulars of European land-use drivers (policy and socio-economic factors). She then showed that the ATEAM study estimated that by 2080 a sizable amount of land would be "surplus", or open for all uses, since less land would be needed in Europe to satisfy agricultural demands (this considered global market development using the IMAGE integrated assessment model; Schröter et al., 2005). While the same trend was found in all scenarios, the extent of this projected development varied: The A-scenarios showed particularly strong potential reductions in crop- and grassland. Schröter then pointed out that this finding was in contrast to the very sub-title of the workshop: "So little land so many services", and left the matter open for debate: Is there a lot of land open for planning, or not?

Assuming that we can always do a better job in planning our land, she then went into the use of the ecosystem service concept to structure research and debates about land management. Showing the multitude of ecosystem services we derive from our land and waters, she offered a qualitative matrix approach as a first step in ecosystem service based land management, where ecosystem services are evaluated against the types of land use found in a particular area. Schröter then showed that this approach highlights a bundle of open questions of two general kinds: (1) which ecosystems under what management supply which ecosystem services and to what extent? And (2) how is this supply of ecosystem services related to our well-being? She stressed that the ecosystem service approach to land management offers a wider perspective than e.g. approaches focussed only on biodiversity, since it opens up the evaluation approaches to states, as well as *processes*. Refocusing on the more detailed goal of the workshop, Schröter then showed that "land efficiency" of a particular technological development is a very relevant variable besides energy efficiency, the more commonly used indicator. In an example she compared the land efficiency of driving an electric vs. a biofuel powered car, showing that the electric solution uses far less land. She went on to show how the EU directive on renewable energy sources reflects consideration of this kind already partly, with respect to comparing the 2003 directive with the directive of 2009. She stressed how further research is needed to specify more clearly the valuable niche that bio-energy production could fill in a mix of renewable energy sources in the European energy system. Concluding, Schröter summarised that any scenarios developed during or from the workshop could (1) explore if (and which and how) bio-energy production could make sense for climate mitigation, and (2) explore the interactions of bio-energy production with (a) other land uses, (b) ecosystem services (including biodiversity) and (c) quality of life, in the national, European and global context. Finally, touching on some ethical consideration that had been debated in the discussions of the two previous talks, Schröter showed some global maps from a book called "Neotopia – Atlas of equitable distribution of the world" by Manuela Pfrunder (based on her final examination project in studying Graphic Design) illustrating how the world would look like if all natural resources were divided up equally between earth inhabitants (http://www.neotopia.ch/).

The **second set of lectures** was selected with the aim to provide in depth overviews of the state of knowledge of bioenergy production and its environmental and socio-economic impacts in Europe.

Marc Londo presented critical issues in the biofuels dossier and ingredients for a policy road map for biofuel production in Europe. He made the statement that biofuels are part of a long-term sustainable energy portfolio. However, the road ahead is currently blocked due to uncertainties regarding environmental impacts, market development, agricultural development, technological development of 2nd generation fuels and policy. Londo addressed the key issue that responsible biofuels development requires a combination of

developments in feedstock production, conversion and end-use, including consistent support from several policy domains. In this respect, policy makers should also be aware of the various drivers that underlie biofuels. Key issues for long-term sustainability are competition for feedstocks, e.g. with food production, and (indirect) land-use changes.
Londo discussed that a crucial issue for further development is a secure assessment of the competition between food and fuel feedstock and of the indirect land-use change cause by increased biofuel production. A massive problem for the assessment is that underlying mechanisms are very complex and as a result, projections and models for biofuel potential vary considerably. Given a "food first" paradigm, one problem are the massive variations in the predictions of studies on agricultural productivity growth. If we can not accurately asses how agricultural productivity could be increased by which amount in which regions, it will be very difficult to assess the potential for biofuel production.

Londo showed that 2nd generation biofuels could be part of a solution because they help broadening the feedstock base and introduce the possibility of using marginal and degraded lands for their production. Critical issues however still remain such as technology and finance, feedstock supply and stability, and synergies with power and heat. To overcome some of the issues Londo suggested a cost-effective policy mix: In an initial phase, investment subsidies would be most effective/efficient and a double counting would facilitate the introduction of the 2nd generation feedstocks. After first development years, due to technological learning and improvement of financing parameters, specific support could gradually be phased out as well as double counting.

Finally Londo suggested some elements for a robust biofuels policy. In terms of the target pathway, there is an inherent tension between ambitions, which require a long-term orientation and related target setting, and the uncertainties in feedstock availability and sustainability, which require an 'emergency brake' if potentials appear lower than expected. Also, clear accounting of indirect land use change effects is important, although it may not be possibly to do this in a (scientifically) ideal way. An important aspect of biofuels policy should be the further enhancement of agricultural productivities worldwide, both by raising investments and by supporting R&D. Finally, 2nd generation biofuels deserve (initial) support, by supporting R&D and by searching for synergies with other (innovations in) parts of the energy system.

The effects and prospects of energy crops with respect to ecosystem services and multifunctional agriculture were highlighted by **Angela Karp**, based on the results of the UK projects RELU-Biomass (www.relu-biomass.org.uk/) and TSEC‐Biosys (www.tsec‐biosys.ac.uk). She showed that biomass crops, such as short rotation coppice (SRC) willow (*Salix spp*) and Miscanthus grass (*Miscanthus x giganteus*), have strong potential for sustainable bioenergy production in the UK. They are fast growing, produce large yields from low inputs of fertilisers and pesticides, and show high energy gains and greenhouse gas reductions in life‐cycle analyses. UK, government incentives are encouraging increased plantings of SRC willow and Miscanthus. However, the plantations are quite different from conventional arable crops. They are very tall (3‐4 m), dense and may attract different wildlife. Large expansion would, thus, constitute a major land‐use change and this has raised concerns over possible social, environmental and economic impacts.
Karp presented the impacts of increased planting on a range of ecosystem services and socio-economy: Water use was compared with other land-cover types and biomass crops showed higher water use than permanent grass and winter wheat, Miscanthus being higher than SRC. Biodiversity was sampled in 16 fields each of crops and generally, biodiversity indicators were significantly higher in SRC willow than Miscanthus and significantly greater in both biomass crops than in cereals/arable crops. Economic surveys of farmers/farm managers demonstrated low returns. Thus biomass is unlikely to dominate on most farms, except in special circumstance where the farmers wish to reduce commitments or manage risks. A public survey was undertaken in town centres within the two regions and GIS‐based computer generated real‐time landscape models used in focus groups. Over

75% respondents felt both Miscanthus and willow would fit 'very well' or 'reasonably well' into the landscape and focus groups were mostly concerned with increased lorry movement.

