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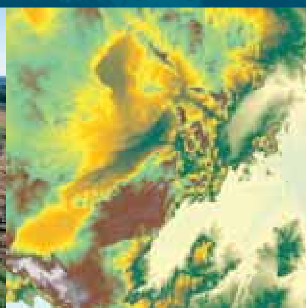
Bioenergy and Food Security

The BEFS Analytical Framework





ENVIRONMENT AND NATURAL RESOURCES MANAGEMENT WORKING PAPER

ENVIRONMENT CLIMATE CHANGE [BIOENERGY] MONITORING AND ASSESSMENT

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ENVIRONMENT AND NATURAL RESOURCES MANAGEMENT WORKING PAPER

ENVIRONMENT CLIMATE CHANGE [BIOENERGY] MONITORING AND ASSESSMENT

BEFS

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FOREWORD

Recent years have witnessed a renewed interest in bioenergy both within the developed and the developing world. Bioenergy, and particularly liquid biofuels, have been promoted as a means to enhance energy independence, promote rural development and reduce greenhouse-gas emissions. Compared to other sources of energy, bioenergy potentially offers poor countries many advantages if properly managed. However, bioenergy developments have also been a cause for deep concern regarding their economic, social and environmental viability, because of their potential negative impacts on food security through crowding out of staple food production and on the environment due to natural resource scarcity and intensive agriculture production. While there has been a rush by many governments to develop bioenergy alternatives to fossil fuels this has often been done in the absence of a wider understanding of the full costs and benefits of bioenergy. In this context, the Food and Agricultural Organization of the United Nations (FAO) with generous funding from the German Federal Ministry of Food, Agriculture and Consumer Protection (BMELV) set up the Bioenergy and Food Security (BEFS) project to assess if and how bioenergy developments could be implemented without hindering food security.

The BEFS project sought to approach the problem of food security in an integrative and comprehensive manner. The project inherently understood that promoting food security through bioenergy or indeed any other instrument could not be done in a one-dimensional way. Rather, it required balancing the many issues that have an effect on bioenergy and food security and considering them jointly to arrive at a set of considerations that better reflected reality and could support policy in a more meaningful way.

The project developed an analytical framework that is published in the present document. The BEFS Analytical Framework offers the tools to assist policy makers in making informed decisions on the basis of clear information concerning the many varied consequences of bioenergy developments on food security, poverty reduction and agriculture development and economic growth. This analytical framework has been implemented in Peru, Tanzania and Thailand/Cambodia. The results of the country implementations are published in the FAO Environment and Natural Resources Management working paper series.

The BEFS Analytical Framework with its tool box is now available for use by other countries to support considering food security within the context of bioenergy.

Heiner Thofern
Senior Natural Resources Management Officer
BEFS Project Coordinator

ABSTRACT

A potent argument for bioenergy development lies in the ability of the sector to unlock agricultural potential by bringing in much needed investments to raise agricultural productivity to spur food security and poverty reduction. This document presents the BEFS Analytical Framework (AF) developed to test this argument. Agriculture lies at the heart of the BEFS AF and allows governments to consider viable pro-poor strategies for bioenergy development. The set of tools within the BEFS AF offers an integrated approach to decision-making that combines the technical viability with the country's prevailing social and economic development objectives.

This document explains the rationale and structure of the BEFS AF, provides a general overview of the tools and their application, and illustrates how the analytical information generated assists policy makers in making informed decisions concerning the many varied consequences of bioenergy developments on food security, poverty reduction and agriculture development and economic growth.

Bioenergy and Food Security: The BEFS Analytical Framework

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The various parts and chapters of this document drew upon country work and references listed in the respective parts and chapters.

Part I "The BEFS Analytical Framework" was prepared by Yasmeen Khwaja.

The Part II technical chapters were prepared by the following authors:

- BEFS (NRC) and COSIMO (EST) teams: chapter 7 "Diagnostic Analysis: Agricultural Outlook";
- Mirella Salvatore (NRC): chapter 8 "Natural resources analysis: Land Assessment";
- Erika Felix (NRC): chapter 9 "Natural resources analysis: Water Resource Management"; chapter 10 "Natural resource analysis: Woody biomass and residues"; chapter 11 "Techno-economic and environmental analysis: biofuel production costs"; chapter 12 "Techno-economic and environmental analysis: Greenhouse gas emissions";
- James Thurlow of the International Food Policy Research Institute (IFPRI): chapter 13 "Socio-Economic Analysis: Economy-wide impacts";
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CONTENTS

DEFINITIONS[1]

Agricultural by-products represent biomass by-products originating from production, harvesting and processing in farm areas.

Agrofuels are biofuels obtained as a product of energy crops and/or agricultural (including animal) and agro-industrial by-products (see definitions below) (FAO, 2004).

Agro-industrial by-products represent several kinds of biomass materials produced chiefly in food and fibre processing industries.

Animal by-products are agricultural by-products originating from livestock keeping. It includes among others solid excreta of animals.

Bioenergy is energy produced from biofuels. It comprises electricity, heat and a wide range of transportation fuel.

Biofuel is energy produced directly or indirectly from biomass. Biofuels can include for example, liquid biofuels i.e. fuel derived from biomass for transportation uses, gaseous biofuels such as methane gas, and solid biofuels like fuelwood, charcoal etc.

Biofuels from municipal waste include municipal solid waste incinerated to produce heat and/or power, and biogas from the anaerobic fermentation of both solid and liquid municipal wastes (FAO, 2004).

Biomass is material of biological origin excluding material embedded in geological formations and transformed to fossil. Sources of biomass include energy crops, agricultural and forestry wastes and by-products, manure or microbial biomass.

Biomass streams are biomass products that can be used to produce bioenergy. Some examples are leaves, residues, cutover residues, sawdust, bark, chip, and corn husks among others.

Biomass supply chain is an integrated approach to describe the entire bioenergy production system. The supply chain incorporates all of the required production processes that are critical to the production of the end energy carrier. The starting point in a biomass supply chain is the production of biomass feedstock. This is typically followed by the industrial conversion of the biomass to energy, an energy carrier that is then used to generate energy.

Energy carrier is a substance or phenomenon that can be used to produce mechanical work or heat or to operate chemical or physical processes. To create an energy carrier

1 Bioenergy related definitions are extracted from the Unified Bioenergy Terminology of FAO (2004).

from an energy source a conversion process must occur. Typical energy carriers include electricity, gasoline, heating oil, diesel, ethanol, biogas, biodiesel, propane, and methane.

Food security exists when all people, at all times, have physical, social and economic access to sufficient amounts of safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life. There are four dimensions to food security as it relates to bioenergy: availability, access, stability and utilization.

Net food producer is someone for whom total sales of food to the market exceed total purchase of food from the market.

Net food consumer is someone for whom total sales of food to the market is less than the purchases of food from the market.

Woodfuels are all types of biofuels originating directly or indirectly from trees, bushes and shrubs (i.e. woody biomass) grown on forest and non-forest lands[2] (FAO, 2004).

2 For the purpose of this project, "traditional" (unsustainable) fuelwood and charcoal production will not be considered.

PART ONE
THE BEFS ANALYTICAL FRAMEWORK

CHAPTER 1

INTRODUCTION

Recent years have witnessed a renewed interest in bioenergy both within the developed and the developing world. Bioenergy, and particularly liquid biofuels, have been promoted as a means to enhance energy independence, promote rural development and reduce greenhouse gas emissions.

Bioenergy potentially offers poor countries many advantages. Firstly, bioenergy developments offer the opportunity for enhanced energy security and access by reducing the dependence on fossil fuels and providing a localized solution. Increased energy security in turn can have positive effects on food security. Secondly, a bioenergy sector can create a new market for producers as well as offer new forms of employment that will positively affect agricultural and rural incomes, poverty reduction and economic growth. Thirdly, bioenergy has the potential to contribute to environmental objectives including the reduction of greenhouse gas emissions. Not surprisingly, bioenergy has been placed high on the policy agenda of developing countries.

However, recently bioenergy developments have also become a cause for deep concern. The reason for this lies with their actual social, economic, and environmental viability due to the potential negative impacts on food security and on the environment caused by food production and natural resource competition and intensive agriculture production.

For the first time since 1970, the number of hungry people has been increasing climing over the one billion of hungry and undernourished people as stated in the FAO report *The State of Food Insecurity in the World* 2009. Two main factors explain the increase in food insecurity. First, 2005-2008 witnessed the first major global food crisis in 30 years which saw the prices of basic staples increase several fold. While prices have fallen since their peak in 2008, they remain at a historical high and subject to ongoing volatility. Second, the financial crisis in 2009 meant that developed countries cut back significantly on development assistance, with implications for food security in particularly vulnerable countries. In this context, bioenergy has been recognized, although to a varying degree, as one of the additional pressures on agriculture production and since the 2008 food crisis, serious concerns have been raised as to the extent of opportunities afforded by bioenergy because of the competition the sector creates for resources used for food production and environmental preservation. Moreover, bioenergy developments expose countries to new sets of risks related to the industry that derive from domestic changes in natural resource use as well as international changes in bioenergy policy, both of which could affect food security.

These crises have made governments understand more firmly the very essential role played by agriculture in supporting the food and livelihood needs of the poor. This has been accompanied by a clearer understanding that the agricultural sector in a large number of developing countries requires a new "revolution" to regenerate the sector in a *sustainable* way.

Initially the rush to develop bioenergy has tended to take place in the absence of a wider understanding of the full costs, benefits and impacts of bioenergy. The question now faced by governments is whether the investments brought in by bioenergy can be channelled to ensure that bioenergy developments are viable and sustainable and that ultimately they become a vehicle for much needed agriculture growth, food production enhancement, rural development and poverty reduction.

The BEFS analysis demonstrates that the impacts of bioenergy, and more specifically biofuels, on food prices, economic growth, energy security, deforestation, land use and climate change vary by feedstock, by the method and location of production, and centrally hinge on the management of the sector. This illustrates that it is difficult to draw *general* conclusions about the net impacts of bioenergy for countries, particular groups and households. Sustainable biofuel development relies on accurate management of the sector and of the trade-offs that may arise from the development. Consequently, sound bioenergy policy development needs to be the outcome of a context or country specific analysis of the net costs and benefits.

In order to assist governments in this and in developing a broader understanding of the issues at stake, the Bioenergy and Food Security (BEFS) project developed the Bioenergy and Food Security Analytical Framework (BEFS AF). While there are a number of issues that surround bioenergy, the central focus of the BEFS AF is to examine how bioenergy development can be implemented without hindering, and potentially enhancing, food security.

In this context,

1. **The BEFS Analytical Framework** (BEFS AF) identifies four areas of analysis required to examine the relationship between bioenergy and food security;

2. **The BEFS tool box** comprises the analytical tools needed within the four analytical areas supporting the understanding of the dynamics of the bioenergy and food security interface through a quantitative analysis.

The BEFS AF and its tool box provide the means for examining the many varied consequences of bioenergy developments on food security, poverty reduction and rural development in specific country contexts. The information generated by the tools is key in providing information to policy makers to ensure that bioenergy policy development is evidence based and in line with the above.

The main endeavour throughout the analysis in BEFS is to identify a management system that is smallholder inclusive, food secure, and vulnerability safeguarding in order to ensure that countries reap the benefits of bioenergy developments but manage and are aware of the risks involved.

The BEFS AF was implemented in Peru, Tanzania and Thailand and supported biofuel policy formulation and implementation in these countries. The BEFS tool box is available for use by other countries in considering food security within the context of bioenergy.

The document is divided into two main parts. Part I presents the structure of the BEFS AF and the underlying rationale. Part II provides an overview of all the tools that support the BEFS AF.

CHAPTER 2

THE BEFS ANALYTICAL FRAMEWORK

2.1 BIOENERGY AND FOOD SECURITY: DEFINITIONS AND LINKAGES

FAO defines bioenergy[1] as energy derived from biofuels (solid, liquid fuels and gaseous fuels). It can come from a variety of sources, including crops like sugar cane and beet, corn and energy grass or from fuel wood, agricultural wastes and by-products, forestry residues, livestock manure and other sources.

The definition of Food Security and its dimensions are listed in Box 1. Food security is usually analysed in terms of its four dimensions: availability, access, stability and utilization. While these dimensions are linked, specific factors can drive the availability of and access to food. These factors then determine the stability in access to food and the way food is utilized for human health benefits. The BEFS AF has focused on the availability and access dimensions of food security[2] but acknowledges the importance of the other two food security dimensions.

BOX 1

DEFINITION OF FOOD SECURITY

"Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life". (World Food Summit, FAO, Rome 1996)

Food Security has four dimensions:

Food availability: The availability of sufficient quantities of food of appropriate quality, supplied through domestic production or imports (including food aid).

Food access: Access by individuals to adequate resources (entitlements) for acquiring appropriate foods for a nutritious diet. Entitlements are defined as the set of all commodity bundles over which a person can establish command given the legal, political, economic and social arrangements of the community in which they live (including traditional rights such as access to common resources).

1 Further background information can be found in Annex 1.

2 A background note on this is contained in Annex 2.

Utilization: Utilization of food through adequate diet, clean water, sanitation and health care to reach a state of nutritional well-being where all physiological needs are met. This brings out the importance of non-food inputs in food security.

Stability: To be food secure, a population, household or individual must have access to adequate food at all times. They should not risk losing access to food as a consequence of sudden shocks (e.g. an economic or climatic crisis) or cyclical events (e.g. seasonal food insecurity). The concept of stability can therefore refer to both the availability and access dimensions of food security.

The starting point of the BEFS AF considers the balance between the natural resource base and food security. Three-quarters of poor people in developing countries live in rural areas and rely on agriculture for their livelihoods and food security. More specifically, the poor are heavily dependent on the natural resources used to support the agricultural sector. High levels of poverty and food insecurity can result in natural resources being used in an unsustainable manner. Over time, this leads to a vicious circle of poverty and degradation of the natural resource base.

The evidence in developing countries clearly shows that since the mid-1970s agricultural investment as a proportion of GDP has declined. Cheap global food prices for over thirty years removed the incentives for many poor country governments to focus on agriculture, thereby compounding the vicious circle of poverty and natural resource degradation. It took the food crisis in 2008 to revive interest in agriculture, particularly for food security. However, the current state of agriculture in developing countries is not adequate to support food security.

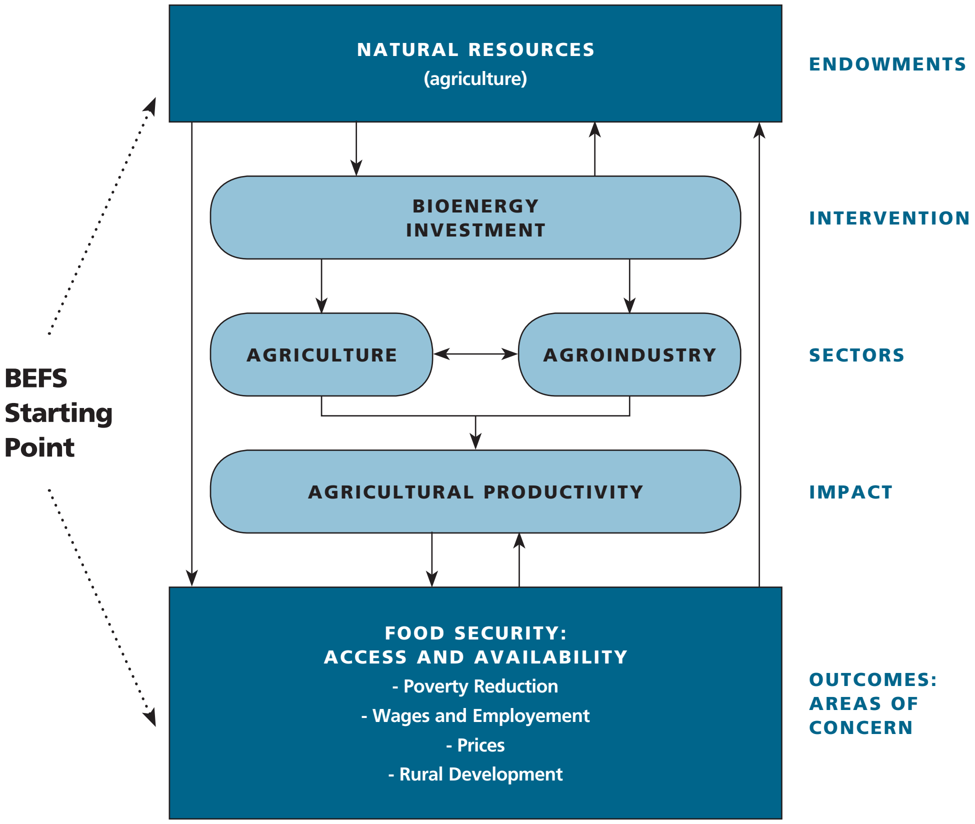
Agricultural development is critical to achieve long-term sustainable food security. The core objective of the BEFS AF is to identify to what extent bioenergy interventions can play an instrumental role in improving agricultural performance for food security. A priori, it cannot be determined whether bioenergy has a positive or a negative impact on food security. The issue is a complex one.

The BEFS AF illustrated in Figure 1 describes this complex relationship between bioenergy development and food security. The BEFS AF is not fully comprehensive in considering all the dimensions for food security and all forms of bioenergy. It has for analytical clarity confined itself to key issues surrounding food security and bioenergy.

Figure 1 shows that bioenergy interventions affect food security through two principal channels. First, they compete for many of the same natural resources used to support food production. Second, the structure of bioenergy interventions can have an impact on agricultural productivity and affect food security outcomes. Each of these channels is considered separately in sections 2.2 and 2.3.

Figure 1

The BEFS Analytical Framework



2.2 Bioenergy, Natural Resources and Food Security

Bioenergy interventions, through their effects on the use of natural and agricultural resources, affect food security in a number of ways. Environmental constraints already limit the biophysical and technical production of food crops in many poor countries. Bioenergy developments can put additional pressure on the use of natural resources and could compete with food production.

