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BIOFUELS and FOOD SECURITY

38

Implications of an accelerated biofuels production

Summary of the OFID study prepared by IIASA

March 2009
Vienna, Austria

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The full OFID Study prepared by IIASA will be issued in April 2009.

This Summary prepared by IIASA has received only limited review. Views or opinions expressed herein do not necessarily represent those of IIASA, its National Member Organizations, or other organizations sponsoring the work.

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BIOFUELS and FOOD SECURITY

Implications of an accelerated biofuels production

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Vienna, Austria
March 2009

International Institute for Applied Systems Analysis
IIASA
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THE OPEC FUND FOR INTERNATIONAL DEVELOPMENT
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Contents

List of Tables, Figures and Boxes

Tables

Figures

Boxes

Foreword

Biofuels development has received increased attention in recent times as a means to mitigate climate change, alleviate global energy concerns and foster rural development. Its perceived importance in these three areas has seen biofuels feature prominently on the international agenda. Nevertheless, the rapid growth of biofuels production has raised many concerns among experts worldwide, in particular with regard to sustainability issues and the threat posed to food security. The UN Secretary General, in his opening remarks to the High-level Segment of the 16th session of the UN Commission on Sustainable Development, stated that: "We need to ensure that policies promoting biofuels are consistent with maintaining food security and achieving sustainable development goals".

Aware of a lack of integrated scientific analysis, OFID has commissioned this study, *Biofuels and Food Security: Implications of an accelerated biofuels production,* which has been prepared by the renowned International Institute for Applied Systems Analysis (IIASA). This seminal research work assesses the impact on developing countries of wide-scale production and use of biofuels, in terms of both sustainable agriculture and food security. The unique feature of this study is that its quantified findings are derived from a scenario approach based on a peer reviewed modelling framework, which has contributed to the work of many scientific fora such as the Intergovernmental Panel on Climate Change (IPCC), and the United Nations (Climate Change and Agricultural Vulnerability, World Summit on Sustainable Development, Johannesburg).

One of the key conclusions of the study is that an accelerated growth of first-generation biofuels production is threatening the availability of adequate food supplies for humans, by diverting land, water and other resources away from food and feed crops. Meanwhile, the 'green' contribution of biofuels is seen as deceptive, with only second-generation biofuels appearing to offer interesting prospects. Sustainability issues (social, economic and environmental), the impact on land use, as well as many risk aspects are amongst the key issues tackled in the research.

With the publication of this study, OFID seeks to uphold its time-honored tradition of promoting debate on issues of special interest to developing countries, including the OFID/OPEC Member States.

Suleiman Jasir Al-Herbish
Director-General

1. Objectives of the study

The transport sector is a critical sector of the socio-economy as it enhances societal cohesion through human mobility and it contributes to economic growth through effective and efficient movement of goods and services. Demographic changes and economic growth over the next half century will result in more than a doubling of world transport capacity and substantially higher fuel demand, particularly in the developing countries. Transport fuels account for about a fifth of anthropogenic carbon dioxide emissions and a similar amount is emitted from agriculture and land use changes together.

The year 2008 will perhaps be remembered as the defining moment when the world experienced the reality of the inter-linkages and interdependencies between food and energy. A number of factors including the adoption of mandatory biofuels policies, high crude oil price volatility, increasing food import demand from major developing countries and below average harvests in some countries as well as low level of world food stocks resulted in sudden increases in world food prices causing domestic prices of staple foods in a number of countries to increase by over 50 percent in a matter of weeks.

A number of developed countries have embraced the apparent win-win opportunity to foster the development of biofuels in order to respond to the threats of climate change, to lessen their dependency on oil and to contribute to enhancing agriculture and rural development, which is also of concern to developing countries where more than 70 percent of the poor reside in rural areas. Countries such as the United States, Member States of the European Union, China, India, Indonesia, South Africa and Thailand have all adopted policy measures and set targets for the development of biofuels.

Whilst the justification of biofuels targets to enhance fuel energy security and to contribute to climate change mitigation and agricultural rural development is appealing, the reality is complex since the consequences of biofuels developments result in local, national, regional and global social, environmental and economic impacts, well beyond the national and regional setting of domestic biofuels targets.

There has been a lack of comprehensive assessments, including thorough analyses of the potential impacts of biofuels developments on international food prices, food insecurity, greenhouse gas savings as well as the risks of biodiversity loss.

The objectives of the study are threefold:

(i) to present a comprehensive review of the status of biofuels developments around the world and the policy regimes and support measures driving this evolution, (ii) to assess the agro-ecological potential of all major biofuels crops – first and second-generation and (iii) to comprehensively evaluate the social, environmental and economic impacts and implications of biofuels developments on transport fuel security, climate change mitigation, agricultural prices, food security, land use change and sustainable agricultural development.

II. Methodology

The Modelling Framework

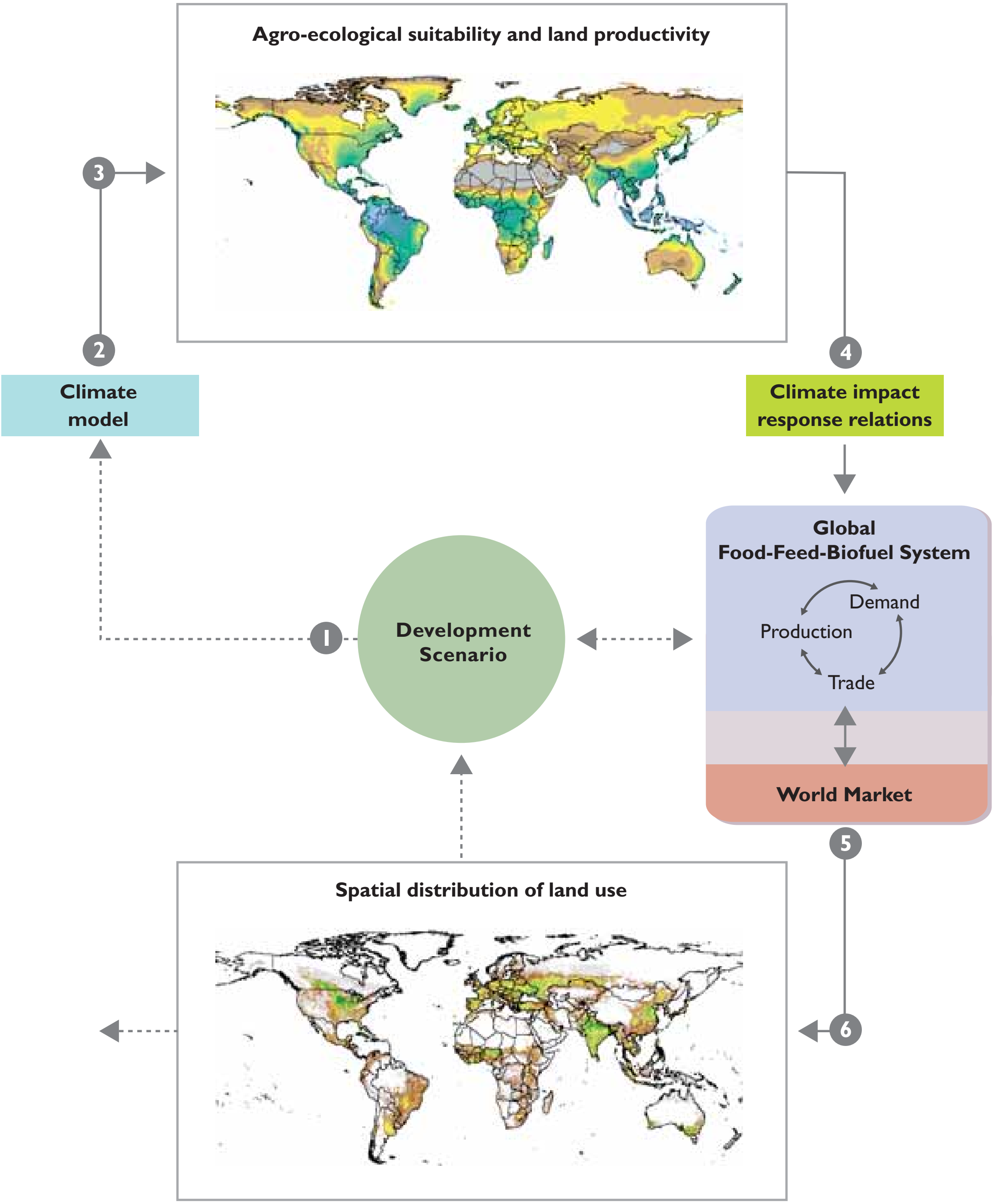
The study is based on a state-of-the-art ecological-economic modelling approach. The scenario based quantified findings of the study rely on a modelling framework which includes as components, the FAO/IIASA Agro-ecological Zone model and the IIASA global food system model. The modelling framework encompasses climate scenarios, agro-ecological zoning information, demographic and socio-economic drivers, as well as production, consumption and world food trade dynamics.