Karp suggested two tools for decision makers: (i) yield and suitability mapping and (ii) sustainability appraisal (SA). In the constrained mapping approach, circa 4.7 million hectares of suitable land was identified in the UK, without conflicting with nine environmental constraints. Suitable land was reduced to just over 3 million hectares when Agricultural Land Classification Grades 1 and 2 were excluded to reduce competition between food and biomass production. Karp concluded that the remaining land area was sufficient to cover the domestic demands of biomass in the UK. A sustainability appraisal (SA) framework could be used to integrate results of different disciplines. The SA identifies regional specific objectives and indicators, generates a Sustainability Framework, checks against Regional Spatial Strategies and uses the completed framework to test scenarios. So far, the SA has suggested that positive sustainability implications are most enhanced where small scale CHP is the biomass end use. Karp concluded that many positive benefits could accrue from growing energy crops in the UK. Recommendations on management and field size (and margins) will encourage landscape compatibility and help ensure that the positive benefits on biodiversity are realised. GIS-based yield and suitability mapping can help identify important land-use implications at regional or finer spatial scales and SA is a useful tool to appraise impacts of different planting scenarios. Currently these results are being discussed with UK government departments to update recommendations for planting and management that will ensure environmental benefits are gained and to explore whether these could be used as the basis of grants/awards to farmers as part of a revised energy crops scheme.

Finally, **Ülle Roosmaa** disclosed economical and social aspects of biofuel production. She highlighted that in general social and economic contexts, energy systems form an integral part of the society. The availability of energy is a basic requirement for most tasks in a modern economy. In contrast to the presentation by Bringezu but in accordance with the presentation by Karp, Roosmaa stated that biomass has the greatest potential, among renewable energies, to supply a large amount of energy for the European Union.
In the last decades it has become more obvious that the apparent value of energy supply in the social perspective goes further than the money price per kWh or GJ. In the development of biofuel systems, there are a number of considerations which are associated with current socio-economic goals, like food security, human well-being, and the functioning of ecosystems. But individuals or societies can differ on their relative valuation of these goals. Roosmaa outlined that renewable energy is often preferred by individuals, groups and decision makers, but the preference should comprise socio-economical aspects. Often these aspects are only treated as "secondary effects", although they can greatly influence a particular project's suitability and sustainability in a local context.

Roosmaa had a more optimistic view on the wide range of social and economic benefits offered by the use of biomass and different biofuels. The latest research project, Employ-RES, which was based on an input-output model, the total gross employment in the RES sector in the EU-27 in 2020 will amount to 2,310 million people. Economic considerations are an important element of criteria for any biofuel development. In the neo-classic economic models the socio-economic effects are expressed in terms of new jobs and additional income formation. Impact of energy output evaluation of biomass on employment trends is dependent on a number of factors that are difficult to define in detail and they may significantly differ from one country to another. Roosmaa made the important point that in many cases there is a lack of data particularly regarding the social indicators.
Same as the previous presenters, Roosmaa expected energy demand continuing to grow due to increases in income and population, and more land will be needed to assure the same percentage of fuel coming from biofuels. Several economic and social issues should therefore be taken into consideration in assessment of the biofuels:
Scale - Strategies for developing biofuels are often formulated at international scale, and may conflict with local scale preferences, which represent specific socio‐environmental goals, benefits and constraints of the particular situation under consideration.

Regional perspective and economic analysis - At a regional level the socio‐economic analysis might be an important tool for complementing and strengthening the applications for funding assistance with a view to achieving regional development goals.
Research needs - There is still relatively little literature available directly evaluating the social impacts of large‐scale production and even less on that of small‐scale production.
Roosmaa concluded:
1. Development of biofuel systems vary from region to region depending on the different priorities and motivations and implementation strategies selected within their regional context.
2. There can be no one-size-fits-all policy, or even a predictable common response to the same policy across multiple countries.
3. The biofuel systems development timeline and the placement are influenced by certain policy and market incentives.
4. There is a lack of data, particularly regarding the social indicators.
5. A unified methodology is missing to compare the results of biomass potential assessment for EU on a regional, national and international level.
6. It is responsibility of the scientist to do more extensive research to provide an appropriate method for determining economic and social impacts and for developing several quantitative assessment methods and indicators.

Overall, the lectures have applied a critical view on the trends, prospects and current situation of bioenergy crop production in Europe and on the associated global implications. Some presentations were more optimistic about the future of bioenergy (and biomass crop production in particular) in Europe (e.g. Karp and Roosmaa), whereas others were more sceptical whether sustainable solutions for our energy and climate change mitigation problems could be found within the bioenergy sector (e.g. Bringezu). Independent of their respective bias, recurrent themes in almost all presentations were:

- **Dimensions of biofuel production**

  Although crop based biofuels might have a comparatively small share in the renewable energy portfolio, the participants agreed that the land-demand of bioenergy crops is large. There was dissence however in whether Europe or individual European countries would be able to self-provide the feedstock necessary for their bioenergy demand and whether there is enough surplus land for energy crop production. Most participants were convinced that it is necessary to consider impacts of EU bioenergy policy on the global level and that indirect impact of EU bioenergy production (e.g. indirect land-use change) on countries outside of Europe have to be taken into account (e.g. so as not to overestimate the C-mitigation potential of biofuel production in Europe). EU bioenergy policy should be improved and if necessary revised: e.g. RES Directive (2009/28/EC) states that, for example, an impact on food prices or impacts of indirect land-use change will need to be further elaborated and improved. Moreover, these issues are also subject of the IEA Bioenergy Tasks 40 and 43.

- **Energy crops on marginal land**

  It is quite common in conceptual approaches for future bioenergy production to advocate the use of marginal or degraded lands so as to avoid competition with food production. Although some countries seem to have a lot of so called marginal land available, considerable regional differences in the definitions of marginal land have to be expected. In general, land is marginal in its suitability for agricultural production due to adverse soil, topographic or climatic conditions and/or remoteness to the markets. If it can hardly be use for food crops, it is questionable whether it would be suitable for growing energy crops. If the marginal land is covered by permanent grassland, a carbon dept might occur when converted to energy crops. Further, if only dispersed areas of marginal land are used for energy feedstock production, the CO2 emissions associated with transport of the feedstock to the end user could negate all the potential C-mitigation. Failing in C mitigation could put a break on the development of energy crop production and full life-cycle and regional specific Life-Cycle Analysis (LCA) would be necessary to assess the GHG mitigation potentials of energy crops.

- **Intensity of food- and energy-crop management**

Aspects of optimization of energy crop management to increase yields as well as increasing yields of food production for freeing-up land for energy crop production were raised in the presentations. There was concern among the participants that a holistic perspective of those optimization processes would need to be developed. An increased use of fertilizers for example could strongly affect the GHG balance. How the management of energy cropping systems will evolve is not clear, because it will depend on the driving forces mentioned by most presenters. The point is that the management of these cropping systems may be likely configured in various ways, and these configurations will influence their economic profitability and environmental impact. Therefore, on the one hand it would be interesting to predict how intensive the cultivation of energy crops will be in the future, according to local and global driving forces. Moreover, on the other hand it is necessary to set up crop management practices (tillage, fertilisation, irrigation, pest management) that minimise the impact on the environment.
A further aspect is the increased use of organic waste and residues drawn from food crop fields for fuel or energy production. If those materials are not added to the soil of fields, maintenance of soil organic matter and thus soil fertility will be affected, inducing impacts on the GHG balance and environmental condition.