The main issues for food security may arise from the following:

- **Land displacement and degradation**
  Bioenergy could displace food production in the use of land. Any reductions in food output could be accompanied by higher prices for staple food crops. Shortfalls in domestic production could require increases in food imports, with implications for the public purse. Where bioenergy feedstocks are grown to service an export market, pressures may increase on small farmers to sell their lands. Bioenergy feedstock production tends to be resource-intensive, which could affect long-term soil quality and therefore land productivity. Different crops and methods of production affect

land quality in the long term. In order to maintain its output levels, the bioenergy industry might have to further increase its use of land at the expense of agricultural land used for food. If land displacement occurs, food producers may have to move to new lands where soil quality may be lower. This can be the case where land previously used for livestock grazing is brought under crop production, since grazing may negatively affect soil quality.

- **Water resource management**
  Agriculture already uses more than 50 percent of all available water in many developing countries. Many poor regions of the world are water scarce and climate change may worsen the situation. Bioenergy interventions compete for the same water resources used for agriculture. Depending on the bioenergy feedstock, water demand by the sector can be very high further depleting water stocks. If a system of water pricing is put in place that reflects water scarcity, small farmers could be priced out. The bioenergy industry is likely to be developed under an intensive system of agricultural management, with widespread use of agrochemicals and fertilizers to boost yields. Excessive use of these inputs reduces water quality. This affects food security through reduced agricultural productivity and adverse health effects associated with clean drinking water and sanitation.

2.3 Bioenergy, Agricultural Productivity and Food Security

The second channel through which bioenergy interventions affect food security occurs through the impacts on the agricultural and agro-industrial sectors. Agricultural production of bioenergy feedstock constitutes an input into the agro-industrial sector. In turn, the agro-industrial sector driven by a profit-maximizing motive will exert strong influence on the way the agricultural sector is organised for bioenergy. This involves both the crop choice, the type of agricultural management system and the scale of operation used for production. Private investors could favour large scale production because they entail lower production costs.

Meeting the requirements of a bioenergy agro-industrial sector in developing countries necessarily involves increasing production and productivity within agriculture, if bioenergy is to be a serious alternative to fossil fuels. Increased agricultural productivity may positively affect poverty reduction and food security either because small and poorer farmers are able to benefit from productivity gains improving their incomes, and/or because agricultural productivity may increase food productivity, reducing food prices. Strong arguments exist for the role bioenergy interventions may play in enhancing agricultural productivity but without careful management of the sector the poor may be bypassed in accessing any benefits. There is concern that productivity gains may accrue only to large scale farmers with very little trickle down effects on small and poor farmers. Second, increased agricultural productivity may actually be associated with increased food prices, if feedstock production competes with food production.

The case to support the development role of bioenergy needs to be validated with careful analysis. The food security dimensions of access and availability are driven by a number of factors relating to prices, employment and incomes, rural development, and poverty reduction in general. Bioenergy interventions in principle could have an ambiguous impact on each one of these factors, as discussed below:

- **Incomes and prices.**
  Bioenergy can impact on food security through changes in incomes and food prices. Income is an important element in the food security status of the poor. Income influences both the quantity and quality of food purchased by households. The exact effects of food prices on food security are more complex and require an understanding of whether households are net food producers and net food consumers. In general, higher food prices hurt net food consumers but farmers who are net food producers are likely to benefit from higher prices and increase their incomes, other things being equal. Some people will find they are better off while others are worse off.

- **Employment.**
  Bioenergy investment can create new forms of employment. Opportunities could arise in the areas of biofuel production, processing, transportation, trade and distribution. There could be positive employment spillovers both geographically and in related sectors. According to some estimates, the potential for job creation in bioenergy is higher than for other renewable energy sources, and entails lower investment costs per unit of job generated.

- **Rural development.**
  The provision of power generated from biomass sources can contribute to rural development by improving the energy of rural communities that previously may have had inadequate access to electricity. Improved energy access can enhance agricultural productivity, food preparation and education, all of which have direct consequences for food security. However, the success of bioenergy developments very much depends on what happens to prices in the long term in fossil fuel markets. A permanent fall in oil prices, for example, would render the biofuel sector uncompetitive.

CHAPTER 3

THE BEFS ANALYTICAL COMPONENTS AND TOOLS

The impacts of bioenergy interventions are not always clear. In order to influence food security outcomes positively, it is important to consider the relationships between natural resources, bioenergy interventions and food security. Consequently, the BEFS approach identifies four key areas of analysis necessary to examine how food security outcomes are affected. These are

(i) Diagnostic analysis
(ii) Natural resources analysis
(iii) Techno-economic and environmental analysis
(iv) Socio-economic analysis

A set of tools were developed to identify the key issues affecting food security, poverty and rural development within each area of analysis called the BEFS tool box. The diagram in Figure 2 illustrates how the tools developed support the BEFS AF and the instruments are listed in Table 1 below.

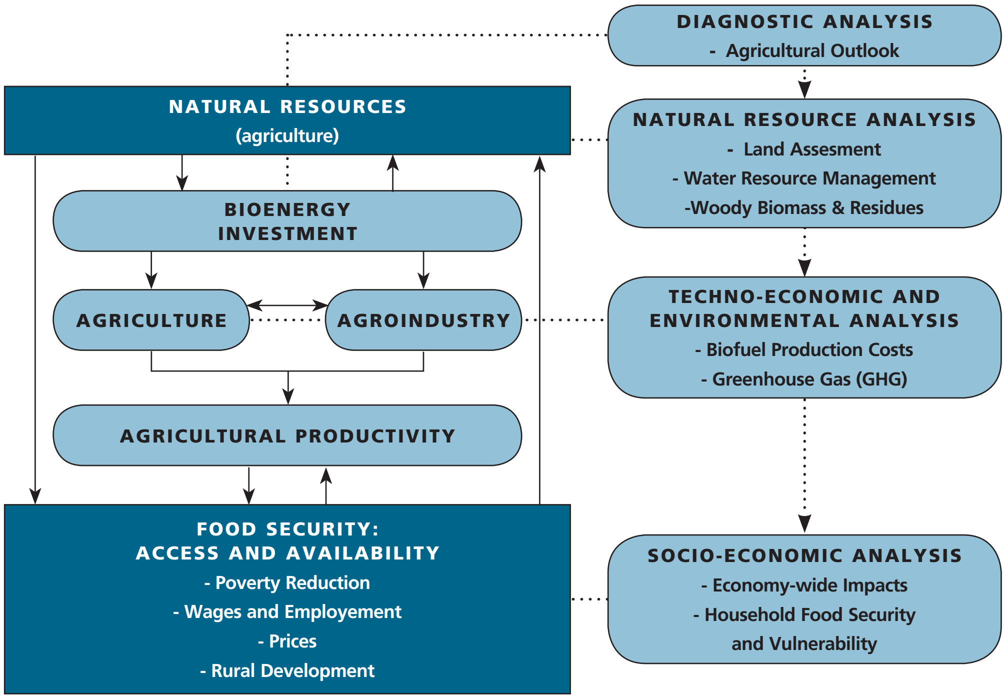
Table 1
The BEFS AF: Areas of analysis and relative analytical components

AREA OF ANALYSIS	TOOL
Diagnostic	Agricultural outlook
Natural resource	Land assessment
	Water resource management
	Woody biomass and residues
Techno-economic and environmental	Biofuel production costs
	Greenhouse gas emissions
Socio economic analysis	Economy wide impacts
	Household food security and vulnerability

The BEFS tool box considered a number of instruments to understand the critical interactions and trade-offs between food security, natural resource use for bioenergy, and the structure of the bioenergy industry.

Figure 2

Supporting the BEFS AF through the BEFS tool box.



Each of these tools was identified as being important for supporting bioenergy policy in Peru, Tanzania and Thailand- the BEFS project countries.

3.1 Diagnostic Analysis: Agricultural Outlook

The agricultural outlook component uses the OECD-FAO Agricultural Outlook to develop projections for production, utilization (i.e. consumption in the form of food, feed, fuel or fibre), imports, exports, stocks and prices for the main agricultural commodities and biofuels of the countries influencing world agricultural markets. The study identifies the pressures on domestic agricultural markets over time with respect to a set of macroeconomic conditions, trends and current agricultural policies employed in countries influencing world markets.

3.2 Natural Resource Analysis

3.2.1 Land Assessment

The analysis undertaken in the land assessment component identifies the suitability of a specific area of land for bioenergy crop production under a stated system of management. Land suitability is assessed considering climate, soil and site factors that can affect potential productivity. Filters are used to identify the amount of suitable land that is available for bioenergy feedstock production by excluding areas already under agricultural production for food crops or areas that are designated protected regions such as forests.

3.2.2 Water Resource Management

The AF considers two water analysis tools to evaluate water implications and bioenergy development.

A software tool called the Water Evaluation and Planning system (WEAP). WEAP examines the water resource and socio-economic implications of bioenergy crop expansion. This tool is used to create simulations of water demand and supply taking into consideration runoff, evapo-transpiration, reservoir operations, and other variables to examine water usage for biofuels using different feedstocks.

An additional tool to asses the implications of water resources and bioenergy is the water footprint assessment. This tool assesses how water resources are being used by various sectors in an economy and serves as a screening tool. The results generated by the analysis can then be used to identify areas i.e. "hotspots" that required a more comprehensive analysis.

3.2.3 Woody Biomass and Residues

The woody biomass and residues analysis considers how woody biomass and residues, as one component in the bioenergy portfolio, can be developed to create local energy sources for local use. The analysis uses the Woodfuel Integrated Supply/Demand Overview Mapping model (WISDOM), a spatially explicit analysis of the supply and demand of biomass and from residues derived from agricultural production and forest product industry. The results identify areas according to the balance between the supply and demand for biomass residues.

3.3 Techno-economic and Environmental Analysis

3.3.1 Biofuel Production Costs

The biofuel production cost analysis derives production cost profiles for biofuels under different industrial set-ups to examine the degree to which smallholder inclusion in the biofuel supply chain can be competitive when compared to large-scale production. The analysis is carried out for both bio ethanol and bio diesel production using different feedstocks.

3.3.2 Greenhouse Gas Emissions

This component uses a life-cycle analysis to establish a green house gas baseline for ethanol and biodiesel production from different feedstock crops. As liquid biofuels development has been promoted as a means to reduce greenhouse gas (GHG) emissions, it is important that the definition of sustainability includes the impact that possible changes in crop to crop and land-use changes may have on the overall GHG balance in the production of liquid biofuel as this may influence the climate benefit. The analysis therefore considers GHG balances under scenarios that incorporate land use change and under crop-to-crop changes.

3.4 Socio-economic Analysis

3.4.1 Economy-wide Impacts

The economy wide component of the analysis builds on the production cost scenarios constructed in the biofuel production costs component. This component is based on a Computable General Equilibrium (CGE) model and it assesses the effects of specific bioenergy developments on a number of socio-economic variables such as poverty reduction, agricultural growth, GDP growth and employment.

3.4.2 Household Food Security and Vulnerability

The household food security and vulnerability component measures the household welfare effects of increases in the price of key food staples. It is a vulnerability profiling tool that identifies which households are most susceptible to food price increases and where they are located.

Each of the tools developed under the BEFS project is discussed in more detail in Part II of this document where a generic model is presented and its application to the project countries illustrated. For a fuller examination in the precise use of the tools and how the fundamental model changes according to the country context, a country analysis is available for each of the BEFS countries and is referenced in Part II.

Not all the tools were applied in all the countries. The use of specific tools within the BEFS tool box varied across each country according to the bioenergy priority of the country. Table 1 summarizes which tools were used where.

In Tanzania, the main emphasis has been the consideration of liquid biofuels in order to promote energy security. However, there is understandable concern that biofuel development should not compromise the food security goals of the country so the BEFS tools have provided the basis for examining where the policy priorities should lie in pushing for a bioenergy industry.

Peru has already set mandates for liquid biofuels. In addition, the geographic diversity of Peru means that many people do not have access to grid electricity. Thus, finding local energy alternatives for local populations is seen as important to enhance energy security with positive implications for poverty reduction and rural development. In the case of Peru therefore, the BEFS tools have been used to guide policy implementation to support poverty and rural development goals.

Thailand has set an ambitious policy for biofuels and bioenergy in general. The energy plans of the country seek to increase biofuel provision for domestic use but also possibly for international markets. Enhancing energy security lies at the heart of bioenergy policy in Thailand but there is clear recognition that bioenergy initiatives can do much to enhance rural development. The BEFS tools have been largely used to support future policy goals related to bioenergy and rural development.

Table 2

The BEFS analytical components in Tanzania, Peru and Thailand

	TANZANIA	PERU	THAILAND
DIAGNOSTIC ANALYSIS			
Agricultural Outlook	*	*	*
NATURAL RESOURCE ANALYSIS			
Land Assessment	*	*	*
Water Resource Management		*	*
Woody Biomass Residues		*	*
TECHNO-ECONOMIC AND ENVIRONMENTAL ANALYSIS			
Biofuel Production Costs	*	*	*
Greenhouse Gas Emissions			*
SOCIO-ECONOMIC ANALYSIS			
Economy wide Impacts	*	*	*
Household Food Security and Vulnerabilitly[3]	*	*	*

3. Note that within the BEFS Thailand portfolio the household food security analysis was also conducted in Cambodia. This illustrates the use of the tool in the Asian context.

The set of tools developed for the BEFS project are not exhaustive and may not necessarily be the critical tools for other countries. The BEFS tool box is adaptable in the sense that for each of the areas of analysis identified by the BEFS AF existing tools may be modified or new tools may be added that reflect the priorities and context of specific countries. For example, environmental objectives such as biodiversity and deforestation have an impact on local livelihoods and thus food security, but this is not considered in the current BEFS analyses. However, existing tools can be modified to capture some of the effects arising from decreased biodiversity and deforestation and/or new tools can be introduced that look specifically at these dimensions.

CHAPTER 4

SUPPORTING POLICY WITH THE BEFS ANALYTICAL FRAMEWORK

The BEFS AF identifies the structure of relationships between bioenergy interventions and food security. The BEFS tool box includes a range of tools which after implementation provides an information set that can directly support the policy machinery in individual countries. The information set generated helps decision-makers in three key ways:

- **Reduces the time governments spend in their various roles as decision-maker and resource allocator when considering the direction of bioenergy developments.**

If governments can use a pre-existing framework like the BEFS AF it allows them to prepare better for the period of change induced by bioenergy developments. By understanding how each tool examines interactions between bioenergy and food security, policy-makers better understand the analytical patterns and how they link to other relationships within the BEFS AF. This helps reduce the time spent searching for solutions to specific concerns.

- **Assists governments in identifying teams of experts that have the correct abilities and skills to carry out the required analyses.**

This is especially important when a particular standard of expertise is required. The skills set needed for each analytical tool are identified within the discussion of the tools.

- **Identifies training needs.**

The BEFS AF can provide the basis for an in-country training plan.

In practice, the experience within each of the project countries has amply demonstrated that these three functions have been endorsed and accepted by relevant stakeholders. The application and use of the tools is subject to the availability of data and the right technical expertise (see Part II for full details for data and skills required to carry out a specific analysis). It is important that countries identify experts, define training needs and consider the required data sources and consider how this may affect the time frame for implementation of the tools. While the use of all the BEFS analysis permits a quantitative identification of the many relationships between natural resources and food security, individual countries may wish to focus on specific relationships. Consequently, countries may be selective in terms of the tools they use in order to reflect the policy priorities of the country.

This discussion is taken up in the policy work for all the countries and has been a theme in the policy training. Even where a country is unable to carry out the analysis, the diversity of the BEFS countries means that the analyses undertaken in one country can provide an important knowledge base for other countries in their consideration of bioenergy developments and the impacts on food security.

CHAPTER 5

THE DIRECTION OF FUTURE WORK AND THE USE OF THE BEFS AF FOR CLIMATE CHANGE ANALYSIS

The BEFS AF and its analytical components and relative tools are a flexible instrument that can be integrated with additional components as necessary. The selection of additional components will depend on the countries' development priorities and strategies and also on the context the BEFS AF may be applied in.

Currently, as discussed, the focus of the BEFS AF has been on food security and food security implications of the bioenergy developments. However, the discipline interlinkages within the BEFS AF are able to accomodate detailed work on the environmental, labour market and climate change impacts of bionergy developments. More details can be added on all of these aspects where the user can decide to detail a specific issue further and focus on that specific side of the problem. With the additions, conclusions on the theme at hand can be drawn out further. For example, the BEFS AF has the capacity to integrate additional environmental information so as to specifically evaluate the green house gas emissions reduction potential of selected biofuel supply chains. On the other hand, if the main focus were rural development and employment, more details can be added on the local use of bioenergy and on local employment implications. Again, all of the analysis has to be crop and country specific and industrial set up specific.

In recent years the issue of climate change has dominated the development agenda. One of the main elements of the climate change thesis rests on how it will affect the natural resource base and what this will mean for poverty and food security. Figure 3 illustrates the importance of the BEFS AF as a building block for a specific climate change analysis. The tools already developed for the bioenergy and food security nexus can be adapted to incorporate specific climate change effects.

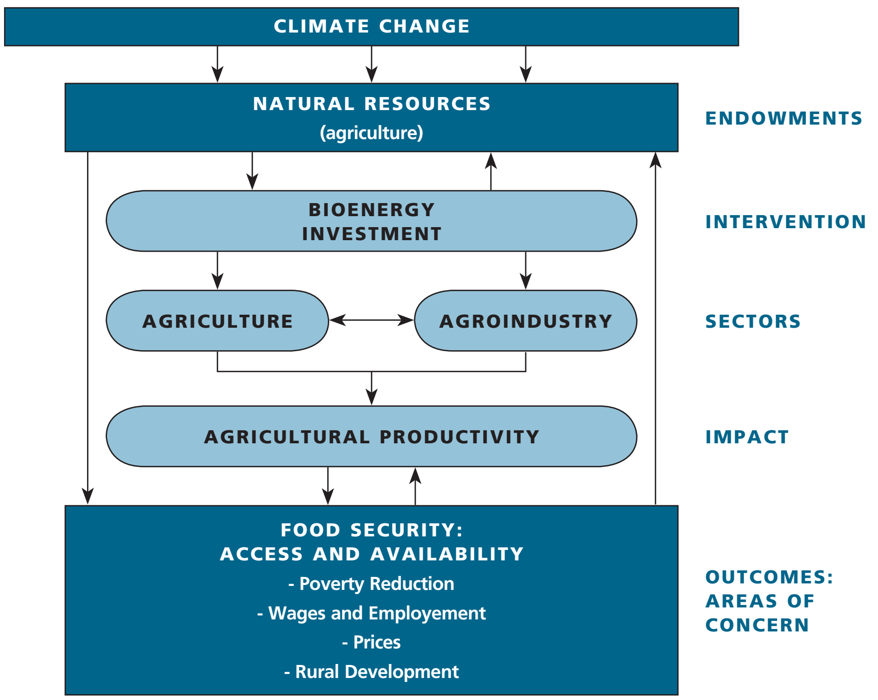
Furthermore, within the existing BEFS AF, the core relationship of the BEFS AF is that between natural resources and food security. This is, in the current era, a fragile relationship because past climate change effects and past land use practices have affected the ability of the natural resource base to support livelihoods. Indeed, the ability to reach targets set by the Millennium Development Goals (MDGs) hinge on this very relationship. Moreover, continued poverty tends to result in the unsustainable use of natural resources which has implications for all the other MDGs.

