Biofuels

and

Rural Economic Development

in

Latin America and the Caribbean

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The authors are José Falck-Zepeda, Research Fellow and Co-Leader of the Genetic Resources Policies Project, Environment and Production Technology Division, IFPRI, Siwa Msangi, Research Fellow, Environment and Production Technology Division, IFPRI Timothy Sulser, Research Analyst, Environment and Production Technology Division, IFPRI Patricia Zambrano, Research Analyst, Environment and Production Technology Division, IFPRI, and Cesar Falconi, Chief of Latin America and the Caribbean Service, Investment Centre, FAO.

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BIOFUELS AND RURAL ECONOMIC DEVELOPMENT

IN LATIN AMERICA AND THE CARIBBEAN

Prepared by

José Falck-Zepeda
Siwa Mangi
Timothy Sulser
Patricia Zambrano
Cesar Falconi

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CONTENTS

ANNEXES

ACRONYMS

CIAT	The International Centre for Tropical Agriculture
CLAYUCA	Latin American and Caribbean Consortium to Support Cassava Research and Development
EU	European Union
FAO	Food and Agricultural Organization of the United Nations
FEDEPALMA	National Association of Palm Oil Producers
GDP	Gross Domestic Product
GHG	Green House Gases
GM	Genetically Modified
IADB	Inter American Development Bank
IFPRI	International Food Policy Research Institute
IMPACT	International Model for Policy Analysis of Agricultural Commodities and Trade
LAC	Latin America and the Caribbean
MDG	Millennium Development Goals
OECD	Organization for Economic Co-operation and Development
OPEC	Organization for Petroleum Exporting Countries
ProAlcóol	National Alcohol Program - Brazil
R&D	Research and Development
S&T	Science and Technology
ST&I	Science, Technology and Innovation
UNCTAD	United Nations Conference on Trade and Development

PREFACE

The potential expansion of biofuel production in Latin America and the Caribbean (LAC) is widely believed to offer large opportunities for growth and development in agriculture and other related sectors, within the region. In spite of the numerous global-level analyses and discussions that have taken place on the subject of biofuels, little attention has been paid to LAC countries, except for Brazil. This knowledge gap has become even more critical as recent increases in food prices have raised concerns over food security in developing countries, and the connection to first-generation biofuels programs. The objectives of this report were, first, to assess the existing biofuels production potential considering present limitations on production capacity and agricultural productivity , as well as to develop a forward-looking analysis of the long term impact of biofuel expansion in Latin America. The forward-looking analysis considers effects on prices, trade, food security, malnutrition, among other outcome indicators.

The analysis in this report shows that most countries in Latin America continue to lag behind in crop productivity, with few exceptions. From a technical and productivity standpoint, the best crops in which to base biofuel expansion will continue to be sugarcane and palm oil. Most countries in Latin America will be unconstrained in their production of biofuels and will be able to meet existing and projected mandatory blends requirements. However, if the goal is to obtain high levels of energy independence, then this will only be feasible for a few countries, with obvious food security implications as countries dedicate higher shares of their agricultural land to biofuel expansion. Simulations show that negative impacts of biofuels on food security and malnutrition will likely happen in those countries where the feedstock used for biofuel production is a critical subsistence crop for a large share of the population. Thus, these results point to the need to implement food support and other targeted programs in relevant countries to assist the most vulnerable households, if current feedstock production possibilities and conditions remain the same.

In order to maximize the benefits and reduce risks of a potential biofuels expansion, LAC countries need to carefully assess policy and implementation alternatives. These efforts will likely include agriculture expansion at an accelerated growth beyond what is needed to ensure food security. Therefore, biofuel expansion needs to be examined within the broader context of economic and agricultural development policies, poverty alleviation efforts and achieving the Millennium Development Goals.

TECHNICAL DEFINITIONS AND UNITS

joule = International System of Units defines joule as a unit of energy measuring heat, electricity and mechanical work. One joule is the work done, or energy expended, by a force of one newton moving one meter along the direction of the force.

1 joule (J) = 0.238845896628 cal (calorie) (small calories, lower case c) = 2.390×10^{-4} kilocalorie, Calories (food energy, upper case C) = $9.47817120313 \times 10^{-4}$ BTU (British thermal unit) = 2.7778×10^{-7} kilowatt hour

Megajoule (MJ) = 10^{6} Joules
Gigajoule (GJ) = 10^{9} Joules
Terajoule (TJ) = 10^{12} Joules
Exajoule (EJ) = 10^{18} Joules

Kwt-hrs = Kilowatt hours

EXECUTIVE SUMMARY

Expansion of biofuels produced from agricultural biomass has increased significantly over the last years. Expansion of biofuel expansion is seen as a way to reduce dependence on fossil fuels, as an alternative energy source for transportation and other uses, as a way to reduce Green House Gases, and as way to revitalize the agricultural sector in many countries. In spite of the ample discussions on biofuels globally, very little discussion have been focused on Latin America, except for Brazil. Governments have implemented policies for biofuels expansion both in Latin America and elsewhere.

A strong push for biosafety expansion in several countries, have induced an increase in the price of commodities used as feedstock. For example, ethanol production from maize in the United States has induced a significant increase in domestic and international prices. This development may have an impact on food security in developing countries, especially in those countries where poor farmers are net importers of grains, and in some cases, where the tendency is for them to spend 70% of their income in food. This development along with other potential negative impacts, such as potential expansion on fragile ecosystems, point to the need to perform more in depth analysis of the potential impact of biofuel expansion, particularly on rural economies in Latin America.

The objectives of this report where first to estimate biofuel production potential based on current land use, productivity patterns and available technologies. Second objective, is to examine the determinants of energy and biofuel supply and demand that will likely have an impact on biofuel supply, demand and trade. Finally, develop a forward looking analysis of the long term impact of biofuel expansion in Latin America and its effects on prices, trade, food security, malnutrition and other indicators.

Our analysis of the current feedstock production possibilities show that most countries in Latin America continue to lag behind in terms of productivity, with a few exceptions. This conclusion leads to the need to further support strengthening the agricultural sector by improving input and output markets and value added chains. As has been shown in the literature major components of productivity in agriculture are ensuring a constant flow of improved plant genetic resources, technologies and the institutional issues surrounding production. Therefore, additional attention needs to be directed towards these issues, especially when the expectation is that productivity will have to increase significantly not only to address food security and food diversification issues but now biofuel expansion.

Our analysis of the specific crops show that from a technical and productivity standpoint, the best crops in which to base biofuel expansion will continue to be sugarcane and palm oil trees. This analysis also shows that most countries in Latin America will not have a production constraint in terms of meeting existing and projected mandatory blends requirements. However, if the goal is to obtain energy independence, this result only holds for a few countries, with obvious food security implications as countries dedicate higher shares of their agricultural land to biofuel expansion. Our analysis, and those made in other studies, show that strictly speaking biofuel expansion is not likely to have a binding land production constraint in Latin America, with a few exceptions. This conclusion needs to be tempered with the potential social and economic consequences of expanding biofuel into fragile lands and ecosystems, and the potential impacts on land displacement of resource poor farmers. However, this conclusion also signals Latin American countries the pressing need to explore and implement alternatives in terms of crops, technologies, policies, modernization of the agricultural sector; thus opening the possibility of capturing the benefits of biofuel expansion while

minimizing the risks and potential negative effects. This should be done as part of a broad, inclusive and forward looking plan that integrates targeted incentives for producers to respond.

The forward looking estimations from the IMPACT model show that Brazil will continue to be the major player in the ethanol market in the future. Brazil will expand its ethanol exports to meet growing demand in other countries including some in Latin America. Brazil will continue to be a net export of sugar to world markets, although results of our simulations show that sugar export volumes will decrease in the near future in a direct correlation with expansion of ethanol exports. Other countries such as Argentina and Colombia will likely continue their biofuel expansion plans, although our estimate show that they will not likely meet their demand based on current production potential.

Our simulations show that biofuel impacts on food security and malnutrition will likely happen in those countries where the feedstock used for biofuel production is a critical component of a major share of the population, other things equal. An example of this potential is Mexico and most of the Central America region, where a high proportion of the diet is composed of maize. These results do not consider potential gains from additional income from increased maize (or feedstock) prices in those households who may commercialize surplus production, as this analysis would demand a general equilibrium model.

Results obtained in this study point out to the need in some countries, of implementing food supplementation programs and other targeted programs to address the most vulnerable households in a country, if current feedstock production possibilities and conditions remain fairly constant. In addition, governments may implement policies to adjust management of grain stocks to reduce price and quantity fluctuations that tend to affect most, vulnerable households. The later negative impacts are expected to be stronger in Africa, but some regions in Latin America may be of concern. The scenarios and simulations conducted in this study did not show a significant impact on food security induced by changes in land use patterns, especially for low yielding oilseed crops, although there may be some concerns over biodiesel produced using higher-yielding plantation crops. These results further advance the idea that here is the need to carefully evaluate how and where land expansion will occur, particularly so as to reduce the impact of this expansion of fragile and/or sensitive land areas and ecosystems.

To conclude, biofuel expansion may bring significant benefits in terms of opening possibilities and production alternatives for farmers in Latin American. To maximize the benefits and to avoid the pitfalls, described in this report and others, Latin American countries must carefully assess this policy alternative before embarking in an activity that has the potential to change its agriculture. The assessment needs to include, as an integral part, plans to modernize agriculture even further and to expand its production and productivity at a much more accelerated growth rate than that needed to ensure food security. Production of biofuels needs to be examined within the broader context of economic and agricultural development policies, poverty alleviation efforts and compliance with the Millennium Development Goals, and sustainable improvements in the livelihoods of the poor; especially in rural areas. The extent to which biofuel efforts can contribute towards addressing or affecting all of these broader contextual issues depend on a series of strategic determinants of impact success, ranging from the characteristics of installed capacity and industrial organization and coordination to whether any nascent market for biofuels will be economically sustainable and financially viable without continuous government support or interventions.

1. INTRODUCTION

1.1 Interest in biofuels produced from agricultural biomass has grown dramatically over the past few years. The increased interest by countries for biofuels is a result of explicit national government policies that seek to reduce dependence on fossil fuels, minimize negative environmental impacts, and increase the use of alternative energy sources for transportation and other uses. Consequently, there is a growing body of literature discussing the potential for biofuels production and use. Most of the literature has focused on the energy replacement effects of developing biofuels, while very few studies have studied in detail the interface between biofuels, agriculture and development. In particular, there has been very little discussion of the effects of biofuels expansion on the agricultural sector and food security, and even less on finding alternative strategies to ensure that biofuels will contribute to rural and overall economic development especially for Latin American and The Caribbean countries.

1.2 Biofuel production needs to be examined within the broader context of economic and agricultural development policies, poverty alleviation efforts and their contribution to meeting the Millennium Development Goals, particularly eradicating poverty and hunger, while ensuring environmental sustainability[1] (See Box 1). The extent to which biofuels can contribute towards addressing or affecting all of the broader contextual issues listed above depends on a series of strategic determinants, which range from the characteristics of industrial organization and coordination to whether any nascent market for biofuels will be economically sustainable and financially viable without continuous government support or interventions.

1.3 This report is divided into five sections. Section two introduces the background, rationale, and substantive issues relating biofuel generation to agricultural and innovation capacity in Latin America. Section three provides an overview of the capacity and policy issues related to agricultural and biofuel production, energy, governing institutions, and innovation in Latin America. The analysis performed in this component is based on indicators estimated from publicly available literature and databases. Section four introduces a forward-looking analysis of the potential for biofuels growth in Latin America and the Caribbean. This component seeks to evaluate the plausible growth trajectory of biofuels production in Latin America and the Caribbean, with a special view to its implications for the agricultural economies and markets within the region. This component also highlights key implications for critical natural resources, such as water, and the potential that biofuels markets can have in relieving the pressure on agricultural food and feed supply within the region. Section five discusses policy issues related to biofuels expansion in Latin America and the Caribbean while section six concludes with final thoughts based on the knowledge accumulated and/or generated during the elaboration of this report.

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[1] A complete assessment at the national level needs to examine improvements in the livelihood of the poor, both in rural and urban areas that ideally are sustainable in the long run.

Box 1 The Initiative of UNCTAD

Bioenergy fuels derived from sustainable agricultural practices provide an opportunity for developing countries to utilize their own resources and attract the necessary foreign and domestic investment to achieve sustainable development goals. Greater biofuel production, domestic use and eventual trade bring multiple benefits. In the context of the current (and increasing) historically high oil prices, the economics are sound as a greater share of biofuels in total primary energy supply can help reduce dependency on oil imports and promote nationally-developed energy sources. From a developmental perspective, it fosters the agricultural production of well-known energy crops and promotes rural development thanks to the availability of accessible technologies to a large extent developed and tested in developing country regions.

Contribution to the United Nations Millennium Development Goals (MDGs)

Goal 1 - Eradicate extreme poverty and hunger

Promoting the use and production of biofuels in developing countries would provide greater energy security, improved quality of life and economic development, opportunities for job creation, and poverty alleviation especially in rural areas. It also fosters the agricultural production of well-known energy crops and promotes rural development.

Goal 7 - Ensure environmental sustainability

The use of biofuels derived from sustainable agricultural practices provides an alternative lower carbon intensive development path, by offering a way to reduce greenhouse gas emissions, while pursuing energy development goals and by taking advantage of the financial incentive embodied in the Clean Development Mechanism (CDM).

Source: UNCTAD http://r0.unctad.org/ghg/biofuels.htm

2. RATIONALE AND CONTEXTUAL BACKGROUND

Objectives

2.1 This report has two main objectives. The first objective is to examine the current agricultural capacity in the Latin American and the Caribbean (LAC) countries to supply materials or feedstocks and thus obtain estimates for the production of biofuels. Second, to examine the potential impacts that large-scale expansion of biofuel production in LAC countries would have on food and energy balances, and whether there would be significant impacts on food security, the environment and the welfare of the rural poor in the region. The effects on international trade and markets are also considered in the context of the LAC region. Following preliminary work done by IFPRI globally, welfare impacts will be centered on Latin American countries, but will also be assessed in relation to global trends. This study takes into account the response of farmers in other potential feedstock-producing nations, both in LAC and globally, in order to induce changes in world market prices of maize, sugarcane, and palm oil; as well as those of other important biofuel feedstock crops. In addition, this study takes into account the implied pressures on agricultural land use, food availability and water availability, when assessing the potential expansion of alternative feed stocks for bioethanol or biodiesel production under the currently available conversion technologies.

2.2 One important consideration is obtaining a consensus on which are the priority uses for biofuels produced in Latin America. This is an important issue as it helps frame the factors affecting supply and demand for biofuels. For the purposes of this paper we will assume that the most likely use is providing energy sources for transportation purposes. Although there are other significant uses for biofuels produced in Latin America, the most likely formal market to rise – and establish information signals in terms of prices and quantities demanded and supplied- is the one for biofuels for transportation.[2]

2.3 While a portion of our analysis looks at the current large-scale producers of biofuel, such as Brazil, United States, EU and South East Asia -as these are currently major players in the ethanol and biodiesel production – we consider crops and selected Latin American countries that could potentially benefit from scaled-up biofuel production in order to estimate impacts on their agricultural economies. Given the limited set of large-scale biofuel producers in Latin America, our analysis focuses on those Latin American countries which would be the most likely candidate to use feedstock crops for either bioethanol or biodiesel production and who may use available conventional technologies. Although the main focus of our analysis is the agricultural sector in Latin America and its interaction with global agricultural commodities markets, we also give some general discussion of the potential impact of agricultural and energy policies on Latin American and global energy markets and the trade in the biofuel products themselves, using externally generated scenarios and available modeling tools. Therefore in this report we attempted to address both positive and negative impacts of biofuel expansion (See Box 2), while discussing alternatives to minimize risk and other negative aspect of this development policy option.

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[2] Although in Latin America firewood is still used as an energy source, Martinot (2005) indicates that "GDP and the use of modern fuels are correlated. In fact above a GDP (per capita) of US$1,000 there is an almost complete shift to modern fuels from firewood." Implication of this quote is that considerations to replace firewood in favor of modern fuels may be a determinant factor in those countries in Latin America and the Caribbean with a Gross Domestic Product per capita less than $1,000 per year.

Box 2. Potential Positive and Negative Impacts from Biofuels Expansion in Developing Countries

Positive Impacts

- Creation for new demand for agricultural products
  - Alternative income sources in areas with depressed agricultural prices
  - Alternative employment opportunities in the biofuel production chain (transport, transformation, etc.)
- Global trade in feedstocks (or biofuel) is an opportunity for developing agricultural economies
  - A means of expanding markets for food, feed, or biofuel feedstock crops
  - Higher prices for farmers
  - Reduced environmental costs
- Health and environmental benefits
  - Displacement of wood fuel in household use
  - Potential reduction in fuel emissions and greenhouse gases including carbon dioxide, hydrocarbons, sulphur and particulate matters.
  - Carbon sequestration
- Energy security

Negative Impacts

- Food security impacts
  - Displacement of food producers
  - Higher food prices on net consumers
  - Poor, vulnerable and food-insecure households may not be able to cope with higher prices
- Binding environmental impacts
  - Competition for water (e.g. sugarcane in India, maize in Northern China)
  - Where water might be available - might also be constraint on available land for expansion (e.g. Southern China)
  - Extensive use of crop residues (by 2nd generation technology) would threaten sustainability of crop land resources
  - Excessive use of fertilizer and other capital-intensive methods of production - impacts on water quality, human health, wider ecosystem
  - Clearing of tropical forest and cultivation of ecologically fragile land

Background and Rationale

2.4 Rising world fuel prices, the desire to promote domestic energy security and self-sufficiency in energy supply, the need to meet growing demand for energy in industry and transportation that is more sustainable, and concerns about the effects of emissions on global warming are key factors driving the renewed interest being shown in renewable energy sources and in biofuel, in particular[3]. Within the Latin American and the Caribbean (and the global) context, fossil fuel consumption still dominates the energy economy, despite increasing pressures on supplies and market prices. However, the uncertainty in future energy supply, currently unsustainable patterns of energy consumption and the costs of expanding proven reserves of fossil fuels have lead many policy-makers in the region and around the world to explore alternative energy sources from renewable resources, such as biofuels.

[3] Part of the push for national government exploration of biofuels as an alternative and sustainable energy sources comes from the need to meet environmental quality standards including greenhouse emissions, through mandatory blending and reductions of sulfur and carbon content in fuels.

2.5 Biofuels already constitute the major source of energy for over half of world's population, making up more than 90% of the energy consumption of those living in the world's poorest countries, for whom access to electricity or liquid fuel is limited, compared to fuel wood (FAO, 2005). The feedstocks from which these biofuels are produced vary according to the comparative advantage that the nations producing them have, both in terms of yield productivity, land area and conversion technologies. As any other alternative biofuels have a distinct set of advantages and disadvantages (See Box 3) which vary between individual biofuels including ethanol and biodiesel.

Box 3. Euroactiv: "Biofuels: the Next Generation"

Advantages of second-generation biofuels:

A public consultation carried out by the Commission between April and July 2006 shows that the majority of stakeholders believe that second-generation biofuels are more promising than their first-generation counterparts because:

- They have a more favorable GHG balance. Cellulose ethanol could produce 75% less CO_2 than normal petrol, whereas corn or sugar-beet ethanol reduces CO_2 levels by just 60%. As for diesel, Biomass-to-Liquid (BtL) technology could slash CO_2 emissions by 90%, compared with 75% for currently-available biodiesel;
- They are able to use a wider range of biomass feedstocks, and do not compete with food production;
- They could be produced at cost-competitive prices, especially if low-cost biomass is used, and;
- They offer a better quality of fuel than first-generation biofuels.