- **Scales**

A conflict was identified between the scales at which strategies for bioenergy are developed, the impacts of bioenergy production and the assessments of the impacts. Targets for developing bioenergy are formulated at national and international scales but those targets may conflict with regional or local scale preferences or preconditions. Likewise, current models of bioenergy induced land-use change are designed to operate well at national, continental or global scales but they are less well equipped to model local/landscape level change. In this context it is important to consider that different drivers (i.e. social, technological, economic, environmental, policy governance) play out at different scales.

- **Uncertainties**

An important issue is that policy targets for bioenergy use rely on uncertain environmental and economic performances. There are considerable knowledge gaps about environmental impacts, market development, agricultural development and technological development with respect to large-scale bioenergy production. There are controversial views about whether there is enough land area for large-scale bioenergy production that is sustainable, not harming the environment and socio-economically viable. Reasons behind this uncertainty are difficulties in a secure assessment of the competition between food and fuel feedstock and the possibilities of optimization of food and fuel production. Further, the “learning effect” that could make renewable energy technology cheaper rapidly, within a decade or so (see e.g. “100% renewable energy electricity – a roadmap to 2050 for Europe and North Africa, report by PricewaterhouseCoopers LLP, PIK, IIASA and ECF, 2010, pp. 138) is difficult to assess and to take into account in economic scenarios. “Emergency brakes” required to deal with uncertainties and lack of stability in policy however might impede the development of a robust market is affecting farmers decision regarding adoption or expansion of bioenergy crop production. Governmental “u-turns” will not provide the needed security for a bioenergy industry to develop. There is in particular a lack of data regarding social indicators.

- **Tools**

An urgent need for development or adaptation of tools for decision making and landscape planning was identified. It became apparent that there is in particular a need for multi-scalar approaches, for better representation of human decision making processes and for probabilistic instead of deterministic thinking. The regional scale was identified as being of particular importance for decision making and strategic planning tools and here socio‑economic analysis might be helpful for complementing and strengthening applications. Spatially explicit yield and suitability mapping could help identifying important land-use implications at regional or finer spatial scales and sustainability appraisal could help bridging between spatial scales. For this an inventory of data and of the spatial resolution of data for the European countries would be useful to assess the applicability of such tools at a European level.

- **Research needs**

  To tackle the scaling issues and the uncertainties, further research is needed. In particular socio-economic research has some catching up to do with respect to social impacts of bioenergy production at both coarse and fine scales. New information on landscape scale processes including individual decision making, social structure and interactions need to be generated so that behaviour of individuals and communities can be put into land-use models. For this, an appropriate method for determining economic and social impacts and for developing several quantitative assessment methods and indicators needs to be developed. Furthermore, we have to find unified ways of accurately assessing agricultural productivity and its regional potentials for increase. A multidisciplinary approach should be taken for assessing which ecosystems are affected by what kind of bioenergy management and which ecosystem services are affected to what extent? An ecosystem service approach to land management would offer the opportunity to study the topic in a wide and multidisciplinary perspective and to relate the developments of bioenergy to human well-being.

2.3 Results of plenary group discussions

Fuelled by the keynote lectures the plenary discussions aimed at identifying the most important statements, questions and objectives to be dealt with during the workshop.
In a first step, the participants formulated the most important questions related to energy crop production in Europe, viewed from a socio-economic and environmental sustainability perspective:

- Is European policy on bioenergy in its current form adequate to achieve its energy security and climate change mitigation targets, without causing risks for society and environment to occur?
- Is bioenergy going to be a major form of land use in Europe?
- Is there enough land area available within Europe to feed and fuel itself?
- If yes, could this be achieved in a sustainable way?
- Which portfolio of bioenergy feedstock will be necessary to meet the EU bioenergy directive and what share will bioenergy have in the whole renewables sector?

The participants agreed on the fact that policy on bioenergy is running ahead of science and that it is a major challenge to find a way of catching up with policy. In order to meet this challenge, important steps to be taken would be:

- Determine the niche (spatial and economic) of crop related bioenergy in Europe,
- Develop methods for an accurate assessment of agricultural production potential and considerably improve existing baseline information on land use,
- Identify constraints to bioenergy crop production in Europe,
- Use those constraints for projecting land allocation and freeing up of land for bioenergy production,
- Check whether farmers decisions in taking up bioenergy production match the modelling projections,
- Assess the scaling and spatial distribution of land allocation for bioenergy crops,
- Consider socio-economic aspects of land allocation and possible changes in land ownerships, and
- Identify regional specific environmental impacts and implications for ecosystem services.

At the policy-science interface, some effort would have to go into finding ways for policy to adapt to taking uncertainty into account and how “emergency breaks” could be implemented in directives to allow for quick response in case developments shift towards unintended outcomes. Given the uncertainty in whether we could or would have to increase crop yields per unit of land within Europe to make space for energy crops and in what environmental and socio-economic effects this would have, a strategic discussion including all stakeholders (or society as a whole) would be necessary to address the question of how we can make the best/optimal use of our land. The basic idea steering this discussion should be “Think EU, act regional”. While science is working on catching up with policy decisions, communication strategies between the scientific community, policy makers and other stakeholders should be developed to facilitate implementation of scientific findings.

Scenario based models of future land use could be valuable tools for facilitating the decision-making process. They could project the spatial locations and dispersion of various types of feedstock of energy crops as well as reveal potential mechanisms for achieving ‘optimised distributions’ under economic and environmental aspects.

Further tools or combinations of tools that might be developed or extended for application in the decision-making process are regional scale assessment and monetising of ecosystem services, macroeconomic models linked with environmental impact assessment and life-cycle analysis improved for taking environmental impacts at a range of scales into account.

As bioenergy as a whole would be too big a subject for the workshop, the participants agreed on limiting the discussions to crop based bioenergy. It was further decided to split into two working groups, one discussing development of spatially explicit scenarios of energy crop distribution in Europe, and the other group discussing ecosystem service assessment and development and scaling of decision-making tools.

2.4. Results of working group discussions

2.4.1. Scenario building

The working group believed that development of scenarios of future bioenergy production in Europe would serve as a basis for identifying gaps in current research and in turn prioritising future research directions in this field. It therefore would have a potential impact on new developments in bioenergy science and policy.
The working goup decided not to build on the existing SRES scenarios (compare Hellmann & Verburg 2008) but to develop a basis for the construction of own more bioenergy focused storylines instead. Based on the presentations and the previous plenary discussion, the group found that freeing up land within Europe is the most crucial prerequisite for an increased crop based bioenergy production. Three ways of freeing up land were identified: Increased import of food (Global Trade), intensification of food production to increase yields within Europe (Techno), and lifestyle change within Europe (Lifestyle). The three pathways are not exclusive but could interact or complement each other.
The basic storylines behind the three scenarios are:
Global Trade: More food and feed is imported from outside Europe so that land area currently used for food and feed production will become available for energy crops.
Techno: Food and feed production within Europe will be locally intensified and optimised so that equal or even higher yields can be produced on less land. The freed up land will be used for energy crops.
Lifestyle: European society changes its lifestyle e.g. by eating less meat, using less fuel and energy and building more energy efficient housing and transport. As less land is required for crop based than animal based diets, land is freed up for energy crops. In total, less land for energy crops is required due to more efficient use of energy.
For the first two scenarios at least two variants are possible: sustainable or non-sustainable. For **Global Trade**, the sustainable variant restricts imports to certified, sustainable goods that do not cause environmental damage and indirect land-use change outside Europe and for **Techno,** the increase of yields within Europe will be achieved by environmentally friendly improvements of agricultural production. Both sustainable variants are however less plausible than the non-sustainable variants. All three (or five) scenarios will result in land freed-up for other land use such as energy crop production but for each scenario, different types of current land use, probably located in different regions will become available (Table 2.4.1.). The sustainable variants would probably be less efficient in freeing up land than the non-sustainable scenarios.