Bioenergy is often seen as a means to offset adverse climate change effects. Incorporating bioenergy interventions within a "Climate Change BEFS AF" will permit a quantitative examination of the interactions between climate change, bioenergy and food security. Such information will be a useful aid to specific policy developments in the context of food and energy security and climate change.

Finally, the focus of analysis in the BEFS project has been on bioenergy interventions but in practice the intervention to be analyzed can be any change that affects the use of natural resources in agriculture. The BEFS AF remains central to the exploration of multiple themes. What will change is the composition of the BEFS tool box as new relationships are identified.

Figure 3

Building on the BEFS AF to examine climate change effects



In conclusions the existing BEFS AF and the underpinning tools can be customised or augmented with additional components and tools to reflect the specific priorities of individual countries.

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PART TWO
THE BEFS TOOL BOX

CHAPTER 6 OVERVIEW

The BEFS AF analyses the impacts of bioenergy developments on food security, identifies feasible bioenergy development paths that are sustainable (economically, socially and environmentally) and informs policy based on the information set generated from the implementation of the BEFS tool box. Four areas of analysis are covered within the BEFS AF (Diagnostic, Natural Resources, Techno-economic and Environmental, and Socio-economic) and implemented through the BEFS tool box. The structure of the BEFS AF has been discussed in detail in Part I. The BEFS AF analysis areas and relative tools are summarized in the table below.

Table 3

AREA OF ANALYSIS	TOOL
Diagnostic Analysis	Agricultural outlook
Natural Resources	Land assessment
	Water resource management
	Woody biomass and residues
Techno-economic and Environmental	Biofuel production costs
	Greenhouse gas emissions
Socio-economic Analysis	Economy-wide impacts
	Household food security and vulnerability

Part II of the BEFS AF provides an overview of the methodologies used within each analysis component. These methodologies are presented in the next chapters. Fuller details of how the methodologies were applied in different country contexts are available in the country analyses that are part of the BEFS portfolio of work. Each methodology provides full reference to the country work.

CHAPTER 7

DIAGNOSTIC ANALYSIS: AGRICULTURAL OUTLOOK

Introduction

Agricultural markets are characterized by constant change, whereby they are continuously responding to factors that influence supply and demand such as drought, disease, income growth, exchange rate fluctuations, energy prices and government policies. Even though agricultural markets are continuously reacting to shocks in the short term, there are still long-term trends that are prevalent within the sector. It is important to get a picture or conceptualize what the implications are for agricultural markets if trends continue, as this allows policy-makers to be proactive in developing policies to deal with potential challenges or opportunities. However, there are not many impartial, publicly available long-term projections for agricultural markets that are consistent across countries[2]. The Organisation of Economic Cooperation and Development (OECD) and the Food and Agriculture Organization (FAO) of the United Nations jointly produce an annual ten-year projection for national and global agricultural markets, called the OECD-FAO Agricultural Outlook. This Outlook provides projections for production, consumption in the form of food, feed, fuel or fibre, imports, exports, stocks and prices for the main agricultural commodities and biofuels of the countries influencing world agricultural markets[3]. The Outlook is an important tool that can highlight future challenges or opportunities in agricultural markets for some countries. It provides a picture of how agricultural markets could evolve over time with respect to a set of macroeconomic conditions, trends and current agricultural policies employed in countries influencing world markets. The commonly used Outlook methods provide medium-term projections based on relatively simple, but transparent assumptions. Their value lies in their consistency and completeness as well as in their usefulness to control scenario simulations.

7.1 Methodology: An Overview

The OECD-FAO Agricultural Outlook uses a partial equilibrium simulation model called AGLINK-COSIMO to produce projections of national and global agricultural markets. The model, along with the Outlook which serves as a baseline, is used to conduct market and policy analyses to determine impacts on agricultural markets. The robustness

2 Many countries produce forecasts for agricultural commodity markets, but these forecasts are from their perspective of the world and are not necessarily peer reviewed for consistency.

3 For further information regarding commodity and country representation within the OECD-FAO Agricultural Outlook please refer to www.oecd.org/publishing/corrigenda.

of the Outlook as a baseline and the model's comprehensive coverage of commodities and markets make them both very effective tools in analysing the impacts of biofuels and agricultural markets.

The major agricultural sectors, including the biofuel sector, are connected and are integrated within the model so that the main characteristics of the crops and livestock sectors influence the final equilibrium. As with most models of this type, AGLINK-COSIMO is driven by elasticities, technical parameters and policy variables. Buyers and sellers are assumed to have no market power; the model determines equilibrium prices under the assumption of perfect competition. Agricultural markets can be global or regional depending on the commodity market structure. Supply and demand curves are explicitly modelled for each commodity covered. AGLINK-COSIMO is a recursive dynamic model that clears agricultural commodity prices on an annual basis. The main drivers for the change over time are key macroeconomic variables, such as income growth, inflation, energy prices (i.e. world oil price), and exchange rates. Technological change is incorporated through improvements in crop yields and livestock genetics over time. While investment in new agricultural production capacities is not explicitly included, the area on which a crop is produced is endogenously influenced by prices. Competition for land is thus modelled by cross-price effects. Also, crop yields depend on prices and are modelled endogenously. Production costs of agricultural commodities are approximated using the commodity production costs indices, which depend on key macroeconomic variables.

Biofuel Sector Representation & Data

AGLINK-COSIMO only has specification for the major agricultural commodities that are traded in world markets or those representing a significant level of production. Biofuels specification is included because of its strong influence on the agricultural sector. The agricultural commodities modelled are: wheat, coarse grains (maize, sorghum, oats, rye and barley), rice, oilseeds (soybeans, canola/rapeseed and sunflower), oilseed meals, vegetable oils (oilseed oil and palm oil), roots and tubers (potatoes, cassava and yams), milk, butter, cheese, whole milk powder, skim milk powder, fresh dairy products, whey powder, casein, beef and veal, pig meat, poultry meat, sheep meat, eggs, sugar, molasses, ethanol and biodiesel. In some countries not all these commodities are represented because production or consumption is not significant enough to warrant specification. Within the BEFS project, the analysis concentrates on those commodities that are identified as being important to the country by its share of production/consumption, or if the commodity was to be used as a biofuel feedstock.

The biofuel components include a relatively complete representation of biofuel supply chains. This includes the investment decisions related to increased biofuel production capacities as well as capturing existing capacities. Feedstock use is directly linked to the production of biofuels from individual feedstocks, with limited substitution across feedstock types. Ethanol production is specifically represented, together with its feed use in the livestock industries. Similarly, the model reflects the increased availability of oilseed meals as oilseed crush for biodiesel. The model also represents the production of second-generation biofuels with respect to ethanol from cellulosic and biodiesel from biomass to liquid (BtL).

Data

The OECD-FAO Outlook and the AGLINK-COSIMO model rely on information from a large number of sources, including experts' judgment when necessary. Data for the model comes from information provided by national statistics sources and supplemented by external sources such as the United Nations and World Bank. This provides a first insight into possible market developments and establishes the key assumptions to be used in the Outlook. The model was extended to include the biofuel sector. Additional technical data was required to generate a world commodity database for ethanol and biodiesel, along with country-specific baseline data on different feedstocks and subsequent processing costs of production.

The AGLINK-COSIMO model and Outlook projections are reviewed annually by OECD member countries and FAO experts to ensure consistency and to reach a consensus solution among the main stakeholders. Due to this process, the OECD-FAO Outlook represents a consistent picture of agricultural markets over the medium-term as it brings together countries' perspectives of not only their own markets, but also world agricultural markets.

7.2 Using the Outlook Results

An agricultural outlook analysis seeks to give a medium-term picture of countries' supply and demand disposition for its main commodities and to show the potential impacts of biofuels. A country should consider future demands for agricultural commodities, whether food, fibre, or fuel, along with its productive capacity to meet all of these demands. Biofuels could represent a new source of demand for a country's crops and could potentially offer a source of export earnings that contribute to the balance of payments. However, the development of biofuels could create challenges for food security and imply increased imports, which would not only be economically inefficient but also socially undesirable. Moreover, model results are based on current productivity levels and a country wishing to offset potential future demands may want to invest in boosting agricultural productivity (i.e. yields). Also, the viability of a biofuel sector is very much linked to oil prices and government biofuel policies. Both are subject to volatility. Lower oil prices would lead to an increase in world crop production, particularly in developed countries, and consequently this would lead to lower costs and lower crop prices. Scenario analysis can exhibit the vulnerability of agriculture markets, especially biofuel feedstocks, to movements in oil prices. With respect to foreign policy risk, previous OECD analysis (OECD, 2008) has shown the consequences if support policies, that is, consumption mandates and production subsidies, are removed, and how this would affect biofuel markets and consequently, agricultural markets, particularly biofuel feedstocks. It is important to take into account this foreign policy risk if a country is looking to produce biofuels to capitalize on export markets, as these policies are subject to change and as foreign countries seek ways to protect their domestic markets.

Biofuels may offer opportunities for some countries, but there are challenges which will need to be addressed depending on the food security status, biofuel feedstock availability and the functioning markets within specific countries. The OECD-FAO Agricultural Outlook and AGLINK-COSIMO, BEFS analysis provides a picture for agricultural commodity markets given a set of macroeconomic and policy assumptions. It can be used to understand key relationships not only within agricultural markets, but also the linkages to biofuel markets. It should be noted that the results represent projections, based on a set of rigid, but transparent assumptions, and not a definitive forecast. Any deviation from these assumptions will result in alternative outlook paths. Most of all, the constant weather assumption, which is necessary, never holds. There are many other factors that could cause markets to change, such as adoption of new technology, climate change, trade agreements or economic shocks, which would change the outlook or picture for a country. However, scenario analysis can be conducted to understand the possible implications of changing policy or market conditions. This part of the BEFS analysis is important as it allows policy-makers to understand the possible market implications of shocks or continuing recent trends and to assess how to mitigate shocks or threats and capitalize on opportunities for their agricultural markets.

7.3 Discussion

For any country, the production of biofuels from agricultural feedstock can be a contentious issue with regards to the food versus fuel debate, but it is particularly sensitive for those countries that are deemed food insecure. Biofuels could possibly offer a country a new source of demand for their crops, rural development and income growth, but it could also present challenges in terms of food security. It is important for government officials to understand how biofuel demand for feedstock might affect the commodity supply-disposition[4] within their country over time. Agricultural markets are continuously reacting to changes in demand and supply, thus in order to gauge the possible impact biofuel production might have on commodity markets, it is important to have a picture or outlook of future potential supply and demand conditions. This module presents the agriculture market outlook for a country over a ten-year period, and an assessment of the market implications of biofuel production.

The production of biofuels and blending or consumption mandates in many countries has created a stronger relationship between energy markets (mainly oil) and agricultural

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4 Commodity supply-disposition refers to beginning stocks, production, imports, consumption, exports and ending stocks and the equilibrium condition that balances the market, i.e. beginning stocks + production + imports = consumption + exports + ending stocks.

markets. The prices of agricultural feedstock used to produce biofuels are now linked to movements in oil prices not only through the traditional (fuel and chemical) cost components, but also through a demand side link. Even in a country where there are no government policies intervening in biofuel markets, domestic biofuel production would remain vulnerable to the movement in world oil prices and the consequential impacts on world crop prices. Likewise, biofuel policies of other countries could possibly change, which could significantly alter the profitability of biofuel production and influence crop

BOX 2

THE AGRICULTURAL OUTLOOK FOR TANZANIA

Tanzania, despite having a considerable arable land base, faces challenges with respect to food security. A number of firms have expressed interest in investing in biofuel production. Consequently, the Government of Tanzania has received several requests for land allocation. Currently, the Government of Tanzania is considering a biofuel consumption mandate.

The OECD-FAO Outlook was initially reviewed by Tanzanian officials to ensure data and consequent projections were consistent with Tanzanian data sources. Upon review, officials requested that the sugar-cane yield and acreage be adjusted upwards to reflect recent market developments. The Outlook was revised with Tanzanian data and this revised Outlook was used for the Tanzanian baseline for assessment of biofuels production and consumption mandate scenarios. Firstly, Tanzanian officials, along with private investors, had identified 314 000 hectares of additional uncultivated arable land that could be developed to produce biofuel feedstocks. The actual volume of biofuel that could be produced was then determined based on the additional land and the production technology available in Tanzania. Sensitivity analysis was conducted whereby the same amount of biofuels production would be produced but only from the existing cultivated land base (i.e. no additional land) to determine the impacts on Tanzanian commodity supply-disposition for the crops used as biofuel feedstocks. This allowed Tanzanian officials to see the potential impacts on food security - if biofuels production would displace commodities used for food. Secondly, the Tanzanian government was considering a blending mandate of 10 percent for ethanol and 5 percent for biodiesel that was then assessed against the biofuels production levels from the 314 000 hectares. Further, considering that biofuels markets are linked to energy markets (i.e. oil prices) and government policies, a scenario with a lower oil price was carried out. In addition, the highlights from the OECD study on Biofuel Support Policies (OECD, 2008) were used to illustrate to policy-makers the vulnerability of biofuels and agricultural markets to changing oil prices and foreign government biofuels’ policies.

Overall the OECD-FAO Outlook and AGLINK-COSIMO model were used to show a plausible ten - year picture of Tanzanian agricultural markets and to conduct various biofuel scenarios to help inform the policy debate regarding biofuel production and consumption policies in Tanzania.

prices. The development of biofuel production within a developing country should be explored with prudence. Before governments pursue biofuel policies they should analyse the potential domestic and international market opportunities and the impacts of biofuel production on the agricultural sector. The dynamic nature of the energy and agricultural markets warrants a continuous monitoring and adjustment of such policies. The OECD-FAO Agricultural Outlook and AGLINK-COSIMO model is used primarily to produce medium-term market projections but can also be used to conduct scenarios examining the impacts of policy instruments such as consumption and production mandates. (For further information on scenario applications of the Outlook, please see BEFS documents for Tanzania, Peru and Thailand).

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CHAPTER 8

NATURAL RESOURCE ANALYSIS: LAND ASSESSMENT

Introduction

Sound resource assessment is needed to assist policy-makers with sustainable resource management. Land is one of the natural resources that should be considered carefully in order to establish which areas are better suited to which crops and which are available for bioenergy crop production, taking environmental and food security issues into account. The land suitability assessment presented here is a part of this and based on a sound scientific methodology.

Bioenergy development could potentially negatively affect food production if the sector is not appropriately managed. Accurate land planning could therefore help ensure that new bioenergy developments do not negatively influence food production or the environment (protected areas, biodiversity, forests etc.). Policy-makers need to use efficient land-use planning tools to decide whether a country has land for expansion into bioenergy crops and if not, how existing land can be managed in a sustainable way and also allow for both food and bioenergy crop production.

It is important to emphasize that within the BEFS project, the focus of the land assessment was on bioenergy crops. Nevertheless this type of analysis can be expanded to any number and type of crops. In fact, generally the land assessment should be based on a larger number of crops in order to have a full information set to support agricultural planning consistent with the prevailing agriculture development strategy.

It is important that land assessment results are analysed alongside socio-economic considerations, such as population distribution, the poverty index, food insecurity indicators, infrastructure and access to credit, as it provides a better way of targeting interventions to improve the agricultural sector, induce rural development and achieve poverty reduction.

8.1 The Methodology of Land Assessment

Land assessment is composed of two main elements: the land suitability assessment (LSA) and the availability of suitable land.

LSA is based on a zoning approach developed and used by FAO since 1978. It is used to evaluate the suitability of a specific location for producing a particular crop under a well-defined agricultural management system based on the agroclimatic (i.e. temperature and rainfall), soil and landform conditions (i.e. soil type, acidity/alkalinity levels, nutrients, texture and slope). The suitability of a given portion of land is expressed as a percentage of the maximum attainable yield for each crop. The LSA then evaluates the potential production and return for such areas. There are three steps to this analysis:

- define the Land Utilization Type (LUT), which is a combination of crop, production system and level of inputs;
- create the *Land Resource Inventory*, which is geo-referenced information on climate, soil and landform; and
- formulate the climatic and soil-related suitability assessment criteria.

The LUT definition is the crucial starting point of the analysis. The level of detail to which the LUTs are defined is principally determined by the objectives of the study. More details in the LUT definition can provide information for estimating crop production costs.

The following factors should be implicit in the LUT definition:

- The description of an existing or anticipated agricultural production system in terms of crops, production techniques, and expected type and range of inputs.
- The identification of important factors which affect the production potential, such as limits to mechanization on sloping lands, and soil requirements for irrigation.
- The production scenarios to be modelled and the level to which production constraints are assumed to be overcome in each scenario.
- The quantification of human and financial capital (labour, materials, capital, etc.) associated with various production scenarios.

The LUT definition allows estimating the anticipated output or maximum attainable yield, which correspond to a certain level of input. The maximum attainable yield is based on agronomic expertise as well as field surveys at farmer level. Contextually geo-referenced and tabular information on climate and soil attributes should be compiled to run the suitability analysis. For more details refer to the *Data* section.