Challenges:

- Cost: Relatively high production costs (currently higher than those for both mineral oil-based petrol and conventional bio-ethanol) mean that second-generation biofuels cannot yet be produced economically on a large scale.
- Technological breakthroughs: Key developments are needed on enzymes, pre-treatment and fermentation in order to make processes more cost- and energy-efficient. Biotechnology could offer a solution by offering the opportunity to change the characteristics of feed materials for fuels.
- Infrastructure needs: The commercialization of second-generation biofuels will also necessitate the development of a whole new infrastructure for harvesting, transporting, storing and refining biomass.

Euroactiv.com http://www.euractiv.com/en/energy/biofuels-generation/article-165951 extracted October 18, 2007.

2.6 Table 2.1 shows where large-scale bio-ethanol producers like Brazil, USA, EU countries, China and India stand globally, both in terms of the volume produced and their share of the global market. Brazil stands alone as the largest ethanol producer from sugarcane, while the US almost matches its output of ethanol from maize feedstocks. Brazil leads the overall bioethanol production with 50% of its sugarcane production (357.5 million tons in 2003-2004) devoted to ethanol (Szwarc, 2004). The U.S. is a very close second producer, while China, the EU and India are increasing their production over time.

2.7 Among the current large-scale producers of biodiesel, EU countries such as Germany, France, and Italy accounted for almost 89 percent of all biodiesel production worldwide in 2005 (Table 2.2). Today, Germany alone produces half of the world's biodiesel, with production continuing to expand rapidly. India is an emerging producer of biodiesel for transport. Yet, India had

a promising potential for ethanol production from sugarcane, the country has faced many unexpected constraints that have limited the expansion of sugarcane production to supply feedstock for ethanol production. The United States is a major player in international agricultural markets with growing bio-energy production from both maize and soybean.

Table 2.1 Global Production Volume and Shares of Bio-Ethanol

Country or Region	2005 Ethanol Production (million liters)	Share of Total (percent)
Brazil	16,500	45.2
United States	16,230	44.5
China	2,000	5.5
European Union	950	2.6
India	300	0.8
Canada	250	0.7
Colombia	150	0.4
Thailand	60	0.2
Australia	60	0.2
World Total	36,500	100.0

Source: F. O. Licht 2005.

Table 2.2 Global Biodiesel Production

Country or Region	Biodiesel Production (Million liters)	Share of Total Biodiesel Production (percent)
Germany	1,921	54.5
France	511	14.5
Italy, Austria, Denmark, United Kingdom, Czech Republic, Poland, Spain, Sweden	9 - 227	0.1 – 6.4
Europe Total	3,121	88.6
United States	290	8.2
Other	114	3.2
World Total	3,524	100

Source: F. O. Licht, 2005.

2.8 Table 2.3 shows the principal feedstocks utilized in the production of biofuels worldwide, together with the energy products that are generated from them, with a vast majority of crop fuels listed used for transportation purposes. Table 2.4 introduces potential agricultural crops of interest to Latin America for the generation of biofuels. As we are interested in the interface between biofuels and agriculture, the focus of this report is on production of ethanol and biodiesel. Given the available feedstock conversion technologies, the most viable feed stocks for ethanol production for

transportation in Latin America are sugarcane and maize/sorghum[4], while those for biodiesel are oilseed crops like palm oil and coconuts.

2.9 Other oilseed crops like soybean, canola (rapeseed), Castor seeds and *Jatropha spp*., may have a more limited (in some cases more promising) role in the generation of biodiesel. The later two crops, Castor seeds and *Jatropha spp*, are of special interest for poor smallholders as these two crops can be planted in marginal soils, may provide cover against erosion, and are hardy plants as they are relatively resistant to drought. As such, they may be potential alternatives for oil and biodiesel production that would probably not compete with other food security and/or subsistence crops and thus a potential component for community-based development strategies to generate energy[5]. Therefore, the choice of crops for biofuel generation may have a distinct impact on the livelihoods of the rural poor depending on the importance of the crop for their sustenance, the potential effect of changing cropping patterns on rural communities, and the interaction with existing land property ownership arrangements.

Table 2.3 Types of biomass resources and bio-fuel produced

Biomass Resources	Bio-fuel produced	Energy services
Agriculture and forestry residues	Wood pellets, briquettes, biodiesel	Heat, electricity, transport
Energy crops: biomass, sugar, oil	Char/charcoal, fuel gas, bio-oil; bioethanol	Heat, electricity, transport
Biomass processing wastes	Biogas, bioethanol, solvents	Transport
Municipal waste	Refuse-derived fuel, biogas	Heat, electricity

Source: Adapted from IEA Bioenergy 2005.

2.10 While each of these feedstocks have comparative advantages within a particular country, due its climatic and agronomic characteristics, there is a limit to the productivity level that each of these feedstock crops can achieve, given the available land area, soil quality, climatic suitability and water availability that prevail. It is widely acknowledged that the potential biomass that would be available from grassland, rangeland, forest sources – or even from the residues and other by-products of agricultural activities like straw, corn stover and bagasse from harvested sugarcane – would be much greater than that from the conventional cultivated feedstock crops currently being used. However, the “Second Generation” technology that could unleash the potential of these cellulosic feedstock sources is still under development, for large-scale production, and is not yet developed to the critical point so that it could economically replace the conventional conversion technologies currently being used for large-scale biofuel production. In many cases, the development of second generation technologies will open possibilities for the development of cottage industries and community development projects that may contribute to sustainable development efforts.

[4] This list may be expanded to other conventional crops with high starch content such as cassava or sweet potatoes.

[5] The benefits derived from the potential that alternative crops such as Castor or Jatropha have of producing even marginal soils, may be tempered by institutional issues such as producers not having land title or equivalently producing in communal lands. These may be a disincentive to producing feedstock crops for biofuels derived from these crops.

Table 2.4 Potential crops of interest to Latin America as source of biomass/feedstock

	Ethanol	Biodiesel
Sugar/amylase/oil sources		
Sugarcane	X	
Maize / sorghum	X	
Palm oil		X
Canola (rapeseed)		X
Soybeans		X
Jatropha spp. (especially the species curcas).		X
Castor Oil (Ricinus communis L., Euphorbiaceae)		X
Cassava	X	
Wheat	X	
Sugar beet	X	
Cellulosic source		
Grasses and rapid growth trees	X	
Primary residues (straw, stalks, wood chips and other by-products)	X	
Secondary residues (sawdust, sugarcane bagasse, nutshells)	X	
Tertiary residues (municipal solid waste, discarded wood products)	X	

Source: Authors review of literature.

Evaluation issues related to the Impact of Biofuels on Agriculture

2.11 The following is a general discussion of critical issues related to the evaluation of the potential global, regional and national impacts of biofuel production systems. This section centers the discussion within the agricultural context in LAC countries so that it helps illustrate the complexity of the biofuel and agriculture interface, while at the same time examining the potential gains from investing resources in careful and detailed modeling of these production systems in Latin America and the Caribbean.

2.12 One of the most important issues that need ample discussion is the food versus biofuel production trade-off. With the apparent push for biofuel production, some policymakers and analysts have voiced the concern that aggressive growth in bio-energy production could potentially “crowd out” food crop production in some of developing (Graham-Harrison, 2005). This line of argumentation posits that the development of biofuel production might be able to address rising energy demands but may have adverse effects on the needed growth in agricultural production for food and feed demands. In the minds of these critics, a tension emerges between competing national priorities. The question remains unanswered – which one will be given more importance – the need for energy or that for food and feed supply?

2.13 Hall and House (2004) point out that the cultivation of energy crops need not compete with that of food crops, as a select group of crops may be able to occupy marginal agricultural lands and require a minimal level of input. These crops nevertheless may be significant competition for

food production, depending on the path of development of energy crops. One point that requires further attention is the effect of the expansion of fuel crops to less favored lands over the livelihoods of the most vulnerable farmers that tend to be localized precisely in these areas. It could certainly be the case that poor farmers benefit, but if the expansion is based in large scale farming, it could create undesirable effects over land price and use, as is the case for commercial crop production. While we do not have a detailed model of land use that can fully evaluate the underlying drivers of agricultural and non-agricultural land use change, we made use of detailed agricultural land use data that helped us identify potential areas of expansion or intensification.

2.14 Another key trade-off, which is explored in this study, is substitution between energy sources. We accessed available equilibrium models of energy use and trade that helped us identify opportunities for energy supply expansion, substitution and trade, in a way that's consistent with the drivers of energy use being considered. Distorted and highly subsidized water and energy prices for agriculture could also affect the development of biofuels and energy crops. In this sense, the economic viability of producing biofuels in LAC and other developing countries should be assessed by estimating the opportunity costs of land, water, and production inputs such as fertilizers, diesel and electricity. This would ensure that the costs of subsidized inputs along with the whole range of alternative uses of the resources are fully reflected in the economic net returns being considered. This is an exercise that needs to be done on a country by country basis.

2.15 We undertook, nevertheless, a simplified but robust analytical approach that generated useful indicators for a subset of key countries within the LAC region, to support further discussion of the potential of biofuels within countries of similar socio-economic or agro-ecological characteristics and a forward looking (projection) exercise to examine likely pathways for biofuel expansion in the region. This focused approach help us move closer towards the end goal of providing a framework that can lead, later on, to a larger comprehensive assessment of biofuel potential within the LAC region that in turn can lead to even more detailed country-by-country assessments. These assessments should be the basis for the development of explicit plans for the deployment of biofuels, including business plans and roadmaps for action, and explicit studies exploring production and export potential for the region. An excellent example of the type of work needed is presented in Box 4.

Box 4. Production and Export Potential for Latin America and the Caribbean

Ludeña et al. (2007) and Razo et al. (2007) summarize the situation for LAC countries indicating that the regional biomass energy potential is approximately 50-300 ExoJoules (EJ)/year by 2050 (Smeets et al. 2007; De Vries et al. 2007). These values, based on surplus agricultural land, represent between 17-26% of global production. Bio-energy could cover regional energy demand, more than 100% (range 120-580%) thus becoming a potential source of exports. In addition, biofuels production costs in 2000 have been estimated at $10 to >$20 per Giga Joule (GJ) of energy. Although, De Vries et al (2007), estimates that more than 25% of global potential in 2050 could be produced at costs lower that $12/GigaJoules (GJ). In turn, estimates for Latin America indicate that more than 70% of total supply in 2050 could be produced at costs <$12/GJ, making biofuels an attractive regional export.

Source: Ludeña, Razo and Saucedo (2007), Razo, Astete-Miller, Saucedo, and Ludeña 2007.

2.16 An important point to consider, however, is whether the threat to food security arises primarily in those countries which would divert feedstock crop production output from their own food consumption, towards biofuel production. Alternatively, a negative outcome may arise from reduced exports or from higher commodity prices, particularly for those countries that rely heavily on food imports to meet the food requirements of their growing populations. Runge and Senauer (2007) argue that if biofuel output were to expand considerably in countries already engaged in large-scale production there will undoubtedly be impacts on crop prices, and these will likely harm the poorest people. However this does not need to happen in all situations. As WorldWatch (2006) notes, while extremely poor urban dwellers are unlikely to benefit from biofuel programs, many of the world's 800 million undernourished people are farmers or farm laborers, who could benefit from biofuels expansion in their countries through higher prices for their farm products.

2.17 Among the trade-offs that may arise from large-scale uptake of crop-based biofuel production is the decrease in surplus cereal stocks, which could decrease the ability of grain markets to compensate for price fluctuations and thus increase food insecurity, or to supply food aid needs. On the other hand, if biofuel programs in industrialized countries absorb much of the current stock surplus of grain crops, farmers in the developing world would not continue suffering from the effects of commodity "dumping" and artificially low prices induced by the existing excess supply. Of course this would be a temporary benefit for farmers in developed countries, as long as the market distortions that allowed the excess supply are removed, and thus corrections occur resulting from market forces (IFAD, 2002)[6].

2.18 Besides the major biofuel producing countries that are often the focus of most assessments of bio-energy production potential – we may also focus on the potential that could be realized in the developing economies globally, and whether the pre-conditions for an effective and economical large scale processing of biofuels are in place. The possible land quality improvements that might occur if biofuel production were to occur on marginal and otherwise unusable land, is also of importance to the livelihoods of poor, rural farmers who depend heavily on the productivity of land and soil resources.

6 The potential economic and environmental trade-offs that are embodied in the potential for expansion of biofuel production from food or non-food crop feed stocks have direct bearing on the performance of both food production and processing systems of the developing economies that fall within IFPRI's research mandate.

2.19 In order to fully evaluate the potential economic and environmental impacts of policies that promote large-scale cultivation of energy crops in LAC countries and elsewhere, a fairly comprehensive modeling framework is required. Within this framework, the production characteristics of energy crops would need to be adequately represented, as well as the likely substitution effects vis-à-vis other cash or food crops.

2.20 In addition to these considerations, there is the need to evaluate land use changes that would need to occur in order to accommodate an expansion in biofuel feedstock cultivation. This evaluation will need to be directed towards the feedstock crops currently being used as well as other potential alternatives. Each of the potential feedstock crops embodies fertilizer, labor and/or water use. The relative input intensity use would have to be considered in order to evaluate the comparative advantage of a country in undertaking a large-scale expansion of its cultivation for biofuel production. The specific input use intensities for feedstock crops, especially fertilizer and water, translate to different environmental impacts that would need to be assessed. Lastly, a proper modeling framework needs to reflect the welfare impacts that could occur if agricultural subsidies, for instance, are dropped in favor of energy crop subsidies – both in terms of prices facing producers and consumers in all countries that are linked through commodity trade. A complete evaluation of biofuel production may help avoid pitfalls shown in Box 5.

Box 5. Excerpts from "Biofuels: Is the Cure Worse Than The Diseases?"

- "The effects on farm commodity prices can already be seen today. The rapid growth of the biofuels industry is likely to keep these prices high and rising throughout at least the next decade."
- "When such impacts as soil acidification, fertilizer use, biodiversity loss and toxicity of agricultural pesticides are taken into account, the overall environmental impacts of ethanol and biodiesel can very easily exceed those of petrol and mineral diesel."
- "Second-generation technologies hold promise but depend on technological breakthroughs"
- "Regulations mandating usage or blending percentages and fuel-tax preferences to stimulate production are used by many countries. In most cases these policy measures do not distinguish among biofuels according to their feedstocks or production methods, despite wide differences in environmental costs and benefits. This implies that governments could end up supporting a fuel that is more expensive and has a higher negative environmental impact than its corresponding petroleum product."
- "The current policy response to the environmental consequences of biofuel production is to develop criteria designed to ensure a sustainable production of biofuels. However, biofuel mandates are still targeting ambitious market shares without an in-depth understanding of a sustainable production level and from where this biofuels could be supplied."
- "In short, competition for arable land among food, fibre, biomaterials and energy production cannot be avoided."
- "For the time being the obstacles for biofuels trade to expand are high, and therefore the prospects for the costs of biofuels to drop, and their potential for oil displacement (on a global basis) to increase substantially are limited."

Source: Richard Doornbosch and Ronald Steenblik (2007), OECD Paris, 11-12 September 2007, Author's opinion manuscript listed at OECD as document SG/SD/RT(2007)3.

2.21 The foundation data and indicator analysis in section 3 and the methodology described in section 4 incorporates some of the necessary elements into a unified and integrated crop production and commodity trade modeling framework that will attempt to link demand for biofuel feedstock from agriculture with the growth of energy demands within the chosen study countries of the Latin American region. By using this modeling approach it will be possible to capture all relevant socio-economic and environmental impacts of large-scale bio-energy crop production and consumption. In the end, one of the most important questions that need to be answered is whether complementary investments and policies exist that could enhance both food supply and availability, as well as creates favorable conditions for the expansion of biofuel production in Latin America. Furthermore, defining what are the conditions by which to maximize the net social returns and minimize the risks from using biofuels in each country, is warranted. We provide some initial answers to these questions in the following sections of this report.

3. DIAGNOSTIC OF THE CURRENT CROP SITUATION IN LAC: THE INDICATOR APPROACH

3.1 The objectives of this section are to present the results of the initial data gathering and estimation of quantitative indicators that would provide a concise guide to the current situation of the biofuel and agricultural feedstock production in Latin America. In addition, this section introduces a rapid assessment of the current potential to produce biofuels maintaining constant production and allowing for a significant expansion to cover all area harvested to particular crop. This initial estimation will give an idea of the maximum demand for ethanol or biodiesel that could be covered with current production and technical capacities. Data collected for this section served as a foundation to derive the scenarios and estimations in section 4.

Regional Potential for Latin American Feedstock Production

3.2 We first consider the potential for the production of agricultural feedstock that may be used for biofuel production across all Latin American countries. This approach helps frame biofuels potential in terms of production possibilities within Latin American agriculture. We are only considering agricultural crops which in our literature review and experience; appear to be potential candidates for biofuel production in Latin America. We did not include non-agricultural feedstocks or non-traditional crops such as *Jatropha spp* or *Pongamia spp*. In addition, we limit ourselves to those biofuels for transportation. Table 3.1 lists the countries included in the study for both the indicator component in section 3 and the IMPACT-WATER projections in section 4.

3.3 Table 3.2 presents current production of potential target feedstock for ethanol and biodiesel, as well as the relative shares of the largest producers for 30 countries in LAC. The purpose of including all LAC countries is to obtain a complete picture of the current production of crop feedstock that may be used for biofuel production in the region. As can be seen in this table, LAC countries have significant production totals relative to the total production of the rest of the world only in the case of sugarcane and soybeans. The share of total world production for sugarcane and soybeans is 45% and 44% respectively for the LAC region. In terms of the largest share of total world production for a LAC country, the highest share of sugarcane is 29% for Brazil. The share of total world production of soybeans is 24% for Brazil, while Argentina trails in second place with 16% of the total production.

3.4 In other crops, the share of LAC countries' production is relatively modest. For example, in the case of palm oil, world production is dominated by Malaysia, Indonesia and Thailand, thus Latin America only produces 2% of world production. The cases of sugar beet (<1.2%), potatoes (1%) and rapeseed (0.1%) and others crops are illuminating as these represent rather small areas harvested and thus production. This fact signals a reduced potential in terms of number of crops available as potential feedstock that may be used for biofuel production in Latin America.[7]

[7] An indirect corollary of this fact, may be the higher difficulty of introducing new crops such as *Jatropha*, *Pongamia* or *Ricinus*, as there may be difficulties in terms of a generalized lack of knowledge even with somewhat – but cultivated commercially- similar crops such as rapeseed, potatoes, or sugar beet.

Table 3.1 List of Latin American and Caribbean Countries and their associated groupings

Regional definitions in model	Countries within aggregate regions in the IMPACT-WATER analysis
Argentina	
Brazil	
Chile	
Colombia	
Ecuador	
Mexico	
Peru	
Uruguay	
Central America and Caribbean*	Costa Rica, Dominican Republic, El Salvador, Guatemala, Haiti, Honduras, Nicaragua, Panama
Central-South America	Bolivia, Paraguay
Northern-South America	Guyana, Suriname, Venezuela

Notes: * other countries include Barbados, Bahamas, Belize, Cuba, Jamaica, Trinidad & Tobago, Saint Lucia, St. Vincent and the Grenadines.