Framework for ecological-economic world food system analysis Box 1

The modeling framework comprises six main elements, as sketched in the figure:

1. A storyline and quantified development scenario (usually chosen from the extensive integrated assessment literature) is selected to inform the world food system model of demographic changes in each region and of projected economic growth in the non-agricultural sectors. It also provides assumptions characterizing in broad terms the international setting (e.g. trade liberalization; international migration) and the priorities regarding technological progress. It quantifies selected environmental variables, e.g. greenhouse gas emissions and atmospheric concentrations of CO_2. In this study it also defines scenarios of demand for first- and second-generation biofuels.
2. The emission pathway associated with the chosen development scenario is used to select among matching published outputs of simulation experiments with general circulation models (GCMs). The climate change signals derived from the GCM results are combined with the observed reference climate to define future climate scenarios.
3. The agro-ecological zones (AEZ) – See box 2 below – method takes as input a climate scenario and estimates on a spatial grid of 5' by 5' latitude/longitude the likely agronomic impacts of climate change and identifies adaptation options.
4. Estimated spatial climate change impacts on yields for all crops are aggregated and incorporated into the parameterization of the national crop production modules of a regionalized agro-economic world food system model.
5. The global general equilibrium world food system model is used – See box 3 below – informed by the development storyline and the estimated climate change yield impacts, to compute internally consistent world food system simulations.
6. In a final step, the results of the world food system simulations are 'downscaled' to the spatial grid of the resource database for quantification of land cover changes and a further analysis of environmental implications of production of biofuels feedstocks.

Framework for ecological-economic world food system analysis



Agro-Ecological Zone (AEZ) Methodology Box 2

The AEZ model uses detailed agronomic-based knowledge to simulate land resources availability, assess farm-level management options, and estimate crop production potentials. It employs detailed spatial biophysical and socio-economic datasets to distribute its computations at fine gridded intervals over the entire globe. This land-resources inventory is used to assess, for specified management conditions and levels of inputs, the suitability of crops in relation to both rain-fed and irrigated conditions and to quantify expected attainable production of cropping activities relevant to specific agro-ecological contexts. The characterization of land resources includes components of climate, soils, landform, and present land cover. Crop modeling and environmental matching procedures are used to identify Crop specific environmental limitations, under various levels of inputs and management conditions.

IIASA World Food System Model Box 3

The world food system model used for the purpose of the study comprises a series of national and regional agricultural economic models. It provides a framework for analyzing the world food system, viewing national food and agricultural components as embedded in national economies, which in turn interact with each other at the international trade level. The model consists of 34 national and regional geographical components covering the world. The individual national/regional models are linked together by means of a world market, where international clearing prices are computed to equalize global demand with supply.

The world food system model is an applied general equilibrium (AGE) model system. While focusing on agriculture, all other economic activities are also represented in the model.

Linkage of country and country-group models occurs through trade, world market prices, and financial flows. The system is solved in annual increments, simultaneously for all countries in each time period. Within each one-year time period, demand changes with price and commodity buffer stocks can be adjusted for short-term supply response. Production in the following marketing year (due to time lags in the agricultural production cycle) is affected by changes in relative prices. This feature makes the world food model a recursively dynamic system.

All-encompassing Scenarios

Internally consistent sets of assumptions were formulated as model scenarios and used to quantify impacts of expanding biofuels use on agriculture and world food system outcomes. The scenarios used in the modeling framework were designed to cover a wide and plausible range of possible future demand for biofuels. Scenario specification consisted of three steps: first, an overall energy scenario was selected, detailing as one of its components the regional and global use of transport fuels. Second, pathways were chosen as to the role played by biofuels in the transport sector. Third, the assumptions were made explicit as to the role and dynamics of second-generation biofuels production technologies in each scenario, or conversely, what fraction of total biofuels production was expected to be supplied by first-generation feedstocks, i.e. being based on conventional agricultural crops (maize, sugar cane, cassava, oilseeds, oil palm, etc.). In total twelve such scenarios were developed in the study including a reference case scenario and a scenario where the current biofuels targets in OECD countries and in some developing countries are implemented by 2020. In the study the latter scenario is called 'biofuels target scenario'.

Selected biofuels scenarios analyzed in the study Table 1

Acronym	Description
REF-01	Based on historical biofuels development until 2008; biofuels feedstock demand kept constant after 2008; used as a reference simulation to which alternative biofuels scenarios are compared for their impact.
WEO-V1	Assumes transport energy demand and regional biofuels use as projected by International Energy Agency (IEA) in its WEO 2008 Reference Scenario. Second-generation conversion technologies become commercially available after 2015; deployment is gradual.
WEO-V2	Assumes transport energy demand and regional biofuels use as projected by IEA in its WEO 2008 Reference Scenario. Assumes that due to delayed arrival of second-generation conversion technologies all biofuels production until 2030 is based on first-generation feedstocks.
TAR-V1 *Biofuels target scenario*	Assumes transport energy demand as projected by IEA in its WEO 2008 Reference Scenario. Assumes that mandatory, voluntary or indicative targets for biofuels use announced by major developed and developing countries will be implemented by 2020, resulting in about twice the biofuels consumption compared to WEO 2008. Second-generation conversion technologies become commercially available after 2015; deployment is gradual (percentage as in WEO-V1).
TAR-V3 *Biofuels target scenario*	Assumes transport energy demand as projected by IEA in its WEO 2008 Reference Scenario. Assumes that mandatory, voluntary or indicative targets for biofuels use announced by major developed and developing countries will be implemented by 2020. Accelerated development of second-generation conversion technologies permits rapid deployment; 33 percent and 50 percent of biofuels use in developed countries from second-generation in 2020 and 2030 respectively.
SNS	Sensitivity scenarios assuming low, intermediate, high, and very high share of first-generation biofuels in total transport fuels.

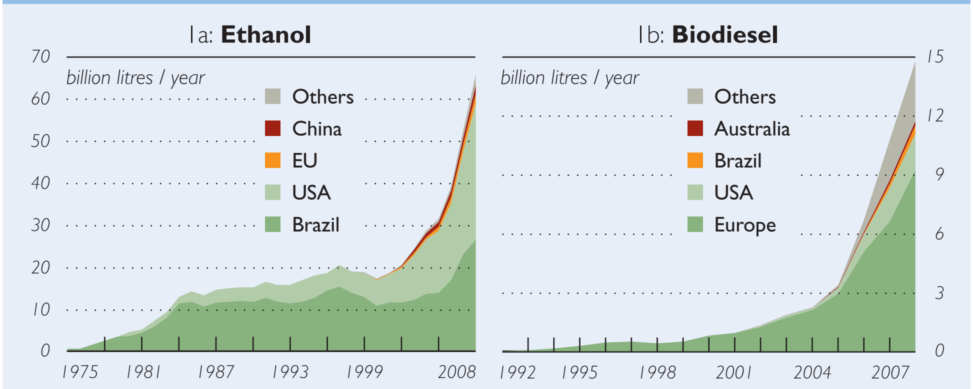
III. Key findings of the study

The results of this study include a comprehensive review of the status of biofuels developments around the world and the public policy regimes and support measures driving this evolution. Different types of biofuels and their associated feedstocks are covered. Feedstocks for first-generation biofuels include sugar cane, maize, cassava, rapeseed, oil palm, soybean and jatropha. For second-generation biofuels different woody and herbaceous lingo-cellulosic feedstocks are considered.

The study provides an integrated agro-ecological and socio-economic assessment of the social, environmental and economic impacts of biofuels. The study addresses the issues of transport fuel security, climate change mitigation, agricultural prices, food security, land use change and sustainable agricultural development. The main conclusions and selected policy implications are summarized below.

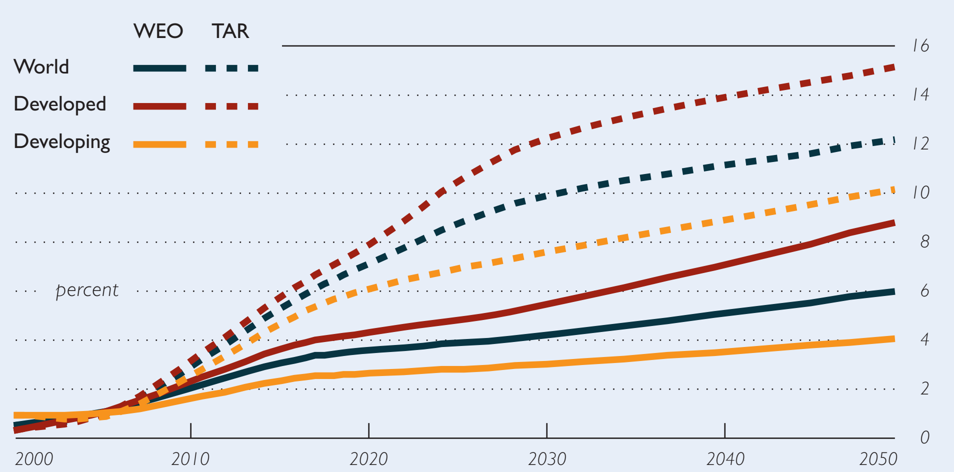
Biofuels have emerged in just a few years as a transport fuel resource option with the aim to contribute to addressing the challenges of climate change, energy security and rural development. The interest in biofuels has been accelerated by governments adoption of polices and support measures, including time bound targets for biofuels consumption. Commercial agriculture has embraced this opportunity of assured long-term government support and responded with investments and efforts to increase production to meet the market demand for biofuels feedstocks. This has resulted in increased national and world market prices of current first-generation biofuels feedstocks which are also important food and feed crops. Figure 1a and 1b below show the historical production of ethanol and biodiesel which are the two main types of biofuel:

World fuel ethanol and biodiesel production Figure 1



Source: F.O. Licht World Ethanol & Biofuels Report, October 2007 and May 2008.

Share of biofuels in final consumption of total transport fuels Figure 2



The implementation of announced biofuels targets in OECD countries as well as in developing countries such as China and India will result in an increase in the share of biofuels in transport fuel from about 1.5 percent on average today to 8 percent in the developed countries and 6 percent in the developing countries in 2020 – see Figure 2. The corresponding shares in 2030 are respectively 12 percent and 8 percent.