The criteria are formulated by interpreting climate and soil-related information as limiting factors to achieve the maximum attainable yield for a specific LUT. The results are expressed in terms of a suitability index (SI), defined as the potential of a specific location to achieve a certain percentage of the maximum attainable yield for a specific crop because of its agroclimatic and soil conditions. The SI has been classified according to Table 2. A detailed flowchart of the LSA methodology can be found in Figure 4.

Table 4

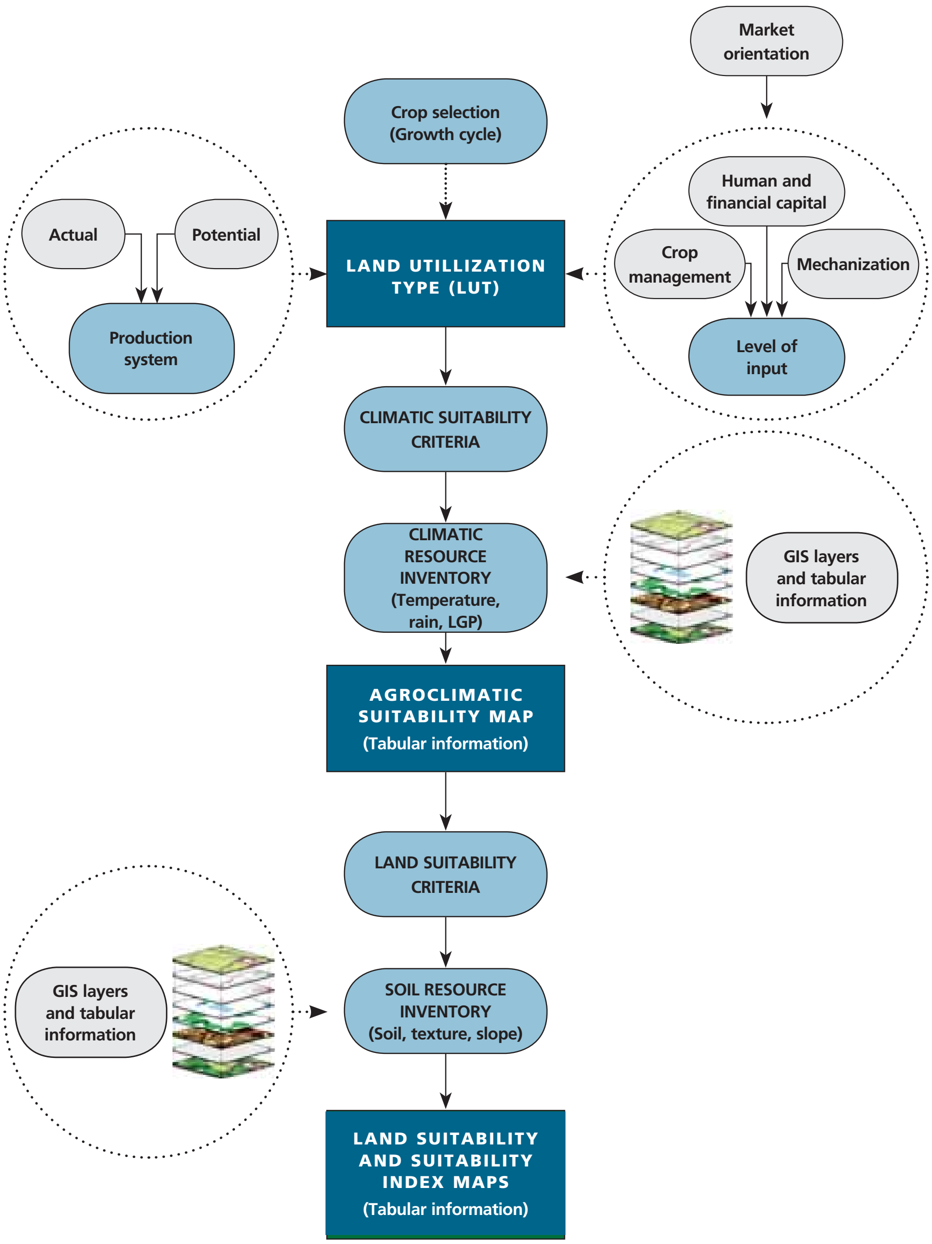
Suitability Index

SUITABILITY INDEX	PERCENTAGE RANGE OF MAXIMUM ATTAINABLE YIELDS
Very suitable	80 – 100
Suitable	60 – 80
Moderately suitable	40 – 60
Marginally suitable	20 – 40
Very marginally suitable	> 0 – 20
Not suitable	0

The suitability assessment considers all land as potential area for expanding each crop although, obviously not all land is available for agricultural expansion and/or bioenergy development for various reasons. Areas designated for other use, such as urban areas, or areas assigned by law to commercial activities, such as forestry concessions, cannot be considered even if they are highly suitable. Areas with environmental concerns or areas already under agricultural food production should be analysed carefully. The availability of suitable land is often determined by political priorities.

Figure 4

Land Suitability Assessment flowchart



8.2 Data, Skills and Software

Land assessment requires collecting a wide range of information and requires the technical support and expertise of a multidisciplinary team.

The required information requires typically geo-referenced (or GIS[5]) data and a statistical database that includes climatic, soil-related, protected areas, and land cover and land use information. The climatic and soil-related databases comprise the bulk of information of the *Land Resource Inventory* and they are mainly used in the LSA. The remaining refer to the assessment of the availability of land, and identification of areas where environmental and food production competition could occur.

The use of geo-referenced information is essential for characterizing a specific location and consequently understanding, combining and interpreting different factors to present a more comprehensive picture that could support effectively the land planning.

Land assessment requires technicians with varied expertise: GIS experts and agriculture statisticians for the creation of databases; agro-meteorologists to define climatic variations; agronomists define the LUT and formulate the suitability criteria; soil scientists support the agronomist in the formulation of the related-soil criteria and forestry and environmental experts are required to identify hotspot areas. Agricultural policy and crop promotion officers should be part of the team to support technical experts in addressing policy objectives.

GIS software is necessary mainly for the preparation of the geo-referenced information. This is the most time consuming part of the assessment and the timeframe will depend on how familiar local experts are with data manipulation, interpolation and harmonization.

Under the BEFS project, software was developed to support country experts in performing the assessment. The software is designed in Visual Basic and uses a GIS programming language, Arc Macro Language (AML), the native programming language of the ArcInfo Workstation GIS software produced by ESRI.

8.3 Limitations and Extensions

Even though the use of geo-referenced information is the main advantage of this analysis, its availability and quality could be limiting factors.

Frequently, the necessary data are not developed nor maintained by a single entity or institution. Different sources or management of data can create problems concerning data compatibility. The main concerns relate to format, scale and resolution, and legend

5 Geographical Information System

and definition. A process of collection, standardization and harmonization is therefore required. The creation of a Spatial Data Infrastructure (SDI) could help to resolve these issues. as it is a framework of spatial data, metadata, users and tools that are interactively connected to use spatial data in an efficient and flexible way.

The suitability of the assessment and its interpretation depends on data quality: coarse GIS data, in terms of scale and resolution, cannot be used for a detailed assessment but only for a country seeking to identify the main areas of interest.

The main reason for using AML, a licensed software, stems from the scarce availability of free GIS software capable of manipulating raster datasets.

One of the limitations of the current version of the BEFS Land Assessment software is single crop analysis. Land assessment of cropping patterns is often more appropriate to gain a realistic picture of agriculture and bioenergy crop production opportunities in a specific location. The software developed in BEFS carried out the assessment under *rainfed* and *irrigated* conditions but no specific analysis was carried out on water availability and water stress. The software-related limitations are currently being addressed by FAO.

The assessment could be used also for evaluating the impact of climate change scenarios on agricultural production and the country's potential to feed its population in 2030-2050.

In Peru, the BEFS team consulted with the Instituto de Investigaciones de la Amazonía Peruana, responsible for the Ecological and Economic Zoning whose present zoning activities being undertaken using a similar approach to the one of the BEFS Land Assessment and some complementary economic features. Potential integration of the two approaches is currently under investigation. Forestry experts in Peru identified a further extension of the Land Assessment methodology and software to assess the suitability of trees in helping to identify opportunities in deforested areas.

BOX 3

APPLYING THE LAND SUITABILITY ASSESSMENT

Land assessment was carried out in three countries: Tanzania, Peru and Thailand. The analysis had a slightly different approach in order to illustrate the wider range of opportunities on how the assessment could be employed. In all cases the crops assessment was based on country-specific interest or policy.

In **Tanzania**, where bioenergy is still in an elementary stage, a top-down approach was used. Five crops were selected, namely cassava, sugar cane, palm oil, sweet sorghum and sunflower and analysed under four agriculture management configurations in terms of production systems and levels of input. The main objective was not only to provide a picture of what they can do under current agriculture management but primarily to illustrate which opportunities exist and what changes and improvements can be achieved in a sustainable manner.

In **Peru**, the analysis examined sugar cane, palm oil and jatropha based on the current agricultural management configuration. A major concern relates to water especially because sugar cane plantations are located in the most arid part of the country, i.e. the coastal area. Here the sugar cane assessment was carried out under *irrigation* conditions whereas the other crops are assessed under *rainfed* conditions.

In **Thailand**, the Land Development Department of the Ministry of Agriculture and Cooperatives carried out the analysis for cassava, sugar cane and palm oil. Compared to the other countries, Thailand already has very detailed information and regularly carries out surveys and validation in the field. This permits a full picture of the cropping pattern, land competition, production costs and provides information to farmers on alternative opportunities. The tool is mainly used to test agricultural policy targets and crop promotion, but also helps to support farmers in identifying high value crops and how to achieve higher returns through sustainable agriculture management, for example, where the use of organic fertilizer is presented to farmers as an opportunity to reduce their costs and increase their yields.

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CHAPTER 9

NATURAL RESOURCE ANALYSIS: WATER RESOURCE MANAGEMENT

Introduction

Water resources are already significantly constrained in certain regions of the world due to increased competition between agricultural, urban, and industrial users. In this context, water demand for biofuel crop production might increase competition with traditional users. This will depend on whether the biofuel crop is derived from fully irrigated crops grown in semi-arid areas or rainfed crops grown in water- abundant regions. Thus, under a scenario of biofuel crop expansion, a challenge may be how to ensure that water supplies are adequate to meet future needs. As such, considerations on the implications of biofuel policies and trends in water resources supply and demands are an integral part of the decision making process. Therefore, planning becomes essential to guarantee that this limited resource is managed sustainably and distributed accordingly among the different sectors to prevent any future conflicts that may arise from additional demands.

The objective of this analysis is to illustrate the impact of biofuel crop production in light of increased competition for scarce water resources in regions already facing water resource management challenges. The analysis follows an integrated approach looking at both the supply of and demand for water. It provides a basis to evaluate allocation of limited water resources between agricultural, municipal, industrial and environmental uses. The model used in this component of the BEFS analytical framework is the Water Evaluation and Planning System (WEAP) tool. WEAP is used to represent current water conditions in a given area and to explore a wide range of demand and supply options for balancing environment and development concerns. WEAP is used to create simulations of water demand, supply, runoff, evapotranspiration, infiltration, crop irrigation requirements, instream flow requirements, ecosystem services, groundwater and surface storage, reservoir operations, and pollution generation, treatment, discharge and instream water quality, all under scenarios of varying policy, hydrology, climate, land use, technology and socio-economic factors.

The behaviour of the water system is modelled or simulated under various scenarios. The simulation results are assessed and evaluated using supply reliability and demand coverage as measuring criteria. On one hand, the analysis considers an average 75 percent supply reliability as the acceptable level for agricultural water demand and the percentage coverage for each development scenario is determined. On the other hand, a sustainability analysis is carried out to assess the impact that each of the development scenarios has in the reliability of the system. In this case, the demand coverage remains static and the reliability of the system is then measured. In general this model can be used as a decision-support tool to assist water management authorities and policy-makers in the selection of appropriate water policies and in the establishment of priorities for reform of institutions and incentives that affect water resource management and allocation. In this particular case, the model was used to assess the implications of biofuel development policies on water resources management.

The results of this work provide information on the effects that biofuel development scenarios will have on water resources management at the desired level of analysis i.e. basin, valley and compares them to the baseline situation. They are used to identify the availability of water resources to potentially support biofuel development and also highlight key issues to support the efficient and sustainable management of water resources. Although the focus of this study is on biofuel development, the results are very relevant to water management even in the absence of this. These results serve as a foundation to guide sustainable planning of water management and to support policy actions, in this particular case to contribute to biofuel policy decision making.

9.1 Methodology: An Overview

The analysis seeks to define the effects of biofuel crop production in light of increased competition for scarce water resources particularly in water-deficient areas. The study applies and demonstrates the effective use of a water-modelling tool to support integrated water resources planning and policy analysis. The WEAP modelling is a dynamic model and consists of an integrated approach to water development considering water supply in the context of demand-side management. WEAP places demand-side issues such as water use patterns, equipment efficiencies, re-use strategies, costs, and water allocation schemes on an equal footing with supply-side topics such as stream flow, groundwater resources, reservoirs, and water transfers. WEAP is also distinguished by its integrated approach to simulating both the natural (e.g. evapotranspirative demands, runoff, baseflow) and engineered components (e.g., reservoirs, groundwater pumping) of water systems, allowing the planner access to a more comprehensive view of the broad range of factors that must be considered in managing water resources for present and future use.

The first step in the analysis is the characterization of the river basin system. This involves collecting water supply and demand data and insertion into the WEAP. Once the system is represented in the WEAP software tool, the model is formulated and calibrated, after which a baseline scenario representing the current situation is then prepared. A set of alternative assumptions, or scenarios, on future impacts of policies, for example, on water demand i.e. from expansion of biofuel crops, supply, hydrology, and pollution, can be used for exploring the full range of options. These scenarios are built based on information collected in the country and assumptions about potential biofuel crop development. The scenarios are then simulated and the results evaluated with respect to reliability of the system, demand coverage and vulnerability of the systems.

What data and skills are needed to run the analysis?

The water supply data includes hydrological data on reservoirs (locations, capacity and operation rules), flow gauging station (flow requirement and ecological reserve), information on river head flows, groundwater in addition to irrigation infrastructure and efficiency coefficients, and water returns estimates. The water-demand data includes identification of water uses and their allocation, identification of existing agricultural activities, selection of a representative crop mix and water consumption, information on projected expansion agriculture in general but particularly data related to biofuel crops information on projected population and industrial water uses.

Running the WEAP analysis requires a technical expert with knowledge of computer modelling in the field of water resources.

9.2 Limitations and Suitability

The WEAP as a database provides a system for maintaining water demand and supply information. As a forecasting tool, it simulates water demand, supply, flows and storage. WEAP as a policy analysis tool, evaluates a full range of water development and management options and takes account of multiple water users, the complexity of the system. The tool is designed to assist water professionals and planners.

It is a transparent and user-friendly decision-support tool for engaging stakeholders in an open process. The model is available in multiple languages and currently been used in many countries applied in a wide range of contexts to answer particular questions. Access to the model for developing countries and education institutions is free of charge. The data structure and level of detail can be easily customized to meet the requirements and data availability for a particular system and analysis. Once the system is set up, it is easy to create new scenarios for analysis.

The level of analysis employed in the BEFS AF required data on hydrological information, demand, and infrastructure that are important for the appropriate representation of the water system. As such the implications on any limitations on data availability for the development of the analysis need to be assessed by the water expert. If the decision to proceed with the WEAP development is made, this implies the need for future data collection which is likely to involve fieldwork and further processing of any existing data sets on hydrology, land use or socioeconomic data to improve or make the representation of the system more accurate.

Long-term water planning requires taking into account the potential effects of climate change on future water availability. The application of the WEAP model can be extended to examine water supply impacts and adaptations to climate change. These provide a comprehensive quantitative analysis useful to elicit promising water resource management alternatives when future supply is at stake. The present application of the WEAP in BEFS did not take into account these effects and therefore may be presenting a somewhat optimistic scenario on water availability. However, the BEFS tools are designed so that they can be embedded in a comprehensive climate change analysis. Thus, it is envisaged that future use would evaluate the biophysical suitability considering the effects of climate change. The

WEAP model can also be linked to other models evaluating aspects of groundwater and water quality or socioeconomic models.

BOX 4

ANALYSING WATER RESOURCES IN PERU

In the case of Peru, the coastal region has more than 100 000 hectares of "tierras erizas" (non-cultivated land due to water disposition) that has been targeted for biofuel crop production. The coastal region is semi-arid and experiences dry conditions. It relies on water flowing to the Pacific from the mountain regions and on groundwater well systems to provide fresh water resources. This region also contains Peru's largest cities and its largest commercially irrigated agricultural areas.

The development of 23 976 hectares of sugar cane for ethanol production that will be progressively planted in the Chira valley on idle costal land will require the establishment of new irrigation systems to meet the water demand of energy crops. To assess the implications of this development, a water analysis was carried out using the Water Evaluation and Planning System (WEAP). The analysis evaluates water provision under four different scenarios. Considering a 75 percent confidence as the minimum acceptable water availability needed for agriculture, results shows that, 1) under current conditions of water provision, there is not enough water available to support the additional 23 976 hectares of sugar cane projected to be grown in the Chira valley for ethanol production; and 2) The current supply of water would only be enough to support an additional 10 000 hectares of sugar cane in the Chira valley (50 percent of what has been planned).

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CHAPTER 10

NATURAL RESOURCE ANALYSIS: WOODY BIOMASS AND RESIDUES

Introduction

Woody biomass is an important energy resource and, if managed sustainably, can have a positive impact on the environment, forests, and social and economic development. It is a local resource, which could contribute to regional rural development and to security of energy supply. Biomass by-product (residues) sources from agricultural and agro-industrial residues have significant potential as a feedstock for bioenergy production. However, the use of these resources should not affect other key essential functions and services vital for the food security and energy independence of the people living in the areas involved. As such, understanding the potential availability of woody biomass and residues becomes central to promote their use as energy sources. A spatially-explicit consideration of what and where the resources are available for existing and possible energy use is therefore crucial to evaluating their bioenergy potential.