3.5 The production of those crops that enter in direct competition with human or animal consumption such as maize, wheat or cassava is somewhat limited in Latin America compared to the rest of the world. However, examining overall production in Latin America hides not only country to country variations, but also gives an incomplete picture as to current agricultural situation in each country. In addition, we also need to examine yields -as an indirect measure of productivity- as well as land, water, irrigation and general constraints to an individual country expansion of a particular crop.

3.6 Table 3.3 introduces yield of potential crops that may be considered as target for biofuel production in LAC countries. Of all the crops listed in Table 3.3, only soybeans, oil palm and cassava have a higher proportion of LAC countries whose yield is above the global average. In addition, the region as a whole has a significant yield gap compared to the global average. The only crop where LAC does not have a yield gap compared to global average is oil palm. Other crops have a yield gap that varied from 26% in sugarcane to 68% with sugar beets. The implication of the findings on Table 3.3 is the need to improve yields and to examine individual crops and countries in much more detail in order to define total factor productivity and the causal agents (e.g. access to credit, irrigation, improved germplasm, and access to fertilizers or pesticides) that defined such measure. Although this exercise falls outside the scope of this report, this is a knowledge gap where compilation of available data and/or estimations is warranted.

Table 3.2 Indicators of Feedstock Production for all Latin America

Feedstock	Production LAC (Tons)	Ethanol / Biodiesel yield per ton of feedstock (lts/ton)	Ethanol / Biodiesel yield per hectare (lts / ha)	LAC Share of Total Production (%)	Largest LAC Producer's Share of Total Production (%)	Share of Largest World's Producer (%)
Ethanol						
Sugarcane	594,457,243	75-83	5,300- 9,000	45	29	29
Maize	72,417,355	300 - 375	2,500-3,100	13	6	40
Cassava	33,368,000	200	5,000-6,000	17	12	19
Potatoes	15,799,000	650-830		5	1	22
Sugar Beet	2,845	100	5,000-5,500	1.2	<1.2	13
Wheat	25,548	336	2,500	4	2	16
Biodiesel						
Palm Oil	1,548,032	335	4,000-6,000	5	2	46
Rapeseed	100,412	610	1,000–1,200	0.2	0.1	30
Soybeans	84,968,431	305	500-700	44	24	40
Cottonseed	2,373,298	275	350-600	6	5	29

Notes: a) Table is authors estimations based on data from FAOSTAT (2007), b) Includes all countries in Latin America and the Caribbean and is the average for the period 2001-2005.

Table 3.3 Indicators of Potential Yields for Target Feedstock Crops

Indicator	Maize	Soybeans	Sugarcane	Palm nuts	Cassava	Wheat	Sugar Beet
Global average yield (Kg/ha)	3,678	1,513	58,492	12,557	103,404	28,813	382,851
Yield of highest yielding country in the world (Kg/ha)	21,446	3,384	118,716	25,417	318,822	89,353	750,957
Highest yield of a LAC country (Kg/ha)	10,463	2,846	114,538	25,417	201,139	47,358	427,487
Rank of LAC country with highest yield	7	4	2	1	3	18	26
Number of LAC countries with yields higher than global average	3	13	14	8	16	1	1
Number of LAC countries with yields lower than global average	26	4	14	6	11	11	3
Average yield gap in LAC (Kg/ha)	-1,693	-601	-14,931	3,170	-39,972	-14,039	-258,543
Average yield gap in LAC (%)	46%	40%	26%	-25%	39%	49%	68%

Notes: a) Table are author's estimations based on data from FAOSTAT (2007), b) Includes 30 countries in Latin America and the Caribbean. C) Average for year 2001-2005.

Indicators of the Potential for Individual LAC Country Production of Feedstock and Biofuels: The Supply Side

3.7 In this section the discussion centers on the potential for individual countries to produce feedstock and biofuels using an indicator approach. Although, data will be presented for each of the 19 countries chosen for this study, we will limit our discussion to the relevant cases where a lesson may be learned at the national and regional levels. The sources of biofuels are the agricultural feedstock produced in a particular country. As we discussed briefly in our analysis of the Latin America region as a whole, land and water availability may become a major constraint of agricultural production in the near future. Other productivity constraints such as water, abrupt climate changes, erosion, biotic pressures, and the ability of the country's scientific and research systems to address these issues will also be significant and will grow in importance as time goes by.

3.8 Table 3.4 showcases indicators for total land availability but also the land which may be used for agricultural production. Although not presented here, there has been a significant amount of land in Latin America which has been reserved or retired from agricultural production due to environmental concerns or to be kept as natural reserves for biodiversity purposes. This fact, coupled with the reality that a significant amount of land currently classified as arable may in fact be too fragile or poor for cultivation, may indeed put additional pressures on existing land and agriculture's mission to increase food production. In some countries, land may therefore constitute a limitation for biofuels expansion and thus may lead to competition with food/feed production for consumption.

3.9 The impact of land availability on agricultural production is further aggravated by the fact that in some countries current levels of irrigation are rather low. As seen in Table 3.4, countries like Peru, Paraguay, Nicaragua or even Brazil (amongst others) have low shares of land that is currently being irrigated. For some countries and areas there may be sufficient rainfall for agricultural production, in others, significant expansion of agricultural production may be directly related to a country's ability to increase the share of land that is irrigated.

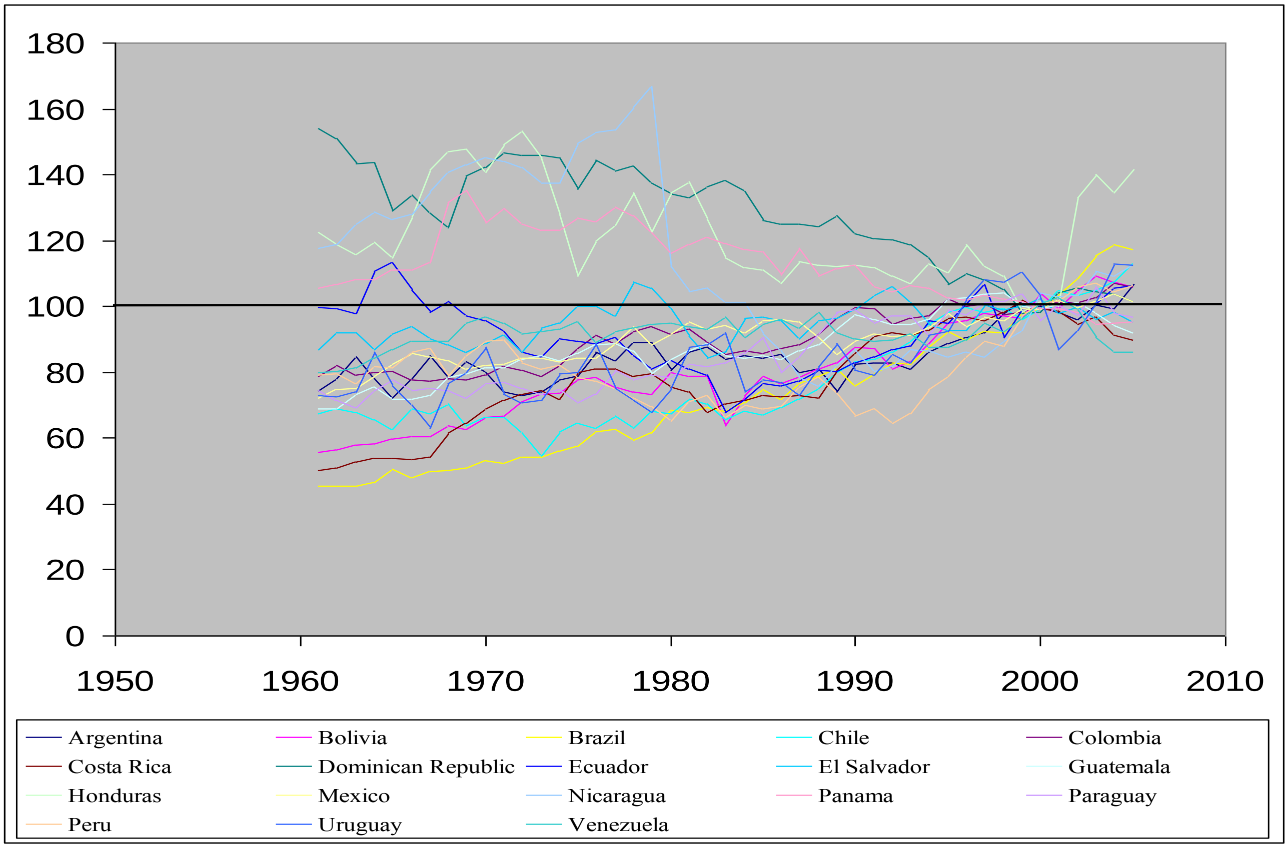
3.10 Figure 3.1 presents an indicator that contrasts countries in terms of their food production per capita over time. The indicator is calculated as a percent of the average food production per capita for years 1999-2001. This indicator shows that from 1960 through 2005 (projected to 2010); food production per capita in Dominican Republic, Honduras, Nicaragua and Panama has decreased significantly. Nicaragua food production per capita decreased rapidly the later part of the 1970s reaching its lowest point early 1990s, but is showing signs of recovery. In turn the other countries apart from the four mentioned previously, their food production per capita has been increasing.

3.11 The time pathway shown in Figure 3.1 may be the result of a combination of changes in food production, changes in population growth, or changes in both parameters. From the standpoint of biofuels, there is the need to examine in greater detail those countries whose per capita food production has been declining or remain static, to ensure that there will not be conflicts between food security and biofuels production[8]. Table 3.5 reports the current production in (1,000 tons) of those crops that may be a source of feedstock for biofuel expansion in Latin America.

[8] The suggested analysis should include disaggregation into the potential and likely causes of such changes over time.

3.12 Table 3.5 is based on Tables A1-1 and A1-2 in Annex 1, which contain data on the area harvested and yields by target crop and country for Latin America. Data on area harvested has the disadvantage of not reflecting planting intentions or total area that may be planted to a particular crop. The planted area that is lost due to biotic and abiotic causes is not reflected in this data. However, the only complete data available on land use is FAOSTAT and only for area harvested. Brazil has significant areas harvested for all crops with the exception of sugar beets. In fact, the only countries that have any area planted to sugar beets are Chile, Ecuador and Venezuela.

Figure 3.1 Agricultural Production Indexes: Food production per capita index [Percent (%) of the 1999-2001 average food production per capita]



Note: Figure extracted by the authors from data compiled by the World Resources Institute (WRI) as included in the USAID Socio and Economic Indicators for Latin America (2006).

Table 3.4 Selected Land Availability Indicators

Country	Land Area (Km^2)	Arable Land (1000 ha)	Arable and permanent Crops (1000 Ha)	% Arable Land (% of Land Area)	Irrigated land (% of cropland)
Argentina	2,736,690	27,367	28,900	10	5
Bolivia	1,084,380	3,253	3,256	3	4
Brazil	8,459,420	59,216	66,600	7	4
Chile	748,800	2,246	2,307	3	82
Colombia	1,038,700	2,077	3,850	2	23
Costa Rica	51,060	204	525	4	21
Dominican Rep.	48,380	1,113	1,596	23	17
Ecuador	276,840	1,661	2,985	6	29
El Salvador	20,720	663	910	32	5
Guatemala	108,430	1,410	2,050	13	6
Honduras	111,890	1,119	1,428	10	6
Mexico	1,908,690	24,813	27,300	13	23
Nicaragua	121,400	1,942	2,161	16	3
Panama	74,430	521	695	7	6
Paraguay	397,300	3,178	3,136	8	2
Peru	1,280,000	3,840	4,310	3	28
Uruguay	175,020	1,400	1,412	8	14
Venezuela	882,050	2,646	3,400	3	17
TOTAL	**19,524,200**	**138,669**	**156,821**	**-**	**-**

Notes: a) Source: FAOSTAT(2007), b) Indicators estimated as averages from years 2003-2005, except for Arable and Permanent Crops which is for year 2003.

Table 3.5 Current Production of Crops that may serve as Feedstock for Biofuel Expansion, by Country (tons)

Country	Cassava	Cottonseed	Maize	Oil palm fruit	Sorghum	Soybeans	Sugar Cane	Wheat	Sugar Beet
Argentina	1,700,000	194,528	16,733,137	0	2,570,215	34,803,669	19,457,500	178,883,440	0
Bolivia	3,916,733	48,002	669,037	0	165,770	1,623,098	5,011,188	1,103,233	0
Brazil	239,127,440	1,290,359	41,588,677	548,452	1,827,915	55,245,824	404,188,837	48,950,017	0
Chile	0	0	1,336,980	0	0	0	0	17,999,227	0
Colombia	18,840,440	63,706	1,707,788	2,980,183	274,012	84,157	37,744,215	440,267	0
Costa Rica	3,159,000	160	13,641	674,585	0	0	3,684,492	0	0
Dom. Rep.	1,050,700	0	39,293	158,121	4,140	0	4,294,431	0	0
Ecuador	864,500	1,553	819,650	1,785,709	10,607	95,417	6,646,073	89,133	39,440
El Salvador	191,987	1,479	667,209	0	143,316	2,497	4,698,600	0	0
Guatemala	145,000	1,500	1,066,064	590,100	51,980	35,150	17,721,600	98,490	0
Honduras	160,867	1,200	475,735	1,139,333	42,580	155,258	5,376,971	10,000	0
Mexico	227,200	180,139	20,113,040	222,667	6,336,685	4,954	46,914,070	28,120,960	8,540
Nicaragua	1,220,080	1,886	525,671	56,477	97,610	259	3,976,540	0	0
Panama	283,920	0	88,848	64,192	7,945	1,364,096	1,608,343	0	0
Paraguay	46,953,600	138,528	998,332	126,017	24,846	3,262	2,820,440	5,136,947	0
Peru	9,592,727	40,382	1,264,300	193,591	129	98	8,019,580	1,706,640	0
Uruguay	0	0	219,739	0	71,342	425,802	164,778	3,315,253	0
Venezuela	5,492,593	12,138	2,060,854	291,166	523,075	4,131	9,244,704	1,340	186,200
TOTAL	**332,926,787**	**1,975,560**	**90,387,995**	**8,830,593**	**12,152,167**	**93,847,6728**	**581,572,362**	**285,854,947**	**234,180**

Notes: a) Source: FAOSTAT 2007, b) Production is the average 2003-2005, c) Production measured in tons with the exception of the total which is expressed as 1,000 tons.

Indicators of the Potential for Individual LAC Country Consumption or Use of Biofuels: The Demand Side

3.13 The fundamental economic indicators for Latin America are well known. Table 3.6 presents selected economic indicators for Latin America. Fundamental economic data presented in this table serves to frame potential demand trends that may be extrapolated from existing data as has been done in our estimations of energy demand in section 4.

3.14 The economic situation in the region is characterized by significant contrasts between countries in terms of economic development, perspectives and reliance on agriculture for the livelihood of its citizens. From the standpoint of biofuels, growing populations measured by the rates of population growth imply additional pressures for consumption of fuels in a particular country. Although the rate of population growth has stabilized in most countries, it remains relatively high (>2%) in a small group of countries. Countries like Honduras, Guatemala and Paraguay, have the highest population growth in the region and also tend to have the lowest per capita income.

3.15 Countries with both high population growth and lower per capita income also tend to depend more on agriculture and less on industrialization for their livelihoods. If this development path remains relatively the same in these countries, or if there no major change in these indicators, pressures for fuel will tend to increase with increases in population, but may be dampened to a degree by the reduced levels of per capita income. This situation may imply an increase in public transportation needs compared to privately owned vehicles. In countries such as Brazil, Argentina, Mexico and Chile, which have the highest GDP per capita, coupled with high industrialization rates and lowered reliance on agriculture, the transportation demand for fuels mix may tend to move to privately owned vehicles. The net effect in each country will be the result the trade-off between the relative cost of public and private transportation, which is directly connected with the price of fuel and its source.

Table 3.6 Selected Fundamental Economic Indicators for Latin America and the Caribbean

Country	GDP (Millions, Constant 2000 US$)	Population in 2004 (Millions)	Annual Population Growth (%)	Expected Population 2050 (Millions)	Average GDP per capita 2000-2004 (Millions, 2000 international dollars)	Value added agriculture (% of GDP)	Industry Value Added (% of GDP)
Argentina	275,606	38	1.0	49	7,168	7	32
Bolivia	9,081	9	2.0	14	1,015	16	30
Brazil	636,319	179	1.4	228	3,480	9	37
Chile	84,756	16	1.2	19	5,136	6	42
Colombia	91,018	44	1.6	65	2,019	13	32
Costa Rica	17,573	4	2.1	6	4,136	11	30
Dom. Republic	21,322	9	1.5	14	2,455	12	31
Ecuador	18,452	13	1.5	20	1,370	12	29
El Salvador	13,978	7	1.9	12	2,090	12	32
Guatemala	20,711	12	2.4	23	1,723	23	19
Honduras	6,559	7	2.4	13	939	18	31
Mexico	602,730	101	1.5	148	5,871	5	27
Nicaragua	4,260	5	2.0	9	799	21	30
Panama	12,745	3	1.9	5	3,979	8	17
Paraguay	8,070	6	2.4	15	1,380	24	25
Peru	58,539	27	1.5	38	2,098	10	30
Uruguay	19,608	3	0.7	4	5,723	8	26
R. B. Venezuela	116,948	25	1.8	37	4,530	5	49
Average for all countries in Latin America/Caribbean	112,126	28	2	40	3,106	12	31

Source: WB World Development Indicators 2006 and FAOSTAT (2007).

3.16 As seen in Table 3.7, countries considered major oil producers in Latin America and the Caribbean are Argentina, Colombia, Ecuador, and Venezuela R.B. Other countries such as Bolivia, Chile, Guatemala, and Peru produce relatively small amounts of oil (less than 100,000 barrels per day). The implication for biofuels is that oil producing countries will have fewer incentives to promote biofuels policies, unless there are other considerations such as other energy demands or environmental considerations.

3.17 Although the focus of this report is biofuels for transportation it is worthwhile to review other major energy demand variables including energy and electricity consumption as they will give an idea of potential (future) drivers for the demand for bioenergy and biofuels. Note that in many countries a high proportion of electricity is generated by diesel generators. Electricity consumption in Table 3.7 is correlated with income and population size. Highest consumption occurs in Brazil, Mexico and Argentina. Smallest consumption occurs in Bolivia, Paraguay and the Central American countries. Electricity consumption per capita is highest in Venezuela, Chile, Argentina, and Uruguay. These countries have electricity consumption per capita greater than 2,000 Kwt-hours. Primary energy consumption per dollar of GDP (adjusted for purchasing power) is fairly stable around 4,000-6,000 BTU per dollar of GDP. Exceptions are Paraguay and Venezuela who are spending significantly higher quantities of energy per unit of income. Countries with higher levels of electricity and/or energy consumption may face increased pressures to develop and produce alternative energy production processes.

3.18 Table 3.8 has additional indicators of energy security and environmental indicators. In terms of natural gas production Mexico, Venezuela, Brazil and Argentina produce significant amounts of natural gas. Production of natural gas represents an alternative energy source for cooking, heating and transportation which may serve as a negative incentive for biofuel production. In summary, countries which produce significant quantities of petroleum and/or natural gas will have fewer pressures for expanding biofuel production. Therefore, other considerations such as environmental impact of petroleum base products may become more important for the decision making process.