Two scenario variants were analyzed with regard to availability of second-generation biofuels. With gradual deployment (scenario TAR-V1), second-generation biofuels would contribute 4 percent in 2020 and 18 percent in 2030 of the biofuels in the developed countries. In developing countries second-generation biofuels come into play only after 2020 and contribute some 4 percent share in 2030.

The results of the biofuels scenario with accelerated development of second- generation biofuels (scenario TAR-V3), assumes that the share of second-generation feedstocks in the developed countries will increase to 33 percent and 51 percent in 2020 and 2030 whereas the corresponding average shares in the developing countries will be 3 percent and 19 percent respectively.

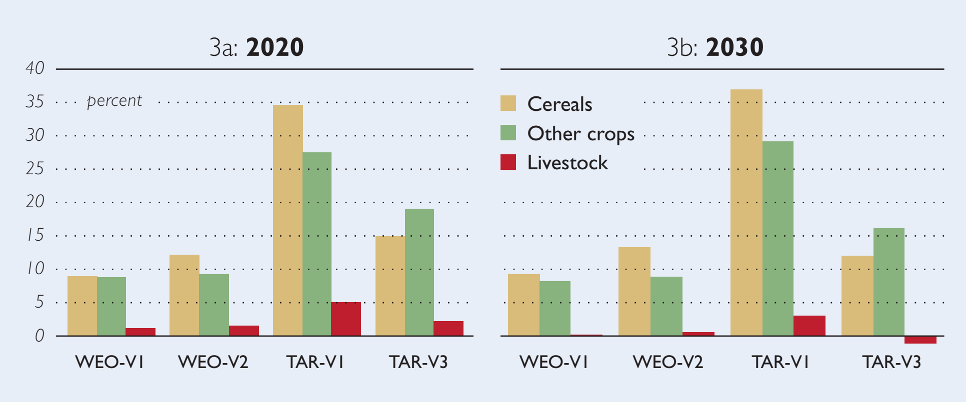
Upward Pressure on World Food Prices

During the period from the late 1970s to the early 1990s, world food prices gradually halved and then stagnated until 2002. The long term trend in declining food prices has been the result of several drivers including demographic changes, technological developments such as the Green Revolution and agricultural support policies maintaining relatively inelastic supply.

Between 2002 and 2007, world food prices increased by some 140 percent due to a number of factors including, increased demand for biofuels feedstocks and rising agricultural fuel and fertilizer prizes. The world market price increases for food and feed cereals, oilseed and vegetable oils triggered a number of countries around the world to implement policy measures to protect their domestic markets.

In the world food system model, when simulating scenarios with increased demand for food staples caused by production of first–generation biofuels, the resulting market imbalances push international prices upwards. Figures 3a and 3b shows the results for selected scenarios for year 2020 and 2030.

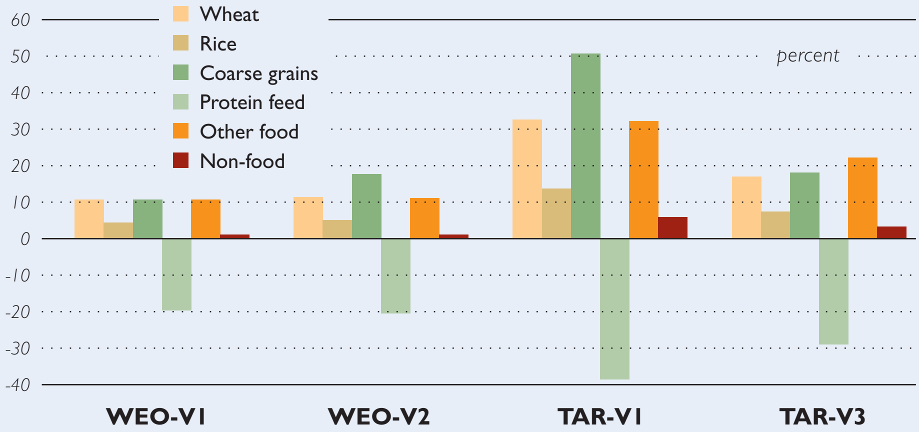
Impacts of first-generation biofuels on agricultural prices. Price changes relative to the reference scenario REF-01 Figure 3



In Figure 3a, for biofuels demand as specificied in the biofuels target scenario (TAR-V1), the impact on crop prices in 2020 is very substantial, of the order of 30 percent compared with the reference run without biofuels. With accelerated introduction of cellulosic ethanol, as assumed in TAR-V3, the price impact on cereals would be halved to 15 percent. Due to high targets in developing countries, with a higher share of biodiesel and somewhat slower access to second-generation technologies, the impact on non-cereal crops (in particular vegetable oils) is stronger than that simulated for cereals. As shown in Figure 3b the pattern of price impacts for 2030 remains similar to 2020.

Price impacts simulated for different crops and scenario variants in 2020 are shown in Figure 4 below.

Impact of first-generation biofuels on agricultural prices in 2020 Figure 4



In the above figure the scenario TAR-V1 (Biofuels target scenario) assumes that mandatory, voluntary or indicative targets for biofuels use announced by major developed and developing countries will be implemented by 2020. Second-generation conversion technologies become commercially available after 2015 (see Table 1).

In Figure 4, the results highlight that the largest price increase is observed for coarse grains: an increase of about 50 percent compared to the reference scenario without biofuels. Maize, a major biofuels feedstock in the USA, is a staple food crop in many developing countries, particularly in Africa and high world market prices as projected for coarse grains are of concern with regard to the implications for food security.

In the case of protein feeds, prices decline by 30 to 40 percent in comparison to the reference run. This is caused by biofuels by-products entering the market in large volumes, such as livestock feed from starch-based ethanol production or protein meals and cakes from the crushing of oilseeds. Access to cheaper feed sources results in only modest increases of livestock product prices as shown in Figure 3a and 3b.

Biofuels development scenarios indicate a strong relationship between agricultural prices and the share of first-generation biofuels in total transport fuels. For example the cereal price index increases by 20 percent with a biofuels share of 4 percent and by 40 percent with a 7 percent biofuels target. Hence biofuels development policies should give serious consideration to food price impact as higher prices will profoundly affect food security.

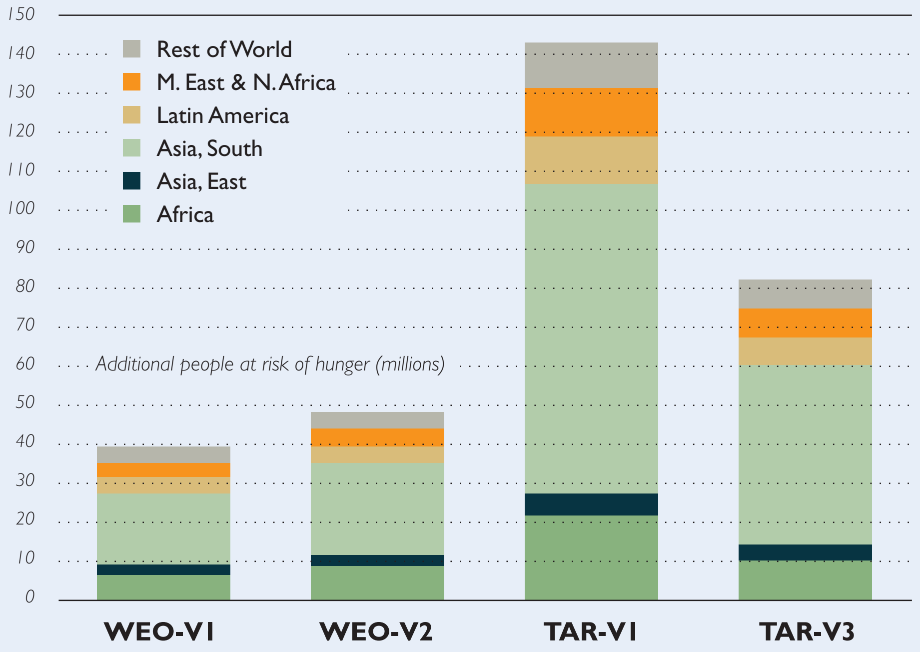
A Factor in Rising Hunger

In 1970 about 900 million people in the developing world, a third of the total population was chronically undernourished. Almost four decades later the number of undernourished in the world totaled some 923 million in 2007.

The food price crisis in 2008 added a further 100 million to the world's undernourished. This situation of more than a sixth of the world's population living with chronic hunger is a sad indictment of the failure of the international community to reduce world hunger in spite of countless world food conferences and summits during the last four decades.

The higher food prices resulting from expanding biofuels production, as seen in the previous section, would consequently reduce food consumption in developing countries, which in turn would result in increased undernourishment. Figure 5 below presents the simulated regional distribution of *additional* people at risk of hunger in different biofuels scenarios, showing a large impact in particular in South Asia.