The overarching objective of this work is to support the decision-making process for the sustainable use of woody and residue biomass resources for energy production. To this end, the analysis specifically focuses on assessing the availability of these resources based on the development of a planning tool that consolidates spatially-explicit information on agricultural, agro-processing and forestry residues and wood energy consumption patterns. This allows the integration and multi-scale analysis of bioenergy demand and supply and thus captures local heterogeneity. The analysis is carried out through the implementation of the Woodfuel Integrated Supply/Demand Overview Mapping (WISDOM) methodology[6]. This is a spatially-explicit methodology that maps the supply and demand of biomass for energy uses and quantifies the supply of biomass from direct and indirect sources. Direct sources include sustainable biomass exploitation from activities in native forests and forest plantations, as well as residues from agricultural activities. Indirect sources include residues from agricultural and wood processing industries. On the demand side, the residential, industrial and commercial uses are considered. Residential uses include the use of fuelwood and charcoal for cooking and heating. Industrial uses include the use of fuelwood and charcoal in the industrial sector, while commercial uses include the demand from restaurants, hotels among others. The main output is the creation of a geo-referenced database that incorporates both supply and demand aspects which can then be used to generate maps and information on biomass resource availability, woodfuel consumption and quantifies demand-supply balances.

6 WISDOM was developed by FAO/Forestry Department.

10.1 Methodology: An Overview

The analysis seeks to define the woody and residue biomass readily and sustainably available for energy uses. This is done by incorporating information on both sustainable biomass supply and woodfuel consumption in a GIS-based platform. This spatially explicit representation allows an understanding of spatial differences in biomass supply from direct and indirect sources and woodfuel use patterns and to highlight areas showing surpluses or deficits. It assesses the potential for bioenergy development taking into account current woodfuel consumption situations.

The implementation of the methodology involves five main steps: 1) selection of the spatial base, 2) development of the demand module, 3) development of the supply module, 4) development of the integration module and 5) identification of hot spots/ areas of intervention. The establishment of the spatial resolution is based on the desired level of detail or the availability of the main parameters i.e. existing demographic data, land use/land cover. The demand module portrays the spatial distribution of woodfuel consumption, disaggregated if possible by fuel type i.e. fuelwood or charcoal and by sector users, household or industrial, and by area (rural vs. urban). The supply module comprises information on natural and planted woodfuel biomass sources, residues from agricultural activities, indirect biomass residues from agro processing and forest products industry. The main scope of the integration module is to analyse the relevant interactions between the demand and supply modules in order to infer situations and derive supply and demand balance i.e. deficit or surpluses. The last step involves the identification of areas needing urgent intervention in terms of demand, supply or both. The identification of hotspots is based on a priority index that reflects the key aspects of the analysis.

What data and skills are needed to run the analysis?

Data requirements include digital sets for administrative units, census and other socio-economic and demographic information. The demand module requires data on consumption from surveys normally covering only part of the country and using different methodologies/assumptions with socio-economic variables. The data required for the supply model includes a national forest inventory, biomass stocking from non-forest land-use classes (typically from local studies), disaggregated statistics, detailed land use/ land cover inventories, infrastructure accessibility, preparation of digital terrain models, legal constraints/restrictions for access to forest, agricultural information including area, productivity and use of agricultural field residues, information on agro-industry and forest products industries to determine the generation of residues or by-products.

The set of skills necessary to run this analysis include: a multidisciplinary team of experts in forest, agriculture, energy, GIS, database management, cartography, statistics, and natural resources management. The added value of this multidisciplinary set of skills is that it promotes intersectoral communications and synergies with different actors in both the private and the public sectors.

10.2 Limitations and Suitability

Gaps in data are a major issue, particularly, access to reliable data on woodfuel supply has historically been a main challenge in wood energy analysis. Often the most important piece of data available for the supply module is the national forest inventory. Rarely detailed information on non-forest and other land use classes is available. Consumption data information is normally available for only part of the country and sometimes is acquired using different methodologies. This data gap can be overcome by: 1) using a proxy variable to "*spatialize*" discontinuous values; 2) extrapolating information available at the project level to an entire study region; and 3) filling specific or critical data gaps with new data coming from field studies. The main challenges are finding direct or proxy variables available at the national level that can be used to estimate production/ consumption parameters and their spatial distribution.

Results from a recent Strength, Weakness, Opportunities and Threats (SWOT) analysis on WISDOM indicated that the methodology is flexible and adaptable to different conditions and scales and can provide a basic structure of sustainability studies, including extensions to application in carbon inventories, to carry out GHG measurements and lifecycle assessments. Some of the weaknesses identified relate to the high demand in terms of human resources, the non-standard methodology which necessitates adjustments to country specifics, and the need to make the methodology more user-friendly.

BOX 5

BIOENERGY POTENTIAL FROM WOODY BIOMASS AND BIOMASS FROM RESIDUES ANALYSIS IN PERU

As in many countries, woodfuel and charcoal in Peru are the main sources of energy in rural areas and poor urban dwellings. Currently about 11 percent of the total energy production of Peru comes from the use of solid biomass sources, mostly firewood and charcoal. As such, forests are very important for rural populations since they supply wood and other essential goods for rural households. Furthermore, agricultural residues –especially in the costa (coast) but also in the selva (jungle) – can also be an important source of energy use, although little has been done to take advantage of this potential.

Mapping of woodfuel supply and demand showed that, of a total of 194 provinces in Peru, 58 have deficits in woodfuel. These deficits are mainly concentrated in provinces of the coastal and Sierra regions. The Sierra shows a deficit "hotspot" driven by woody biomass for cooking and heating where the forestry resource is endangered. Taking into account indirect biomass generated from residues from field crops, agro-industry and wood processing industries, the situation improves for several provinces in the coastal region. Surpluses, however, are found in the Amazonian provinces.

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CHAPTER 11

TECHNO-ECONOMIC AND ENVIRONMENTAL ANALYSIS: BIOFUEL PRODUCTION COSTS

Introduction

A strong argument for the development of liquid biofuel relates to the ability of the sector to unlock agricultural potential by bringing in much needed public and private investments in order to raise agricultural productivity for the benefit of food security and poverty reduction. In this context, the production of biofuel crops may offer income-generating opportunities for smallholder farmers. The integration of smallholder participation in biofuel crop production may yield economic benefits for the poor but this will require support to enable small producers to improve their productivity. However, the development of pro-poor strategies for liquid biofuel development has to be consistent with the profit maximization principles of the private sector. That is, the private sector needs to see that smallholder participation does not necessarily erode profit levels.

Biofuel development will also depend on how far existing agro-industry is able to transform biomass for biofuels, and the roles that public and private investment may have in the development of the sector. These factors are key determinants of the economic viability of the biofuel industry and are fundamental in determining the potential for eventual commercialization of biomass-derived fuels, in particular in developing countries. In some cases, industrialization of liquid biofuel production will probably bring about the installation and acquisition of new and foreign technologies. A key priority is to fit these technologies more closely to the country's conditions paying particular attention to the availability of local capacity and skills for the maintenance and operation of bioenergy plants. Moreover, if local capacity is low, future perspectives for building capacity and the associated supplier market should be considered.

This analysis looks at production costs from a social perspective through an explicit consideration of how liquid biofuel production set-ups can incorporate small scale farmers and still be profitable. In essence, the study carries out a feasibility analysis with the consideration of competitiveness through smallholder participation. The analysis lends support to governments in their dialogue with the private sector. Specifically, it permits some degree of harmonization between the profit-motivated interests of the private sector and wider social objectives.

The results of this work provide information on estimates for cost of biofuel production based on local conditions in the country, make recommendations on biomass to biofuel production technology pathways that are more adaptable to the country and raise issues and needs to enable and make the sector more competitive. This analysis generates biofuel productions cost profiles according to crop type, fuel type, and based on feedstock production characteristics and industrial technology conversion schemes. It helps to determine the best technological schemes for producing fuel-grade alcohol from the various raw materials analysed and how biofuel production chain can incorporate small-scale farmers and still be profitable.

11.1 Methodology: An Overview

The BEFS project uses methodology developed by the University of Colombia in Manizales. The analysis, divided into two main components, seeks to establish production costs using technology features and specific crop information.

The first component is the f*eedstock production cost* whose objective is to determine, based on average existing production practices both at the smallholder and commercial level, the feedstock production cost that is then used to establish the feedstock price at the biofuel plant gate. The second – the *technology component* - looks at the industrial conversion of biomass to liquid biofuel to determine the production cost of one litre of liquid biofuel based on the price of feedstock and the production technology options suitable for the country.

Within the analysis, scenarios are identified to determine how much fuel is to be produced, what feedstock is to be used in the process and who is to supply the feedstock i.e. small-holder (outgrower), commercial (estate) or mix of both (outgrower scheme). These scenarios are built based on information collected in the country and to a large extent reflect potential biofuel investment ventures. The feedstock are either identified by the country or, alternatively, an inventory of potential feedstock options can be generated. Based on the scenarios and the selected feedstock, the agricultural production costs are estimated. Information in literature on agricultural production systems for small-scale farmers is collected and the production cost estimated. The commercial scale farming costs are estimated based on literature reviews and information provided by the private sector or agricultural experts in the country. The transportation and profit margin for selling the feedstock is established based on existing information or expert opinion and added to the production costs. Based on feedstock supply options, the feedstock selling price delivered at plant gate is then determined.

Industrial production configurations or systems are defined on the basis of desired production capacity, feedstock chemical composition, and desired fuel type. For this, a first step is to carry out a technology and human capacity assessment to determine the technological capability in the country. Further to this assessment, the various production technologies with potential for application to the country conditions are then selected. The selected technologies are used to generate conversion pathways or process flow sheets representing the different ways for producing liquid biofuels. The production system is divided into processing steps including the conditioning of feedstock, reaction or transformation of feedstock, product recovery, utilization of by-products, and disposal of the waste streams.

A commercial process simulator, ASPEN plus™ (Aspen Technologies, Inc., USA)[7] is used, in conjunction with additional special software, to analyse specific stages of the industrial production process, i.e. fermentation and distillation. The methodology also takes into consideration the management of industrial wastes and effluents to generate commercially co-products such as biocompost, biofertilizers and electricity that can contribute to the competitiveness of the overall process, making the industry more profitable and bringing additional revenues to the government. Factors related to the local conditions, for example, resources, labour cost, and most important of all, the potential for the communities involved to adopt technologies, are also considered. The production scenarios are simulated in ASPEN plus™ giving the energy consumption and mass balances of the various proposed technological schemes.

The energy[8] and mass balances generated by the simulation of the various scenarios together with the price of raw material (cost of feedstock at plant gate) are entered into the Aspen Icarus Process Evaluator (element in the ASPEN plus Process Engineering applications). The Aspen Icarus Process Evaluator is also used to calculate the capital and operating costs, however, specific parameters regarding the country conditions such as income tax, labour salaries, cost of utilities, chemical inputs among others, are incorporated in order to calculate the biofuel per-litre production cost for each of the scenarios under investigation.

In the case of Thailand a spreadsheet model was developed by the Joint Graduate School of Energy and Environment (JGSEE) and adapted with data captured from field surveys. Two main criteria are used in the financial evaluation, were the production cost and rate of return. In this model standard input and default values are defined (prices, financial parameter etc.) and applied to the different scenarios. These scenarios correspond to financial and operational data from production of feedstock and factory options analysed in the context of Thailand.

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7 Aspen Plus is a process modelling tool for conceptual design, optimization, and performance monitoring for the chemical, polymer, specialty chemical, metals and minerals, and coal power industries. Aspen Plus is a core element of AspenTech's aspenONE® Process Engineering applications

8 For this the thermal energy required in the heat exchangers and re-boilers was taken into account, as well as the electric energy needs of the pumps, compressors, mills and other equipments.

What data and skills are needed to run the analysis?

In defining the scenarios to be evaluated, it is necessary to be familiar with the existing situation in both the agro - industry in general and liquid biofuels (or any planned developments for liquid biofuel production in the country), in particular. For example, information on producer associations industrial organizations, number of sugar and oil mills, level of technologies employed, use of co-product is necessary. The data requirements for undertaking the analysis include information on agricultural production of feedstock crops under investigation, including varieties, yields, cropping patterns, literature on feedstock production costs disaggregated according to seeds cost, fertilizer, agricultural supplies, labour, irrigation, harvesting and post-harvest transportation. Establishing the feedstock production cost requires inputs from local agronomists and agricultural economists, particularly knowledgeable of the biofuel crop under investigation and of commercial and smallholder farming practices in the country.

In order to evaluate the technology capacity in the country, data on the availability of technical skills necessary to support biofuel processing operations are required, including both skilled and unskilled labour requirements. Other areas of technology capacity assessment cover engineering capacity in basic and more specific fields (including microbiology and biochemistry); the availability of electrical and plumbing technicians); access to technologies and equipment from local suppliers and provision of services; capacity for manufacturing and technology development of liquid biofuel processing equipment; access to processing inputs for operating liquid biofuel plants, including chemical, solvents, additives, etc. Local engineering experts, preferably with expertise in industrial engineering, are needed to advise on the technology selection process and to define the production technology configurations that best fit the countries' capability. To carry out the processing engineering simulations, the chemical composition of the biofuel crop varieties requires information on moisture, fibre, total carbohydrate, reducing sugars, fats, starch, oil, ash etc. To evaluate the production cost estimates, information on local conditions such as income tax, labour salaries, cost of utilities, chemical inputs are needed.

The simulation and modelling of the conversion of biomass to biofuel were performed using different commercial packages as well as specialized software. The simulation for each technological flow sheet included all the processing steps for conversion of feedstocks into biofuel. For this, the main simulation tool used was the package Aspen Plus version 12.0 (Aspen Technology, Inc., USA), although some preliminary simulations were carried out with the simulator SuperPro Designer version 7.0 (Intelligen, Inc., USA). Specialized packages for performing mathematical calculations such as Matlab, Octave and Polymath were also employed. Some specific optimization tasks were carried out using the GAMS package (GAMS Development Corporation, USA). In addition, software especially designed and developed by the consultant research group like ModELL-R was used for performing specific thermodynamic calculations for defining thermo-physical properties not found in literature. Additional data on components physical properties required for simulation were obtained from the work of Wooley and Putsche (1996). One of the most important issues to be considered during the simulation is the appropriate selection of the thermodynamic models that describe the liquid and vapour phases. The Non-Random Two-Liquid (NRTL) thermodynamic model was applied to calculate the activity coefficients of the liquid phase and the Hayden-O'Connell equation of state was used for description of the vapour phase. Expertise in process engineering to specify parameters and operating conditions on each of the production units comprise in the conversion of biomass to biofuel is required to run the simulations.

11.2 Limitations and Suitability

A large portion of the production cost derives from the cost of the feedstock or raw material and as such, assumptions on the feedstock price at plant gate have a significant impact on the estimated biofuel cost. The production costs that have been used in this analysis are based either on secondary sources or on cost indications from assessments made by local experts. The analysis considers an *average* production cost for the investigated crop or raw material for a country. However, there may be variations in feedstock production costs within a country that can have substantive effects on the estimated production cost. As such, a more localized analysis reflecting local agricultural practices and capturing local production cost patterns can provide a better estimation of the costs of biofuel production. The analysis only superficially captures post-harvest and profit margin aspects. These two aspects need to be better incorporated into the analysis in order to assess the expected profitability under different production conditions.

The process engineering methodology applied to date has been limited to a simulation for the production of *first generation* liquid biofuels. However, with more knowledge and information on feedstock, the applied methodology can be extended to investigate second generation liquid biofuel and other types of bioenergy. The methodology as developed by the University of Colombia in Manizales, incorporates an environmental evaluation component that was not carried out in the context of the BEFS project, but this can be used in a future analysis. In addition, the methodology in the industrial phase quantifies the mass and energy balances that can be used as direct inputs to a life cycle assessment to carry out a GHG balance. However, a component to assess the GHG generated in farming activities will be needed in order to generate a GHG for the complete liquid biofuel production chain. In the case of Thailand, the production cost analysis is linked to GHG lifecycle assessment (see chapter 11 for more details). Another important aspect is that employment generation at the industrial plant is easily qualified and quantified but the on-farm employment generation is not captured. Potentially, a component to capture the on-farm employment potential can be developed to strengthen the social dimension of the analysis.

BOX 6

ANALYSING BIOFUEL PRODUCTION COSTS IN TANZANIA

Addressing the development of the biofuel agro-industry in Tanzania required an assessment of the technological accessibility and capability of the country. Carefully reviewing these two factors ensured that the production scenarios presented options that best fit the country's specific social and economic situation. The assessment comprises criteria including: the availability of the human skills that are necessary to support biofuel production, access to services and to technologies in the local markets and access to processing inputs for operating biofuel plants.

Based on these results, three production technology options suitable for Tanzania were defined. These options are differentiated based on the level of complexity of the technologies involved in each of the industrial processing steps. In the case of the first technological development level, this represented the easiest level to be implemented in Tanzania since it implies already mature conventional technologies proven worldwide but overall less efficient technologies. For the second level of production technology, a suitable transfer of technology and an appropriate degree of investment from the private sector is required in order to guarantee the success of the production process. The third level of technology comprised complex and not yet commercially available technologies not recommended for implementation in Tanzania, however, it demonstrated how the sector can potentially evolve over time. In the context of Tanzania, the general observation is that technology transfer and building of local capacity will be crucial for the long-term sustainability of a national biofuel industry.

ANALYSING BIOFUEL PRODUCTION COSTS IN PERU

The liquid biofuel production cost analysis in Peru assesses its competitiveness when a portion of the feedstock to the industry is supplied by smallholders. The analysis comprises nine production scenarios investigating the production of biofuels from sugar cane, palm oil and *jatropha*. The scenarios simulated feedstock production where 40 percent of feedstock is supplied by smallholders and 60 percent by a single large plantation as well as where 100 percent feedstock production is carried out by a single large plantation.

The results suggest that including smallholders in the supply chain can, *under some conditions*, be competitive with liquid biofuel production systems that are purely large scale. However, there is a need to promote institutional constructs that support collective action by smallholders so that they can access more of the financial dividends offered from the bioenergy sector. Smallholders that operate under associations may also have better access to technology that allows them to have higher yields comparable to those of large operations.