Table 3.7 Selected Indicators of Energy Security by Country

Country	Oil production (Thousand barrels per day)	Petroleum consumption (Thousand barrels per day)	Energy imports, net (% of energy use)	Total electricity consumption, net (Billion Kwt-hrs)	Electricity consumption per capita (Kwt-hrs per person)	Primary energy consumption per dollar of GDP using Purchasing Power Parities, Total (Btu per 2000 U.S. Dollars)	Energy use (kt of oil equivalent)
Argentina	866	458.2	-41	83.5	2,220	6,409	58,195
Bolivia	39	46.7	-63	3.7	432	6,853	4,384
Brazil	1,848	2133.3	18	354.3	1,980	6,279	190,161
Chile	17	235.3	67	42.9	2,723	5,983	25,941
Colombia	555	269.7	-159	40.5	931	4,201	28,099
Costa Rica	-0.3	40.8	53	6.5	1,581	4,927	3,526
Dominican Rep.	0.01	124.1	81	10.3	1,214	5,856	7,983
Ecuador	411	143.9	-162	10.8	850	6,832	8,847
El Salvador	-0.5	40.9	46	4.1	623	6,189	4,352
Guatemala	22	65.6	27	5.7	483	3,292	7,330
Honduras	0	35.7	52	4.1	614	5,973	3,420
Mexico	3,799	1969.2	-50	188.8	1,872	6,489	155,807
Nicaragua	-0.4	25.9	44	2.4	464	1,062	2,898
Panama	0	78.4	73	4.7	1,543	8,627	2,687
Paraguay	-0.03	25.5	-65	2.4	412	14,651	3,940
Peru	92	154.1	23	20.0	747	4,129	12,047
Uruguay	0.5	36.5	56	7.3	2,161	5,108	2,577
R. B. Venezuela	2,581	553.9	-266	81.8	3,243	16,578	56,088

Notes: a) Oil Production includes the production of crude oil, natural gas plant liquids, and other liquids, and refinery processing gains. Negative data values indicate net refinery processing losses, b) Source is the International Energy Annual 2005 – IEA (2005).

3.19 The last two columns of table 3.8 have data on total carbon dioxide emissions from consumption of petroleum sources and emissions per capita. Not surprisingly largest countries have the most emissions in total. Countries with larger quantities of carbon dioxide emissions may encounter additional positive pressures to provide incentives for biofuels expansion. Identical situation may be argued for per capita emissions of carbon dioxide derived from petroleum products. Interestingly table 3.8 shows that most countries with high total emissions will also have relatively high emissions per capita.

3.20 Table 3.9 presents data on the ratio of domestic production to domestic consumption by crop and country. This ratio is one (albeit indirect) indicator of food security. This may also help understand additional incentives for countries to pursue a strong biofuels policy. Most LAC countries have positive ratios in the case of cassava and sugarcane. Note that Chile does not produce either crop. There are 4 countries whose consumption is greater than their own production in maize and oil palm. These countries may have trouble expanding their own biofuels production as they are in a production deficit already. The case of soybeans in particularly interesting as two countries, Brazil and Argentina are top world producers, whereas most LAC countries have production deficits. Expanding biofuels based on soybeans as a feedstock will be more difficult for those countries with current production deficits.

Estimating potential biofuel production using current production area and yield data

3.21 In this section we seek to answer two distinct questions of interest to LAC countries. The first one is how much of a country's current production needs to be set aside to meet its own expected mandatory biofuel blending requirements? The second one is: how much of any given country's fuel demand can be met by dedicating 100% of area harvested (and thus production) to biofuels? The later question can expressed alternatively as how much biofuels can be produced by setting apart 100% of current area planted to a particular crop. We provide a partial answer to these questions, taking into consideration current land area and yields.

3.22 The procedure used to answer the questions above, is to take data on current area and yield (See Annex 1) in order to estimate the potential production of ethanol and biodiesel in each LAC country, for those crops with significant area harvested in those countries.

Table 3.8 Selected Indicators of Energy Security and Environmental Drivers by Country

Country	Crude oil imports (1000s barrels per Day)	Apparent consumption of motor Oil (1000s Barrels per Day)	Dry natural gas production (1000s Barrels per Day)	Natural gas plant liquids production (Trillion Cubic Feet)	Carbon dioxide emissions from the consumption of petroleum (million metric tons of carbon dioxide)	Carbon dioxide emissions from the consumption of petroleum per capita (Metric tons of carbon dioxide per person)
Argentina	32.7	84.9	1.58	64.4	64.9	1.72
Bolivia	-	11.9	0.35	12.5	6.8	0.79
Brazil	351.2	277.5	0.34	61.5	257.7	1.44
Chile	200.2	48.7	0.04	5.0	31.8	2.02
Colombia	1.2	92.7	0.22	4.0	36.5	0.84
Costa Rica	10.6	13.6	-	-	6.0	1.47
Dom. Rep.	41.8	23.3	-	-	18.2	2.14
Ecuador	-	41.9	0.01	2.0	20.3	1.60
El Salvador	20.1	9.7	-	-	6.1	0.94
Guatemala	-	18.4	-	-	9.6	0.82
Honduras	-	7.5	-	-	5.6	0.83
Mexico	-	587.9	1.46	442.0	253.0	2.51
Nicaragua	17.9	3.9	-	-	4.2	0.81
Panama	-	9.4	-	-	12.8	4.18
Paraguay	1.6	3.9	-	-	3.9	0.68
Peru	83.6	19.1	0.03	14.2	22.4	0.84
Uruguay	32.8	5.8	-	-	5.6	1.65
Venezuela	-	208.4	0.96	180.0	75.0	2.97

Notes: Source of crude oil imports and apparent consumption of motor oil is EIA (2003). Rest of indicators in table extracted from EIA (2004), b) Emissions per capita of carbon dioxide is estimated from data in total emissions divided by population totals in Table 3.1.

Table 3.9 Ratio of domestic production to consumption

Crop	Cassava	Cottonseed	Maize	Oil palm fruit	Soybeans	Sugar Cane
Argentina	2.4	2.3	23.2	-	104.1	1.5
Bolivia	2.2	1.1	2.6	-	58.8	1.6
Brazil	3.2	1.9	10.1	1.2	7.1	3.0
Chile	-	-	4.3	-	-	-
Colombia	1.2	1.7	0.8	2.3	0.1	1.8
Costa Rica	20.6	0.9	1.0	12.1	-	1.8
Dominican Republic	1.1	-	0.6	0.8	-	1.6
Ecuador	1.4	6.2	4.3	1.8	0.4	1.5
El Salvador	1.0	0.3	1.1	-	0.0	2.4
Guatemala	1.1	0.4	0.9	14.9	0.2	4.0
Honduras	1.0	1.0	0.9	3.7	0.1	1.8
Mexico	1.1	1.9	1.5	0.2	0.1	1.3
Nicaragua	2.6	0.5	1.8	0.7	0.1	2.3
Panama	1.2	-	1.3	3.4	0.0	1.8
Paraguay	7.1	3.1	3.1	1.6	18.4	2.5
Peru	1.3	1.4	3.4	1.1	0.0	1.1
Uruguay	-	18.0	1.6		4.6	0.2
Venezuela	1.7	1.4	1.4	0.8	0.0	1.0

Source: a) FAOSTAT Supply Utilization Accounts (Average 2003-5 ratio), b) A number <1 implies a production deficit as it does not meet demand. These are highlighted in the table.

3.23 We make use of a set of assumptions with regard to biofuels yield extraction and conversion factors to take into consideration either volume or energy content with respect to fuels derived from petroleum sources[9]. The basic formulas to estimate maximum production of ethanol and biodiesel are presented in Annex 1. Results of our estimations are in Tables 3.10 through 3.13. Tables 3.10 and 3.11 present our estimations of potential production with current area harvested and the maximum share of current production for selected crops to meet mandatory or stated ethanol and biodiesel blending standards using yield per ton of feedstock. Note that we have been unable to document any actual or projected blending standards for Chile, Ecuador, Nicaragua and Uruguay for ethanol. In turn, Tables 3.12 and 3.13 present the results of our estimations of production and the maximum share of production for ethanol and biodiesel demand that could be met with all current area harvested, yield and extraction variables.

Question 1 What is the current crop production needed to meet mandatory blending requirements?

3.24 Table 3.10 shows that the best alternative for meeting the actual or stated blending standards for ethanol is sugarcane, followed by maize and cassava. Note that we were unable to document actual or stated blending requirements for Chile, Ecuador, Nicaragua and Uruguay. Furthermore, Chile and Uruguay did not harvest measurable amounts of sugarcane or cassava in the period contemplated in our data collection. These estimates maintain constant base assumptions with regard to area, yield and ethanol extraction. Changes in these variables will change these results.

3.25 Table 3.11 present results for meeting biodiesel blending requirements. Results in this table are limited as we were able to document very few countries with mandatory or stated blending requirements for biodiesel. In terms of those countries that do have a blending requirement, Colombia is able to supply a significant proportion of its biodiesel demand with current production of oil palm. In the case of soybeans, Argentina, Brazil and Bolivia would be able to meet their biodiesel blending requirements. However, the high costs of soybean oil may preclude such option. Finally, cotton seed is not a good alternative in any of the countries in Table 3.11.

Question 2 How much of any given country's fuel demand can be met by dedicating 100% of area harvested with current yields (and thus production) to biofuels?

3.26 Results in Table 3.12 show that the best alternative to produce ethanol is sugarcane, followed by maize and then cassava. Not surprisingly Brazil has the highest potential for biofuel production in terms of meeting ethanol demand, representing 167% of total production. This result does not consider vast areas of land not cultivated at the present time, outside to the Amazon region. In addition, other countries such as Guatemala, Nicaragua, and Paraguay would be able to meet their current demand for ethanol with current production. There would be a need to explore the tradeoff with sugar and alcohol production and other industrial uses from sugarcane production. In contrast maize shows mixed results in terms of potential. Countries such as Argentina and Paraguay exceed meeting their demand needs for ethanol with current production. Brazil and Nicaragua come close to meeting their ethanol demand, having maximum shares of 90% and 81% respectively. Low shares in other countries may be explained with low yields, relatively low ethanol extraction, or relatively

[9] We also estimated potential biofuels production using data available in the literature for yield of ethanol or biodiesel per hectare of land using values such as those presented in Figure 3.2. Annex 2 presents results of this exercise.

small harvested areas. As maize is a staple crop in many countries, estimations presented here need to be connected with energy demand and its outcomes explored in greater detail. We perform parts of this analysis in Section 4 of this report. Results in Table 3.12 also show that cassava is not a good option to produce ethanol, except in the case of Paraguay. The demand for ethanol met with cassava in Brazil and Peru is 26% and 15% respectively.

3.27 Results in Table 3.13 clearly show that the best alternative for biofuels production in terms of maximum diesel demand met is palm oil. In Colombia, Costa Rica, Ecuador and Honduras if the current area harvested is fully dedicated to biodiesel production, the maximum share of demand met varied between 19% in Ecuador to 32% in Honduras. As indicated in the description of the formulas used in the estimation of these values, current values used are base values for area harvested, yield and fuel extraction. Any changes in terms of any of these variables will indeed change these estimations. In turn this table shows that both soybeans and cotton seed are not very good alternatives except for soybeans in Bolivia, Brazil and Argentina. However, share of production varies between 36% and 100% in Argentina to meet current demand for biodiesel. Tradeoffs with demand for soybean oil for animal and feed consumption are certain. Cotton seed is clearly not a good alternative to produce biofuels. This result is a consequence of the low yields per hectare of cotton seed. As such, cotton seed has been a by-product of cotton lint production.

Institutional, Governance, Science and Technology Limitations for Biofuel Expansion

3.28 This section discusses institutional, governance and innovation limitations to biofuel expansion in Latin America and the Caribbean. The main trust of this section is to discuss existing and potential limitations at the country and regional levels.

Institutional and Governance Limitations

3.29 Countries in the Latin American and Caribbean region have advanced at a very different pace in establishing an institutional and regulatory framework for the development of a biofuels industry (See Table 3.14). For example, Brazil -a world leader in ethanol production- has had clear government involvement with strong incentives as an explicit polity to drive the ethanol industry at least since 1975. In contrast, there are many countries in the region that have not established biofuel policies to date. Of the 18 IADB member countries listed on Table 3.14, less than half have mandatory biofuel blends.

3.30 Brazil position as world leader in ethanol production is in great part the result of decades of government incentives that have enabled the private sector to invest heavily in the industry. In 1975, at the height of the oil prices, Brazil established the National Alcohol Program (ProAlcóol) with government involvement. Government facilitated building up several ethanol distilleries close to sugarcane mill, to be followed later by other distilleries for hydrated ethanol. In addition, the Brazilian government engaged the auto industry to manufacture engines that could run on ethanol. In essence, many incentives were put in place to involve all stakeholders to secure production, distribution, and consumption of ethanol.

3.31 ProAlcóol endured heavy losses due to declining oil prices in the 1980s, as this development made it difficult to compete with fossil fuels. In 1993, the Brazilian government established mandatory E5 blending requirements and introduced a set of tax breaks and other incentives in an effort to try to recover the ethanol industry from its mounting losses at the time.

Situation has changed significantly at the present time. With the current soaring oil prices, Brazil is using gasoline blended at a 23% with almost 2 out of every 3 new cars being flex-fuel, meaning they are capable of using several types of ethanol blends.

3.32 Aside from Brazil, to which no country in the region can compare in terms of the size of its ethanol industry, only Argentina and Colombia (and with less intensity Ecuador, Paraguay, Peru, and Uruguay) can show advances in establishing specific laws and/or regulations for biofuels. Colombia in particular now plays a lead role in production of biodiesel in the region and overall in the production of palm oil. According to the National Association of Palm Oil Producers (FEDEPALMA) tax breaks created by Law 939 of 2004 and other incentives have had a direct effect in creating the right channels to increase production. Parallel to these tax incentives the Colombian national government has started to eliminate costly gas subsidies, which will be fully phased out by 2009. All of these contributing factors have make it possible that by January 2008 not only the B5 mandatory blending will be met, but also that by 2010, according FEDEPALMA estimates, the palm industry will be able to guarantee blending of up to 15%. In Argentina, there is long history of enacted regulations, laws, or programs targeting biofuels production. Regulations and decrees enacted in 2001 established tax exemptions and blending standards. In early 2007, a law was enacted to enact a 5% biofuel blending standard, and establish subsidies and further fiscal incentives by 2010.

3.33 A pressing question for the rest of Latin American countries, which have not implemented regulations, is whether mandatory blending, subsidies and other policy instruments are necessary to provide incentives to the development of a nascent biofuel industry in their countries. Taking into consideration the long history of failed (untargeted) import substitution policies and subsidies, which in most cases crowded-out private investments, this question is of specially relevant to the region and is one that does not have an easy answer, nor a general answer for all the region. The case can be made for developing targeted subsidies for specific areas or targeted investments in terms of technology creation and dissemination. Interesting to note that for many of the countries where the government has set mandatory fuels blending, a pressing issue is whether governments that have enacted regulations will also commit the necessary resources to ensure that industry can reap the benefits from the application of the enacted regulations. An example of this public government problem may be Ecuador that has established a National Biofuels Program with specific fuel blending and required steps to move ahead with such a program. Nevertheless the resources to support these initiatives have not been made available by the Ecuadorian government. Finally, there is the set of countries, including many in Central America and the Andean regions, where not much progress has been made in terms of having a working regulatory system in place. Changes in this matter are most likely in their way and many lessons can be learned from neighboring countries, as most of the countries appear to have an interest in developing a biofuels policy to suit their needs.

Table 3.10 Current productions and share of current production selected target crops to meet mandatory or stated ethanol standards using yield per ton of feedstock

Ethanol			**Sugarcane**		**Cassava**		**Maize**	
Country	**Mandatory or stated blending standards (as %)**	**Ethanol requirements (1,000 lts)**	**If all production from targeted crop was destined for ethanol (1,000 lts)**	**% of current production to meet blending standards**	**If all production from targeted crop was destined for ethanol (1,000 lts)**	**% of current production to meet blending standards**	**If all production from targeted crop was destined for ethanol (1,000 lts)**	**% of current production to meet blending standards**
Argentina	5%	246,493	1,257,895	20	29,565	834	5,820,222	4
Bolivia	20%	137,797	172,254	80	63,088	218	232,708	59
Brazil	23%	3,704,658	26,832,202	14	4,150,064	89	14,465,627	26
Chile		-	-	-	-	-	465,036	0
Colombia	10%	538,032	2,547,799	21	336,048	160	594,013	91
Costa Rica	7%	55,065	247,328	22	54,940	100	4,745	1161
Dom. Rep.	5%	67,746	335,152	20	17,852	379	13,667	496
Ecuador		-	408,327	0	15,901	0	285,096	0
El Salvador	9%	50,657	303,234	17	3,214	1576	232,073	22
Guatemala	10%	106,874	1,172,087	9	2,783	3841	370,805	29
Honduras	30%	129,795	357,668	36	2,732	4752	165,473	78
Mexico	10%	3,411,838	3,014,932	113	4,174	81742	6,995,840	49
Nicaragua		-	259,947	0	18,471	0	182,842	0
Panama	10%	54,658	110,862	49	4,888	1118	30,904	177
Paraguay	20%	45,028	233,249	19	865,770	5	347,246	13
Peru	8%	86,430	478,869	18	167,246	52	439,756	20
Uruguay		-	9,672	0	-	-	76,431	0
Venezuela	10%	1,209,386	618,444	196	92,096	1313	716,819	169

Source: Authors estimations.