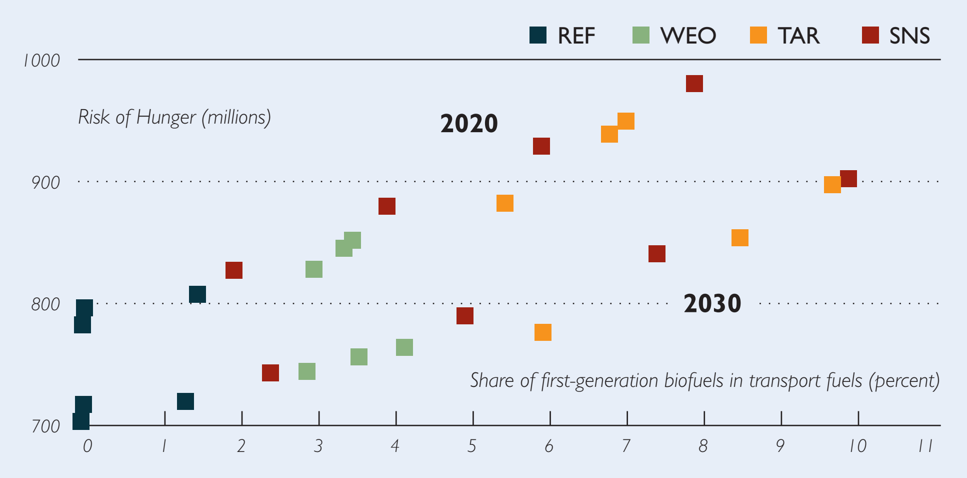
Additional number of people at risk of hunger relative to baseline REF-01, in 2020 Figure 5



In the biofuels target scenario, about 140 million additional people are threatened by hunger. Even with relatively swift deployment of second-generation technologies, as assumed in scenario TAR-V3, the results for 2020 still show an increase of 80 million people.

Figure 6 summarizes results concerning the risk of hunger in developing countries obtained across all simulated biofuels scenarios.

Risk of hunger versus share of first-generation biofuels in total transport fuels Figure 6



It is worth noting that for the range of simulated global shares of first-generation biofuels in total transport fuels of 0 to 8 percent in 2020 and of 0 to 10 percent in 2030, the resulting impact on the expected number of undernourished people is substantial, up to about 200 million, for both time points, albeit with the total numbers higher in 2020 by about 100 million.

South Asia and Africa are the most affected regions with a third and a quarter of their total population undernourished. The Millennium Development Goals put a time bound target to reduce world hunger by half in the period to 2015 and it is estimated that this would require public funding of some US$ 50 to 80 billion annually. Putting this in perspective, the OECD agricultural subsidy budget amounts to over US$ 300 billion annually.

The mandates and targets together with substantial funding and subsidies to develop biofuels in the presumed interest of transport energy security should raise ethical and moral concerns regarding the failure of the international community to make decisive progress towards achieving world food security.

The reference scenario without biofuels project for developing countries the number of undernourished people in 2020 and 2030 at respectively to 807 and 720 million. The biofuels target scenario estimates for developing countries that an additional 131 and 136 million people will be at risk of hunger in 2020 and in 2030 respectively. In the biofuels target scenario with accelerated second-generation biofuels, the corresponding number of additional people at risk of hunger decreases to 75 million and 57 million respectively in 2020 and 2030. Africa and South Asia account for two-thirds to three-quarters of the additional population at risk of hunger in developing countries across biofuels scenarios in 2020 as well as in 2030.

The risk of increased food insecurity that may boost the number of people at risk of hunger by more than 15 percent in the developing countries needs to be considered when interpreting an enhancement of "energy security" by achieving a share of biofuels in transport fuel of just 8 percent in the developed countries.

The international community needs to view food security and fuel security as interdependent and requiring integrated solutions since both are critical to human survival and well-being.

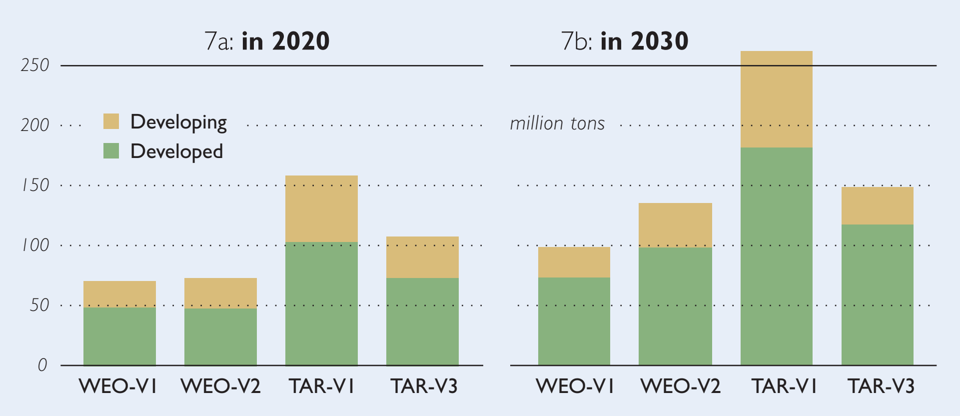
Absorbing Cereal Production

Crop production is driven by yield and acreage developments. In many developing countries crop yields for most commodities are lower than those attained in developed countries. During the period 1970 to 1990 world grain yields increased by an average of some 2 percent per annum but since then this remarkable yield growth has been reduced by half.

Starting from 2.1 billion tons in 2000, the reference scenario REF-01 projects total production of cereals of 3.1 billion tons in 2030 and 3.7 billion tons in 2050. While developing countries produced about half the global cereal harvest in 2000, their share in total production increases to about 60 percent by 2050. Their share in global consumption also increases, from about 50 percent to some 65 percent and in turn net imports of cereals by developing countries increase, from 110 million tons in 2000 to about 210 million tons in 2030, and to some 240 million tons by 2050.

The rising agricultural prices in the biofuels scenarios provide incentives on the supply side, for intensifying production and for augmenting and reallocating land, capital and labor. At the same time, consumers react to price increases and adjust their patterns of consumption. Figure 7 shows the producer response of cereal sectors for different biofuels scenarios in 2020 and 2030.

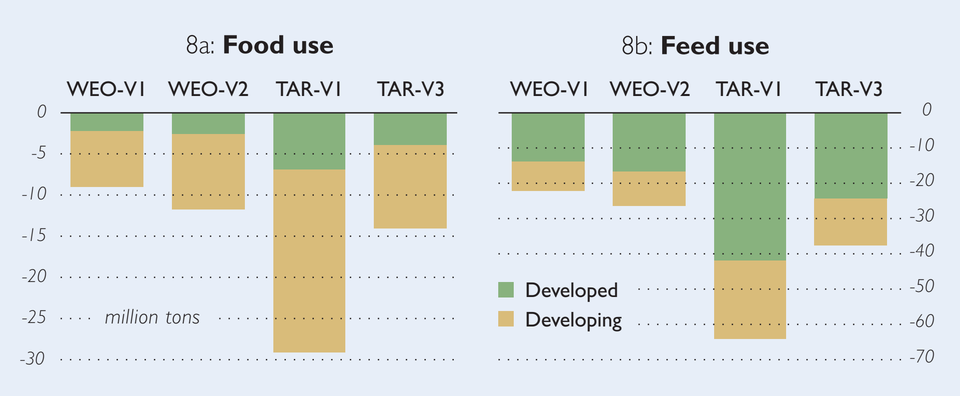
Change in cereal production relative to baseline REF-01 Figure 7



The results of the biofuels target scenario on Figure 7b indicates that there is an increase in global production of an additional 260 million tons in 2030 and in the scenario with accelerated second generation biofuels, an additional 150 million tons.

As shown in Figures 7a and 7b, the cereal production increase is more pronounced in developed countries. Similarly, as presented in Figure 8b, the reduction in feed use is more significant in developed countries. When it comes to food use, however, consumption in developed countries is much less responsive than in developing countries. Lower consumption in developing countries accounts for 75 percent of the 'forced' reduction in cereal food consumption (Figure 8a).

Change of cereal food and feed consumption relative to baseline REF-01, in 2020 Figure 8



Where do the cereals needed for biofuel production come from? Box 4

On average about two-thirds of the cereals usd for ethanol poduction are obtained from additonal crop production.

The remaining one-third comes from consumption changes. The reduction in direct cereal food consumptin accounts for ten percent of the amount of cereals used for biofuel production, reduced feed use accounts for about a qarter.

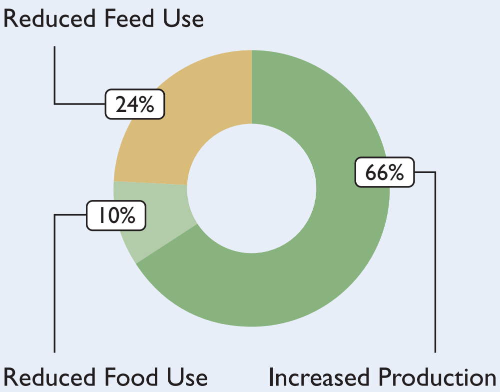
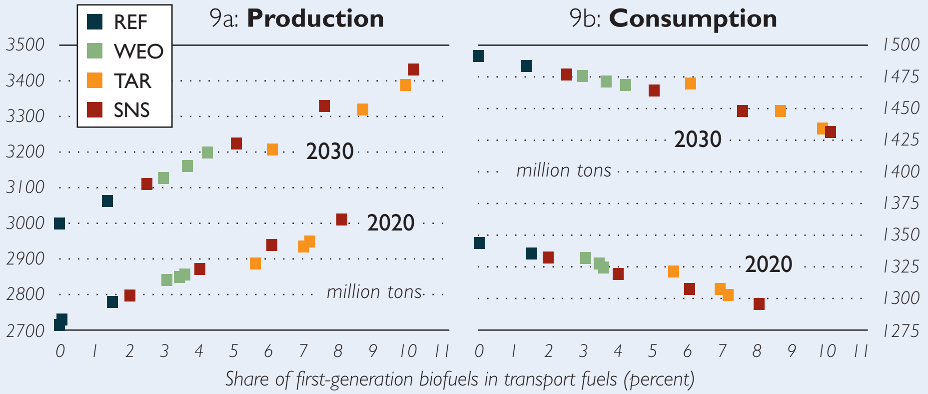


Figure 9 below summarizes for 2020 and 2030 the level of global cereal production (Figure 9a) and of global cereal food consumption (Figure 9b) across all simulated biofuels scenarios. The horizontal axis indicates the percentage of first-generation biofuels[1] in total transport fuels associated with a particular scenario. In 2020 the range of scenarios results in cereal production of 2.7 to 3.0 billion tons and in 2030 of 3.0 to 3.4 billion tons.