Table 2.4.1: Impacts of the scenarios Global Trade, Techno and Lifestyle on land use in Europe. The table depicts the development of the land area covered by the respective land use under the three scenarios. D = decrease of area; I = increase of area; NC = no change

Land use	Global Trade	Techno	Lifestyle
Grass	D	D	D
Crop	D	D	I
Feed	D	NC	D
Forest	I	I	NC
Urban	NC	NC	?

The scenarios also differ in their regional impacts as land areas of different productivity grades would be freed-up by the respective developments. In the Techno scenario, food will be produced on the most fertile land and more marginal land will become available whereas for Global Trade, both high and low grade land will be freed-up. As mentioned earlier, the three pathways are not exclusive and each one could have a certain share in future developments. Also they could operate in parallel but become apparent in different regions within Europe. A novel and challenging task would therefore be to develop a modelling approach for an “interaction triangle” of the three scenarios in which the importance of each pathway could increase or decrease at the expense of the respective other pathways (Fig. 2.4.1). Such an “interaction triangle” of scenarios could be a helpful tool in depicting societal choices and for regional adaptations of the storylines.

The outcomes of the scenarios can be used for defining filter systems for constraint analysis on allocation of land for energy crop production. An example for a spatially explicit constraint analysis had been demonstrated in the talk by Angela Karp and is published by Lovett et al. (2009). A modelling chain for allocation of energy crops at a European level has been developed by the EURURALIS project (Hellmann & Verburg, 2008). Further refinement of the scenarios would include taking supply chains, nature and locations of end-users, technology of energy production, and socio-economic indicators into account. The working group identified the need for development of more sophisticated approaches with respect to the scaling of scenarios (e.g. downscaling of land-use change to a regional level) in order to make European trends spatially explicit at the regional scale. How socio-economy and decision-making processes at the levels of individuals could be included into the scenario development and subsequent modelling process is also an issue which requires further consideration as it is still very hard to represent individual decision making in a model in a reproducible way.

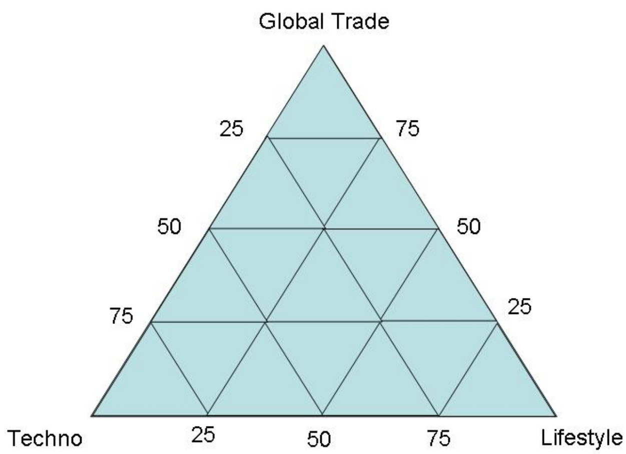


Fig. 2.4.1: “Interaction triangle” of the three scenarios Techno, Lifestyle and Global Trade.

2.4.2. Ecosystem services assessment

Scenario input

The assessment of the impacts of energy crops on ecosystem services (ES) necessitates information on reference land uses and energy sources that will be replaced (or displaced) by energy crop cultivation and bioenergy generation. The outputs of scenario building are thus critical inputs to ES assessment (Fig. 2.4.2). In particular, assumptions regarding the quantity, intensity and type of food production in Europe will determine the type and quantity of land on which energy crops are cultivated (direct displacement effects), and the landscape context in which energy crops are cultivated (landscape scale ES effects). Meanwhile, assumptions on the quantity and sourcing of food imported from outside Europe will determine which indirect global land-use effects should be considered (in particular, encroachment of agricultural production into natural habitats). Finally, consequences for ES will also depend on the pathways of bioenergy production, including processing chains (income and employment generated per unit land), and the type and quantities of fossil fuels displaced (resource extraction and emission implications). Ultimately, the relationship between scenario development and ES assessment should be a two-way iterative one.

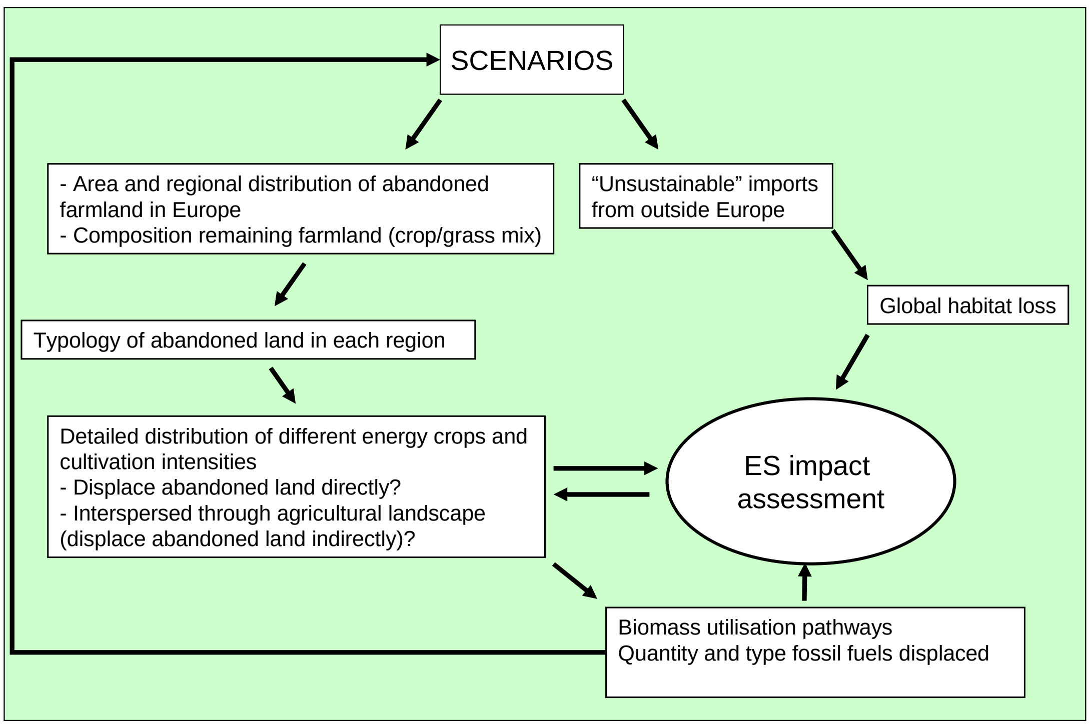


Fig. 2.4.2: Relationship between critical factors (inputs/outputs) for scenario development and assessment of energy crop ES impacts.