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CHAPTER 12

TECHNO-ECONOMIC AND ENVIRONMENTAL ANALYSIS: GREENHOUSE GAS EMISSIONS

Introduction

The increasing demand for liquid biofuels could lead to an expansion or change in agricultural land uses with possible adverse effects on the environment. Therefore, sustainability criteria need to be put in place to ensure that the development of the biofuel sector is carried out appropriately. As liquid biofuels development has been promoted as a means to reduce greenhouse gas (GHG) emissions, it is important that the definition of sustainability includes the impact that possible changes in land use[9] and direct land-use changes[10] may have on the overall GHG balance in the production of liquid biofuel as this may influence the climate benefit. A range of biofuels life-cycle-analyses have already been performed and initial data are available but do not necessarily account for direct or indirect land use changes. Furthermore, in most cases these analyses were carried out using default values or average literature values. In this context, a comprehensive analysis that accounts for GHG emissions from direct land use changes coupled with emissions from the industrial process can provide a more insightful perspective into its sustainability performance.

The objective of this work is to analyse the effects that may arise from agricultural production of bioenergy crops including direct land-use changes and crop-to-crop changes and how these affect the overall GHG emission in the biofuel production chain. The study uses a life-cycle assessment to evaluate the GHG emission. An LCA assessment is a tool for the systematic evaluation of potential environmental aspects and impacts associated with a product, process or activity, from production of the raw materials to its final disposal. The LCA methodology applied consisted of an analysis of biofuel production from cradle (farming) to factory gate[11] that considers the implication of land-use change and crop-to-crop changes in the production of bioenergy crops. In this particular case, the LCA is performed using the programme for emission calculation from the GEMIS program, a German software developed by

9 A change in the use of land refers to a crop-to-crop change i.e. cassava replacing rice.

10 Direct land-use changes according to the definition of IPCC is the conversion on land-use category i.e. forest land to crop land.

11 The cradle to gate analysis consists of evaluating the GHG emission generated from farming, transportation of crop from field to plant, the physical and chemical conversion of the feedstock including intermediary processes such as chipping and industrial conversion of feedstock to biofuel.

the Oeko-Institute and widely used internationally[12]. GEMIS can be used to calculate and display GHG emissions, other emissions, energy inputs and outputs, demand for raw materials and other inputs and environmental implications. To incorporate the land-use and crop-to-crop changes requires identifying potential land-use changes and crop-to-crop changes. For this, a survey is first carried out to assess current agricultural production trends and to establish potential mechanisms for land-use change/crop-to-crop changes. Thereafter, the Intergovernmental Panel on Climate Change (IPCC) guideline methodology for national greenhouse gas inventories volume 4 are followed to assess changes in carbon stocks above and below ground, methane emissions, and nitrous oxide emissions.

12.1 Methodology: An Overview

The analysis seeks to define the GHG balance for the production of biofuels accounting for impacts related to potential direct land-use changes and crop-to-crop changes. This is done by closely investigating and identifying potential changes in the agricultural sector that can arise from expansion of bioenergy crops. The GHG emissions stemming from changes in the agricultural production are then incorporated into the overall GHG to assess the production pathway sustainability.

The study set up a range of biofuel production scenarios representing diverse setups for feedstock production i.e. low vs. high input agriculture considerations on land-use change and crop-to-crop change and biofuel production configurations, e.g. dry cassava vs. fresh cassava, use of co-generation, etc. The analysis then uses the principles of life-cycle assessment. The implementation of the LCA methodology involves five main steps: 1) setting the systems boundary for evaluation, 2) data gathering to establish data inventory, 3) defining and calculating emissions from the land-use change crop-to-crop changes on agricultural production of biofuel crop, 4) calculating the GHG balance for the overall biofuel production and 5) analysing sustainability using GHG emissions and energy demands as criteria.

What data and skills are needed to run the analysis?

The establishment of a system boundary indicates processes and or activities that are being analysed - in this particular case the focus is on cradle (farm) to plant gate. The system of analysis includes stages in agricultural production, crop transport to plant and plant processing. Agricultural inputs into the system include fertilizer, chemicals, pesticides, organic fertilizers, seeds, machinery, diesel consumption in farm operations[13] and transport of goods to the farm, application of pesticides, chemicals and fertilizers also accounts for land-use changes, crop-to-crop changes and potential changes in crop production management. The transportation of crop to biofuel processing facility

12 free download at www.gemis.de

13 This may include post-crop harvest activities i.e. dried chip production

includes data on type of transport used, average distances from field to biofuel production plant, and fuel consumption. The data on biofuel production are based on the country industrial production configurations and their operating conditions. The type of data needed is feedstock demand, amount of energy use (steam, heat, and electricity), type of fuel used, conversion efficiencies, water demand, co-generation potential.

As the objective of the analysis is to reflect the situation in the country as fully as possible, the information used in the analysis should come from country-based local sources. In particular, potential land-use changes, crop-to-crop changes and changes in crop production management in the current BEFS study were obtained from fields surveys[14]. However, if limited resources are available, information can be inferred from country specific literature or interviews with country experts. Information on factory configurations may come from visits or interviews with refineries. In cases where countries do not have a biofuel sector, potential set-up can be inferred and data from countries under similar conditions can be used as proxies.

The emission values from the land-use change and crop-to-crop changes are calculated based on the IPCC guideline methodology for national greenhouse gas inventories volume 4[15]. Equations to calculate changes in carbon stock above and below ground, methane emissions, and nitrous oxide emissions and defaults values are used[16]. The summary of emission calculated from the above parameters are then added up to assess the implications that each potentially studies land-use change or crop-to-crop changes may in terms of emissions. The results are presented in tons of CO_{2eq}/ha[17].

The GHG calculations for the overall biofuel production are carried out using the GEMIS software. This software is freely available ("public domain"), and can be copied and distributed without restrictions. If results from GEMIS analyses are published, a reference must be made to GEMIS. In the program, products and processes for each of the scenarios of interest are defined and linked i.e. ethanol is defined with technical data such as heating value elemental composition etc. The data inputs from the LCA are then incorporated into the GEMIS program to carry out the calculation[18]. The results are discussed based on grams of CO_{2eq}/MJ output fuel and also yield information on energy requirements that can be used as parameter for analysis. The energy requirements can be disaggregated into renewable, non-renewable and other; these parameters can be used to

14 Note that this survey is not statistically significant and are used only to draw on some of the implications that changes in or resulting from biofuel crop production may have on the overall GHG balance.

15 IPCC 2006, 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 4, Prepared by the National Greenhouse Gas Inventory Programme, Eggleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe K (Eds). Published: IGES Japan.

16 The IPCC formulas use are: carbon stock equation: 2.25 and EU simplified Methods; methane emission equation 5.1 and 5.2; field burning equation 2.27; nitrous oxide equation 11.1.

17 Note conversion of methane and nitrous oxide emission to CO_{2eq} uses global warming potential of 21 and 310 factors respectively.

18 Note data conversion takes place to have all values in energy content basis.

compare various production configurations to assess the degree that fossil fuel savings are associated with each of the production system.

The set of skills requires experts in agriculture, energy, process and engineering to run this analysis. Agricultural expertise is important in order to grasp the realities in the country and project future scenarios in biofuel crop production as fully as possible. Energy specialists can contribute important inputs into the existing energy matrix in the country (such as projected changes in the incorporation of renewable energies). Engineering expertise is needed to understand how products and processes interact and to assess industrial configurations.

12.2 Limitations and Suitability

Lifecycle assessment as an objective process to evaluate environmental impacts has received both positive and negative feedback. LCAs involve a data-intensive methodology that requires a wide range of information on material processes and products. Input data come in different measuring units and need to be unified and systematically assembled making the process of data management more complex. The use of primary data is critical to have an accurate analysis but it may be impossible to collect primary data for all of the required inputs thus LCA practitioners rely on accumulated databases. This can be problematic in terms of accuracy as geographical and local conditions with sensitivity implications should be considered in order to obtain an accurate analysis. Moreover, LCA represents a static analysis, and databases or input information needs to be updated routinely to reflect current advances on production which may yield different results. There is a wide range of LCA models and data analysis techniques and although there is considerable overlap, it is still complex to compare across studies. The main issue is on the different setting of the boundary conditions for the analysis. This is critical because it determines the level of data details and information which influences the results. Despite these difficulties, the LCA is a valuable tool for environmental impact analysis. It allows the identification of more efficient and less polluting alternatives.

The Global Bioenergy Partnership has developed a GHG lifecycle analysis for a bioenergy methodological framework to guide some of the LCA applications on biofuel. This framework provides guidelines on a set of questions to increase transparency and facilitate comparison across methodologies. The framework does not set data standards and does not specify the use of any particular emissions model; the goal is to ensure that countries and organizations evaluate bioenergy in a consistent manner, using methods appropriate to their circumstances, conditions and studied production systems.

BOX 7

GHG EMISSIONS IN CASSAVA-ETHANOL PRODUCTION CONSIDERING DIRECT LAND-USE CHANGES AND CROP-TO-CROP CHANGES IN THAILAND.

Thailand has established a policy measure for supporting biofuel development with the aim to reduce petroleum imports, to diversify the energy matrix and to mitigate adverse climate change effects. Current production of ethanol comes from molasses feedstock. However, newer operations are looking into cassava as an alternative ethanol feedstock. The potential expansion of cassava for ethanol production can raise issues on sustainability in particular from land-use changes and crop-to-crop changes. The study assessed the sustainability of ethanol production using green house gas emissions as a sustainability indicator.

A survey analysis on cassava production indicated that some crop changes and land-use changes may occur, primarily a shift from productive rice fields to cassava and land-use change from degraded lands to cassava. Results indicated that the highest impact on GHG for cassava cultivation comes from converting rice fields to cassava generating between 48 to 88 CO2eq/MJ depending on the level of agricultural intensification - low and high respectively. The GHG emissions from cradle (farming) to factory gate, incorporating crop to crop and land uses changes for the production of cassava-ethanol for a crop shift from productive rice fields to cassava is calculated at about 160 CO_{2eq}/MJ. In the case where land use changes from degraded lands to cassava occurs the cassava-ethanol GHG emission is less than 40 CO_{2eq}/MJ. The European Union Directive sets the ethanol sustainability requirement of 54.5 CO_{2eq}/MJ.

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CHAPTER 13

SOCIO-ECONOMIC ANALYSIS: ECONOMY-WIDE IMPACTS

Introduction

Expanding biofuels production can have important implications beyond the biofuel feedstock and downstream processing sectors. This is because biofuels production may generate growth linkages (i.e., multiplier or spillover effects) to the rest of the economy. For example, producing biofuels requires intermediate inputs, such as transport services to get the biofuels to consumers or export markets. In this case, expanding biofuels use generates additional demand for locally-produced services, which may create new jobs and income opportunities for workers and households linked to the biofuels supply chain. Moreover, these new incomes will eventually be spent on consumer goods and services, which again generate additional demand for non-biofuel products. Finally, there are macroeconomic linkages through which biofuels may stimulate economy-wide growth. For example, biofuels exports can relieve foreign exchange constraints, which often limit developing countries' ability to import the investment goods needed for expand production in other sectors. Together, these economic linkages can generate gains that are far larger than those generated within the biofuels sector alone.

However, while there are economy-wide gains to be had from expanding biofuels production, there are also constraints that may reduce production and incomes elsewhere in the economy. For example, biofuels production requires factor inputs, such as land and labour, which may be in limited supply in some countries. In this case, allocating land to biofuels feedstock may reduce the land available for other crops. Indeed, increased competition over agricultural crop land has received considerable attention in the biofuels debate, largely because of concerns over food crop production and the possible implications of biofuels for developing countries' food security. However, even if unused land is available to produce biofuels, there may still be a displacement of labour from non-biofuel sectors, as labourers are drawn into biofuels estates/plants, or as smallholder farmers reallocate their time to producing feedstock crops. This means that as biofuel production expands, it may cause production in non-biofuels sectors to fall, thus offsetting at least some of the economy-wide gains mentioned above. Finally, biofuels producers may require tax incentives or supporting investments from the government, which reduce public revenues or investments for other activities, such as education or infrastructure (i.e., opportunity costs). This "fiscal displacement" may also slow development in non-biofuels sectors.

The above linkages and constraints imply that, in order to evaluate the full impacts and trade-offs of biofuels production, we need an analytical framework that looks beyond the direct private sector gains of biofuels producers. This framework would need to capture indirect or economy-wide linkages and constraints, while also considering both the macro- and microeconomic implications of biofuels. The economic method specifically designed to capture these impact channels is known as "computable general equilibrium" (CGE) modelling. Two recent studies for Mozambique and Tanzania show how CGE models can be used to examine the economy-wide impacts of biofuels (i.e., Arndt et al 2010; Thurlow 2010).

13.1 A Typical Country CGE Model

What's inside a CGE model?

CGE models are often applied to issues of trade policy, income distribution and structural change in developing countries. They have a number of features that make them suitable for these kinds of analysis. First, CGE models simulate the functioning of a market economy, including factor and product markets, and provide a useful perspective on how changes in economic conditions are mediated through prices and markets. This enables them to capture many of the production and demand linkages mentioned earlier. Secondly, the structural nature of these models allows us to introduce new phenomena, such as biofuels, and to consider differences in the way biofuels can be produced (e.g., smallholders versus large estates, or using cassava instead of sugarcane). By contrast, most statistical methods can only be used long after new sectors have been established and data has been collected. Thirdly, CGE models ensure that all economy-wide constraints are respected. As mentioned above, biofuels could generate substantial foreign exchange earnings (or savings if fuel imports are reduced) and use large quantities of land and labour. It is important then to consider constraints, such as the balance of payments and the supply of useable land and labour. Fourthly, CGE models contain detailed sectoral breakdowns and provide a "simulation laboratory" for quantitatively examining how different impact channels influence the performance and structure of the economy. Finally, CGE models usually link sectoral production and incomes to a detailed array of household groups, and so provide a theoretically consistent framework for conducting welfare and distributional analysis.

In CGE models, economic decision-making is the outcome of decentralized optimizing by producers and consumers within a coherent economy-wide framework. In other words, CGE models contain a large number of representative agents who behave according to their own interests. For example, representative producers in each sector of the model attempt to maximize their profits (or minimize production costs) subject to available technologies and prevailing factor and product market prices. Similarly, representative household groups attempt to maximize their utility (i.e., similar to total consumption spending) given current wage levels, employment demands and consumer prices. The behaviour of these agents in CGE models is governed by a series of production and demand functions. Moreover, a variety of price-based substitution mechanisms are specified, including substitution between different types of land, labour and capital, and between imports, exports and domestic goods. So, for example, if unskilled labour becomes more expensive relative to capital, then producers will demand more capital and less labour. However, CGE models do not necessarily assume perfectly functioning markets. Rather, institutional rigidities and imperfect markets are captured by limiting factor mobility across sectors, and segmenting labour markets, such as by skill or education levels. This permits a more realistic application of this class of model to developing countries, and to the local context to which the model is applied.

CGE models also capture the workings of the government, including direct and indirect tax revenue collection, and current and capital expenditures. In fact, the maintenance of fiscal balances is a key feature of this class of models because it ensures macroeconomic consistency in the analysis. For example, if the government is required to spend public resources to support new biofuels production, then these resources will have to be paid for by either increasing taxes, reducing other expenditures, or borrowing from abroad (thereby incurring interest and debt repayments). CGE models therefore capture trade-offs between biofuels and other investment options. A second macroeconomic consistency that is maintained in CGE models is the balance of payments. In order to ensure the availability of foreign exchange, these models keep track of exports, imports and foreign transfers. So if biofuels exports increase (or petroleum imports decline) then the real exchange rate in the model adjusts to maintain external balances (i.e., it appreciates or depreciates). Finally, CGE models keep track of all savings in the economy and translate these into investment and capital accumulation rates. This is combined with demographic projections and rates of technical change (i.e., productivity improvement) in order to determine the speed at which individual sectors and the overall economy is growing.

When the CGE model simulates the expansion of biofuels production, it predicts changes in consumer prices and household incomes. This can be used to estimate changes in poverty, both at the national level and for different regions or households groups (e.g., rural/urban or farm/nonfarm). This is done by directly linking the CGE model to the same household income and expenditure survey used to construct the model. Thus, each aggregate household group in the CGE model actually represents a collection of individual households in the survey. This allows us to use the price and demand results from CGE model to estimate changes in households' real consumption spending in the survey. We can then compare households' initial and final consumption levels with the poverty line in order to determine whether poverty rises or falls after biofuels production expands. Thus, the CGE model not only captures macroeconomic constraints or balances, but it also translates changes at the sector and national-level into changes in individual household incomes and poverty.

What data and skills are needed to run a CGE model?

CGE models cover many areas of a country's real economy, and so it is not surprising that they require fairly comprehensive datasets. The dataset typically underlying a country

CGE model is called a "social accounting matrix" (SAM). A SAM is a consistent macroeconomic accounting framework that captures all income and expenditure flows within an economy in a given year. Building a SAM can be time-consuming, since it requires collecting data from a wide range of sources (e.g., national accounts, household income and expenditure surveys, trade and tax data, and the balance of payments). Once collected, these data must be reconciled with each other, since inconsistencies almost always exist between data collected by different agencies. Most countries, however, already have a SAM and this can be used to study the effects of biofuels. This is true even if a country's SAM is not particularly recent, since the underlying structures of an economy do not usually change rapidly. If a SAM does not exist, then there are numerous publications that explain the process of building one (see, for example, Thurlow and Wobst 2003, and Breisinger, Thomas and Thurlow 2009).

Assuming a SAM does exist then the next step is to "insert" the new biofuels sectors into the database (if they do not already appear in the SAM). To do this it is necessary to collect information on biofuels' production "technologies" (i.e., input costs per litre of biofuels produced). Information on biofuel feedstock production (e.g., sugarcane) is usually available from farm budgets and crop surveys compiled by local ministries of agriculture. The collection of biofuel processing costs is documented in another BEFS brief entitled "Techno-economic analysis: biofuel production costs". If biofuels processing information is not available for a specific country, then it might be possible to draw on information from other countries that have already established biofuels sectors and have included these in their SAM.