Cereal production and food use versus share of first generation biofuels in transport fuels Figure 9



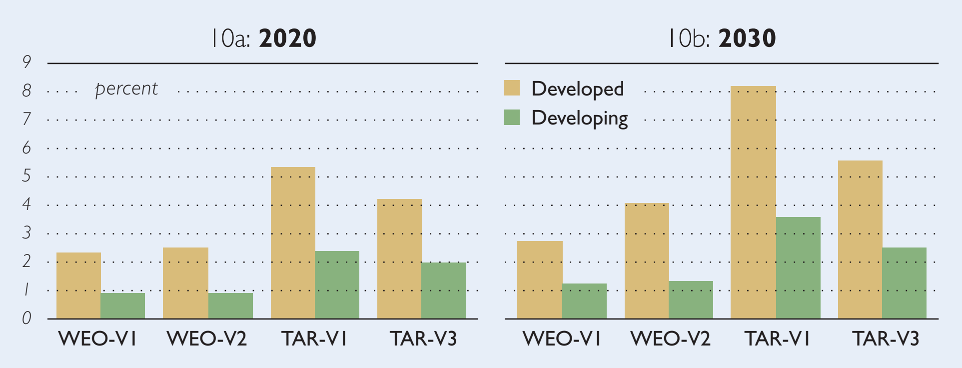
1 This share is achieved by a variety of feedstocks including cereals, sugar crops, and cassava to produce first-generation ethanol and various oilseeds and oil crops to produce biodiesel.

Modest Benefits for Rural Development

In spite of the fact that less than 5 percent of the populations in many developed countries are economically dependent on agriculture for their livelihoods, the agricultural lobby in these countries is politically influential. In contrast, in many developing countries rural populations derive their livelihoods directly or indirectly from agriculture and yet the rural agricultural community often has no political voice. It is the urban poor, subsistence farmers and the landless in food insecure developing countries where livelihoods and food security will be most affected by food-feed-fuel competition.

Biofuels development has been seen as a means to diversify agricultural production and – especially in developed economies – has shaped agricultural support policies. The study has considered as to what extent the additional production of crops developed on arable land as feedstock for biofuels production will increase value added in agriculture. The percentage change relative to the reference case is shown in Figure 10.

Change in agricultural value added relative to baseline REF-01 Figure 10



The figure shows that agricultural sectors in developed countries benefit relatively more than developing countries in terms of percentage gain relative to the baseline REF-01. For instance, in scenario WEO-V1 the increase in 2020 recorded for developed countries is 2.3 percent compared to only about 1 percent for developing countries. While Africa and Latin America achieve gains of about 1.3 percent, the gains achieved for the Middle East & North Africa region and for Asian regions are only 0.6 to 0.9 percent.

The biofuels target scenario shows that the increase in agriculture value added (measured in constant 1990 US$) as a result of biofuels development is projected at US$ 31 billion and US$ 51 billion in the developed countries in 2020 and 2030 respectively. The corresponding values for the developing countries are US$ 27 billion and US$ 41 billion respectively.

These results highlight that the increase in agriculture value added induced by first-generation biofuels production is relatively small and this puts into perspective the scope of biofuels to foster rural development. Also these results need to be viewed in the context of substantial biofuels subsidies in developed countries that will distort and constrain biofuels export opportunities for developing countries.

Will Biofuels Slow Climate Change?

Estimated global greenhouse gas emissions in 2006 amounted to 45 Gt in carbon dioxide equivalent, of which some 62 percent of total global emissions is energy-related. The transport sector globally contributed 6.4 Gt carbon dioxide equivalent in 2006 equal to some 14 percent of total anthropogenic emissions and 23 percent of energy-related emissions.

Biofuels are produced from biomass and the carbon dioxide released through their combustion matches the amount of carbon absorbed by the plants from the atmosphere through photosynthesis; from this point of view, biofuels appear to be carbon-neutral. However, greenhouse gases are emitted at all stages, from 'cradle to grave' of the biofuels production and uses chain in the production and transportation of feedstocks, during conversion to biofuels, distribution to end user, and in final use.

Greenhouse gases can also be emitted or sequestered as a consequence of direct or indirect land-use changes when natural habitats or previously unused or differently used land is converted to production of biofuels feedstocks. Of particular concern for greenhouse gas impacts is conversion of forests or grasslands to cultivated land or plowing of carbon-rich soils. The impact of biofuels production on land use has been quantified by comparing land use development of each biofuels scenario with the land use resulting in a scenario without biofuels use.

Table 2 compares the estimated greenhouse gas savings obtained by substituting fossil transport fuels with the biofuels produced in the respective scenario with the carbon losses caused by simulated additional direct and indirect land use changes in each scenario. Both indicators compare outcomes of a biofuels scenario to a reference simulation without biofuels. Results are in carbon dioxide equivalent ($CO2e$). Several periods are considered: 2000-2020, 2000-2030 and 2000-2050.

Carbon losses from vegetation and soil due to land use changes occur at the time of land conversion, but greenhouse gas savings from the use of biofuels rather than fossil fuels accumulate only gradually over time.

The net balance of greenhouse gas savings and carbon losses associated with different biofuels scenarios assessed in this study and accumulated for different time periods is shown in Table 3.

Scenario results based on greenhouse gas emission coefficients proposed in a recent draft for an EU Directive on the promotion of the use of energy from renewable sources (Commission of the European Communities, 2008) are shown in Figure 11.

Cumulative greenhouse gas gains and losses of biofuels scenarios Table 2

Scenario	Cumulative GHG savings from firstgeneration biofuels for period			Cumulative carbon losses due to additional direct and indirect land use changes		
Gt CO_2e	*2000-2020*	*2000-2030*	*2000-2050*	*2000-2020*	*2000-2030*	*2000-2050*
WEO-V1	1.7 - 2.4	3.6 - 4.8	9.9 - 14.3	4.0 - 4.1	4.1 - 4.3	4.9 - 5.4
WEO-V2	1.6 - 2.4	3.4 - 5.0	9.0 - 13.2	4.2	4.7	7.1 - 7.2
TAR-V1	2.8 - 4.0	7.0 - 9.3	20.7 - 29.6	8.0 - 8.1	9.9 - 10.2	11.0 - 12.0
TAR-V3	3.0 – 4.3	7.8 - 7.8	23.4 - 33.4	6.1 - 6.7	6.2 - 7.2	6.4 - 8.4

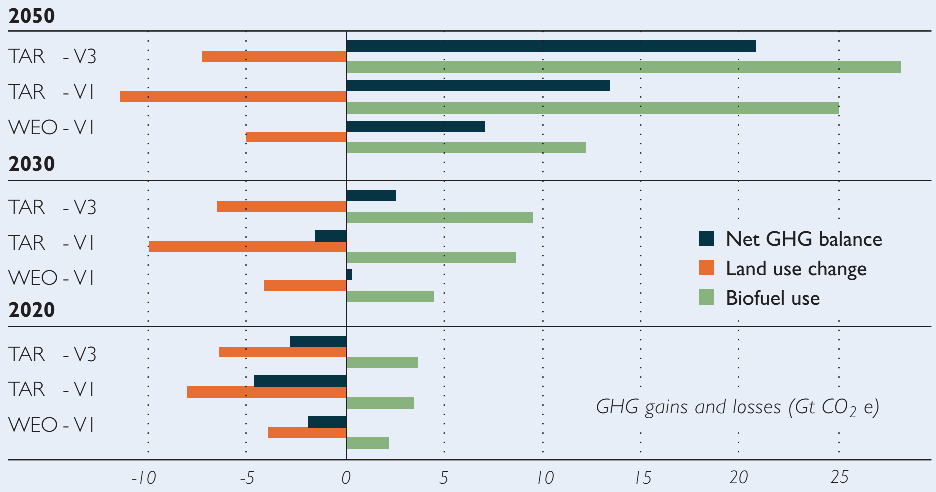
Note: the ranges shown result from using low and high estimates of greenhouse gas savings for biofuels produced from different first and second-generation feedstocks.

Net cumulated greenhouse gas savings of biofuels scenarios Table 3

Scenario	Net greenhouse gas savings of first-generation biofuels		
Gt CO_2e	*2000-2020*	*2000-2030*	*2000-2050*
WEO-V1	-2.4 to -1.6	-0.7 to 1.1	4.5 to 9.4
WEO-V2	-2.6 to -1.8	-1.3 to -1.8	1.8 to 6.1
TAR-V1	-5.3 to -4.0	-3.2 to 0.2	8.7 to 18.6
TAR-V3	-3.8 to -1.8	0.7 to 5.0	15.1 to 27.0

Note: the ranges shown result from using low and high estimates of greenhouse gas savings for biofuels produced from different feedstocks.

Net cumulated greenhouse gas savings of biofuels scenarios Figure 11



Note: computations for first-generation biofuels are based on greenhouse gas saving coefficients in Commission of the European Communities (2008) and IPCC Tier 1 approach for carbon losses due to land use changes (IPCC, 2006). For second-generation biofuels a greenhouse gas saving of 85 percent was used.

