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ESSP Research on Bioenergy and Earth Sustainability: Tapping GEC Programme-Wide Expertise for the Benefit of Science and Society

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The Earth System Science Partnership (ESSP), a partnership of four international global environmental change research programmes dedicated to the integrated study of various aspects of the changing Earth System and its implications for global and regional sustainability, provides a key example of work on the interface of science and policy. Its newest research initiative, Bioenergy and Earth Sustainability, sets a new benchmark for cooperation on biofuels research. The initiative will adopt a multi-stakeholder approach, tapping into expertise of numerous global environmental change programmes and projects as well as intergovernmental agencies and the policy making community.

There have been many earlier studies on bioenergy but this initiative is unique in that it develops an Earth System approach to bioenergy, its opportunities and constraints, its contribution to stabilizing atmospheric CO2 as well as its tradeoffs and synergies for engaging in sustainable development pathways. The study also provides ample opportunities to evaluate the effects of biomass energy production on food availability and prices, water availability, water pollution, and biodiversity, in addition to analysing the capacity of bioenergy in climate protection. The overarching goal is, therefore, to identify the major opportunities and constraints for bioenergy in the context of Earth system sustainability. Although in its infancy, such an initiative provides an apt example of just the type of policy relevant research needed. The following sections will capture highlights from the initiative's scoping workshop, outlining its planned progression.

Bioenergy and Earth Sustainability: Research Questions and Issues

There are now several important natural resources which cannot keep pace with the increasing demand for their services. Productive land is one of these resources. Land is required for many crucial human activities such as the production of food and fibre, settlements, the production of bioenergy and the provision of many other services. At the same time, as the need for more land is growing, the availability of fertile land is threatened by the effects of desertification and climate change.

Human influence on resource needs and on the interplay between the different demands placed on land resources is determined by many factors. How land is used and which technologies are adopted is as important as the availability of these technologies, the ways in which land use is regulated by legal frameworks and political institutions, the influence of cultural norms on land use practices as well as the distribution of land use rights.

A conflict between meeting the increasing demand for food from a growing and more prosperous world population and the desire to replace fossil fuels with bioenergy, among other renewable energy sources, has become apparent over the last few years. A long-term trend of falling food prices has ended and has been replaced by soaring world market prices for grains and oilseeds. In many countries, this has led to dramatic price increases for basic foodstuffs, which has induced social unrest and could also increase the number of people living in hunger. At the same time, the production of biofuels has been increasing at an astonishing rate, such that the increase in food prices has been attributed to the expansion of biofuel production.

Especially in the transport sector, biofuels are currently the only significant energy source that can partially replace gasoline and diesel refined from fossil oil. The so-called first generation biofueis require agricultural crops such as grain, sugar cane, sugar beet or oilseed as feedstock and thus directly compete with food production for scarce fertile land resources.

This political conflict between the attempts to eradicate hunger both through affordable food prices and rising incomes, and the desire to replace fossil energy sources with renewable bioenergy addresses only a fraction of the choices

that societies need to make in order to achieve a significant contribution of bioenergy while maintaining Earth sustainability. The Earth's land area does not only provide food and bioenergy, it is also used and will be needed increasingly for providing living and recreational space for a growing world population as well as for preserving essential biodiversity services that are required to keep the Earth system stable.

This research initiative on bioenergy will, therefore, address several major research questions:

1. How much bioenergy can be grown in sustainable ways (in relation to opportunity cost, assessment of land availability, quality and optimality)?
2. What are plausible bioenergy scenarios?
3. How vulnerable are bioenergy systems to climate change?
4. How climate-protective are biofuels?
5. How can sustainability standards for bioenergy systems be defined?

These research questions will be further elaborated in the next sections.

How much bioenergy can be grown in sustainable ways?

There are several approaches, which are largely complementary, to addressing this research question. These include the establishment of opportunity costs (an economic approach), the establishment of resilient systems and pathways (a systems approach) or assessing land availability, land quality and optimal usage. Such assessments show what can we do with those lands, how one can overlay potentials and constraints and how tradeoffs and synergies can be determined. The results will show that there are combinations that work better than others for any given region.

Opportunity costs

It is important to note that, although opportunity cost approaches are traditionally associated with short-term economic profits, we use this approach as one that would be combined with principles to design long-term resilient systems. This allows for an exploration of the basic concepts and tools of economic opportunity cost in conjunction with resilience approaches in complex system science.

Task 1: Natural and economic potentials for additional food and bioenergy production: Exploring new modelling approaches

There are serious uncertainties concerning the potential to convert additional land currently not used commercially, to produce additional biomass for meeting the increasing demand for food and bioenergy. Current estimates come from biogeochemical model analyses that try to determine the areas suitable for increased biomass production, as well as from economic models focussing on supply dynamics in agricultural markets. The two approaches, however, have not yet been connected. In addition, the agricultural market models, in general, do not consider the economy wide repercussions of large changes in agricultural markets, as observed recently. Different models that look at the repercussions from agricultural markets towards the rest of the economy and vice versa should, therefore, complement the analyses of agricultural markets.