Reference systems for ES assessment

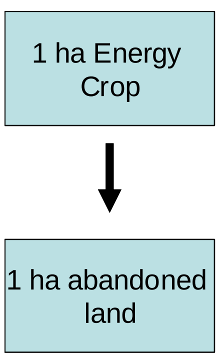
Determination of reference systems for comparison with energy crop cultivation and bioenergy use depends on specific scenarios. The working group proposed a number of rules that could be used to determine reference systems based on scenario outputs, in order to comprehensively and accurately assess net ES impacts of energy crop utilisation chains:

- The EU scale should be used to define geographical boundaries of direct use, but a global scope is unavoidable for assessing impacts (e.g. reduction in fossil fuel imports, indirect land-use effects)
- Ultimately, there are two reference land-use systems for energy crop cultivation that must be accounted for: (i) abandoned agricultural land; (ii) conversion of non-agricultural land (e.g. natural habitat) to agricultural use

- Where scenarios do not assume displacement of food production outside the EU, global land-use effects can more justifiably be excluded from comparisons (although this neglects equity considerations regarding global land appropriation per person)
- Within the EU, assuming no expansion of agricultural land, the primary reference land use will be abandoned (presumably marginal) agricultural land (Fig. 2.4.3)
- "Chains" of land-use change (e.g. when energy crops are interspersed throughout agricultural landscapes) must be fully accounted for as they have important implications for ES assessment (Fig. 2.4.4)
- Some ES effects (especially those influencing wider agroecosystem productivity) will feed back directly into scenario development (Fig. 2.4.3) but are difficult to estimate
- Comparison of different types of energy crop should always be based on net ES impacts relative to respective reference systems

The working group discussed possible ES impacts associated with interspersed energy cropping. It was proposed that energy cropping within the context of intensive agroecosystems dominated by a few crop types could improve many regulatory and supporting ES (see below) and thus increase the long-term productivity of those ecosystems (Fig. 2.4.4). Possible benefits of planting energy crops as break crops include the provision of soil conditioning, erosion breaks, habitats for pollinators, etc (e.g. Borjesson, 1999). It was proposed that there is considerable scope for improvement of net agroecosystem productivity at the EU scale by redistribution of crops to most appropriate areas. This could include establishment of various energy crops on land where their productivity is high compared with food crops (e.g. willow planted on wet soils). However, interspersal of energy crops in the agricultural landscape may also cause negative indirect effects associated with displacement of food production (back) onto marginal lands where it may be more damaging (e.g. to water quality). These constraints will evolve, and become quantified, with feedback between scenario development and ES impact assessment.

On an EU scale, if energy crop establishment does not cause (directly or indirectly) the appropriation of "new" land for agricultural uses, the reference systems may be simplified according to the following examples:



ES impact assessment based on:
•1 ha lower-yield energy crop
•1 ha abandoned land (reference land use)

N.B. Abandoned land highly dependent on region: could be dry (S Europe) or wet (N Europe). Implications for most suitable crops, and their ecological impact.

Fig. 2.4.3: Reference system when energy crops are established directly on abandoned (marginal agricultural) land

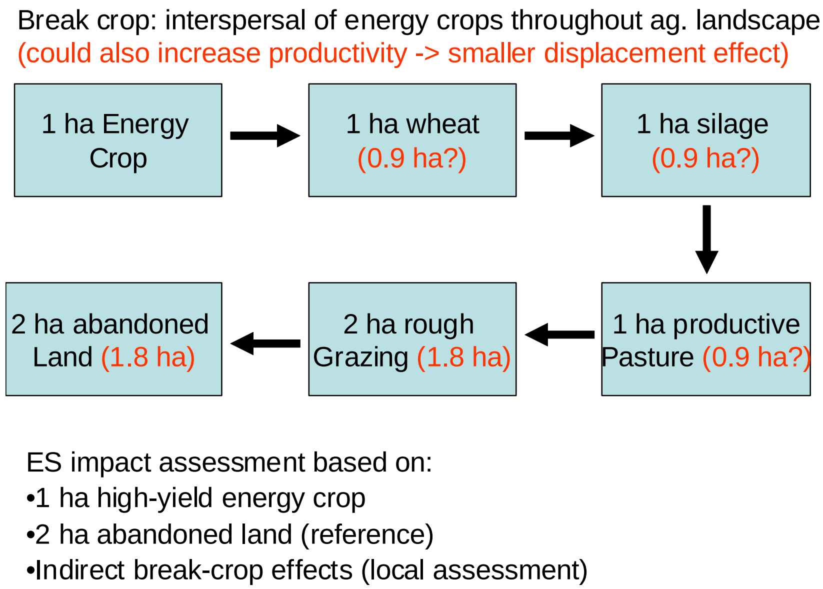


Fig. 2.4.4: Example of a possible reference system when energy crops are interspersed throughout intensive agricultural land areas

It was noted that assessments of energy crop ES impacts, and comparisons across types of energy crop, have hitherto often focussed on direct comparison with other food or energy crops. The preceding paragraphs emphasise the importance of careful reference scenario definition, and the full consideration of indirect effects, in order to accurately reflect net ES impacts of energy crop cultivation - many of which are highly sensitive to the landscape/agroecosystem context in addition to the land use actually displaced. Consequently, where the relative performance of different energy crops is to be compared, assessment should be based on the relevant reference systems, necessitating data or assumptions on landscape and agroecosystem (e.g. surrounding crop type) context. For example, in order to compare the ES impacts of sugar beet (for biofuel production) with willow (for heat production), different reference systems should be used. A chain of land-use change would be more likely for sugar beet (Fig. 2.4.4), whilst willow may be planted directly on abandoned land (Fig. 2.4.3). Net impacts relative to reference systems could then be expressed per hectare of land used or per GWh of useful energy generated for comparison of these alternative energy crops and bioenergy chains.

A major conclusion from the working group was that the characteristics of marginal agricultural land most likely to be abandoned differ considerably across European regions, but are not well defined. A descriptive typology of marginal land prone to abandonement is urgently required. This would provide a sound basis for all impact assessments of land-use change, not just ES impacts associated with energy crop cultivation.