The results show clearly that estimated net greenhouse gas savings resulting from expansion of biofuels can only be expected after 30 to 50 years. For shorter periods, from 2020 to 2030, net greenhouse gas balances are dominated by carbon debts due to direct and indirect land use changes. Even for the period 2000–2050, net cumulated gains of 15.1 to 27.0 Gt carbon dioxide equivalent need to be compared with current annual greenhouse gas emissions of 6.4 Gt CO_2e caused by the transport sector.

Land conversion also entails substantial risks to biodiversity as observed in the case of oil palm land expansion in Malaysia and Indonesia or soybean land expansion in Brazil.

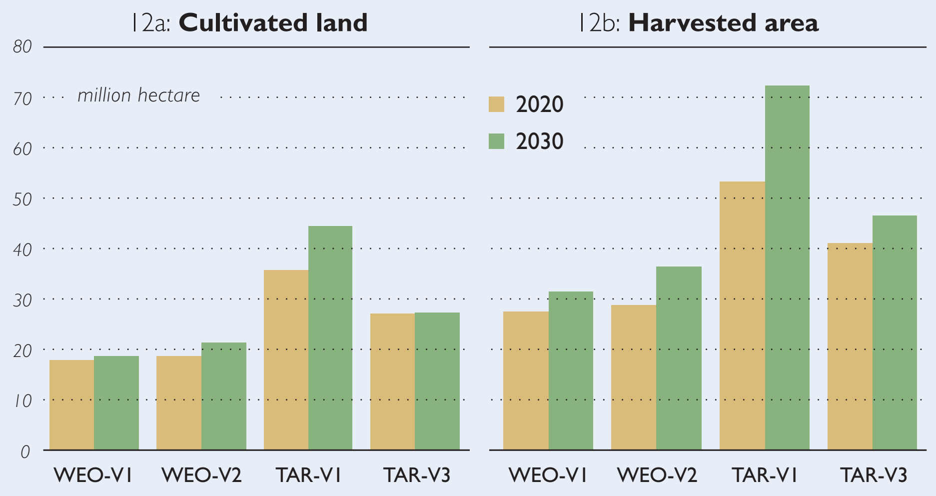
Competition for Arable Land

Some 1.6 billion ha of land are currently used for crop production, with nearly 1 billion ha under cultivation in the developing countries. During the last 30 years the world's crop area expanded by some 5 million ha annually, with Latin America alone accounting for 35 percent of this increase. The potential for arable land expansion exists predominately in South America and Africa where just seven countries account for 70 percent of this potential. There is relatively little scope for arable land expansion in Asia, which is home to some 60 percent of the world's population.

There are three elements how agricultural supply responds to increasing demand for first-generation biofuels feedstocks: (i) expansion of cultivated land beyond baseline REF-01 levels; (ii) reallocation of agricultural resources to producing more profitable commodities due to relative price gains, and (iii) intensifying production per unit of cultivated land by increasing multi-cropping and possibly reducing fallow periods (i.e., increasing the ratio of harvested area to cultivated land) and by increasing agricultural inputs such as fertilizers, the quality of seeds or irrigation.

Figures 12a and 12b show the additional use of cultivated land and the additional harvest area in 2020 and 2030 in comparison to a scenario without crop-based biofuels.

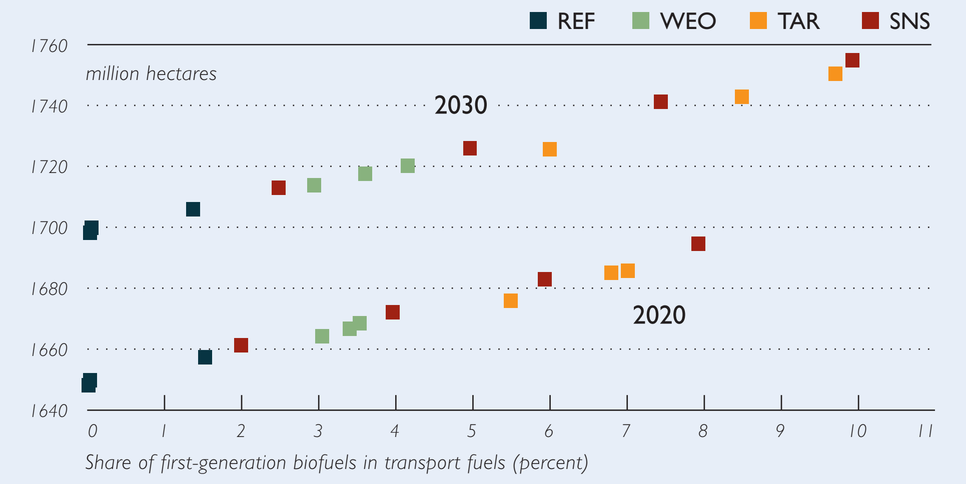
Additional use of cultivated land and harvested area in 2020 and 2030 Figure 12



For the biofuels target scenario (TAR-V1), the additional use of cultivated land is about 35 million hectares in 2020: 13 million hectares for developed countries and 22 million hectares for developing countries. Regarding developed countries, the increase of 13 million hectares should be compared to a net decrease of 1 million hectares in a scenario without biofuels. For developing countries the increase of 22 million hectares resulting from the difference between 114 million hectares (scenario TAR-V1) and 92 million hectares (a scenario without biofuels) is mainly explained by an expansion of 8 million hectares in sub-Saharan Africa and 10 million hectares in South America.

Figure 13 shows the results obtained for cultivated land use in 2020 and 2030 in relation to the amount of first-generation biofuels production demanded, expressed here as percentage of total transport fuel consumption.

Cultivated land use versus share of first generation biofuels in transport fuels Figure 13



For the full range of simulated scenarios the use of cultivated land in 2020 goes from 1649 million hectares to 1694 million hectares, a difference of 45 million hectares, and in 2030 it ranges from 1700 million hectares to 1755 million hectares, i.e. a maximum additional use of 55 million hectares.

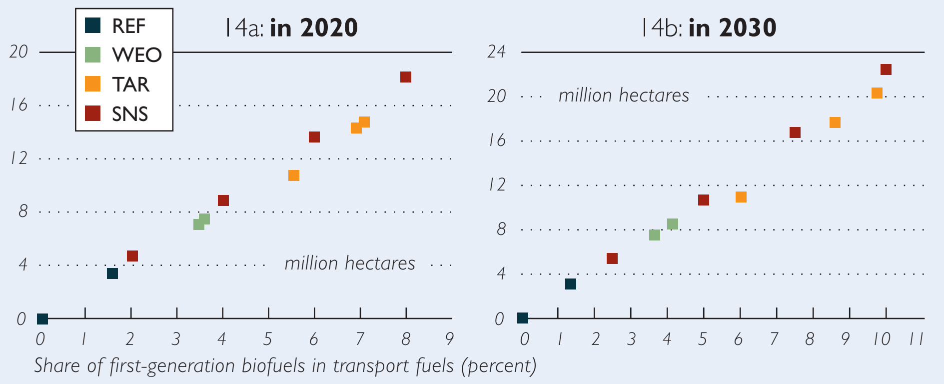
While total global arable land use increases by only 1-3 percent in different biofuels scenarios compared to a situation without biofuels – a number that may seem small at first sight – the impact becomes substantial when expressed in terms of 2000-2020 land expansion. From this perspective, the impact of the biofuels scenarios is to increase the net expansion of cultivated land during 2000-2020 by 20-40 percent, and by 15-30 percent during 2000-2030.

Fueling Deforestation

Forests play an important environmental role in the production of timber, wood, fuel, and other products, in the conservation of biodiversity and wildlife habitats, as well as in the mitigation of global climate change and the protection of watersheds against soil degradation and flood risks. About 30 percent of the world's land surface – nearly 4 billion ha – is under forest ecosystems. Eight

Additional deforestation versus share of first generation biofuels in transport fuels

Figure 14



countries – Russia, Brazil, Canada, the United States, China, Australia, Congo, and Indonesia – account for 60 percent of the world's forest resources. During the past decade, some 127 million ha of forests were cleared, while some 36 million ha were replanted. Africa lost about 53 million ha of forest during this period – primarily from expansion of crop cultivation.

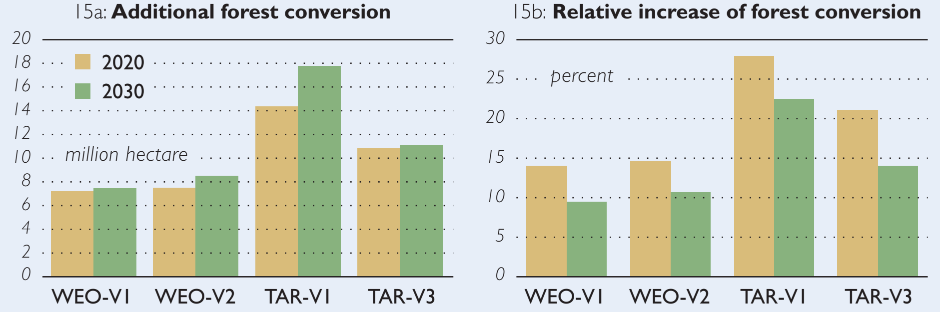
The study provides an estimation of the amount of additional deforestation directly or indirectly caused by biofuels feedstock production. A summary for 2020 and 2030 across all scenarios is provided in Figure 14.