Table 3.11 Current productions and share of current production selected target crops to meet mandatory or stated biodiesel standards using yield per ton of feedstock

Biodiesel			**Oil Palm**		**Soybeans**		**Cotton seed**	
Country	**Mandatory or projected standards (as %)**	**Biodiesel requirements (Million lts/year)**	**If all production from targeted crop was destined for biodiesel (Million lts)**	**% of current production to meet blending standards**	**If all production from targeted crop was destined for biodiesel (Million lts)**	**% of current production to meet blending standards**	**If all production from targeted crop was destined for biodiesel (Million lts)**	**% of current production to meet blending standards**
Argentina	0.05	331.85	-	-	6,668	5	33.3	996
Bolivia	0.1	46.3	-	-	323	14	8.2	563
Brazil	0.05	1366.25	114.9	1189	9,776	14	221.1	618
Chile		0	-	-	-	-	-	-
Colombia	0.05	102.9	624.2	17	15	704	10.9	943
Costa Rica		0	141.3	0.0	-	-	0.03	0.0
Dominican Republic		0	33.1	0.0	-	-	-	-
Ecuador		0	374.0	0	18	-	0.3	0.0
El Salvador		0	-	-	0	-	0.2	0.0
Guatemala		0	123.6	0	7	-	0.3	0.0
Honduras		0	238.6	0	31	-	0.2	0.0
Mexico		0	46.6	0	1	-	30.9	0.0
Nicaragua		0	11.8	0	0	-	0.3	0.0
Panama		0	13.4	0	259	-	-	-
Paraguay		0	26.4	0	1	-	23.7	0.0
Peru		0	40.5	0	0	-	6.9	0.0
Uruguay	0.05	26.1	-	-	71	37	-	-
Venezuela	0.05	83.8	61.0	137	1	11,963.3	2.01	4029

Source: Authors estimations

Table 3.12 Current production and maximum share of ethanol demand satisfied with selected crops using yield per ton of feedstock

		Sugarcane		Cassava		Maize	
Country	**Ethanol requirements (1,000 lts/year)**	**If all production from targeted crop was destined for ethanol (1,00 lts)**	**% of current ethanol demand potentially met with current production**	**If all production from targeted crop was destined for ethanol (1,00 lts)**	**% of current ethanol demand potentially met with current production**	**If all production from targeted crop was destined for ethanol (1,00 lts)**	**% of current ethanol demand potentially met with current production**
Argentina	4,929,870	1,257,895	26%	29,565	1%	5,820,222	118%
Bolivia	688,985	172,254	25%	63,088	9%	232,708	34%
Brazil	16,107,211	26,832,202	167%	4,150,064	26%	14,465,627	90%
Chile	2,823,754	-	0%	-	0%	465,036	16%
Colombia	5,380,323	2,547,799	47%	336,048	6%	594,013	11%
Costa Rica	786,637	247,328	31%	54,940	7%	4,745	1%
Dom. Rep.	1,354,914	335,152	25%	17,852	1%	13,667	1%
Ecuador	2,429,080	408,327	17%	15,901	1%	285,096	12%
El Salvador	562,852	303,234	54%	3,214	1%	232,073	41%
Guatemala	1,068,741	1,172,087	110%	2,783	0%	370,805	35%
Honduras	432,650	357,668	83%	2,732	1%	165,473	38%
Mexico	34,118,379	3,014,932	9%	4,174	0%	6,995,840	21%
Nicaragua	225,141	259,947	115%	18,471	8%	182,842	81%
Panama	546,577	110,862	20%	4,888	1%	30,904	6%
Paraguay	225,141	233,249	104%	865,770	385%	347,246	154%
Peru	1,108,073	478,869	43%	167,246	15%	439,756	40%
Uruguay	337,711	9,672	3%	-	0%	76,431	23%
Venezuela	12,093,860	618,444	5%	92,096	1%	716,819	6%

Source: Authors estimations.

Table 3.13 Current production and maximum share of biodiesel demand satisfied with selected crops using yield per ton of feedstock

		Oil Palm		Soybeans		Cotton seed	
Country	**Biodiesel requirements (Million lts / year)**	**If all production from targeted crop was used for biodiesel (Million liters)**	**% of current biodiesel demand potentially met with current production**	**If all production from targeted crop was used for biodiesel (Million liters)**	**% of current biodiesel demand potentially met with current production**	**If all production from targeted crop was used for biodiesel (Million liters)**	**% of current biodiesel demand potentially met with current production**
Argentina	6,637	-	0	6,668	100%	33.3	1%
Bolivia	463	-	0	323	70%	8.2	2%
Brazil	27,325	114.9	<1	9,776	36%	221.1	1%
Chile	3,207	-	0	-	0%	-	0%
Colombia	2,058	624.2	30	15	1%	10.9	1%
Costa Rica	610	141.3	23	-	0%	0.0	0%
Dom. Rep.	682	33.1	5	-	0%	-	0%
Ecuador	1,931	374.0	19	18	1%	0.3	<1%
El Salvador	519	-	0	0	0%	0.3	<1%
Guatemala	854	123.6	14	7	1%	0.3	<1%
Honduras	753	238.6	32	31	4%	0.2	<1%
Mexico	8,726	46.6	<1	1	<1%	30.9	<1%
Nicaragua	353	11.8	3	0	0%	0.3	<1%
Panama	643	13.4	2	259	40%	-	0%
Paraguay	986	26.4	3	1	<1%	23.7	2%
Peru	2,213	40.5	2	0	0%	6.9	<1%
Uruguay	522	-	0	71	14%	-	0%
Venezuela	1,676	61.0	4	1	<1%	2.1	<1%

Source: Authors estimations.

Table 3.14 Selected Institutional and Governance Indicators

Country	Biofuels Regulatory framework in place	Biofuels related laws	Incentives and Tax Breaks	Mandatory fuel blending standards	Year starting	Potential crop	Foreign investment	Operational ethanol distilleries	R&D investment
Argentina		Ley de Biocombustibles (SFL) 26-093 2006	Exempt of assumed minimum gain tax and hydrological infrastructure rates	5% (art 7 & 8, SFL), equivalent to 600 mill lt biodiesel 250 mill lt ethanol	2010	Soybeans, Sugarcane, Maize	Repsol, Probable Japan Mitsui	20	Repsol, plans for a Research Center
Bolivia		Regulations approved by congress		10-25% alconafta	2010	Sugarcane		0	very little
Brazil	Brazilian National Alcohol Program, ProAlcóol, launched in 1975	Strong government involvement and investment. Innovation Law of 2004. States programs with own incentives.	Many incentives in place, reinforced in 1993, along with deregulation of the sector	Mandatory since 1993, 20-25% for ethanol, and 3% for biodiesel for 2008	1993	Sugarcane, Palm oil, Cotton, Castor	Substantive investing from France and Japan firms, as well as from many other countries.		Ministry of S&T has invested heavily in the sector (i.e. in 2004 invested $4 mill in biofuels related programs). Private sector plays a major role investing R&D (around least 75% of total)
Chile		Biofuels under development, Renewables Law 2003				Rapeseed?	Petrobras has shown interest		

Table 3.14 Selected Institutional and Governance Indicators

Country	Biofuels Regulatory framework in place	Biofuels related laws	Incentives and Tax Breaks	Mandatory fuel blending standards	Year starting	Potential crop	Foreign investment	Operational ethanol distilleries	R&D investment
Colombia	2004 first steps to develop	Law 693 2001. Law 788 2002, other regulations	no VAT	10% ethanol blend	25% target next 20 years	Palm oil , Sugarcane Cassava	Svenks ethanol / signed agreement between Ecopetrol and Petrobras	5	Corpodip
Costa Rica		Law 7447 1994		Established in 2005, declared unconstitutional later		Sugarcane, Cassava, Palm oil			
Dominican Republic		Decree 732 2002	100% tax exemptions, grants10 year income tax holiday for business	5% ethanol	2006	Sugarcane, Maize, Cassava			
Ecuador		Decree 2332 (Programa de Biocombustibles		5% ethanol (one city) 10% biodiesel	2006 ? 	Sugarcane, Palm oil, Cassava Maize,			
El Salvador		in the making	tariff-free imports, and tax exemptions	8 to 10% ethanol	2007	Sugarcane, Maize, Sorghum			
Guatemala	lack of a clear reg. framework			(5% min ethanol, for new distilleries, currently producing at 10%)		Sugarcane, Maize, Palm oil			

Table 3.14 Selected Institutional and Governance Indicators

Country	Biofuels Regulatory framework in place	Biofuels related laws	Incentives and Tax Breaks	Mandatory fuel blending standards	Year starting	Potential crop	Foreign investment	Operational ethanol distilleries	R&D investment
Honduras	draft of legal framework					Palm oil, Sugarcane, Maize	Grupo Pellas (Nicaragua) to invest $150 mill sugarcane for ethanol.		All run by foreign investors
Mexico	2006		VAT exempts, plus others	8% renewable energy use	2012	Sugarcane, Maize,			
Nicaragua	None	biofuels declared a national strategic interest (Decree 42 2006)				Sugarcane, Cassava,			Nat. U of Engineering and Petronic researched alternatives Jatropha
Panama	None			Proposed 10% blend	2008	Sugarcane, Soybeans, Cassava			
Paraguay	Launched ethanol program in 1999	Biofuel Law 2005	reduced standard fuel tax of 50% to 10%	20% raised to 24%		Cassava, Sugarcane, Maize			
Peru	2003 PMB Law, 2005 Supreme decree 03	Program for biofuels promotion		7.8% ethanol 5% biodiesel	Current	Cassava, Sugarcane,			
Uruguay	2003 law 17-567	national biofuels commission				Wheat, Soybeans, Maize			
Venezuela	None	Plan 474 2006, sugarcane				Sugarcane, Cassava Maize			

Innovation, Science and Technology Capacity Issues

3.34 Expansion of biofuels in LAC countries will require significant innovative and science and technological capacity to develop the productive infrastructure, but also to enhance productivity of target crops, improve the efficiency of distillation and esterification processes and others. Innovative and S&T capacity will become more critical as pressures mount for development of 2^{nd} generation ligno-cellulosic technologies and, in some cases, the need to incorporate genetic modifications including enhancing metabolic pathways, modifying lignin content in plant tissues and other architecture modifications.

3.35 Table 3.15 covers basic indicators of innovative capacity in LAC countries. The level of R&D expenditures as a percent of GDP is rather low in most countries (less than 0.4%). The highest levels of investment occur in Brazil (0.97%), Chile (0.58%) and Argentina (0.42%) and Mexico (0.4%). Although there are significant gaps in terms of data, the number of scientists per million persons, more or less track the rate of investments in R&D. Most countries invest significant amounts in education, having education rates of expenditures above 4% of GDP. This level of investments is tempered by the extremely low graduation rates –data not presented here- at primary, secondary and tertiary education levels, therefore, questioning the effectiveness of the associated levels of investment. Examination of indirect measurements of capacity such as computers per million persons or of outcome such as publications in peer reviewed and other technical journals, serve to provide support to the emergent story of a set of countries with significant innovative and science, technology and innovation (ST&I) capacity, compared to the rest of LAC countries. This block of leader countries include Brazil, Argentina, Chile and Mexico. A second level of countries in terms of ST&I capacity are Colombia, Venezuela and to a slightly lesser degree Peru. Two notable exception are Costa Rica and Uruguay, which have significant investments in education and computer use by its population, significant outputs in terms of publications and have a track record of research teams performing advance research such as marker assisted selection and genetic modifications. This capacity may be hampered by the small size of the country, which limits the potential markets for products of innovative system in-country.

3.36 We have examined in great detail the internal capacity to produce agricultural feedstock that may be transformed into biofuels in LAC countries. As we have seen from our estimations in Tables 3.12-3.15, the capacity to deliver sufficient feedstock material is determined by the area planted/harvested, yield per unit of land, extraction efficiency of ethanol or biodiesel. The area planted/harvested is limited by the physical size limitations that each country has in terms of total land and land available for agriculture, as well as, land that if suitable for production of a particular target crop. Extraction efficiency is eminently an industrial process, where the existing procedures such as ethanol distillation or biodiesel esterification is improved through innovations made by the ST&I capacity in country or abroad. Improvements in enzymatic or catalytic processes are indeed possible and in fact are being implemented. In turn, the ability to exploit 2^{nd} generation technologies such as ligno-cellulosic approaches, will be the result of a combination of plant architecture modifications, improvements in distillation and enzymatic processes. These demand significant R&D and ST&I capacity in country, or the ability to tap unto other countries for such capacity.

3.37 The corollary of these developments is an increased need to have appropriate plant genetic resources available to a particular country, as well as, the ability to use this material. This implies significant capacity to characterize existing *ex situ* and *in situ* plant genetic resources, ability to preserve existing collections and the ability to use these resources in an efficient and sustainable

manner. Policy implication of this basic need is the need to have a very good in-country capacity for the conservation, preservation and use of plant genetic resources. These include significant capacity to implement plant breeding and/or biotechnology programs in country. The specific mix of plant breeding and biotechnology techniques that may be used by a particular country will depend on the existing innovative and S&T capacity, specific crop productivity limitations, whether countries have exhausted more conventional approaches, and of course the economic considerations that may affect this decision.

3.38 In the specific case of plant breeding and biotechnology, we know that seed systems and other delivery mechanisms matter quite significantly. In fact, the paper by Atanassov *et al*. (2003) and Cohen (2005) argue quite strongly that most public sector institutions have not yet been successful in transferring GM crops to farmers. There are significant investments needed to transfer the technology to farmers in terms of obtaining biosafety regulatory approval, post-release monitoring, knowledge sharing about technology use, etc, which needs to accompany the technology to maximize its value to farmers (see Tripp 2003 and Falck Zepeda 2006 for a similar argument). Public sector institutions need to find alternative strategies to deal with this new technology transfer environment.

3.39 In Table 3.16 we present selected indicators of biotechnology, biosafety and seed systems' capacity by country, for LAC countries included in our report. The intention here is not to pursue a formal systems analysis such as those done by Trigo (2003) and Fuglie and Pray (2000) of the more formal innovative capacity analysis of Furman, Porter and Stern (2003). This type of analysis is being pursued in a separate project examining biotechnology capacity in LAC countries, currently being implemented by IFPRI and other partners for IADB. Rather, the intention is to point out a couple of very simple observations from the indicators presented in Table 3.16.

3.40 First, eleven of the 18 countries in this table have conducted a confined field trial, which is a very good indicator that proponents intend to move forward with the research project in hand. However, only 7 of the 18 have approved crops for commercialization. A special case is Chile where crops are being planted, mostly to reproduce seed taking advantage of the ability to plant in the off season in the northern hemisphere, but it is not clear whether planting of GM crops is indeed allowed to Chilean producers. Second, one of the main limitations for developers or proponents of GM technologies, in LAC countries and elsewhere, is compliance with biosafety regulations. Proponents of those GM technologies for commercialization need to submit to the appropriate regulatory authorities data on the environmental and food safety characteristics of the GM technology. This process may imply significant investments to generate and/or gather data to demonstrate a socially accepted level of safety. This may imply a limitation to public sector and in-country private sector, which may have resource limitations to complete the regulatory stages described in Table 3.16.

3.41 Third, assuming that countries are able to overcome the innovative and ST&I limitations currently in place, the ability to transfer technology to final users is very limited in LAC countries. Although the data available is very incomplete, with the existing data we can observe significant limitations in terms of potential seed markets and investments in capacity to take seed technologies from the R&D system and market them to farmers. This will prove to be a significant limitation to biofuel expansion in Latin America and the Caribbean. Finally, although countries such as Honduras, Bolivia, Paraguay and others may be able to benefit from the spillovers of technologies created elsewhere, there is the need to create a sustained stream of appropriate plant genetic resources and of biotechnologies to address those constraints not easily addressable through conventional means. As

some of these countries, have significant limitation in terms of size and potential demand, there may be the need to revive and strengthen regional and other approaches to address productivity constraints. Public- private, public-public transfer of technologies, taking advantage of established capacity in leader LAC countries such as Brazil, Mexico or Argentina, as well as other innovative approaches to technology dissemination are just one of the few approaches worthwhile examining in greater detail.

3.42 Although we will discuss in greater detail policy issues and options in the final section of this report, it is worthwhile to re-emphasize that biofuels expansion will be directly tied to the capacity of agriculture to expand its current production possibilities frontier. In addition, there will be the need to firmly situate biofuels, biotechnology, agricultural, plant genetic resources and energy policies within the overall economic development framework in each country. Biofuel policies cannot be disassociated from these other components of a country's strategy for development. People, organizations and the State itself, respond to incentives. Once a country defines its priorities and through strategic assessments, it is a matter of defining the appropriate policy approaches to accomplish these objectives.

3.43 We discuss in detail such policy instruments and issues in Section 5, although we re-affirm the need to implement on a country-by-country basis, a more detailed analysis of the situation in order to derive responses to specific issues in country. In particular, there is a pressing need to define the business and development model (or models) that countries intend to implement. Development of a biofuels policy for agricultural development can follow a portfolio of implementation plans that vary from intensive commercial development of biofuels for replacement of fossil fuels all the way to community development projects that provide additional income while diversifying production possibilities for the community. Of course, any combination of these business models is indeed possible. What is important is for countries to have a clear view of what they intend to do and how. Advancing plans and business models for the deployment of biofuels does not seem to be as clear as desired in the region.

Table 3.15 Selected Indicators of Innovative Capacity

Country	R&D expenditures (% of GDP)	Researchers in R&D (Number per million people)	Public expenditure on education(% of GDP)	Average publications scientific/tech. journals 1986-1999 (Number)	Number of Personal Computers (Number per 1,000 persons)	Enrollment in third level education (Number)	Enrollment in third level education per million inhabitants (Number per million persons)
Argentina	0.42	706	4.2	1837	81	1,953,453	51,901
Bolivia	0.29	97	6.0	18	24	315,146	36,382
Brazil	0.97	344	4.3	3166	75	3,370,900	18,843
Chile	0.58	423	4.0	838	114	530,429	33,632
Colombia	0.18	93	4.8	149	50	1,000,065	22,978
Costa Rica	0.36	n.a.	4.8	62	197	81,277	19,853
Dom. Rep.	n.a.	n.a.	2.1	7	0	290,260	34,087
Ecuador	0.06	45	1.2	22	35	206,541	16,301
El Salvador	0.08	39	2.7	2	29	114,954	17,625
Guatemala	n.a.	n.a.	n.a.	20	15	111,739	9,533
Honduras	0.05	n.a.	n.a.	6	13	108,094	16,045
Mexico	0.40	248	5.3	1585	83	2,143,461	21,254
Nicaragua	0.05	n.a.	3.5	7	30	100,140	19,389
Panama	0.35	97	4.4	34	38	122,510	40,000
Paraguay	0.09	83	4.6	6	36	117,623	20,485
Peru	0.10	n.a.	2.9	66	59	847,856	31,684
Uruguay	0.25	287	2.7	84	115	98,579	29,073
R.B. Venezuela	0.38	n.a.	n.a.	389	62	859,720	34,090

Notes: Sources: a) USAID-LAC Social and Economic Indicators (2007), UNESCO (2007), CEPAL/ECLA (2006), World Bank Development Indicators (2006). b) Enrollment in third level education per million persons was estimated by authors from data contained in sources cited previously. c) Indicators presented here are averages from 2001-2003, with the exception of enrollment in third level education which is for 2003.

Table 3.16 Selected Indicators of Biotechnology, Biosafety, and Seed Systems Capacity

		Biosafety Has each regulatory stage been approved and/or implemented in-country?							
Country	**Number of crops where field trials have been conducted – Total**	**Laboratory / Greenhouse / Contained**	**Confined Field Trials**	**Commercialization Approval / Plantings**	**Area Planted to GM crops 2006 (1000 Hectares)**	**Intensity seed systems regulatory intervention (6= highest 1 = Lowest)**	**Value internal seed market (Million US$)**	**Seed imports (Million US$ FOB)**	**Seed exports (Million US$ FOB)**
Argentina	7	Y	Y	Y	1800	6	930	39	56
Bolivia	1	N	N	Y		4	35	6	2
Brazil	8	Y	Y	Y	1150	5	1,500	50	52
Chile	13	Y	Y	Y/N	0	5	120	26	171
Colombia	8	Y	Y	Y	25	6	40	14	3
Costa Rica	4	Y	Y	N	0	4	n.a.	7	8
Dominican Rep.	0	N	N	N	0	3	7	2	n.a.
Ecuador	0	N	N	N	0	6	12	8	n.a.
El Salvador	0	N	N	N	0	1	n.a.	n.a.	n.a.
Guatemala	2	Y	Y	N	0	6	n.a.	9	14
Honduras	2	Y	Y	Y	4-5	n.a.	n.a.	n.a.	n.a.
Mexico	6	Y	Y	Y	100	2	350	372	109
Nicaragua	0	N	N	N	0	6	n.a.	n.a.	n.a.
Panama	0	N	N	N	0	6	n.a.	6	n.a.
Paraguay	1	N	N	Y	2000	5	70	11	n.a.
Peru	1	Y	N	N	0	4	30	8	12
Uruguay	5	Y	Y	Y	400	5	70	19	3
R. B. Venezuela	4	Y	N	N	0	5	n.a.		