In this light, one or more workshops will be planned with the aim of convening modellers from the natural sciences and economics in order to explore how the different aspects of land use change and land use potentials can be brought together. Only such an effort can produce a balanced and integrated view of the future of food and bioenergy potentials. An opportunity to interact on possible future developments of integrated land use potential assessments should be provided, taking both natural and socio-economic potentials and restrictions into consideration.

Assessment of land availability and quality

From a biophysical perspective, there is an interest to assess how much land would be available for bioenergy production that would not compete with other land uses.This has brought the research community together to explore the availability of land that is currently not in use as a simple criterion to ensure sustainability. Abandoned land, marginal land, waste land or land under optimal productivity is emphasised. There is also a need to develop a functional definition of these types of lands. Once the availability of this type of land has been identified, it will be a combination of social and technical dimensions that will determine the actual potential of those lands to become productive (which links with task 1). This approach needs to include exploring lands with productivity under its realisable capacities, thereby allowing for additional cropping to take place.

Task 2: Top-down assessment of land availability

Implementation of task 2 will involve the following steps:

- Using existing global maps and datasets of land use and land cover to determine the extent of marginal, abandoned, degraded and waste lands and then synthesising the criteria, indicators and estimates underlying each category.

- Generating a biophsyical carbon map so as to determine the potential productivity on the available lands.
- Analysing to which extent these existing classifications are useful to understanding what new land is available for bioenergy crops as well as its potential.
- Identifying and developing sustainability filters that would exclude land such as conservation areas, areas with step topography, areas of high biodiversity areas and others from consideration for bioenergy production

The resulting comprehensive syntheses products are urgently needed.

Task 3: Bottom-up assessment of land availability

We propose to develop a number of regional case studies with a critical analysis of land use, land availability, productivity and opportunity costs based on the regional socioeconomic realities and governance capacity. The ways in which global forces impact these cases must also be evaluated. This would be done by gathering regional and national assessments and bringing a wide group of experts and stakeholders for validations, as well as to complement information on the possibilities and constraints with more detail. In so doing, we will also address the following questions:

- Where is additional carbon/bioenergy potential?
    - What types of assessment approaches have been used in each case?
    - Evaluations of existing local and regional datasets, appraisals of the need to establish new databases and assessment of the different resources will be necessary.
- Why has this potential not been realised?
    - The checking of yield gaps and an understanding of what biophysical and socioeconomic constraints are responsible for these gaps will be necessary.
- Where are the opportunity costs?
    - If we want to achieve these targets, what is required and what is the cost? Tradeoffs will need to be built in.

Candidate regions for the bottom-up assessment of land availability include South America (Argentina, Bolivia, Brazil, Paraguay, and Uruguay); Central America (Guatemala, Honduras and Southern Mexico); Others (China, India and Southern Africa).

Task 4: Assimilation of top-down and bottom-up information to produce realistic estimates of bioenergy potential

Tasks will include:

- The creation of global maps of marginal land by iteration between the bottom-up and top-down estimates
- The further development and use of biogeochemical and integrative assessment models to estimate the potential for bioenergy production
- Outlining of the options for transition to bioenergy, taking into account the regional realities with emerging markets, financial incentives, etc.
- Identification of the sustainability criteria that should underpin any new land-use development
- Scenario development of bioenergy production over time incorporating climate change, technological innovation and the testing of multiple tradeoffs, while constrained by sustainable criteria, etc.

Task 5: EBI Workshop on Bioenergy Crop Modelling and Land Use (9-10 October 2008 EBI, Calvin Lab, UC-Berkeley)

A bioenergy cropland use and modeling workshop, was held in mid-October 2008. This workshop focused on further defining abandoned and marginal land distributions for current and developing bioenergy lignocellulosic crops, as well as designing a bioenergy crop modelling baseline benchmark for validation. This will lead to a well-planned strategy to understand bioenergy crop production potentials on marginal and abandoned lands.

Assessing for optimality

A first approach is to test the resolution of tradeoffs and synergies of multiple bioenergy pathways in order to ensure regional and global sustainability of bioenergy expansion. A key example of tradeoffs involves the water allocation for food, bioenergy, industry and human consumption. A second example is between carbon storage and energy production, whereby a synergy would take place if a biofuel crop could also contribute to long term soil carbon sequestration. This begs the question, do we want to optimise a system to produce bioenergy so as to displace fossil fuel emissions or rather to sequester carbon so as to remove atmospheric CO2? This example is closely linked to the choice of plant functional types, including the choice between annuals versus perennials, in parallel with the environment and economics of an ongoing business as usual bioenergy production. Both examples require the consideration of environmental, social and economic aspects and, hence, further emphasise the uniqueness of this bioenergy study from an Earth system analysis perspective.