Ecosystem service measurement

Ecosystem services, and the potential impacts of bioenergy chains on them, are diverse. Some ES are frequently omitted, or poorly quantified, by the tools commonly used to assess energy crop bioenergy chains (e.g. LCA). Comprehensive calculation of the net impacts of energy crop bioenergy chains necessitates an assessment framework based on the entire suite of relevant ES. Whilst it may not be possible to quantify all ES impacts with acceptable levels of confidence, such a framework would at least enable the identification of important gaps and uncertainties, which could be targeted for future research. Chapter 4 of the Millenium Ecosystem Assessment Report highlights the need for ES assessments to be performed on multiple, inter-related scales (MEAR, 2005). One of the working group's objectives was to ascertain the sensitivity of energy crop ES impact assessment to the scale considered, and to identify the most relevant scales at which different ES should be assessed, in order to guide, and maximise the return on, future assessment efforts. As a starting point, the working group took the list of ES defined in the Millenium Ecosystem

Assessment Report (MEAR, 2005). Each ES was then characterised, in the context of energy crop impact assessment, according to the following criteria:

1. Critical determining factors
2. Most important scales at which these factors operate
3. Most appropriate measurement tools
4. Highest scale at which reasonable ES impact modelling can be performed

Table 2.4.2 summarises the outcome of the working group discussions. Firstly, it was noted that there is considerable overlap across the three categories of natural ES (Provisioning, Regulatory, Supporting). For example, provision of clean water (provisioning) is closely related to water purifaction (regulatory), whilst erosion regulation (regulatory) is closely related to soil formation and retention (supporting). The working group made first estimates of relevant criteria based on initial interpretation of relevant defintions. Difference were inferred based on the ES category: erosion regulation was inferred to include erosion breaks and soil retention, whilst soil formation and retention was inferred to include soil forming processes such as organic matter accumulation and plant-induced chemical and physical breakdown of mineral materials. More work is required to accurately define a list of the ES processes most relevant for energy crop impact assessment, and relevant processes.

Regarding scale, bioclimatic conditions are critical to all ES, and bioclimatic regions provide the overarching context in which comparative land-use assessments must be made. For example, primary production and associated provisioning services are directly dependent upon climatic conditions, but also upon field scale management practices that determine yield. It was proposed that provisioning in terms of fuel can be reliably modelled using crop models, based on bioclimatic limiting factors (or potential) and making assumptions on average management practices. For example, the yield potential of miscanthus has been modelled across Europe based on climatic conditions (Clifton-Brown et al., 2004). For other ES, the bioclimatic region provides important context, but is not the major factor determining the impact of energy crops (although it should be noted that the rate of change in bioclimatic conditions will have serious consequences for reference ES in different regions, and thus the impact of energy crops on them). For example, all regulatory services depend on the bioclimatic context, but in terms of energy crop impacts these services are more dependent on processes occurring at the ecosystem and field scales.

Many regulatory and supporting ES are thought to be strongest in intact natural ecosystems (de Groot et al., in press). Therefore, disturbance of natural (and perhaps also of stable agricultural) ecosystems was considered as a major factor that could impact on these services (Table 2.4.2). Ecosystem modelling was therefore thought to be relevant for estimating energy crop impacts on many regulatory and supporting ES. Meanwhile, the landscape distribution and specific field pattern of energy crop cultivation relative to other crops and natural habitats are also likely to be important determinants of the extent, and possibly also the direction, of impact on a number of regulatory ES (e.g. invasion resistance, erosion regulation). Consequently, accurate modelling of regulatory ES impacts requires high resolution data on energy crop distributions – preferably at the field scale. However, quantitative understanding of many of these impacts is currently lacking, and further experimental and empirical survey data are required.

Table 2.4.2: Important factors for natural ES, at different scales, main assessment tools, and relevant modelling scale. Most important factors and scales highlighted.

Ecosystem Service	Bioclimatic region	Watershed	Landscape	Ecosystem	Field	Assess tool	Modelling scale
Provisioning							
Food	Climate		Soils	Productivity	Management	Crop models	Bioclimatic
Fuel	Climate		Soils	Productivity	Management	Crop models	Bioclimatic
Fibre	Climate		Soils	Productivity	Management	Crop models	Bioclimatic
Clean water	Climate	Water balance		Filtration	Management	From WFD	Watershed
Biochemicals	Climate			Habitat loss		GIS land cover	Ecosystem
Genetic resources	Climate		Composition	Habitat loss		GIS land cover	Ecosystem
Regulatory							
Invasion resistance	Climate		Heterogeneity	Disturbance	Pattern	Experimental	Ecosystem / field
Herbivory	Climate		Heterogeneity	Disturbance	Pattern	Experimental	Ecosystem / field
Pollination	Climate		Heterogeneity	Disturbance	Pattern	Experimental	Ecosystem / field
Seed dispersal	Climate		Heterogeneity	Disturbance	Pattern	Experimental	Ecosystem
Climate regulation	Climate		Composition	Productivity	Management	IPCC method/LCA	Bioclimatic
Pest / disease reg	Climate		Heterogeneity	Disturbance	Pattern	Experimental	Ecosystem
Nat Haz protect	Climate	Disturbance	Composition	Disturbance		Empirical obs	Ecosystem
Erosion reg	Climate	Disturbance	Topography	Disturance	Pattern	Experimental	Watershed
Water purification	Climate	Water balance	Composition	Disturbance	Management	Experimental	Watershed
Supporting							
Primary production	Climate		Soils	Disturbance		Ecosys models	Bioclimatic
Habitat provision	Climate		Heterogeneity	Disturbance		Experimental	Ecosystem
Nutrient cycling	Climate		Soils	Disturbance		Experimental	Ecosystem
Soil formation + retention	Climate	Disturbance	Topography	Disturbance	Management	Ecosys models	Landscape
Prod atmospheric O_2	Climate		Soils	Disturbance		Ecosys models	Bioclimatic
Water cycling	Climate	Disturbance		Disturbance		Ecosys models	Watershed

Table 2.4.3: Important factors for socio-economic ES, at different scales, main assessment tools, and relevant modelling scale. Most important factors and scales highlighted.

Ecosystem Service	Global	Europe	Nation	Landscape	Ecosystem	Farm	Assess tool	Modelling scale
Socio-economic								
Income	Resources	Trade-balance	Trade-balance			Management	Econ model	National
Employment	Resources	Trade-balance	Trade-balance			Management	Econ model	National
Investment	Policy + resources	Policy	Policy			Management	Empirical obs	Europe
Cultural								
Recreation / eco-tourism			Policy	Splendor / change	Diversity		Empirical obs	National
Knowledge / education			Policy				Empirical obs	National
Religious / spiritual			Tradition				Survey	National
“Sense of place”			Identity	Change	Change		Survey	National

Owing to several invitees being absent, the working group lacked expertise in socio-economic impact assessment. Nonetheless, it was proposed that full assessment of socio-economic impacts requires a more complete list of criteria than those presented in the Millenium Ecosystem Assessment Report (Table 2.4.3) and it was perceived that socio-economic and cultural ES impacts are generally not well quantified. Numerous studies have been published on the farm-level profitability of energy crops compared with other crops and abandoned land (e.g. Heaton et al., 1999; Rosenqvist & Dawson, 2005; Ericsson et al., 2006), and also on bioenergy costs compared with other energy sources. Such studies usually focus on either the supply or demand side of bioenergy chains, and appear to neglect criteria critical to determining net socio-economic impacts of entire energy crop bioenergy chains – e.g. balance of trade, value-added to national economies (or the EU in aggregate), and the distribution of this value-added (particularly with respect to employment in rural areas), taking entire bioenergy chains into account. In particular, compared with abandoned land and imported fossil fuels, it is evident that energy crop cultivation will increase economic activity at the EU level. However, this important impact is not captured by traditional economic studies that assess bioenergy based on the comparative cost relative to other (e.g. fossil-based) energy sources. There is a clear need for further work here, and this should tie in with concepts such as value-added supply chains and developing a green economy.