Notes: a) Source of data from authors information, Trigo (2003), James (2006) and SeedQuest (www.seequest.com) and others.

4. QUANTITATIVE ASSESSMENT OF POTENTIAL AND IMPACTS BIOFUELS GROWTH IN LATIN AMERICA AND THE CARIBBEAN

4.1 This section covers a forward-looking quantitative analysis of the potential for biofuels growth in Latin America and the Caribbean (LAC) using the IMPACT-WATER simulation model developed by IFPRI. In this study we evaluate the plausible growth trajectory of biofuels production in Latin America and the Caribbean, with a special view to its implications for the agricultural economies and markets within the region. In this report we also highlight some key implications for critical natural resources, such as water, and the potential that biofuels markets can have in relieving the pressure on agricultural food and feed supply within the region, and on the feedstock prices themselves.

4.2 This study provides an enhanced assessment of biofuel potential in Latin America, using a quantitative basis that is more complete than those which have been previously applied to this kind of study. By combining a global agricultural sector model (the IMPACT-WATER model) with a representation of energy demand and trade in biofuel products, we attempt to provide a complete picture of how both agricultural and energy markets might be affected by alternative growth trajectories for biofuel production (and utilization) within the LAC region.

4.3 The quantitative framework that we have designed for this study allows us to explore the following kind of issues:

- What are the impacts of biofuels growth on agricultural prices?
- What are the likely changes in irrigated and rain fed crop area and production, under these scenarios, and what implications do they have for total land use impacts[10]?
- What are the implications for trade in both agricultural feedstock markets and in the markets for the biofuels products, themselves?
- What are the implications for consumptive water use in agriculture, under these biofuels growth scenarios?
- What are the impacts on food security and malnutrition?

4.4 In our choice of methodology, we have sought to balance the needs of rigor and comprehensive scope of the relevant issues with the limitations of data availability and the ultimate aim of providing a relatively straightforward approach that could be adapted to the quantitative scenarios that were designed for this study. While accommodating these needs has not been easy, we have attempted to highlight the simplifying assumptions in our analysis, and to make the design of model scenarios as transparent as possible, so that they can be revisited in later extensions of this work.

Quantifying Growth Potential for Biofuels in Latin America

4.5 In this section, we explain, in greater detail, the quantitative framework in which we evaluate the potential for biofuels expansion in Latin America and the Caribbean. In addition to

[10] It should be noted that the forward-looking analysis only encompasses agricultural land use and cropping patterns. Projections for non-agricultural land uses are not captured in IFPRI's current modeling framework.

giving the general structure of the analytical approach that is used in this study, we also highlight the important features of the quantitative framework, as well as some key underlying assumptions that govern the behavior of the economic models. Some linkages between the model components are brought out, although it should be noted that they are rather 'soft' – and involve the passing of information from one component to another, rather than simultaneous numerical computation. By describing how the various components of the quantitative framework are connected, we aim to give a better appreciation for the complexity of the relationships involved, and some key factors which underlie the results that we will consider in the scenario analysis.

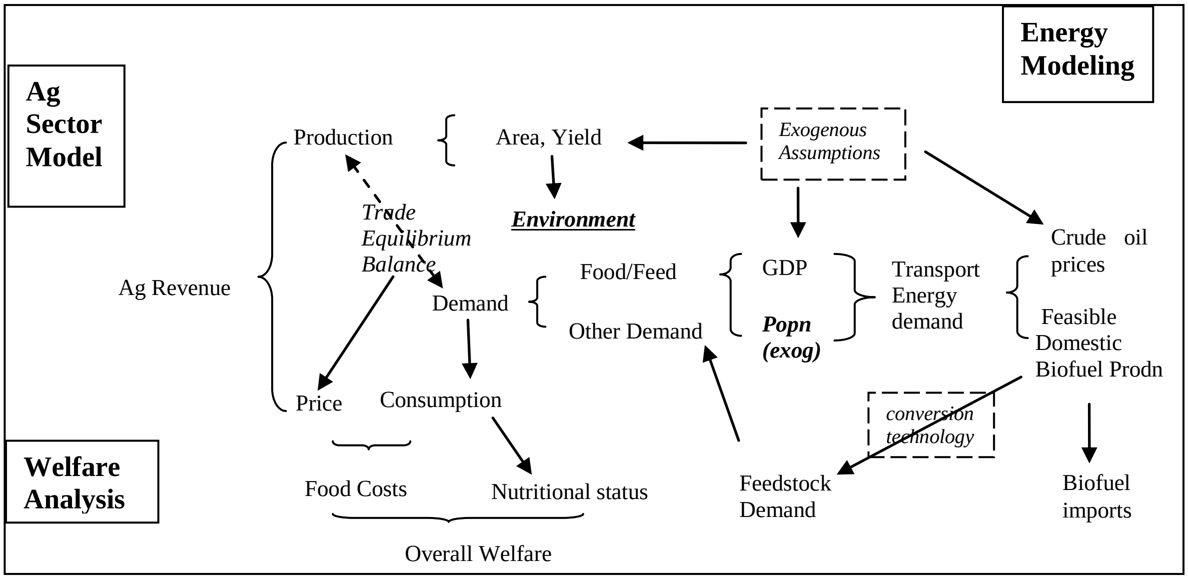
Outline of the Quantitative Scheme

4.6 In this study, we have attempted to bring together a number of key analytical components, to better understand the inter-linkages between agricultural and energy markets, in the study of biofuels growth potential in Latin America and the Caribbean. The main modeling components that were used in this study are the following:

- A global agricultural production and trade model
- A quantitative representation of future crude oil prices on the world market
- A quantitative relationship between energy demand for transport and the socio-economic growth patterns of income and population, over time.
- A simplified spatial equilibrium model of ethanol and biodiesel trade

4.7 A schematic which illustrates how the various modeling components are linked together in order to provide the overall quantitative framework of analysis is included in Annex 3. The key 'drivers' of change within the quantitative framework used, in this study, are those of socio-economic growth in national income and population, which are taken from projections provided by the "Technogarden" scenario of the Millennium Ecosystem Assessment (MA, 2005), and by the medium variant population projections of the UN Statistics Division, respectively. The model linkages shown in Figure 4.1 illustrate how the various components of the energy and agricultural sector modeling are tied together.

Figure 4.1 Graphical Schematic of Quantitative Modeling Components



4.8 From the Figure 4.1 above, we see the translation of energy demands for biofuels into tonnage of feedstock crops, which is expressed within the agricultural trade model as a demand for 'other' uses (besides food and feed). This increase in demand causes the supply side of the agricultural model to adjust, in terms of area, production and crop prices, while there might also be adaptation within energy markets, through trade in the biofuel products themselves.

4.9 Among the exogenous assumptions that can be changed, are those governing patterns of yield productivity improvement and population or policy-driven changes in land use that might affect the potential expansion of agricultural area. These affect the supply side of the agricultural model, directly, and provide an entrée for technological or policy intervention[11].

Modeling Assumptions

4.10 Among the assumptions that will be maintained in this analysis, are the following:

- That markets for both agricultural and biofuel commodities are competitive, and amenable to analysis with a straightforward equilibrium-driven approach;
- All agricultural and biofuel commodities will be treated as homogenous in quality and characteristics (for consumption), and are not differentiated by quality from countries of origin;
- We use the historical trend of environmental variables, such as precipitation, to represent their future realizations in our simulations and do not simulate additional future variability or other changes to the observed trend in our analysis;

[11] Policies affecting energy markets and trade of energy products could also be interventions, but are not explored in this study.

4.11 The geographical regions that will be considered for this study were listed in Table 3.1. As described before a number of Latin American countries are aggregated into larger regions. This is necessary, due to the numerical challenges of solving a global policy simulation model with many regions (currently 281 separate spatial units). The details of the policy modeling framework will now be described in the following section. A more detailed description of the IMPACT-WATER model, as well as, the energy, trade projections are given in the Annex 3.

Scenario Analysis of Biofuels Growth

4.12 In our scenario analysis we seek to capture a number of key projections-based indicators of biofuel growth potential and impact that cannot be captured in a more 'static' set of statistics. In particular, we seek to bring out the implications of growth in crop-based biofuel production for food availability, land and water use, as well as for agricultural market conditions.

4.13 Among the key simulation-based indicators that we will bring out in this section are the following:

- Changes in agricultural prices from baseline levels
- Changes in irrigated and rain fed crop area and production from baseline, and implications for land use
- Shifts in trade patterns within agricultural feedstock markets
- Changes in trade movements within the markets for the biofuels products, themselves
- Impacts on consumptive water use in agriculture, as differences from baseline
- Implications on food security and malnutrition status
- The impacts on gross agricultural revenue, as differences from baseline

4.14 In all these cases, the 'baseline' is a reference run, in which there is no accelerated growth in agricultural commodity demand due to biofuel usage – but, rather, a smooth pattern of proportional growth in the 'other' demand category, according to movements in food and feed utilization levels[12]. Given the fact that the IMPACT-WATER model does not directly deal with crop residues or grasslands, we cannot directly model a scenario in which there is non-food crop biofuel production with ligno-cellulosic technologies. Nonetheless, we will discuss some quantitative results that were produced by the IMAGE model (Hoogwijk *et al.*, 2005), and discuss its implications for the Latin American region, in juxtaposition with our own model results.

Baseline Model Characteristics

4.15 We characterize the baseline situation for our quantitative assessment by describing the allocation of production characteristics for the key biofuel crops in the Latin American region. A complete list of the baseline production, net trade and demand (including utilization shares) is shown in Annex 4. As irrigated and total harvested area, are significant towards explaining the results of our scenarios, we describe them in greater detail below.

[12] Recall that total demand for a commodity is divided into 'food' (human consumption), 'feed' (livestock consumption) and 'other' (which comprise industrial or other uses which are not directly consumed for nutrition).

4.16 The distribution of irrigated area used as a baseline is given in Table 4.1. This table shows a heavy concentration of irrigated grain production in Chile, where all of the existing maize and wheat area is under irrigation. The difference between the agro-ecological conditions in Latin America can be seen from the fact that only 14% of Brazil's sugarcane is irrigated, compared to the share of sugar crop area under irrigation that we observe in the aggregate Central America and Caribbean region, Uruguay, Peru and the Northern South America region – which range between 40-50% of cropped area.

4.17 For grain crops, we see a similar divergence between the low shares of irrigated maize area in Argentina and the Central Caribbean region, compared to the large shares in Ecuador, Mexico the aggregate Northern South America region, and Peru. From these contrasting patterns of irrigation, we can see that an expansion of grain or sugar crop area to accommodate greater ethanol production – even by the same amount – will represent very different implications for the change in water use consumption in agriculture across these countries. Those with higher shares of irrigation will increase their consumptive use more quickly, for a unit increase in area, compared to those countries that have lower intensities for irrigation.

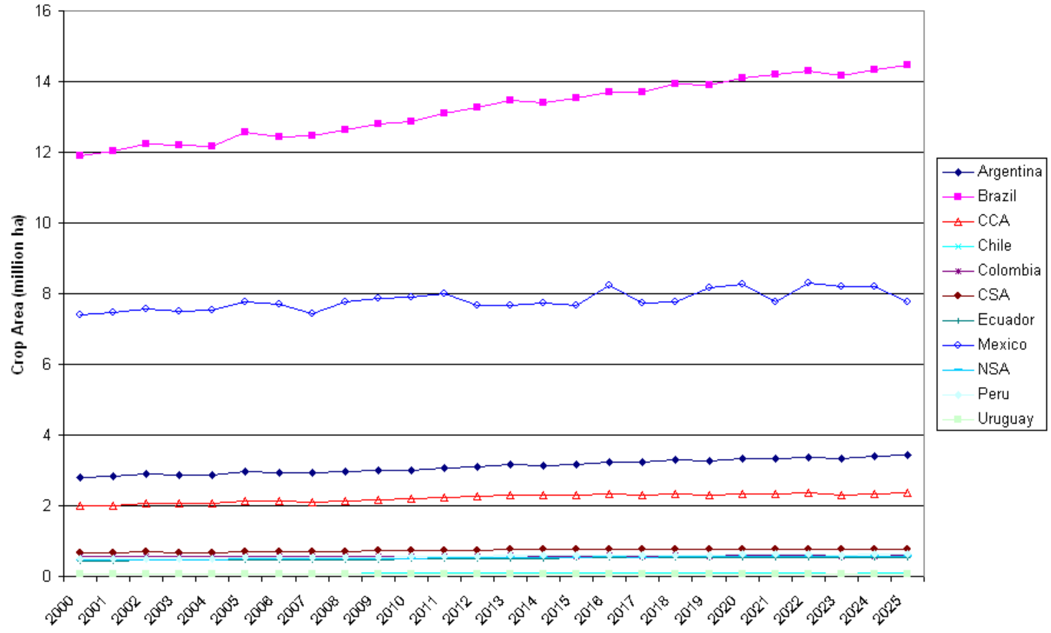
Table 4.1 Irrigated and Total Harvested Crop Area in Latin America for Key Ethanol Feedstock Crops (year 2000)

Country/Region	Crop	Irrigated Area (000 ha)	Share of Total
Argentina	wheat	110.1	2%
Argentina	maize	424.3	15%
Argentina	sugarcane	128.8	40%
Brazil	wheat	10.2	1%
Brazil	sugarcane	787.1	14%
Central America and Caribbean	wheat	3.1	52%
Central America and Caribbean	maize	33.4	2%
Central America and Caribbean	sugarcane	727.7	41%
Central South America	sugarcane	48.6	30%
Chile	wheat	379.5	100%
Chile	maize	74.8	100%
Chile	sugar beet	43.6	83%
Colombia	wheat	9.2	52%
Colombia	maize	40.5	7%
Colombia	sugarcane	148.7	34%
Ecuador	wheat	9.9	42%
Ecuador	maize	234.3	54%
Ecuador	sugarcane	40.2	49%
Ecuador	sugar beet	0.2	36%
Mexico	wheat	317.8	47%
Mexico	maize	3372.9	46%
Mexico	sugarcane	267.9	36%
Northern South America	wheat	0.7	53%
Northern South America	maize	245.9	54%
Northern South America	sugarcane	116.8	58%
Northern South America	sugar beet	0.3	36%
Peru	wheat	13.9	10%
Peru	maize	353.5	72%
Peru	sugarcane	31.9	48%
Uruguay	wheat	28.6	19%
Uruguay	maize	21.5	41%
Uruguay	sugarcane	1.3	43%

Notes: 1) Central American and Caribbean includes: Costa Rica, Dominican Republic, El Salvador, Guatemala, Haiti, Honduras, Nicaragua, Panama, 2) Central South America includes Bolivia and Paraguay. 3) Northern South America includes Guyana, Suriname and Venezuela.

4.18 If we look at the growth of total maize area, under baseline model assumptions, in Figure 4.2 below, we see that the projected growth of Maize area in Brazil is more pronounced than that in other countries or regions of Latin America, such as Mexico, Argentina or Central America and the Caribbean.

Figure 4.2 Projection of Maize Area in Latin America under Baseline Growth

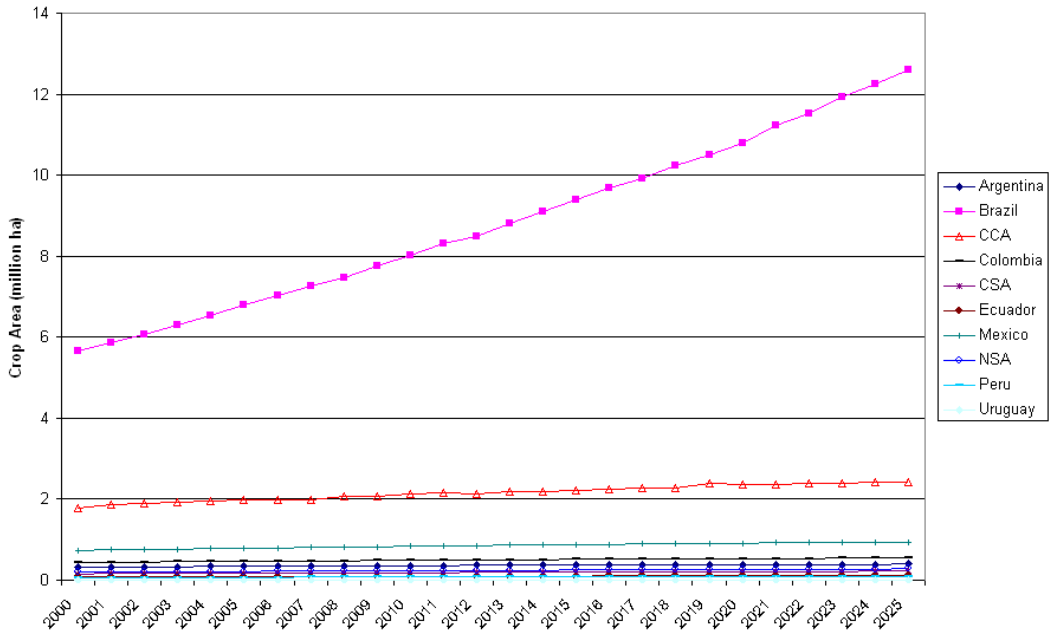


Source: IMPACT-WATER projections.

4.19 Taking into consideration the baseline areas, prices and other structural parameters, IMPACT-WATER is capable of estimating area expansion over time for a baseline growth situation and for the scenarios included in the simulations. 'Baseline' growth trajectories assume proportional growth of industrial uses of crops to that of food and feed uses, such that there are no specific assumptions or drivers related to growth in biofuel production. The basic "baseline" trajectories will be compared with those under two specific biofuel growth (stable and fast) scenarios, so as to see the impacts on growth of area, yield, production, price and other indicators. As indicated previously, we considered three distinct scenarios where expansion occurs for ethanol only, biodiesel only and a combined ethanol and biodiesel situation. A schematic of the resulting 6 scenarios are shown in Figure A4.1 in Annex 4.

4.20 The area expansion trajectory for sugarcane growth (Figure 4.3, below) shows a much more aggressive trajectory for Brazil, which leads the rest of Latin America in both sugar production and exports to global markets. As would be expected, the fact that Brazil's production of sugar far exceeds its consumption allows for a large surplus that is available for raw exports or for conversion to ethanol. While Brazil's exports of sugar are quite large, in comparison to its domestic consumption, its domestic demand for ethanol is a much higher percentage of its own production, and remains so throughout the projection period that we consider.

Figure 4.3 Projection of Sugarcane Area in LAC under Baseline Growth



Source: IMPACT-WATER projections.

Ethanol-Focused Scenarios

4.21 Given the prominence of ethanol in global biofuel production, we have devoted attention to how the path of production growth might evolve within Latin America, and the rest of the world. In one scenario the major world ethanol producers (like Brazil and the US) continue along a strong trajectory of growth, while those Latin American countries which have significant levels of ethanol production remain at a fairly stable trajectory over time. Under an alternative scenario, the Latin American countries which have reasonable potential for growth in ethanol production increase their output over time more aggressively.

4.22 The specific ethanol feedstock crops that are considered in this set of scenarios are maize, wheat, cassava, sugarcane and sugar beet – which are all produced from conventional ethanol conversion processes that use starch and sugar-based raw inputs. Ethanol productions based on ligno-cellulosic technologies are not explicitly considered in this set of analyses, but the results from other global assessments that do evaluate cellulosic potential, will be discussed within the context of the Latin America region.