To run a CGE model it is necessary to use a mathematical computer programming language, such as GAMS or GEMPACK. This language is used to specify the equations of the model and to "calibrate" the models' parameters to the information contained in the SAM. Some government ministries may have the capacity to use these programming languages. However, these skills are usually found within academic departments or research institutes. Once the information on biofuels technologies has been collected, it could take as much as two months to extend the CGE model and run new biofuels simulations. This timeframe will vary depending on how familiar local researchers are with CGE models.

13.2 Limitations and Suitability

Even though CGE models have many advantages, many of which were described above, they do have their disadvantages. Indeed, an economy-wide approach is not well-suited for the analysis of all issues. In striving to develop a comprehensive picture of the entire economy, some details are necessarily suppressed. If details highly relevant to the analytical question at hand have been suppressed, the approach is obviously poorly suited. For biofuels studies, it is recommended that emphasis first be given to estimating plant- and farm-level production costs in order to determine the expected profitability of biofuels producers. Only if it is found that biofuels is profitable within a country, and if economy-wide effects are of particular interest, should more complicated economy-wide analysis be conducted. Moreover, some issues can be adequately addressed with economic frameworks that are less comprehensive allowing the analyst to spend more time on analysis and less time on data issues and modelling. However, if new biofuel investments are large then they are likely to have downstream implications for the whole economy. Moreover, governments may be interested in comparing different kinds of feedstock and institutional arrangements, or in determining indirect impacts, such as on national economic growth or household poverty and food security. In such cases a CGE approach is required.

A CGE analysis can be very helpful in giving policy-makers a sense of how particular bioenergy investments will affect broader development objectives outside of the biofuels sector itself (e.g., national economic growth, household incomes, etc). Knowing, for example, that one particular pathway may impact more on poverty and inequality than another is helpful in terms of shaping the direction of interventions needed to ensure these outcomes actually happen. The main advantage of a CGE analysis lies in capturing the economy-wide implications of bioenergy investments and the consideration of factor markets (e.g., labour wages and employment). This is especially important if a particular factor, for example land, is constrained because this may create tensions between land use for food and for biofuel feedstock.

However, carrying out a CGE analysis is complex and requires specific sets of skills that may not always be available within a country. Countries will generally rely on international CGE experts from renowned institutions that have the specific level of expertise required and experience with the application of CGE analysis in the context of bioenergy and agricultural markets. Thus, policy-makers will need to decide when to request and include a CGE analysis. This decision should generally be based on the scale of the investment (i.e., the likelihood that biofuels investments will have economy wide implications).

Three separate stages in the decision process can be identified

Stage 1: *For fairly small bioenergy developments (say less that 50,000 ha)*

In this case the policy-maker should focus on the feasibility of the investment proposal, including calculating the production costs of specific biofuel supply chains and identifying their vulnerability to fluctuations in world fossil fuel prices. In other words, decide under what conditions domestic bioenergy production can be competitive/ profitable in destination markets.

Stage 2: *For bioenergy developments requiring government support*

Investors often request incentives from government (e.g., tax relief or publically-provided infrastructure like roads and ports), which can have macroeconomic fiscal implications. In this case, policy-makers should not only consider the viability of

BOX 8

APPLYING A CGE TO TANZANIA

A recent study for Tanzania developed a CGE model to estimate the growth and distributional implications of alternative biofuels production scenarios (see Thurlow 2010). The scenarios simulated by the model differed in the feedstock used to produce biofuels (sugarcane or cassava), and the scale of feedstock production (smallholder outgrower schemes versus large-scale estates).

Simulation results from the model indicated that, while some farmers will undoubtedly move away from producing food crops, there is no *national-level* conflict between food and fuel production in Tanzania. Rather it is traditional export crops that would be adversely affected by an appreciating exchange rate caused by increasing biofuels exports (or reducing petroleum imports). Indeed, the large size of Tanzania's agricultural export sector prevents food production from contracting. This is because the amount of land displaced by biofuel feedstock would be smaller than the lands released by traditional export crops. As such, food production actually increases when biofuels are produced. Overall, national incomes would rise and new employment opportunities would be created in biofuels sectors. This should lead to welfare gains throughout the income distribution, albeit following a possible period of adjustment in which prices, farm workers and non-biofuel exporters adapt to new market conditions.

The findings of the study suggest that, while household welfare would improve regardless of which feedstock or institutional arrangement is chosen to produce biofuels, it is small-scale out-grower schemes, especially for smallholder crops like cassava, that are most effective at raising poorer households' incomes. Therefore, the study recommended that Tanzania should explore opportunities to engage smallholders in the production of biofuels, possibly through mixed small/large-scale production systems. However, mixed systems may reduce the reliability of feedstock supply for downstream processors. Despite this concern, and given its strong pro-poor outcomes and greater profitability, the study recommended a smallholder cassava-based biofuels industry for Tanzania.

proposals (see above), but they should also evaluate the effect of subsidies on government tax revenues, and the opportunity cost of providing infrastructure to bioenergy rather than to other sectors.

Stage 3: *For large bioenergy developments (say greater than 100,000 ha)*

In this case the policy-maker is well advised to undertake a proper CGE analysis of the implications of the large-scale investments in order to be clear of economy wide effects and how to account for them within the policy framework design. This is especially the case if it is hoped that biofuels investments will contribute to national development objectives, such as reducing poverty or accelerating growth.

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CHAPTER 14

SOCIO-ECONOMIC ANALYSIS: HOUSEHOLD FOOD SECURITY AND VULNERABILITY

Introduction

There has been widespread concern regarding the surge in staple food prices. Many reasons explain the rise in prices of which bioenergy is one determinant. Importantly the food crisis experienced by many countries has led to increasing concerns as to whether ongoing bioenergy developments will or will not have a marked effect on food prices. First generation bioenergy developments represent an additional source of demand for crop production which can lead to price increases, unless followed by adequate investment in agriculture and related infrastructure to support a supply response that would maintain stability in prices. This analysis sheds light on the impacts of the increase in the prices of key food staples on different household groups and helps to identify vulnerable segments of the population.

The purpose of this component is to alert policy-makers to the price changes that a country is most vulnerable to and also, helps identify those segments of the population that are most at risk. This can allow appropriate targeting measures and specific safeguard programmes to be put into place.

14.1 Household Welfare Impact: Methodological Background

The potential rise in the price of key food staples can have positive or negative impacts on a country depending on its net position vis-à-vis imports and exports. Price increases will have a positive impact for net exporting countries and a negative impact for net importing countries.

At the household level, in order to assess how households fare when food prices rise, it is important to consider the household's net position with respect to production and consumption. Households can be both producers and consumers of crops. For example, a rural household that grows rice on the farm can both sell and consume it. An urban household tends only to purchase rice and not produce it. Due to the potential dual nature of the household, what matters is households' net position with respect to production and consumption, i.e. whether a household is a net producer or net consumer. A net producer household is defined as a household for which total gross income derived from the crop exceeds total purchases. For net-producer households price increases will be beneficial. A net consumer household is a household for which total gross income derived from the crop is less than total purchases. In this case, an increase in the price of the selected crop hurts the household. The overall household impact is measured by the effect of the price change on household's net welfare, defined as the difference between the producer gains and consumer losses. Please see the appendix for more details on this and full references to the relevant literature.

14.2 The Structure of the Analysis and Data Requirements

The overall aim of the analysis is to establish *welfare* impacts due to price changes, i.e. which households gain and which households lose from the price change, and which particular segments of the population are most vulnerable to the price shocks. Initially the analysis defines which are the most important food crops in the country. Based on this list, the country's net trade position is calculated by crop. This information sets the scene for household welfare impact analysis.

Food crop list

The first step in the analysis is to identify the most important food crops in the country.

Data on per capita calorie consumption is used to rank the food crops[19]. An example of the food ranking is contained in the example at the end of this chapter. Generally, between one to three crops constitute the most important food crops and contribute approximately 50 to 60 percent of total calories.

Net trade position by crop

Based on this list of food crops, the analysis then proceeds with establishing whether the country is a net importer or a net exporter for each of the selected crops. This type of information will provide a first indication of the overall impact of price increases in key commodity prices and will guide the results obtained in the household level analysis.

Macroeconomic trade data[20] by commodity are used to calculate the country's net trade position by commodity.

Household welfare impact analysis

The impact of a price change on household welfare is decomposed into the impact on the household as a consumer of the good and the impact on the household as a producer of the good. The household level impacts are calculated as the net household impacts due to an initial 10 percent producer price change.

The producer price is initially assumed to change by 10 percent. The 10 percent price change is merely a reference price change but is useful to set a benchmark for the analysis. The impacts of higher or lower price changes can easily be assessed as the calculation of the welfare impact would simply increase or decrease proportionally. For example, if over the last quarter or year the price of a crop had increased by 50

19 Data on the calories from food consumption can be found at http://faostat.fao.org/ or from relevant country specific sources.
20 Trade data can be found at http://www.fas.usda.gov/psdonline/psdQuery.aspx or http://faostat.fao.org/ or from relevant country statistical institutions.

percent the household welfare impact would be five times larger compared to the impact calculated for a 10 percent price increase.

Recent price changes[21] and simulated price changes can be used in the impact analysis. Recent price changes are useful to understand how severe the household impacts have been over recent years or months in the country at hand. When considering different time periods, seasonality should be accounted for. Simulated price changes would be extracted from other sections of the BEFS analysis[22].

A series of household variables are extracted from the survey to characterize the households. The choice of household characteristics hinges on the nature of the policy question at hand. In the case of poverty and vulnerability work, two initial key household variables are income quintile group and urban/rural location. The households can be further characterized depending again on the policy question and the nature of the country. For example, households can be distinguished by land ownership, household head gender, education level or age, asset ownership, regional location etc. The combination of specific household characteristic variables will ultimately generate household typologies. Accurate characterization of the households will improve the efficiency of household targeting programmes.

The household-level analysis is based on household income and expenditure surveys. Countries generally collect household level surveys but in order to be able to calculate the household level impact of a price change in a key food commodity the survey has to contain data on income and expenditure by crop . All variables required are extracted from the household survey and generate a database to be used in the analysis.

14.3 Limitations and Extensions

The household analysis and typology structuring is useful to identify the most important food crops and the most vulnerable segments of the population. Nevertheless, this type of analysis is limited to *short run* effects whereby more detailed microsimulation analysis or general equilibrium modelling would be required to determine the full breadth of long term and multiplier effects of developing a bioenergy sector within a country. Secondly, a household dataset needs to exist that includes detailed data on both income and expenditure by crop. The analysis requires expertise in household level data handling, household level data analyses and good knowledge of agricultural markets and price movements.

From a household characteristic and location perspective, the household level analysis can be extended to include different levels of detail. On the one hand, governments might

21 Commodity prices are generally obtained directly from the relevant national country institutions, example are the Ministry of Agriculture or the national statistics offices.

22 When considering specific price variations it is important to distinguish between tradable and non tradable food crops and the linkages to international price movements. As a reference on this please see Rapsomanikis, G., 2009, he 2007-2008 food price swing, Impact on policies in Eastern and Southern Africa, Commodities and Trade Technical Paper 12, FAO Rome 2009

be interested in regional differences. In this case, data permitting, the analysis can be run by adding the regional qualifier to the analysis thus allowing for region specific programmes to be put in place. On the other hand, if specific household groups exist, for example households with more than a certain number of dependants, specific household characteristics can be selected and added to the typology construction, again data permitting.

BOX 9

THE HOUSEHOLD LEVEL ANALYSIS IN CAMBODIA

To date, the household level analytical component of BEFS has been run in Peru, Tanzania and Cambodia (please see the references for a complete list of the country work). Extracts from the Cambodia analysis are included here to illustrate some of the steps discussed in this brief and some of the conclusions that can be drawn from this analysis.

The calorie ranking in the case of Cambodia shows that rice is the one most important single food crop in Cambodia, See Table 3.

Table 3

Caloric contribution by commodity for Cambodia, 2004

Ranking	Commodity	Calories (kcal/day/capita)	Calorie share (%)
1	Rice	1 382	65
2	Maize	159	7
3	Pigmeat	88	4
4	Sugar	82	4
5	Wheat	63	3
5	Freshwater fish	41	2
6	Cassava	23	1
6	Palm oil	20	1
7	Bananas	16	1
	Sub-total	1 874	88
Total Calories per capita (kcal/day/capita)			2 131

Source: FAOSTAT (2009).

Consequently within Cambodia, and more generally in the Asian context, primary food security concerns are mostly related to rice, as rice is the major staple in the region, especially when considering the poorer segments of the population. Since rice itself is not a major source of feedstock for biofuel production, the main link between bioenergy production and food security would, therefore, be through changes in land areas dedicated to rice production. If rice production areas were to be used for alternative agricultural production such as bioenergy feedstock production, it could impact on rice production and consequently the price of rice, unless followed by suitable increases in rice production through yield increases. In the absence of yield increases, bioenergy developments would likely impact on the price of rice, ceteris paribus.

Cambodia is a net rice exporter, see Table 4. Thus, overall the country can benefit from an increase in the price of rice. What needs to be clarified is whether any particular segments of the population can be hurt by this price increase calling for specific safeguarding policies.

Table 5

Macro trade data for selected food crops in Cambodia

Item	Production quantity (Tonnes)	Import quantity (Tonnes)	Export quantity (Tonnes)	Net-exporter (%)*
Rice	4,520,000	50,000	800,000	17

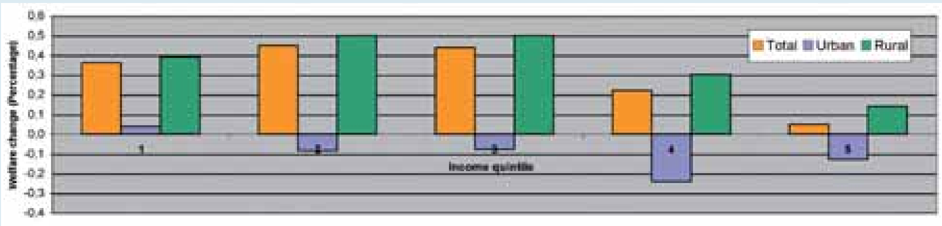
** Calculated as (Exports-Imports)/Production . Source: USDA (2009)*

The Cambodia analysis is based on household data extracted from the Cambodia Socio Economic Survey (CSES) household survey of 2004. This survey contains income and expenditure by crop, and more specifically for this case, household income from rice and household expenditure on rice.

The household welfare analysis confirms that, at the household level, increases in the price of rice are beneficial for the lower income quintile, the poor segment of the population, see Figure 5. This is also the case when distinguishing between urban and rural poor, although the benefit accrued by the urban poor is marginal. When considering the second income quintile, rural households still benefit from the price increase but urban households stand to lose.

Figure 5

Household welfare impacts due to an increase in the price of rice by quintile and location



Note: As discussed, the results reported here are based on a 10 percent producer price increment.
Source: Calculations by Maltsoglou, Dawe and Tasciotti (2010)

When adding household characteristics such as land ownership and gender of the household head, some of the poorer segments are found to suffer from the price increase. In the case of land ownership, all landless poor are negatively impacted by rice price increases. In the case of the gender of the household head, urban female headed households are found to be vulnerable to rice price increase and overall land ownership status has a larger impact on welfare results compared to gender status.

With reference to the actual price changes witnessed in the country, the prices of key food staples surged in Cambodia between 2007 and 2008 and tapered off during 2009, although remaining at high levels compared to previous periods. Between 2007 and 2008 the price of the rice mix, the low quality rice (the most important rice variety for the poor segments of the population), increased by 101 percent.

In conclusion, from a food security perspective, the price of rice should be monitored closely for particular segments of the population as described in the analysis, although overall the increase in the price of rice can be beneficial for Cambodia.

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14.5 Appendix: Household level welfare impacts: methodology and assumptions[23]

As households can be either producers or consumers of a good i, the impact of a price change on household welfare is broken down into the impact on the household as a consumer of the good and the impact on the household as a producer of the good. The net welfare impact will be the difference between the two welfare effects. Thus the short-run welfare impact on households is calculated as

$$\frac{\Delta w^1}{x_0} = \%P_{p,i} \cdot PR_i - \%P_{c,i} \cdot CR_i \qquad (1)$$

where $\frac{\Delta w^1}{x_0}$ is the first order approximation of the net welfare impact on producer and consumer households deriving from a price change in commodity i, relative to initial total income x_0 (in the analysis income is proxied by expenditure)

$P_{p,i}$ is the producer price of commodity i

$\%P_{p,i}$ is the change in producer price for commodity i

PR_i is the producer ratio for commodity i and is defined as the ratio between the value of production of i to total income (or total expenditure)

$P_{c,i}$ is the consumer price of commodity i

$\%P_{c,i}$ is the change in consumer price for commodity i.

CR_i, is the consumer ratio for commodity i and is defined as the ratio between total expenditure on commodity i and total income (or total expenditure).

Income and expenditure by crop are required to calculate PR and CR in the net welfare impact calculation.

The assumptions made on the consumer and producer price changes are shown to be crucial. When calculating the short term impacts of price changes on household welfare based on (1), a natural choice in the literature has been to use equal percentage change for both farmers and consumers. As shown in Dawe and Maltsoglou (2009), this assumption which implies that marketing margins also increase by the same percentage, critically skew the welfare results. This issue has been discussed in some papers and Minot and Goletti (1998) make clear reference to marketing margins.

In this context, Dawe and Maltsoglou (2009) show that if, in line with a true ceteris paribus analysis, real marketing costs and margins remain unchanged in the face of the world food price shock, then the producer and consumer prices are related as follows:

$$\frac{dP_C}{P_C} = \left(\frac{P_P}{P_C}\right) \cdot \frac{dP_P}{P_P} \qquad (2)$$

23 The methodology applied in this part of analysis is as described in Minot and Goletti (2000) and adapted as discussed in Dawe and Maltsoglou (2009). For a full description of the methodology the reader is referred to the relevant papers as discussed in Dawe and Maltsoglou (2009).

whereby the percentage change in consumer price equals the percentage change in producer price multiplied by the ratio of the producer price to consumer price. Therefore, as $P_P < P_C$, the consumer price change will always be less that the producer price change.