Results for 2000-2020 and 2000-2030 across all scenarios indicate that biofuels feedstock use may be responsible for up to 20 million and 24 million hectares respectively of *additional* deforestation (i.e on average 1 million hectares of additional forest conversion per year). This compares to an estimated total forest conversion due to arable land expansion for food production computed for the reference scenario without biofuels in 2000-2020 amounting to about 50 million hectares, and to 80 million hectares by 2030.

Figure 15a shows the *additional* forest conversion recorded in selected biofuels scenarios during 2000-2020 and 2000-2030 relative to a reference scenario simulation without considering biofuels demand. Figure 15b indicates the percentage increase of converted forest areas for the same period. Deforested areas in scenario TAR-V1 increase during 2000-2020 by 25 percent more than in the baseline REF-01. Compared with other scenarios, this is the largest impact as the fast expanding demand for first-generation biofuels increases forest conversion.

Estimates of deforestation are uncertain and causes of deforestation are manyfold. While future forest conversion will depend on the willingness and

Additional forest conversion in different biofuels scenarios — Figure 15

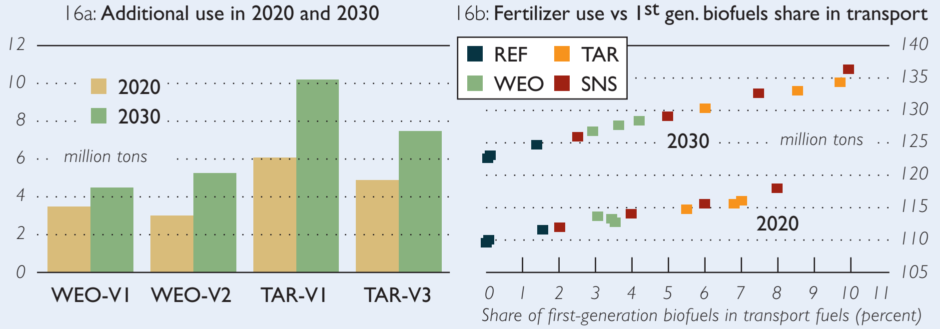


priorities and capacity of national governments and relevant legislation to protect forests and the effectiveness of measures taken and incentives provided to reduce deforestation, the analysis of biofuels development scenarios suggests that any prolonged dependence on first-generation crops for biofuels will result in increased risk of deforestation with the inherent consequences of substantial carbon emissions and biodiversity loss.

The Fertilizer Dilemma

Nitrogen fertilizer use in the reference scenario without biofuels projects an increase of 40 million tons in the period of 2000 to 2030, up from 83 million tons in 2000. Figure 16 indicates that the biofuels target scenario (TAR-V1) will require an additional use of about additional 10 million tons of nitrogen fertilizer projected for 2030, an increase of 8 percent compared to reference scenario.

Nitrogen fertilizer use in biofuels scenarios — Figure 16



First-generation biofuels production based on intensive use of fertilizers results in higher greenhouse gas emissions as well as a range of other environmental risks such as soil and water pollution. An early transition to second-generation biofuels can potentially reduce the application of fertilizers.

A Threat to Biodiversity

There is a wide range of systems and conditions under which biofuels are produced, including different feedstocks used, varying production schemes and management practices, land ownership and land use systems. The impacts of biofuels on biodiversity depend on the extent of associated land use changes and conversion as well as the specific type of biofuels feedstocks.

Conversion of natural ecosystems, for example, natural forest and natural grassland, generally induces high losses of biodiversity; use of abandoned agricultural land or extensively used grasslands causes relatively lower losses. Change of use of intensively used agricultural land for biofuels feedstock production causes least losses or may even have a positive effect on biodiversity. The scale of conversion in combination with mono-cropping without compensating through "habitat islands", and "migration corridors" may have a far reaching negative impact on biodiversity.

Biofuels feedstocks, grown on a large scale in monocultures with heavy fertilizer applications and the use of biocides to control weeds or combat pest and diseases may have a devastating effect on biodiversity, as observed in the case of soybean production.

In contrast, second-generation biofuels feedstocks, grown under minimum tillage systems and best practice principles such as returning residues and by-products to the field instead of using chemical fertilizer only, are by-and-large resistant to pest and diseases and require no or little biocides, while providing eco-topes for a diversified and rich fauna and flora.

Biodiversity is the foundation of all crops and domesticated livestock and the variety within them. It provides and maintains ecosystem services essential to agriculture, which include: regulation of pests and diseases; nutrient cycling, sequestration and conversion, maintenance of soil fertility and biota including regulating soil organic matter and soil water retention and pollination by bees and other wildlife. Hence reducing the impact of biofuels on biodiversity is paramount as any loss of biodiversity will have social, environmental and economic consequences and costs.

Imperative for Second-generation Conversion Technologies

In the long run current first-generation biofuels production on cultivated land is not tenable as the world's limited arable land resources are essential to meet future food demand. Hence it is important to make a fast transition to producing second-generation biofuels from ligno-cellulosic feedstocks such as perennial grasses and tree species. Biomass residues from agricultural crops and forestry form a feedstock source as well. However, careful planning and comprehensive policies are required as these biomass feedstocks are often the main source of local household energy for rural populations in many developing countries.

The key challenge for commercial second-generation biofuels is to develop conversion technologies at industrial scale and at competitive prices. These technologies, still at the laboratory experimentation and demonstration stage, require large scale feedstock supplies and pose substantial logistical and sustainable management challenges.

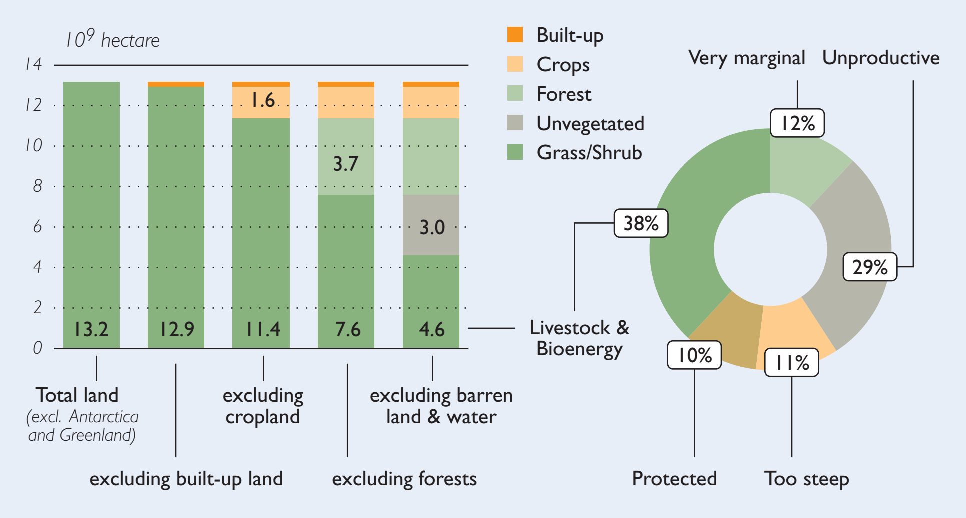
The agro-ecological assessment results in this study indicate a substantial potential for producing ligno-cellulosic feedstocks on currently unprotected grassland and woodlands. Of the world's 4.6 billion hectares of grasslands and

Regional balance of land classified as unprotected grassland and woodland potentially useable for rain-fed ligno-cellulosic biofuels feedstock production Table 4

REGION	TOTAL GRASS- AND WOODLAND	Of which: Protected areas	Of which: Unproductive or very low productive	Of which: Balance of grass- and woodland	Potential rain-fed yield: Average	Potential rain-fed yield: Low	Potential rain-fed yield: High
	mill. ha	*mill. ha*	*mill. ha*	*mill. ha*	*dry t/ha*	*dry t/ha*	*dry t/ha*
North America	659	103	391	165	9.3	6.7	21.4
Europe & Russia	902	76	618	208	7.7	6.9	14.5
Pacific OECD	515	7	332	175	9.8	6.5	20.0
Africa	1086	146	386	554	13.9	6.7	21.1
Asia, East	379	66	254	60	8.9	6.4	19.0
Asia, South	177	26	81	71	16.7	7.6	21.5
Latin America	765	54	211	500	15.6	7.1	21.8
M. East & N. Africa	107	2	93	12	6.9	6.3	10.6
Developed	2076	186	1342	548	8.9	6.7	21.0
Developing	2530	295	1029	1206	14.5	6.8	21.5
World	4605	481	2371	1754	12.5	6.8	21.5

Source: GAEZ (2008)

Balance of land currently classified as unprotected grassland and woodland potentially useable for rain-fed ligno-cellulosic biofuels feedstock production Figure 17



Source: GAEZ (2008).

woodlands about 10 percent is legally protected and some 50 percent is very low productive (tundra, arid lands) or steeply sloped (see figure 17; Box 5). Over two-thirds of the remaining 1.75 billion hectares grassland and woodland potentially suitable for biofuels feedstock production is located in developing countries, foremost in Africa and South America (Table 4).

An important current use of these land resources is livestock grazing. The results of detailed livestock feed energy balances suggests that in year 2000 about 55-60 percent of the estimated grassland biomass was required for animal feeding. This share is about 40 percent in developed countries and on average 65 percent for developing countries. Hence, at current use levels, the land potentially available for bioenergy production was estimated in the order of 700 – 800 million hectares, characterized by a rather wide range of productivity levels.