What are plausible bioenergy scenarios?

Scenario development is important and can proceed in four steps. First, narrative land use storylines that focus on bioenergy development and that are consistent with global or regional energy scenarios must be developed. These narratives should consider resource competition and define clear environmental targets. However, for the final scenario, it is more important to focus on the pathways to reach a target rather than the targets themselves. Second, different dimensions of the choices to be made must be identified and the parameterisation based on global storylines, regional priorities as well as constraints must be provided. Third, feasible pathways to meet bioenergy targets should be identified that take technological availability, resource constraints and regional priorities into account. Finally, scenarios to determine and quantify interactions, tradeoffs and synergies in terms of a common set of system dimensions should be assessed.

Scenario development tasks include:

- Establishing links to existing or ongoing scenario work.
- Defining dimensions and their contrasting endpoints of choices, which can be used in the scenario story lines.
- Incorporating various bioenergy systems keeping technology issues related to feedstock types and productivity, biomass use and conversion, and agricultural technologies in mind.
- Linking to all the other resources such as water, marginal land, intensification potential and biodiversity impacts.
- Establishing a dialogue between the global and regional levels to achieve consistency.
- Assessment of scenario and learning
- Communicating and capacity development.

How vulnerable are bioenergy systems to climate change?

Climate change is predicted to shift temperature and precipitation patterns as well as increase climate variability in the future and, therefore, pose an inherently greater risk to land based industries. As large scale land transformation is driven by socioeconomic changes at the farm and industrial levels, climate change and its climate variability component must be evaluated to avoid creating risks for new agricultural systems. Climate change and climate variability can also put the production of both food and energy at risk. Examples of great success, such as Mauritius where 40% of all energy comes from biofuels, require further analysis to ensure the resilience of food and energy production systems. Target regions should, for example, include semi-arid

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regions and Sub-Saharan Africa. The integrated assessment tools and a series of comprehensive tasks have yet to be further elaborated.

How climate-protective are biofuels?

Concerning the full consequences on radiative forcing including changes in surface albedo and carbon sequestration of bioenergy pathways, the industrial, ecological environmental life cycles of land need to be considered. The first involves cultivation and harvesting aspects and should include a full greenhouse gas lifecycle, also considering, for example, fertiliser use and energy requirements for machinery. It is also important to assess all co-products, which is relatively simple in terms of electricity and heat co-generation but extremely difficult for others. The ecological life-cycle involves the shift from emissions per GigaJoule biofuel or per volume-km to emissions per ha y-1, as well as the required land use changes and the consequent carbon lost from ecosystems. An emerging concept here is the Ecosystem Carbon Repayment Time (ECRT). The environmental lifecycle involves all greenhouse gases, aerosols, sot and biophysical factors such as reflectivity (albedo), evaporation, and surface roughness. All factors influence the radiative forcing balance of the atmosphere.

Task 6: Develop Approaches to Assess a Full Radiative Forcing
This task will extend the mandate of the Full Radiative Forcing activity of the Global Carbon Project, the general goal of which is to develop a complete picture of the global carbon cycle, to include biofuels. At present the group is focusing on plantations for carbon sequestration.

How should sustainability standards for bioenergy systems be defined?

Numerous countries are developing bioenergy plans, yet many have little experience or exposure to the larger issue of sustainability pathways, both at the regional and global levels. The development of sustainability guidelines with principles general enough to be useful to countries around the world that are beginning to develop their bioenergy plans, is envisioned.

One of the first steps in accomplishing this was a presentation and discussion of bioenergy at the Policy Dialogue, Energy, Sustainability and Societal Change, in Santa Barbara, California, USA. This dialogue strongly focussed on the opportunities to provide the world with sustainable and reliable energy as well as the role of science and policy in tackling key energy issues. The opportunities not only included alternative and renewable energy sources but also the required changes in institutional frameworks, behavioural patterns and lifestyles. The potentials for and constraints of bioenergy were presented discussed with an important outcome being to stress the importance of mutual learning. It became clear that with regard to bioenergy as will so many other energy themes, such learning must take place in an integrated way, involving natural scientists, engineers and social scientists on one hand, and policymakers and other stakeholders on the other.

In striving for such mutual learning, research questions must be addressed in a timely manner. The results of global and case studies on the world's most pressing issues, such as bioenergy for the promotion of a sustainable energy future, must be both relevant to the needs of stakeholders and clearly communicated. It is with this in mind that ESSP will carry out its Bioenergy and Earth Sustainability initiative.