Case study energy crop ES assessment

In order to develop a simple but illustrative case study example on how ES assessment might be applied to calculate the impacts of energy crop cultivation, the working group decided to use a basic scenario with abandoned tillage land (fallow) as the reference case, and oil seed rape for biodiesel production, and Miscanthus for electricity or heat production, as potential bioenergy chains (Table 2.4.4).

Both energy crops offer additional ES provisioning, primarily for fuel. Production of biodiesel from oil seed rape generates a solid by-product that is usually used as animal feed (this needs to be accounted for in assessment, as per the practice of impact allocation in LCA). There may be additional provisioning opportunities for fibre and biochemical resources from many energy crops, depending on the utilisation pathways. As described in the ES measurement section, a number of ES impacts, particularly regulatory ES impacts, are dependent on the landscape context and field pattern. The impact of maintaining intensive oil seed rape production on otherwise abandoned land is regarded as negative for many regulatory and supporting ES (Table 2.4.4). By comparison, it is postulated that the effects of interspersing a perennial, low-input crop such as Miscanthus within an intensive tillage landscape may have a number of benefits, including provision of refuge (tall grassy habitat usually left over winter) for various species, wind and runoff erosion breaks, sediment and nutrient interception zones, soil carbon enrichment and structural development, etc. Such effects will also depend on the bioclimatic and landscape context (e.g. exposure to wind, proximity to water courses, etc). It is emphasised that knowledge on the specific context of energy crop cultivation is required to make valid assessment of these ES impacts.

In order to compare results across ES, either some form of weighting system or multi-criteria analysis would be required. Proposing such a system was beyond the scope of the working group, but will be necessary in the future. It was suggested that the relative importance of different ES, and determining processes, will vary considerably depending on the characteristics of 'typical' abandoned (marginal) land across Europe and the most important environmental pressures in a given region. Provision of clean water and erosion regulation are likely to be priority ES in dry Mediterranean regions, whilst pollination, invasion resistance and erosion regulation would be priority ES in fertile regions with high agricultural productivity. More generally, extensive agricultural land management is known to offer ES benefits compared with abandonment (de Groot et al., in press), suggesting that there is considerable potential for overall ES improvement based on cultivation of low-input energy crops on abandoned land. Different types of energy crops will be better suited to different types of abandoned land. The need for a set of regional-specific abandoned land typologies is emphasised. It was postulated that more complete ES assessment will enable the identification of optimised (food and energy) crop distributions across the EU, on a regional and field scale. This would require a feedback loop between scenario modelling and ecosystem assessment. To be realised, it would also require a mechanism to coordinate regional and local crop production patterns, and at times this could be in conflict with (perceived) farm-level profit maximisation. The Single Farm Payment was proposed a possible mechanism to achieve this.

Table 2.4.4: Estimation of ES impacts arising from displacement of abandoned land with oil seed rape and miscanthus.

Ecosystem service	Oil seed rape	Miscanthus	Comments
Provisioning			
Food	+	NA	Fuel OSR animal feed by-prod
Fuel	+	++	Based on yield
Fibre	NA	(+)	Misc could also be used for fibre
Clean water	-	(-)	Transpiration – reduced quantity
Biochemicals	(+)	(+)	Possible biochem uses
Genetic resources	NA	NA	
Regulatory			
Invasion resistance	(-)	(0)	Landscape / ecosystem context
Herbivory	(-)	(-)	Landscape / ecosystem context
Pollination	(+)	(?)	Landscape / ecosystem context
Seed dispersal	(-)	(?)	Landscape / ecosystem context
Climate regulation	(+)	++	Mixed conclusions on OSR
Pest / disease reg	NA	(?)	Landscape / ecosystem context
Nat Haz protect	-	(+/-)	Landscape / ecosystem context
Erosion regulation	-	+	
Water purification	-	(+)	Misc. has low chemical inputs
Supporting			
Primary production	+	++	
Habitat provision	-	(+/-)	Landscape / ecosystem context
Nutrient cycling	-	+	
Soil formation + retention	-	+	Misc: soil C accumulation and perennial crop soil stability
Prod atmos O_2	+	++	
Water cycling	-	NA	OSR water contamination
Socio-economic			
Income	+	+	Reduces fossil fuel imports
Employment	+	+	More labour intensive than oil
Investment	+	+	European energy investment
Cultural			
Recreation / eco-tourism	(0)	(0)	
Knowledge / education	(+)	(+)	New rural supply chains
Religious/spiritual	NA	NA	
"Sense of place"	(+)	(-)	Subjective, local opinion

Initial assessment by the working group suggests that the more positive GHG balance typically found for perennial low-input energy crops such as Miscanthus, compared with intensively-cultivated first-generation biofuel crops, may be extended to other ES impacts.

Furthermore, if scenarios were extended to involve implications for natural habitat displacement by agricultural production at the global scale, a greater differential in ES impacts would be observed for these two energy crops reflecting the relatively low areal energy yield of oil seed rape. To illustrate the importance of land-use change in agricultural impact assessment, land-use change associated with agricultural production is responsible for approximately 12% of global anthropogenic GHG emissions. Future change could have a greater impact per hectare converted owing to remaining exploitable areas being dominated by carbon-rich (and high-nature value) humid forests (Burney et al., 2010). Consequently, there was consensus within the working group that policies promoting biofuel production from intensive feedstock crops within and outside the EU are running ahead of (even divergent to) current scientific understanding. Further quantification of energy crop ES impacts is likely to underline this point.

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3. Assessment of the results, contribution to the future direction of the field, outcome

A major conclusion of the overall workshop was that EU biofuel policy is running ahead of scientific evidence. The scientific community (i.e. socio-economy, environmental sciences, agricultural sciences) is challanged to catch up with the current developments in climate change mitigation and the bioenergy sector to be able to inform policy and to reduce the uncertainties that are currently hampering an environmentally sustainable and economically viable (uptake by farmers, long term investment of bioenergy projects) development. One of the most striking examples of the magnitude of uncertainty regarding the development of crop based bioenergy, as revealed during the workshop, is that the participants could not agree on whether there is sufficient amount of land available within the European countries to cover the domestic demand of crop based bioenergy. On the one hand there were examples how energy plants can be integrated into a landscape management which makes use of "marginal" or set aside land, as practised in the UK, in a way which seems quite acceptable also with regard to biodiversity and nature conservation, while on the other hand the overall consumption of food and non-food in the EU leads to increasing net import of land and contributes to the expansion of cropland in other regions (at the expense of natural eco-systems). The demand of land was identified as one of the major factors determining the environmental and socio-economic impacts of crop based bioenergy production. How many GJ/ha can be produced where, on which type of land, is a problem which is highly debated but not solved. It however determines the global impacts of European bioenergy policy (indirect land-use change) and the pathways to be taken to utilise or free-up land for bioenergy production. It shows that one should carefully design any measures triggering further production and use of energy crops, in order to minimize problem shifting.