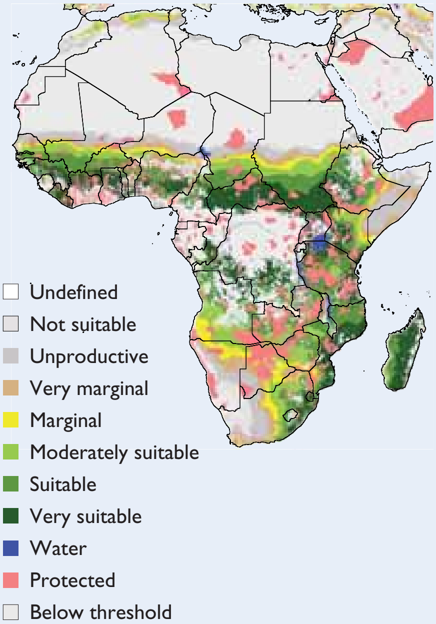
In tropical Africa and Latin America ligno-cellulosic yields have the highest potential, an average of 14 to 16 tons dry matter per hectare, compared to average yields of about 9 tons dry matter per hectare in the developed countries.

The results of the biofuels target scenario with accelerated second-generation biofuels deployment indicate that production of ligno-cellulosic feedstocks on some 125 million hectares would be sufficient to achieve a ten percent biofuels target share in world transport fuels in 2030. The grasslands and woodlands for biofuels feedstock production should be selected such that the risks of soil carbon emissions and biodiversity losses are minimized.

Is there enough land for food and bioenergy in Sub-Saharan Africa? Box 5

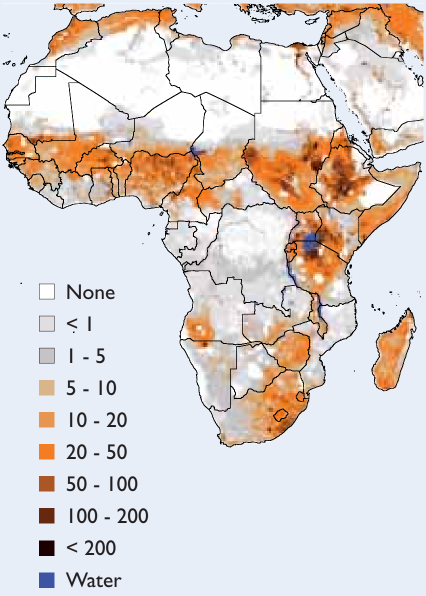
In Africa, less than 9 percent of the total land area of 3 billion hectare is currently used for crop production: 45 percent of the land being water bodies, desert, barren, steeply sloped, or very marginally productive, 18 percent being forest and 6 percent otherwise protected land, and less than 1 percent urban and built-up areas. Pastures, savanna and bush cover 22 percent of the land, with a wide range of bio-productivity. It is estimated that about half of the annual biomass produced in these areas is currently needed to support ruminant livestock (see Figure 18b). Though the key to enhancing food security will be achieving sustainable yield increases on current cultivated land, up to a third of this savanna and bush, i.e. 175-200 million hectares, could be used for food and energy production. While conventional agricultural feedstocks currently used in first-generation biofuels production compete with food crops and perform poorly for environmental criteria, second-generation technologies promise substantial greenhouse gas savings and may permit tapping into land resources currently not or only marginally used.

Figure 18a:
Bio-productivity of grassland and woodland



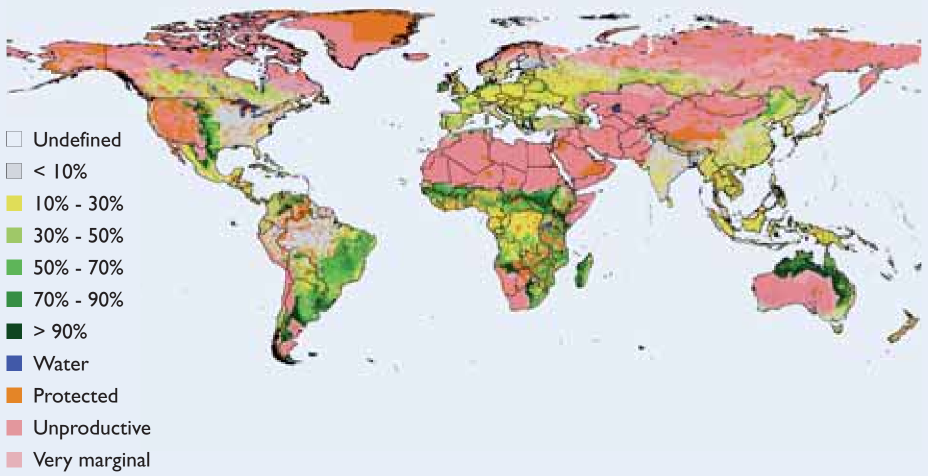
Source: IIASA Options (2008)

Figure 18b:
Density of ruminant livestock



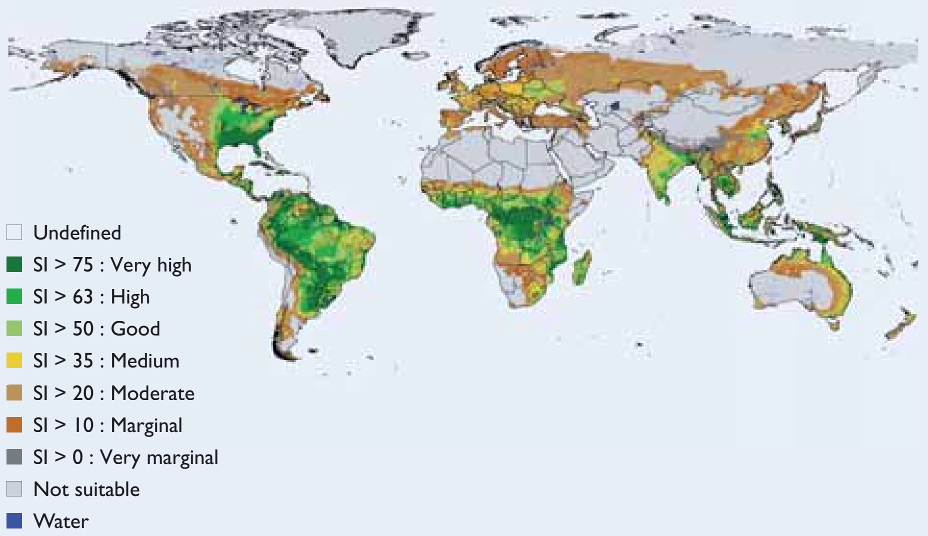
Source: www.fao.org

Spatial distribution and share of land by 5' latitude/longitude grid cell currently classified as unprotected grassland and woodland potentially useable for rain-fed ligno-cellulosic biofuels feedstock production Figure 19



Source: GAEZ (2008)

Global land suitability for second-generation feedstocks (herbaceous and woody ligno-cellulosic plant species) Figure 20



IV. Conclusions

This study, based on an interdisciplinary scientific assessment[2] of the world's agro-ecological productivity and socio-economic conditions at national, regional and global levels, highlights that current polices supporting first-generation biofuels production and consumption need to be reconsidered in the light of direct and indirect impacts on food security, agriculture and the environment.

The results of the study indicate that first-generation biofuels development as has been promoted by national policies is conflicting with goals of achieving food security, results in only modest increases of agricultural value added in developing countries, achieves net greenhouse gas savings only after 2030, creates additional risks of deforestation and threats to biodiversity.

The target of achieving a ten percent biofuels share in transport fuel at the global level can be met but this causes about a fifteen percent increase in the number of people at risk of hunger (i.e., and increase 140-150 million people at risk of hunger as compared to 2008 numbers). In particular the poor urban population, subsistence farmers and the landless in developing countries will bear the brunt.

Moreover anticipated greenhouse gas savings from biofuels use can only be expected after 30 to 50 years and that is about the time when climate change impacts will result in increased agricultural vulnerability, particularly in a number of developing countries.

To avoid negative impacts of biofuels on food security, any use of first-generation biofuels would need to be preceded by concerted research efforts to increase agricultural productivity. The foremost priority is to ensure that future food demand is met and only then any surplus production would be available for biofuels.

Among the first-generation feedstocks, sustainable sugar cane production under rain-fed conditions in former pastures and grassland areas offers environmentally and economically an attractive biofuel option as demonstrated in the case of Brazil.

Second-generation biofuels produced on land other than cultivated land required for food and feed productions may offer opportunities for the development of environmentally cleaner and economically competitive biofuels. However this will depend on the timely delivery of efficient and effective second-generation conversion technologies as well as advances in feedstock production and land use regulation.

Food security, energy security and climate change mitigation are all critical to social, economic and environmental sustainability, not only at the national level but also globally. A successful resolution of these challenging issues requires the goodwill and commitment of all nations to work together. Biofuel development polices have a direct impact on these triple challenges and yet it is national polices with national interests that have been the driving force of setting biofuel targets. The global and spatial agro-ecological and socio-economic methodology and assessments presented in this study provide the analytical means and science-based knowledge to evaluate policy options towards making the right choices that recognize the pitfalls and mobilize the opportunities to make progress towards achieving national and global sustainable development.

For more than thirty years there have been countless debates on the concerns of feeding cereals to livestock in a world where over one-sixth of the population has lived with chronic hunger and debilitating poverty. There is a risk that we might end up for the next thirty years debating the fallacy of feeding cereals to cars. This time the situation though is different as the entire world's population will be affected if we fail to deal with the challenges of coping with climate change, providing clean energy and ensuring food security, all of which are interrelated and need to be tackled together.

2 It employs a peer reviewed scientific ecological-economic modelling approach which is also the basis of many IPCC (Intergovernmental Panel on Climate Change) reports on agriculture and climate change.

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