Biodiesel-Focused Scenarios

4.23 In this set of scenarios, we examine the possibilities for growth in the production of oil-based biodiesel products, within the Latin American region, and what implications it has for other commodities within the regional and global agricultural economy. Given the representation of oil-based crops as an aggregate commodity within the IMPACT-WATER model, we are only able to describe the impacts in terms of a single composite commodity price, but will be able to relate the

results to specific feedstock commodities, based on the observed patterns of oil-based crops within those countries.

4.24 Given that there is no distinction between rainfed and irrigated oil crops in our model, we will not be able to relate the biodiesel-focused scenario results directly to water use. Given that most oil crops are rainfed, and that they have relatively lower yields than the starch or sugar crops, the main focus on the scenario results will be on the implications for crop area and land use. Note that it is not currently feasible to model non-edible oil crops within IMPACT-WATER, therefore such oil crops like *Pongamia spp.* or *Jatropha spp.* will not be explicitly considered within our analysis.

Combined (biodiesel and ethanol) scenario results

4.25 This scenario adds up the previous scenarios into one composite scenario happening in tandem.

Scenario Results

4.26 The following sub-sections present the results of the different biofuel growth scenarios – each focusing on a different fuel product (or combination thereof), so as to better highlight the differential impact that ethanol and biodiesel can have on agricultural market and land outcomes in Latin America.

4.27 Table 4.2, presents the impacts on world market prices for the main agricultural feedstock commodities that are considered in the IMPACT-WATER simulations. Results are expressed as percent difference with respect to the baseline prices, measured as world prices of 2025. Results show that the price impacts are strongest for cassava under the ethanol growth scenarios as they increase significantly over the baseline levels. Given the fact that world markets for cassava are relatively 'thin', in terms of trade volume, when compared to cereal commodities, the rapid, biofuel-driven expansion utilizing cassava as a feedstock tends to cause much stronger impacts on price.[13] Worthwhile noting that cassava, which is considered an 'orphan' crop by some – as it receives relatively little research attention (and funding) relative to other key food and cash crops – is relatively widespread in cultivation throughout the tropical agro-ecological regions of the world, including those found in Latin America.

4.28 The Latin American region, however, so far has not favored the use of cassava as a feedstock crop for ethanol as strongly as it may happen in regions with high production such as Southeast Asia or Africa. Southeast Asia, for example, produces approximately 20% of the world's cassava production. In contrast the share of global cassava production in Latin America (excluding Brazil) is just 5%. Brazil is an interesting case in Latin America, where despite the relatively large cassava production in Brazil (just over 11%) and relatively favorable conditions for high-yielding production, the crop has not been used as a feedstock source for ethanol. This situation in Brazil is unlikely to change in the future, although some opportunities may rise in other countries (See Box 6).

[13] A "thin" market is one in which a relatively small number of transactions determines the price. The small number of transactions may not reflect aggregate demand and supply in a particular country. Price (and volume) in thin markets tend to fluctuate significantly over time. A thin market may lead to pricing imperfections as this market lends itself to manipulations by buyers within the market.

4.29 Explanations for cassava not becoming a feedstock crop for ethanol in Brazil include the historical and continued emphasis placed on sugarcane in the country from the Brazilian government policies. The emphasis on sugarcane paid by the Brazilian government needs to be tied with some disadvantageous characteristics of the crop such as the fact that cassava -compared to sugarcane- does not have the equivalent of bagasse as a fuel for power generation or that the manual harvesting of cassava is labor-intensive and time-consuming. The later is particularly important in those areas with localized labor shortages which may be critical for allowing the crop to become a commercial enterprise or even for the establishment of community development program. Furthermore, large-scale (and in some cases even small-scale) cassava farming failed in Brazil because of pests and diseases which eliminated the crop's economic advantage with respect to other crops. As a consequence there is no commercial production of ethanol from cassava today in Brazil, thus eliminating potential price benefits from cassava expansion (Kojima, 2006).[14]

Box 6. Cassava and Ethanol Production in Colombia

Fueling Cassava's Popularity

Cassava has irrupted into the first decade of the third millennium as a crop that can contribute to agro industrial and small-farmer development in the tropics. One of the most recent advances — using cassava to produce fuel alcohol — has opened multiple opportunities, not least for small farmers. The International Center for Tropical Agriculture (CIAT by its Spanish acronym) in Colombia is among those beginning to play an active role in this development.

The approach promoted by CIAT, in alliance with the Latin American and Caribbean Consortium to Support Cassava Research and Development (CLAYUCA by its Spanish acronym) and the Dutch company Diligent Energy Systems, facilitates the participation of small farmers in the production of cassava as the raw material and in pre-processing activities. These activities see cassava roots initially transformed into ethanol at 50% concentration, which is taken to a central distillery to produce fuel alcohol (ethanol at 99.5% concentration). Artisan-scale processing plants can easily be set up in many rural communities because of their low cost. In addition, processing by-products can be used as animal feed and fertilizer.

IPS News- ENERGY-COLOMBIA: Harvesting Sunshine for Biofuels

Cassava has now become the second source of ethanol in Colombia. The first plant in this country to produce ethanol from cassava -- 20,000 liters a day this year -- is run by the private firm Petrotesting, which also exploits natural gas, oil and coal. It is a two-hour drive from Puerto López in the central province of Meta. Seven million dollars have been invested in the ethanol plant so far. But the company plans to increase output in the medium term to one million liters a day, according to the project director, engineer Jaime Jaramillo. "We started five years ago, and when we decided to build the plant, we already had experience in cassava, as well as in hydrocarbons. It was a perfect marriage," he told IPS. Tests were first carried out with different varieties of cassava, until researchers settled on three that are well-adapted to the acidic soil and the climate of Colombia's eastern plains region, agronomist Álvaro Santos commented to IPS. Petrotesting also signed an agreement with the International Centre for Tropical Agriculture (CIAT), based in the western city of Cali, to research which varieties of cassava would be most profitable in the production of ethanol.

Source: Quoted from CGIAR NEWS June 2007 (http://www.cgiar.org/enews/june2007/story_13.html) and IPS News (http://ipsnews.net/news.asp?idnews=35088).

[14] Cassava is often viewed by farmers around the world as a last resort crop. Cassava is often used as a way to store food on the ground, to be used during "lean years", that is when other crops fail. A small number of projects have been implemented in Colombia, as community development project with a relatively intensive industrialized process for the distillation of ethanol, where very highly productive varieties are used by farmer cooperatives (See Box 6).

4.30 The price impacts on sugar and maize are also very strong, and are driven largely by the preference for maize-based ethanol production in the US, and for sugarcane as a biofuel feedstock in tropical regions, such as Brazil. As has also been expressed in other global assessments of biofuel potential (OECD, 2007; FAPRI, 2007), the current biofuel and agricultural policies within the US that include subsidies, continue to give a much more favorable position to the use of maize as an ethanol feedstock, and is likely to continue for the foreseeable horizon. Given that the tropical regions within Latin America and the Caribbean are particularly favorable towards the cultivation of sugarcane, from an agro-ecological perspective, it is also likely to remain the favored feedstock crop in the production of ethanol, for the near future, and has a distinct cost advantage over alternative feedstock choices (von Lampe, 2006). All the countries with significant sugarcane production and installed refinery/distillation capacity may be able to tap unto nascent ethanol markets for exports.

Table 4.2 Percent differences with respect to baseline prices of feedstock commodities expressed as 2025 World Prices

Commodity	**Ethanol Stable Growth in LAC**	**Ethanol Fast Growth in LAC**	**Biodiesel Stable Growth in LAC**	**Biodiesel Fast Growth in LAC**	**Ethanol and Biodiesel Stable Growth in LAC**	**Ethanol and Biodiesel Fast Growth in LAC**
Wheat	55.0	55.9	0.1	0.1	55.4	56.4
Maize	86.5	85.4	0.2	0.2	84.2	86.3
Cassava	253.1	311.9	0.2	0.2	295.4	318.4
Sugar	87.3	87.7	0.1	0.1	87.3	88.0
Oils*	8.5	8.2	2.3	2.5	10.5	10.9

Notes: 1) Source: IMPACT-WATER projections, 2) In the case Oils, what is shown is a composite price of various oil commodities.

4.31 The impacts observed on irrigated area in the scenario considering a ‘stable’ trajectory of ethanol growth in LAC, in Table 4.3, show that there are strong increases in relative terms (as a %) in the irrigated area under maize and sugarcane, which has significant implications for water use, as well as total land use, within the Latin American region. Given that the increase in world prices (shown in Table 4.2) were strongest for sugar – the strongest area expansion response in relative terms for sugarcane is for Argentina, Mexico and Colombia. Since most of Brazil’s sugarcane is rainfed (Table 4.1), its response expressed as a percent is smaller, here. However, results expressed absolute terms, that is considering the initial baseline area, show that the highest area change response is from Central America and the Caribbean (80,000 ha), Brazil (58,000 ha) and Mexico (37,000 ha) for sugarcane. The total area increase for all countries in the region for sugarcane until 2025 is approximately 241,000 hectares. In contrast the total area changes estimated for maize are 375,000 of which Mexico accounts for 62% of the change. For the estimated response in wheat is approximately 32,000 hectares; of which Chile and Argentina account for 70% of the total area increase.

4.32 The results presented for wheat and maize show policy relevant complementarities as these crops are often grown in rotation with each other and tend to share land area. The implications of the expansion of wheat and maize area are different than those implied by the expansion of sugarcane. An expansion in the sugarcane area in Brazil would most likely come from the conversion

of rangelands and areas that are not currently under production in other food crops, (i.e. such as those in the central-south and north-northeast parts of the country). In contrast when the area under cereals expands in other regions, the possibility exists of a likely displacement of other food crops. The rather special condition under which sugar tends to grow, is often not highly amenable to the cultivation of other crops, and tends to occur in rather large, continuous tracts of farmland that are managed in plantation-style agriculture.

4.33 Cereals, on the other hand, occupy land that can support a wide variety of other food crops, and range in scale of production from fairly large scale farms to smaller-scale operations that can encompass a wider diversity of food crops. So the food-versus-fuel trade-off of land use is more likely to be experienced where the expansion of cereal area for biofuel production occurs, rather than where the growth in sugarcane area takes place. This fact has profound implications for public policy and government interventions in the near future in Latin America.

Table 4.3 Percentage Difference with respect to baseline of irrigated area of feedstock Crops under stable ethanol growth in LAC (in year 2025)

Country	**Wheat**	**Maize**	**Sugarcane**
Argentina	6.7	8.8	15.5
Brazil	7.3		7.4
Central America and Caribbean	4.1	9.4	11.0
Central South America			11.0
Chile	4.1	10.5	
Colombia	4.8	10.1	13.9
Ecuador	4.1	10.5	11.0
Mexico	1.9	6.9	14.0
Northern South America	4.1	10.5	11.0
Peru	4.1	10.5	7.0
Uruguay	4.1	10.5	11.0

Source: IMPACT-WATER projections.

4.34 Examining the impacts on total feedstock crop area under the ‘stable’ ethanol growth scenario, as shown in Table 4.4, gives us a basis for comparing the agricultural land use impacts on crops which are irrigated and those which are mostly rainfed, as in the case of cassava. The strong percent increases in world price for cassava (Table 4.2) encourage the expansion of cassava area, which a few of the countries in Latin America could use as feedstock for ethanol production, domestically. The total area response for Brazil is stronger than what is shown in Table 4.4, since most of it is realized in the expansion of rainfed area.

4.35 In parallel with Table 4.4, the percentage increases in irrigated production under a stable trajectory of ethanol production growth in LAC (Table 4.5), also show very strong increases for sugarcane, which are highest for Argentina and Brazil. Given that the water requirements per ton of crop are roughly 3600 m3/ton for sugarcane, compared with 1900 m3/ton for maize and 1500 m3/ton for wheat, we can see that there would be greater water-related constraints to growth in drier regions such as some of the sugarcane producing states in Mexico, compared with the wetter regions in more tropical areas of Latin America and the Caribbean, such as Brazil, which can rely more on rainfed

sugarcane production[15]. Given its vast land area, Brazil can afford to extensify its rainfed cultivation, whereas other regions might prefer to intensify sugarcane production with irrigation to boost output.

Table 4.4 Percentage difference with respect to baseline for total area of feedstock crops under stable ethanol growth in LAC (in year 2025)

Country	Wheat	Maize	Cassava	Sugarcane
Argentina	6.7	8.8	9.7	16.3
Brazil	7.3	7.8	18.2	15.6
Central America and Caribbean	4.1	10.5	16.0	11.0
Central South America	4.1	10.5	16.0	11.0
Chile	4.1	10.5		
Colombia	4.8	10.1	15.8	13.9
Ecuador	4.1	10.5	16.0	11.0
Mexico	2.6	6.9	7.0	14.0
Northern South America	4.1	10.5	16.0	11.0
Peru	4.1	10.5	16.0	9.1
Uruguay	4.1	10.5		11.0

Source: IMPACT-WATER projections.

Table 4.5 Percentage difference with respect to baseline in irrigated production of ethanol feedstock crops under stable ethanol growth in LAC (in year 2025)

Country	Wheat	Maize	Sugarcane
Argentina	9.4	8.5	23.5
Brazil	9.5		19.9
Central America and Caribbean	11.7	20.5	26.3
Central South America			26.3
Chile	8.3	10.6	
Colombia	12.4	19.3	28.4
Ecuador	12.1	21.4	26.3
Mexico	7.8	12.5	29.8
Northern South America	12.1	21.1	23.2
Peru	11.0	18.7	21.8
Uruguay	12.1	19.1	26.3

Source: IMPACT-WATER projections.

4.36 Examination of the scenario-specific impacts on the net trade levels estimated by IMPACT-WATER can provide indications as to the likely impacts that are likely to occur on global agricultural markets in terms of trade flows of the feedstock commodities. Table 4.6 shows the

[15] For example,compare Brazil and Mexico in Table 4.1.

changes in the volume of net trade for the various regions and feedstock commodities – with positive numbers being increases in exports, whereas negative numbers denote decreases in exports (or increased imports) of commodities[16]. Results in Table 4.6 show the largest changes in net trade for Brazilian sugar, under both ethanol growth trajectories. While Brazil continues to remain a net exporter of sugar under both growth trajectories, there is a sizeable decrease in the exports of sugar from Brazil, as it is increasingly needed to meet the internal demand for ethanol production[17].

4.37 None of the other Latin American countries turn towards imports of sugar to produce ethanol – but increase their net exports to the rest of the world, in response to higher world prices, under both of the ethanol growth trajectories. Argentina turns towards the use of cassava for ethanol production, and turns from a small exporter to a significant importer of feedstock material, under both ethanol scenarios. Under the faster growth scenario for ethanol, Colombia also begins to import more cassava, and changes from a net exporter to importer. Under the faster growth scenario, Argentina also draws upon the use of maize for cultivation, and begins to import more of it – as does Colombia (under both stable and fast growth cases). Whereas the use of maize for biofuel production is restricted to Argentina and Colombia, none of the countries make use of wheat for biofuel production – but, in fact, increase their exports in order to respond to increased world demand for wheat (which is triggered by the changes in the world cereal prices). These results need to be contrasted to potential cost of producing biofuels (See Box 7).

4.38 In these results we notice that there are some compensating effects in net trade, within Latin America and the Caribbean. Brazil, for example, increases its exports of cassava to compensate for the increased imports in Argentina and Colombia that were mentioned previously. Mexico increases its exports of maize, under the faster growth scenario, in response to the increase of maize feedstock demand in Argentina and Colombia. The other Latin American countries increase their exports of maize to the rest of the world, over the baseline levels, but do so to a lesser degree under the faster growth trajectory.

4.39 In the case of biodiesel, Brazil increases imports of oil products to meet its projected demand for biodiesel, under both of the scenarios. Under the faster growth trajectories, however, Argentina and Colombia also increase their imports of oil (over the baseline amount) in order to meet their growing internal demand for biodiesel, while other regions increase their net exports o the rest of the world.

4.40 These results show how trade in agricultural commodities adjust to the increase in feedstock demands over time, and imply the degree to which productivity and output of these feedstocks must also improve, in order to keep pace with the ethanol production growth scenarios that are simulated here. Next we show how global markets in ethanol and biodiesel might also adjust, to account for the energy-driven increases in demand within the domestic economies of Latin America, and elsewhere.

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16 Since trade modeling in IMPACT is not spatial in nature, we can only discern the total net imports or exports from a country, and do not know the precise bilateral trade flows between countries.

17 In IMPACT-WATER, the quantities produced and traded for sugar are expressed in terms of refined equivalent, so as to make it consistent with the units of demand in food and other uses. The quantities for other commodities, however, are expressed in terms of raw product, and follow the changes in tonnage of production and demand that are seen at the country level.

Table 4.6 Changes in net trade from baseline for year 2025 of Ethanol and Biodiesel feedstock commodities under various scenarios (000 mt)

Countries	***Ethanol***				***Biodiesel***
Stable Growth scenarios	**Wheat**	**Maize**	**Cassava**	**Sugar**	**Oils**
Argentina	3231	1397	-1509	937	68
Brazil	2040	21362	17361	-83096	-398
Central America and Caribbean	353	1654	714	3997	40
Central South America	184	804	3656	500	10
Chile	482	413	0	292	16
Colombia	179	-3538	446	1913	34
Ecuador	79	124	158	462	12
Mexico	1315	3359	48	5386	65
Northern South America	201	1253	442	963	17
Peru	268	899	686	801	20
Uruguay	101	130	1	46	2
	Ethanol				***Biodiesel***
Fast Growth scenarios	**Wheat**	**Maize**	**Cassava**	**Sugar**	**Oils**
Argentina	3286	-431	-16644	863	-60
Brazil	2065	21090	20143	-83703	-384
Central America and Caribbean	354	666	826	3932	4
Central South America	186	781	4226	497	11
Chile	488	389	0	290	-1
Colombia	182	-8006	-705	1681	-62
Ecuador	80	113	184	460	13
Mexico	1339	3773	54	5394	70
Northern South America	204	1219	511	957	18
Peru	271	431	794	779	21
Uruguay	103	127	1	45	2

Source: IMPACT-WATER projections.

Box 7. Cost Structure of Bioenergy Products

Costs of biofuels are highly dependent on feedstock, process, land and labor costs, credits for byproducts, agricultural subsidies, food (sugar) and oil market. Ethanol energy content by volume is two-thirds that of gasoline, so costs refer to liter of gasoline equivalent (lge). Sugar cane ethanol in Brazil costs $0.30/lge free-on-board (FOB). This cost is competitive with that of gasoline at oil prices of $40-$50/bbl ($0.3- $0.4/lge). In other regions, costs can be more than $0.40- $0.50/lge, although potential exists for cost reduction. Ethanol from maize, sugar-beet and wheat cost around $0.6-$0.8/lge (excl. subsidies), potentially reducible to $0.4-$0.6/lge. Ligno-cellulosic ethanol currently costs around $1.0/lge at the pilot scale, assuming a basic feedstock price of $3.6/GJ for delivered straw (whereas cereals for ethanol production may cost $10-$20/GJ). The cost is projected to halve in the next decade with process improvement, scaling up of plants, low-cost waste feedstock and co-production of other by-products (bio-refineries). Biodiesel from animal fat is currently the cheapest option ($0.4-$0.5/lde) while traditional trans-esterification of vegetable oil is at present around $0.6-$0.8/lde. Cost reductions of $0.1-$0.3/lde are expected from economies of scale for new processes. The cost of BTL diesel from ligno-cellulose is more than $0.9/lde (feedstock $3.6/GJ), with a potential reduction to $0.7- $0.8/lde.