Based on (2), when a 10 percent producer price change is assumed, the producer to consumer price ratio is required to calculate the consumer price change There are several sources of data that could be used to obtain the producer to consumer price ratio for the specific commodity in question. One possibility is to use the survey data, provided it has data on either prices or quantities (data on expenditures and quantities can be used to calculate an implicit price). Another possibility is secondary data on prices, although one must be careful that such data are nationally representative and pertain to the same quality at farm and retail levels. If secondary data on farm prices are not available, and the survey does not have data for either prices or quantities, it is also possible to use macro level data (production, imports, exports, stock changes) coupled with expenditure and revenue data from the survey to obtain an estimate of relative producer and consumer prices. Please refer to Dawe and Maltsoglou (2009) for a discussion on this.

ANNEX 1

BIOENERGY: BIOFUEL PRODUCTION CHAINS, BIOMASS FEEDSTOCK AND CONVERSION TECHNOLOGIES

Biofuel production chains describe the production process starting from the production of biomass to the technological transformation of biomass to biofuel. A biofuel production chain can be characterized by the type of biomass feedstock and the energy carrier produced (fuel). For example, a type of feedstock could be jatropha and the type of energy carrier produced biodiesel. This type of integrated approach allows analyzing the biophysical, the technical and the economic parameters that are fundamental to this analytical framework. Further, the biofuel production chain approach provides a holistic overview of the biofuel production system, allowing identification of potential implications of bioenergy production chains on food security.

Moreover, biofuel production chains are closely associated to local settings and locally-placed agricultural production systems for example small-holder farming production of jatropha in semi-arid regions of sub-Saharan Africa.

Sources of biomass feedstock for energy production include agriculture crops, agricultural and forest residues, agroforestry residues and other organic waste sources. These various sources of biomass streams can be grouped under the following broad categories:

- *Energy crops:* These are agricultural crops that are suitable for bioenergy production. These include food crops from starch crops such as maize, sugar-based crops such as sugar cane and oil seed crops such as soybean. Non-food crops exclusively grown for bioenergy production are also included in this category, e.g. be grass and woody crops.
- *Forest growth:* This includes potential available woody biomass from sustainable forest management. Using woody biomass for energy purposes however may lead to competition with the forest products industry such as timber, boards, pulp and paper, etc.
- *Primary residues from agriculture and forestry:* These residues are organic by-products from forestry and agricultural harvesting activities. These usually consist of lignocellulosic material, e.g. small branches, leaves, corn stove, that can be used for energy production.
- *Secondary residues from processing industry:* These residues are produced during the industrial processing of wood and food crops. There is a broad range of residues produced from the various industrial processes each having different characteristics.

For example: the wood processing industry produces sawmill and black liquor which can be used as feedstock for energy production. Note that the use of residues from the food processing industry such as molasses or press cake for energy production is only one of its multiple beneficial uses.[26]

- *Organic wastes:* Organic waste such as organic municipal solid waste, demolition wood or used cooking oils comprises a very diverse stream of biomass that can be used for energy production.

All these biomass categories are viable biomass sources for bioenergy production. However, since the objective of this assessment is the impact of bioenergy production on food security, a particular attention is placed on energy crops which potentially have the largest impact on food security. Other types of biomass feedstock offering a viable option for producing bioenergy with minor or no competition for agricultural inputs and food production could also be investigated in the framework analysis.

The biomass-to-energy process options are comprised of an intricate matrix of choices based on feedstock options, technology availability and end-use applications. The choice of the conversion pathway will depend on the types, quantities, and qualities of biomass feedstock available as well as the most suitable and economically-viable type of biomass to energy processing technology locally available. Thus, one can approach bioenergy development by first giving consideration to the available feedstock and then considering the technological options for its conversion. Alternatively, one can first identify the preferred energy carrier i.e. based on energy market needs, then determine the technology and feedstock options available to produce it.

The three main technology conversion routes for converting biomass to biofuel[27] can be grouped into thermo-chemical, physical-chemical and bio-chemical processes. Thermochemical processes are based on the use of thermal energy to carry out the chemical conversion of biomass to an energy carrier. The most common thermo-chemical technologies include combustion, gasification, pyrolisis and/or carbonization. Physical-chemical technologies involve physical and chemical processes such as the production of crude vegetable oil and biodiesel from oilseed crops or from used cooked oil and animal fat. Biochemical conversions are based on biological processes commonly through the use of microorganisms or enzymes to mediate the conversion of biomass or organic waste materials to produce ethanol or biogas, respectively.

26 Alternative uses of secondary residues exist, such as the use of saw mill in the particle board industry or the use of oilseed press cake as fodder.

27 Following the terminology adopted by FAO (UBET – Unified Bioenergy Terminology, 2004 (E)), biofuel is any fuel directly or indirectly produced from biomass i.e. liquid biofuel like ethanol and biodiesel, gaseous biofuel like methane (biogas) and solid biofuel like charcoal.

ANNEX 2

BACKGROUND NOTE ON THE BIOENERGY AND FOOD SECURITY INTERLINKAGES[28]

Food security (FS) is a complex concept with many dimensions and a variety of determinants. Further, bioenergy can be produced via different conversion processes and from a range of feedstocks grown in many different environments. As a result, no short note can describe every possible mechanism through which bioenergy (BE) production might affect food security. In this note, the focus will be on how BE production affects FS through changes in market-based incomes and food prices. In many circumstances, these are likely to be the quantitatively most important effects. However, there is no doubt that BE production may have effects on FS that are not mediated by incomes and prices. For example, small scale production of BE in rural areas may allow some households to stop cooking with fuelwood in enclosed spaces, thus improving their health and the ability of their bodies to more efficiently utilize nutrients contained in the food they already eat. Thus, use of BE could allow for improvements in FS even without any changes in food consumption patterns. For the rest of this note, however, such effects will be ignored, while recognizing that such effects can be very important in some circumstances.

With regard to incomes and prices, it is obvious that income is a critical determinant of food security for the poor. The more income that a given household or individual has, the more food that can be purchased, both in terms of quantity and quality. Food prices are also important determinants, but the precise effects of food prices on food security are more complex.

Food prices are critical for the welfare of the poor

In order to understand the importance of food prices for food security, it is first important to distinguish between net food producers and net food consumers. A net food producer is someone for whom total sales of food to the market exceed total purchases of food from the market, while for a net food consumer the reverse is true. This distinction is also usefully made at the level of individual commodities, as opposed to food in general.

These concepts are quite distinct from rural and urban. While nearly all urban dwellers are net food consumers, not all rural dwellers are net food producers. In fact, very small farmers and agricultural labourers are often net consumers of food, as they do not own

28 This background note was prepared by D. Dawe, Senior Economist ESA FAO, at the start of the BEFS project.

enough land to produce enough food for their family.[29] These landless rural households are often the poorest of the poor. The importance of the rural landless varies greatly from country to country. In some countries, such as India, Indonesia and Bangladesh, among many others, the landless constitute a significant portion of the rural population. In others, such as land abundant Thailand, their importance is much less.

Generally speaking, with the exception noted in footnote 1, higher food prices can substantially hurt net food consumers. In order to understand this effect, one must realize that, for the poor, a very large share of expenditures goes to food. Indeed, in many countries, food can account for 70 to 80 percent of expenditures by the poorest quarter of the population. In such circumstances, food price increases can have large effects on effective purchasing power, even if they do not directly affect nominal income per se. As one example, Block et al (2004) found that when rice prices increased in Indonesia in the late 1990s, mothers in poor families responded by reducing their caloric intake in order to better feed their children, leading to an increase in maternal wasting. Furthermore, purchases of more nutritious foods were reduced in order to afford the more expensive rice. This led to a measurable decline in blood haemoglobin levels in young children (and in their mothers), increasing the probability of developmental damage. A negative correlation between rice prices and nutritional status has also been observed in Bangladesh (Torlesse et al 2003).

On the other hand, farmers who are net food producers are likely to benefit from higher prices, which, other things being equal, will tend to increase their incomes. Since many farmers are poor, higher prices could help to alleviate poverty and improve food security. However, it must also be kept in mind that farmers with more surplus production to sell will benefit more from high prices than farmers who have only a small surplus to sell. Further, in many (but not all) contexts, farmers with more land tend to be better off than farmers with only a little land, so it may be that poorer farmers will not receive the bulk of the benefits from higher food prices.

While these are useful first approximations to the effects of higher food prices on FS, the ultimate impacts can be more complex. First, there can be second round multiplier effects as farmers' higher incomes due to higher food prices create demand for other goods and services, much of it presumably produced locally. However, it must be kept in mind that if farmers' additional income is simply a transfer from the rural landless and urban poor, these new multiplier effects will come at the expense of the previous multiplier effects generated by the spending patterns of the poor, who will now have less money to spend on non-food items as their food bills increase. The point is that a change in relative prices due to either government policy or changes in external market conditions does not create

29 It is also true that whether a given household is a net food producer or consumer depends on market prices. Higher prices will discourage consumption, encourage more production, and possibly convert some households from net consumers to net producers. Lower prices could do the opposite.

multiplier effects in the same manner as does a new technology that increases productivity, such as new seed varieties. The only way to assess the potential for net positive multiplier effects is to carefully measure the change in income distribution and compare the spending patterns of the winners and losers from the new set of relative prices. While it is true that the (marginal) propensity to consume domestic products as opposed to imports decreases from the bottom to the top of the income distribution, it is also true that net food consumers often dominate both the bottom and the top of the income distribution. Thus, it is not clear that the propensity to consume domestic products is higher for net food producers than it is for net food consumers. In practice, it seems that higher food prices are probably not likely to generate large net multiplier effects in either direction.

Second, higher food prices will increase the demand for agricultural labour, which is a prime source of income for the poor (Davis et al, 2007). Ravallion (1990), using data from the 1950s to the 1970s, concludes that the average landless poor household in Bangladesh is a net rice consumer and loses from an increase in the rice price in the short run (due to higher consumption expenditures), but gains slightly in the long run (after five years or more). This is because in the long run, as wages adjust, the increase in household income (dominated by unskilled wage labour) is large enough to exceed the increase in household expenditures on rice. However, this study used relatively old data, when rice farming was a larger sector of the economy and thus had a more profound impact on labour markets. Rashid (2002), updating the data used by Ravallion (1990), found that since the mid-1970s, rice prices in Bangladesh no longer have a significant effect on agricultural wages as employment opportunities became more diversified and agriculture became a smaller share of the economy. Thus, the extent to which induced wage increases will compensate agricultural labourers for higher food prices will depend on the extent to which the agricultural labour market affects the overall labour market for unskilled workers.

To summarize, the net effect of bioenergy demand and higher food prices on food security will vary from context to context. There will always be some people for whom food security improves, while there will always be others who experience a deterioration in food security. The exact net outcome will depend on the socio-economic structure of society, as well as on the specific commodities whose price increases, and the relative position in the income distribution of the farmers who produce the commodities that have experienced the price increase.

On balance, for the world, the net effect of higher food prices on food security is likely to be negative, even for relatively small changes in prices. For example, Senauer and Sur (2001) estimated that if there is a 20 percent increase in food prices in 2025 relative to the baseline (due, for example, to an increase in bioenergy demand), the number of under-nourished people in the world would increase by 440 million people (195 million in sub-Saharan Africa and 158 million in South and East Asia). However, this is a global figure. The situation will be different in different countries, and the outcome will also vary across regions within countries.

Bioenergy production will nearly always compete with resources used by food producers, and will thus tend to raise food prices even if the feedstock itself is a non-food crop. Even if the crop is grown on previously unused land, there will still be a tendency for BE production to put upward pressure on food prices due to use of other resources.

Prices in food markets, despite many government interventions, are still influenced substantially by changes in market supply and demand. Further, the market supply curve for food is strongly influenced by the prices and availability of various inputs: land, labour, water and fertilizer. If BE production does not compete for these resources with food crop producers, then the supply curve for food production will not be affected, and this should serve to mitigate food price increases.

For example, if BE crops are grown on previously unused land with previously idle labour without any fertilizer and exploiting previously unused water supplies, then there should be no effects on the marginal cost of food production. In some cases, these circumstances may be close to the truth; however, in many others, production of BE will seriously compete for these resources and affect the cost of food production.

To illustrate: although jatropha can grow well in marginal environments, it generates larger quantities of oil (and thus more biodiesel) if it is grown with more water. Thus, biodiesel production from jatropha grown on marginal, previously unused land without any fertilizer may still have adverse impacts on food security if it competes for scarce water resources that are currently used by agriculture. Of course, it may be possible to grow jatropha without any irrigation water, but then it will be important to understand if it is possible to produce substantial quantities of biodiesel under these conditions.

In many other situations, BE production will compete seriously for key agricultural inputs. At present, most of the world's agricultural biofuels come from sugar cane in Brazil and corn in the United States; both of these crops are grown with heavy use of inputs, including prime agricultural land, fertilizer and water. While US corn and Brazilian sugar cane are not necessarily major sources of calories for the poor, production of these crops competes heavily for land, fertilizer and water used in the production of crops that are consumed by the poor.

To summarize, an assessment of the impact of BE production on food security will need to consider in detail the inputs used in the BE production process, and how this use of inputs affects market supply curves for food production.

Production of bioenergy will generate employment at both farm and factory levels, which will help to improve food security if targeted at the poor. It is important to note that alternative uses of the land and capital necessary for BE production would have generated employment as well, and this alternative employment needs to be considered in assessing *the impact of BE production on employment and FS. In other words, a critical issue in measuring the impact of BE production on employment and FS is the relative labour intensity of BE production.*

Much of the employment that is likely to come with increased BE production, at least in developing countries, will be due to potentially increased labour use at the farm level to grow the feedstock. Here, it is crucial to understand the labour requirements of the BE feedstock per unit of area-time (e.g. per hectare per year) compared to the labour requirements of alternative land uses. If the land was previously unused, then clearly the planting of BE feedstock will create new employment. However, if the BE feedstock is less labour-intensive than the crops planted previously, then BE production will destroy employment on net at the farm level. The ultimate outcome will vary depending on what crop is used as feedstock and what crops were grown previously before the feedstock.

In terms of fuel production from feedstock, small scale BE production seems likely to generate more employment for the poor than large scale BE production, which will probably be more capital intensive and less labour intensive. Indeed, current bioethanol and biodiesel factories in the USA and Brazil require huge investments of capital, often in the range of 100 to 200 million US dollars. Further, the labour employed in these factories may favour relatively skilled workers (who are usually food secure).

While small scale BE production may be better at creating employment, it is important to consider the ability of small-scale BE production to compete with large scale BE production. Smaller plants may in general not be very competitive, and if not, any increased employment is likely to be short-lived. However, if BE production is used to enhance access to energy in small villages with poor infrastructure, then competition with large scale factories is probably not an important issue. Employment created at such small scale processing plants is likely to have a positive impact on food security at the local level.

As world commodity markets become more integrated, bioenergy production in one country will have important effects on food security in other countries as changes in food prices on international markets affect domestic markets. The effect will depend on domestic trade policies and infrastructure.

BE production may affect food security in small developing countries even if the country concerned is not involved in BE production of its own. The effect is quite simple: higher prices on international commodity markets due to, for example, increased demand for corn as an ethanol feedstock in the United States, will in many cases spill into commodity markets in developing countries. At the country level, a net food exporter will benefit from higher food prices, while a net food importer will be hurt (the effects will depend on which specific food prices increase).

It is important to realize that not all of the recent increases in commodity prices over the past few years are due to biofuels demand. First, higher oil prices lead to higher costs of food production (fertilizer and machinery), leading to higher food prices even in the absence of biofuels demand. Second, demand for maize is increasing substantially independently of its use as a feedstock for ethanol. As consumers in China, India and other rapidly developing countries gain more income, they shift consumption away from cereals toward livestock products that use substantial quantities of maize as feed. Because it requires several calories of grain to produce just one calorie of meat, increased demand for meat means substantially increased demand for grain.

Third, many of the increases in commodity prices are due to exchange rate movements, specifically the weakening of the US dollar. A weak US dollar leads to increased commodity demand (at any given US dollar price) on the part of countries whose currency has appreciated (e.g. the euro and West African currencies tied to the euro), because it is cheaper in domestic currency terms to buy the commodity. A weak US dollar also leads to an inward shift of the supply curve as farmers in countries whose currency has appreciated now receive fewer units of domestic currency (again, at any given US dollar price) per unit produced. The shift in both demand and supply lead to higher commodity prices (as measured in US dollars). This theory is borne out by history as well. For example, the weak US dollar in the mid to late 1980s led to increased commodity prices at that time.

Nevertheless, some of the recent price increases in international markets are due to biofuels demand. The precise impact of increased international food prices on domestic prices will depend upon the trade policy pursued by the country in question. In a country that allows private imports subject only to tariff protection, higher international prices will usually translate into higher domestic prices. This effect may be reduced, or even eliminated, however, if there are high transport and transaction costs that cause domestic prices to be in-between import and export parity prices. A country that permits a fixed quota of imports may not witness an increase in domestic prices after an increase in international prices, but again the result depends on other factors such as whether or not the quota is binding.

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The Food and Agricultural Organization of the United Nations (FAO) has been at the forefront to support member countries in their quest to assess if bioenergy is an alternative and suitable energy option. The organization is working to promote a better understanding of the linkages between bioenergy and food security, poverty alleviation, climate change and sustainable development. The FAO Bioenergy Group is active in building the international knowledge base on sustainable exploitation of bioenergy, building and strengthening institutional capacity at all levels and facilitating opportunities for effective international exchange and collaboration. As part of the bioenergy program, FAO with generous funding from the German Federal Ministry of Food, Agriculture and Consumer Protection (BMELV) set up the Bioenergy and Food Security (BEFS) project to assess if and how bioenergy developments could be implemented without hindering food security.

The publication in this report presents the analytical framework developed by the BEFS project which examines the relationship between food security and bioenergy. The report also provides an overview of the BEFS tool box used to carry out the quantitative analysis on the dynamics of the bioenergy and food security interfaces. The report is meant to acquaint the general public and in particular policy makers with the BEFS Analytical Framework, the tools that it offers and how these tools can be applied to assist policy makers in making informed decisions on the basis of clear information concerning the many varied consequences of bioenergy developments on food security, poverty reduction and agriculture development and economic growth. This analytical framework has been implemented in Peru, Tanzania and Thailand. The results of the country implementations are published in the FAO Environment and Natural Resources Management working paper series.

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