The scenario group of the workshop had picked up on the question how land could be freed-up for bioenergy production and has prepared a framework for the development of three scenarios for the projection of future bioenergy production, sourcing of feedstock and spatial dispersion. A novel approach is the development of an interaction matrix for the scenarios which will make a regional specific parallel development of scenarios and later regionalised projection of the impacts under the respective storylines possible. The scenario group has agreed on commencing with the development of this approach and drafting of a manuscript is envisaged.

The ES working group agreed that impact assessment should play a more central role in both determining maximum sustainable production of energy from crops and identifying optimal energy crop supply strategies to meet given targets. The ES group based their discussion on the use of marginal land in Europe for bioenergy production. A major conclusion from the working group was that the characteristics of marginal agricultural land most likely to be suitable for bioenergy production differ considerably across European regions, but are not well defined. A descriptive typology and an assessment of suitability (e.g. expected yields, ES competition, carbon debt) of marginal land are urgently required. This would provide a sound basis for all impact assessments of land-use change, not just ES impacts associated with energy crop cultivation. Drafting of an opinion paper which will also tackle the scaling issues of ES impact assessment is planned. The major research objectives identified are:

1. Assessment of energy crop ES impacts should <u>always</u> consider displacement of abandoned land (and/or agricultural conversion of natural habitat globally). This is sometimes done in LCA studies, but LCA methodologies do not adequately represent many ES

2. Research on energy crop ES impact needs to be performed at the most appropriate scale, which differs according to the ES being assessed (i.e. full ES impact assessment requires consideration of multiple scales)

3. The value of each ES is region-specific, depending on key environmental pressures in different regions: some form of ES prioritisation or weighting is required

4. The type of marginal agricultural land most likely to be abandoned varies considerably across regions. A regional typology of such land is required for land use assessment

5. Distribution (landscape context and field cropping pattern) has a critical influence on net energy crop ES impact. Ecosystem and field scale data are required to model such impacts

6. To optimise energy crop potential, crop type and distribution (from field to EU level) is critical: policy needs to consider the supply side and not simply set demand-side targets

7. ES impact assessments based on direct comparison with food crops are incomplete, but offer insight into beneficial ES impacts associated with interspersal throughout intensive agroecosystems

8. Energy crop distributions could potentially be influenced at the local (farm management) scale through the single farm payment mechanism in the reformed CAP

Apart from the drafting of two papers, concrete actions decided by the research network founded during the workshop are (i) applying for a COST-action and (ii) identifying a call within the EU Framework programme that could host the research network. A strong emphasis of the planned action will be on socio-economic research as this field has some catching up to do with respect to social impacts of bioenergy production at both coarse and fine scales. Nevertheless, a multidisciplinary ecosystem service approach to land management will be taken for assessing which ecosystems to what extent are affected by what kind of bioenergy management in which particular European region.

4. Final programme

Monday 26 April 2010

12.30-13.30	**Registration**
13.30-13.35	**Welcome by the Dean of Engineering, Mathematics & Science** **Prof. Clive Williams** (Trinity College Dublin, Ireland)
13.35-13.45	**Welcome by Convenors** **Jens Dauber** (Trinity College Dublin, Ireland)
13.45-14.05	**Presentation of the European Science Foundation (ESF)** **Jan Kraic** (ESF Standing Committee for Life, Earth and Environmental Sciences (LESC)
14.05-14.40	**Presentation 1 "Bioenergy use and production in Europe: trends, sectoral patterns and environmental and socioeconomic impacts"** **Stefan Bringezu** (Wuppertal Institut für Klima, Umwelt, Energie, Germany)
14.40-15.15	**Presentation 2 "Effects of environmental and policy change on land-use systems"** **Mark D.A. Rounsevell** (University of Edinburgh, UK)
15.15-15.45	*Coffee / Tea Break*
15.45-16.20	**Presentation 3 "Scenario building as a tool for projecting and assessing impacts of energy crop production"** **Dagmar Schröter** (International Institute for Applied Systems Analysis, Austria)
16.20-16.50	**Discussion and Round of Introductions**
16.50-18.30	**Group work** "Scenario building"
19.30	***Workshop Dinner*** **The Pig's Ear**, 4 Nassau Street

Tuesday 27 April 2010

09.00-09.35	**Presentation 4 "Road map for biofuel production in Europe"** **Marc Londo** (Energy Research Centre of the Netherlands, The Netherlands)
09.35-10.10	**Presentation 5 "Ecosystem services and multifunctional agriculture: effects and prospects of energy crops"** **Angela Karp** (Centre for Bioenergy and Climate Change, Rothamsted Research, UK)
10.10-10.30	*Coffee / Tea Break*
10.30-12.00	**Group Work** "Scenario building continued"
12.00-12.30	**Presentation and Discussion of Scenarios**
12.30-14.00	*Lunch*
14.00-14.35	**Presentation 6 "Economical and social aspects of biofuel production"** **Ülle Roosmaa** (Estonian University of Life Sciences, Estonia)
14.35-15.30	**Group Work**
15.30-16.00	*Coffee / Tea Break*
16.00-18.00	**Group Work**
18.00-18.30	**Presentation and Discussion of Group Work Results**
19.00	*Evening at your disposal*

Wednesday 28 April 2010

09.00-10.45	**Consolidation of Group Work Results; Identification of Knowledge Gaps**
10.45-11.00	*Coffee / Tea Break*
11.00-11.30	**Discussion of Publication Strategy of Workshop Results**
11.30-12.00	**Discussion on Follow-up Activities and Funding Opportunities** **chaired by Doreen Gabriel** (University of Leeds, UK)
12.00-13.00	*Lunch*
13.00-14.30	**Discussion on Follow-up Activities/Networking/Collaboration continued**
14.30	*End of Workshop and Departure*

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6. Statistical information on participants: age bracket: y = young scientist; s = senior scientist

Name	Age bracket	Gender	Country	Expertise
Dauber	Y	M	Ireland	Landscape ecology
Jones	S	M	Ireland	Ecophysiology
Turner	S	M	UK	Socio-economy
Styles	Y	M	Spain	Life cycle analysis
Bringezu	S	M	Germany	Global sustainability assessment
Bechini	S	M	Italy	Sustainability indicators
Fernando	Y	F	Portugal	Bioenergy systems
Gabriel	Y	F	UK	Agroecology
Brown	Y	M	UK	Socio-ecomony
Thraen	S	F	Germany	Bioenergy systems
Schröter	Y	F	Austria	Scenario building
Karp	S	F	UK	Agroecology
Roosmaa	S	F	Estonia	Rural economy
Zah	S	M	Switzerland	Life cycle analysis
Londo	S	M	The Netherlands	Biomass energy
Rounsevell	S	M	UK	Land-use change modelling
Finnan	S	M	Ireland	Biomass production
Van Groenigen	Y	M	Ireland	Soil science
Zimmermann	Y	M	Ireland	Soil science
Vorkapic	Y	M	Kroatia	Energy systems
Stout	S	F	Ireland	Biodiversity
Kraic	S	M	Slowakia	Agriculture