Source: IEA, 2007.

4.41 The results in Table 4.7, show the impact of the alternative biofuel growth scenarios on a key measure of food security-related human well-being – namely, that of malnourishment in small

children. The malnourishment of small children (aged zero to five years) is measured in terms of an anthropometric indicator of how far a child's weight deviates from the standard weight-for-age level. This is a commonly-used measure of child 'wasting', and is sometimes also combined with measures of 'stunting', which capture how much a child's height deviates from the standard height-for-age level. In IMPACT, the number of malnourished children is calculated on the basis of the per capita levels of calorie availability, which are endogenously generated by the model, and other key socio-economic variables[18].

4.42 Table 4.7 shows the baseline levels for the number of malnourished children across all countries and regions of the study. Data in this tables shows that the countries/regions with highest numbers of malnourished children occur in Brazil and the Central America and Caribbean. Considering the ethanol expansion scenario, Mexico endures the largest percent increase in child malnutrition, followed closely by Colombia and Peru. Given the share of the dietary calories that come from maize within these countries, they are the hardest hit by the nutritional consequences of biofuel-induced changes in the market conditions of key cereal food crops like maize. The changes to child malnutrition under the biodiesel scenario are significantly much smaller from those for ethanol scenario.

Table 4.7 Baseline Child Malnourishment levels in year 2025 and Differences from Baseline under Scenarios

Countries	Baseline (000 children)	Ethanol expansion scenario (%)	Biodiesel Expansion scenario (%)	Combined Ethanol + Biodiesel expansion Scenario (%)
Argentina	476	10.8	0.3	11.2
Brazil	2415	13.1	0.4	13.6
Central America and Caribbean	965	24.9	0.4	25.3
Central South America	346	16.2	0.3	16.8
Colombia	135	81.1	2.1	83.9
Ecuador	201	16.6	0.6	17.3
Mexico	261	121.0	1.4	121.4
Northern South America	276	29.2	0.6	29.9
Peru	92	83.5	1.4	86.3
Uruguay	41	13.2	0.3	13.5

Source: IMPACT-WATER projections.

4.43 Table 4.7 shows that Colombia leads other countries or regions, in terms of increases in the headcount of malnourished children under 5 years of age. The difference in child well-being impacts, between these two scenarios, comes from the fact that the biodiesel scenario involves oil-based feedstock crops that represent a much smaller share of the total nutritional intake of households within these regions – whereas the starchy and sugary feedstock crops of the ethanol scenarios have much more importance in the total dietary portfolio within these countries.

4.44 Table 4.8, below, shows how the levels of child malnutrition vary across the biofuel growth scenarios. The variation in the malnutrition levels reflects the changes in the level of calorie

[18] Such variables include the level of access to clean water and the schooling rate of females, which are key regressors in an empirical cross-country relationship defined by Smith and Haddad (2000). See Annex for further details.

availability, as it responds to changes in food production, prices and the market-level consumer demand response[19].The results shown in Table 4.8, below, are closely parallel to those given previously in Table 4.7, and describe an important indicator of food security – namely, per capita calorie availability[20]. This measures the availability of calories from all foods, including those represented by the ethanol and biodiesel feedstock commodities that are under going supply and demand adjustments within the various scenarios. In Table 4.8, the average baseline levels of calorie availability are seen to range between 2600 and 3700 kilocalories per capita per day, and reflect the differences in diet composition in the Latin American and Caribbean region. The degree to which the average diet within these countries depend on cereal grains versus root and tuber crops, such as mandioca and potato varieties, determines the overall level of calorie intake that is realized by the average diet.

4.45 From the results shown in Table 4.8, we see that the decrease in per capita calorie levels is greatest in Mexico, under the ethanol-driven scenarios, as was also reflected in the child malnutrition results of Table 4.7. As was seen previously, in the child malnutrition results, the impacts due to the biodiesel scenarios are minimal, due to the fact that a much larger share of calorie intake comes from meats and grains, rather than edible oils. The changes that are seen in calorie availability, under the biodiesel scenarios, mostly reflects the market-level adjustment in food grain supply and demand levels, as they respond to price changes in oil crops, through cross-price relationships.

Table 4.8 Baseline per capita calorie availability in year 2025 and percentage difference from baseline under scenarios

Countries	Baseline (Kcal/cap/day)	Ethanol expansion scenario (%)	Biodiesel expansion scenario (%)	Combined Ethanol + Biodiesel expansion scenario (%)
Argentina	3454	-6.0	-0.2	-6.2
Brazil	3483	-7.3	-0.2	-7.6
Central America and Caribbean	2679	-11.0	-0.2	-11.2
Central South America	2437	-10.0	-0.2	-10.3
Chile	3137	-10.9	-0.2	-11.1
Colombia	2893	-9.1	-0.2	-9.4
Ecuador	2990	-9.4	-0.4	-9.7
Mexico	3637	-12.6	-0.2	-12.7
Northern South America	2709	-10.2	-0.2	-10.5
Peru	2756	-9.6	-0.2	-9.9
Uruguay	3149	-7.9	-0.2	-8.1

Source: IMPACT-WATER projections.

[19] It should be noted that the malnutrition impacts do not reflect possible changes in household income due to increased land rents or revenue from biofuels-related activities. Such effects can only be picked up within a general-equilibrium modeling framework.

[20] Per capita calorie availability does not fully equate with actual calorie intake levels, which are best measured at the household level. Wiesmann (2006) discusses such food security measures, and how they compare in capturing human well-being.

4.46 Results from both Tables 4.7 and 4.8, shows that the ethanol scenarios have strong implications and impacts on food security and nutrition levels within the Latin American region. As was seen, recently, in the well-publicized increases in prices for maize and the popular maize-based tortillas in Mexico, there are significant market-level linkages between the use of biofuel feedstock crops for ethanol and the availability and price of important food products which depend on these same crops. Given the comparatively strong impact of the ethanol scenarios on child malnutrition and calorie availability in Mexico, compared to the rest of the regions, it would appear that the food consumption portfolio of the average consumer in Mexico is more susceptible to changes in the market conditions of key biofuel feedstock commodities like maize. This highlights the importance of social protection programs in Mexico that might serve to minimize these impacts, through the provision of supplementary nutrition programs that are targeted to those who are most vulnerable, within the population. In addition to the stabilization of maize prices that the government could accomplish through the control of grain stocks policy makers might also put more emphasis on school feeding programs that can help to minimize nutritional impacts to small children, during the critical period of cognitive development[21].

Demand for Biofuels and Market Implications

4.47 We now present the implications for trade in biofuel products, themselves, under the scenarios developed in the previous sections. In the projected demands for transportation energy (See Annex 2), a steadily increasing trend is reported across most of the countries within Latin America and the Caribbean – with some showing more aggressive trends than others. Based on these growth patterns, and on currently observable levels of biofuel production, we can project the demand trend for biofuel products over time, such as is shown for ethanol in Figure 4.4, below. Brazil is excluded from this graphic, as it is at an entirely different order of magnitude (starting from 13.5 million tons). These values should serve as indirect indicators of the overall market potential for biofuels in the region. From this profile, we see a marked difference in ethanol production, if the high-potential countries (that are already producing) were to pursue their biofuels growth policies more aggressively.

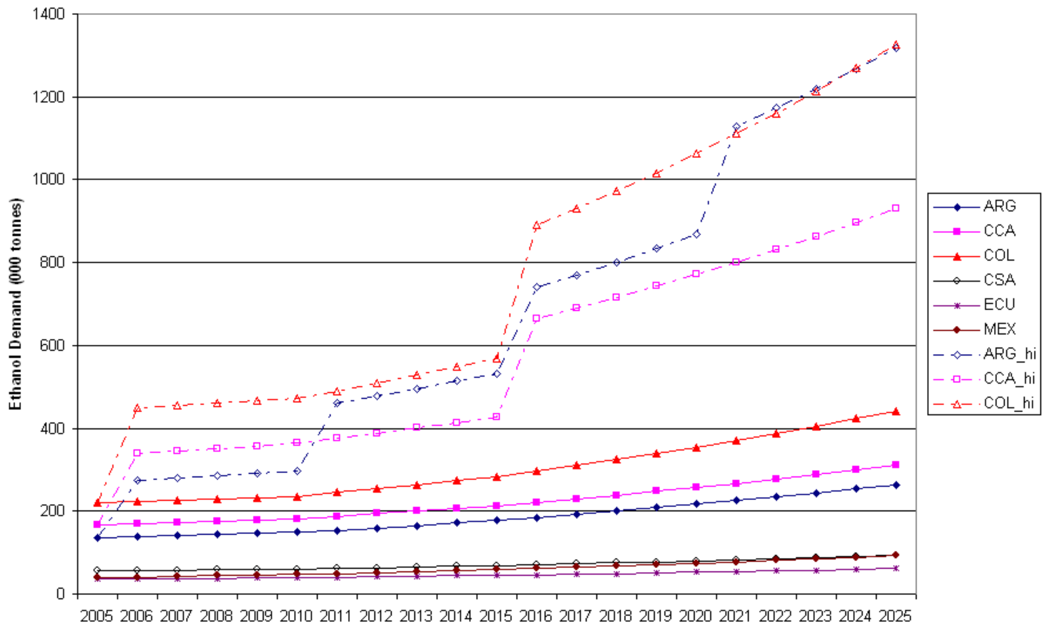
4.48 Figure 4.5, shows us a corresponding time profile for biodiesel demand growth in Latin America, where the internal demand for biodiesel from Argentina and Colombia dominate that of Brazil, and other regions[22]. Whereas Brazil is a clear leader in ethanol production, we see a role reversal when it comes to biodiesel, given the relatively prominent position of producers like Argentina and Colombia. Even the addition of more aggressive domestic blending policies in Brazil will likely not push its trajectory to the point where it will overtake the path of Argentina and Colombia, over time. In particular, the use of soybean for biodiesel production, which would be a likely feedstock of choice, as in the US, because of its extensive cultivation would not be as cost advantageous, or result in comparable levels of yield per ton, due to the high proportion of proteins and pectins that would need to be separated from soybean, in order to produce biodiesel. In this

[21] These results are tempered with the partial equilibrium nature of the IMPACT-WATER model. Estimating the cross commodity market and market effects would require a general equilibrium model. Yet, using the IMPACT-WATER model provides quite profound insights in terms of individual crop response to external factors and their effect on socio-economic variables of interest.

[22] Present levels of biodiesel production in Brazil are around 35 000 tons/yr, whereas those for Argentina and Colombia are orders of magnitude higher (396 000 and 685 000 tons/yr, respectively).

respect, the plantation palm oils would be highly advantageous, and would provide much more favorable cost economies for biodiesel production.

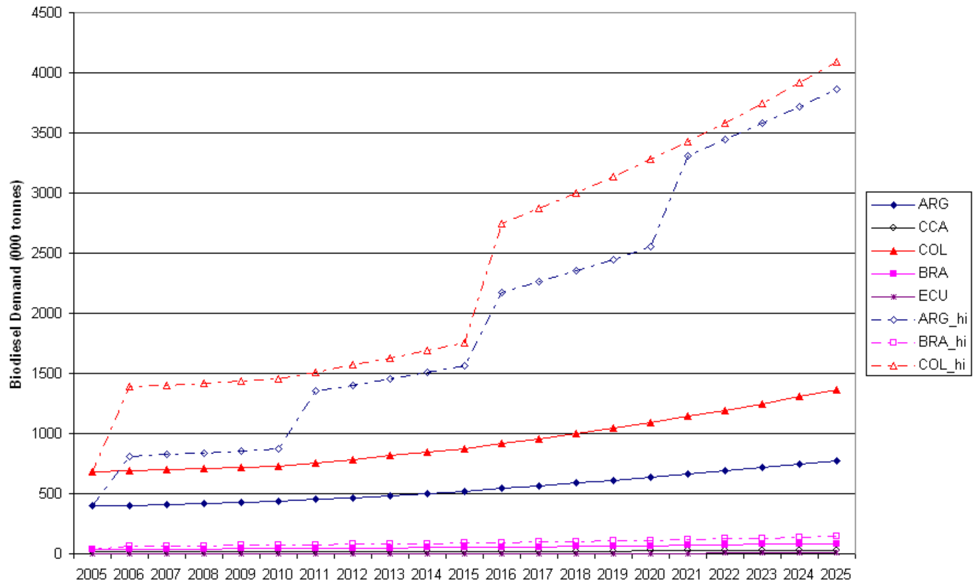
Figure 4.4 Projection of Total Ethanol Demand in Latin America over Time (thousand of metric tons)



Source: Authors calculations.

4.49 Given the constraints on meeting the internal demand for ethanol and biodiesel through own-production, a 'derived demand' for imports was generated for each of the countries, to show the amount that would need to be obtained from global markets for these key biofuel products. Figure 4.6 presents the demand for ethanol over time. This figure shows a steady increase from 2011, when a number of the larger economies begin to require ethanol imports to meet their increasing internal demands for transportation fuel. Countries like Argentina and Colombia have large jumps in their import demand, under the 'high' scenario for ethanol production – which suggests that more stringent standards for blending in those countries will not be able to be realized without significant imports from net global exporters like Brazil.

Figure 4.5 Projection of Total Biodiesel Demand in Latin America over Time (thousand of metric tons)

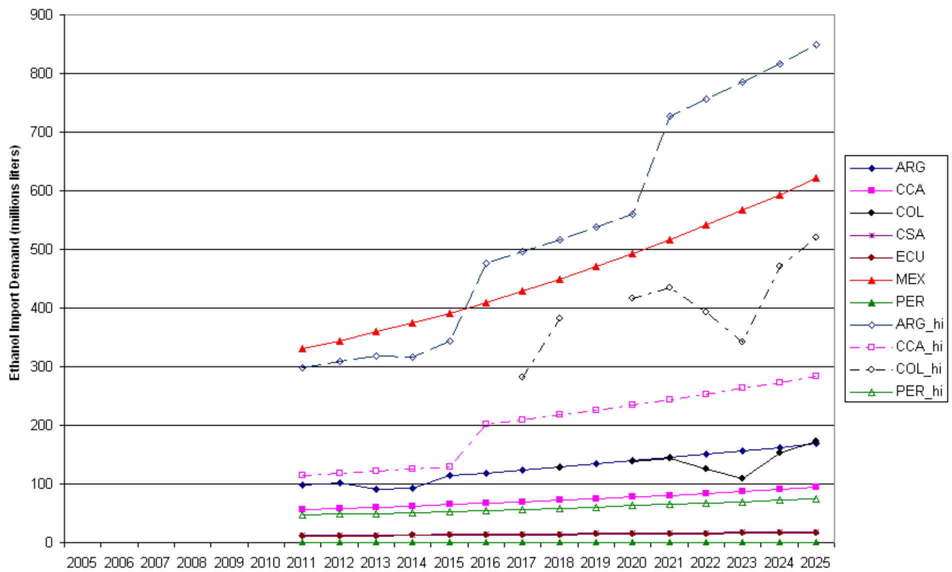


Source: Authors calculations.

4.50 In the case of biodiesel, we also see a steady trend for biofuels imports to meet internal demands in those countries (Figure 4.7). The trend for biodiesel import demand begins from the beginning of the projections horizon, and is fairly steady for all countries across time. The fact that oilseed-based biodiesel feedstock crops tend to be of much lower yield than ethanol feedstocks, means that more land area is needed to satisfy the same volumetric demand for fuel[23], and that such constraints are likely to be met sooner. The relative tightness of markets for food oils also causes constraints to be reached rather quickly, when trying to divert oil from food consumption to fuel production.

[23] While this is generally true of oilseeds, such as rapeseed, sunflower, safflower and others – it may not hold true for plantation-based oil tree crops, such as palm or coconut oil.

Figure 4.6 Projection of Ethanol Import Demand in Latin America over Time (million liters)



Source: Authors calculations.

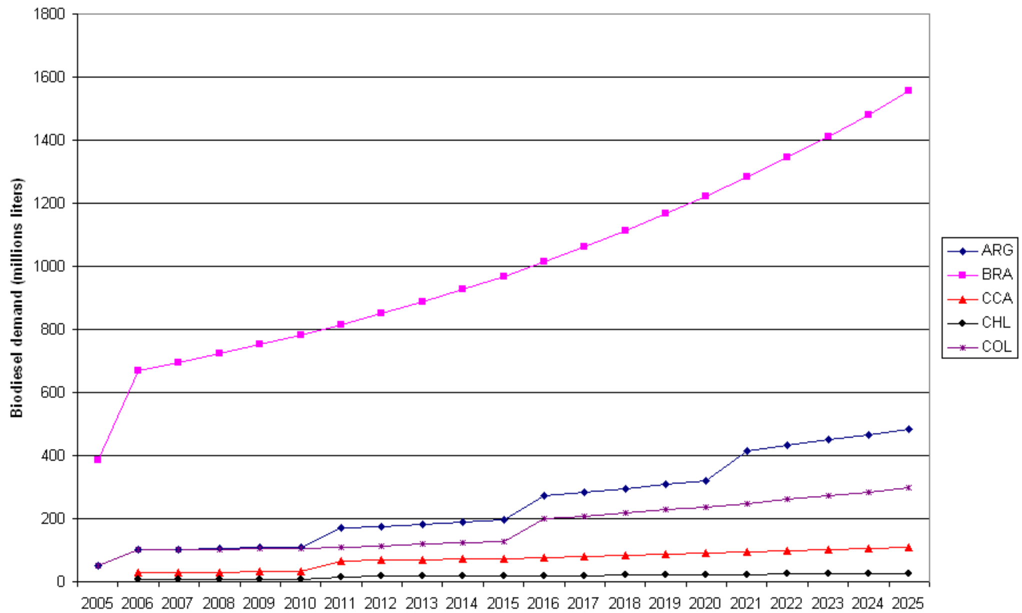
4.51 At present, regions like the EU are able to generate large quantities of biodiesel, domestically, from oilseeds, whereas countries like India, which have a historically large (and foreseeable increasing) demand for food oils, would be unable to do so. In Figure 4.9 there is no distinction between 'high' and 'low', as the differences were relatively small, compared to the case for ethanol. The results imply that in order for Brazil to meet its projected demand for biodiesel, for the foreseeable future, it will have to take on an increasing level of imports over time, unless expansion of oil production capacity were to increase significantly beyond current levels[24]. Looking more closely at global biofuel market effects, we observe a sizeable increase in projected prices for ethanol, under the 'high' and 'low' cases, as the import demand from Latin America increases from 2011.

4.52 Figure 4.8, below, shows the divergence in price trends, as the demand for ethanol increases, and must be met with increasing production and exports from other regions, such as Brazil. We see this clearly from the net trade patterns shown in Figure 4.9, where the increase in imports[25] from the non-Brazilian countries in Latin America under the high scenario is balanced with increased exports from Brazil. In essence, the ethanol trade balances remain intra-American, and one part of Latin America is, essentially, able to supply the increased need for ethanol in another part of Latin America.

[24] Within the current modeling framework, land use changes that extend significantly beyond current agricultural production boundaries cannot be fully captured. Therefore, rapid conversion towards plantation palm production could be an option that can reduce the need for imported biodiesel, especially if considering the large amounts of non-agricultural land in Brazil.

[25] Depicted as negative net exports in the graph.

Figure 4.7 Projection of Biodiesel Import Demand in Latin America over Time (million liters)

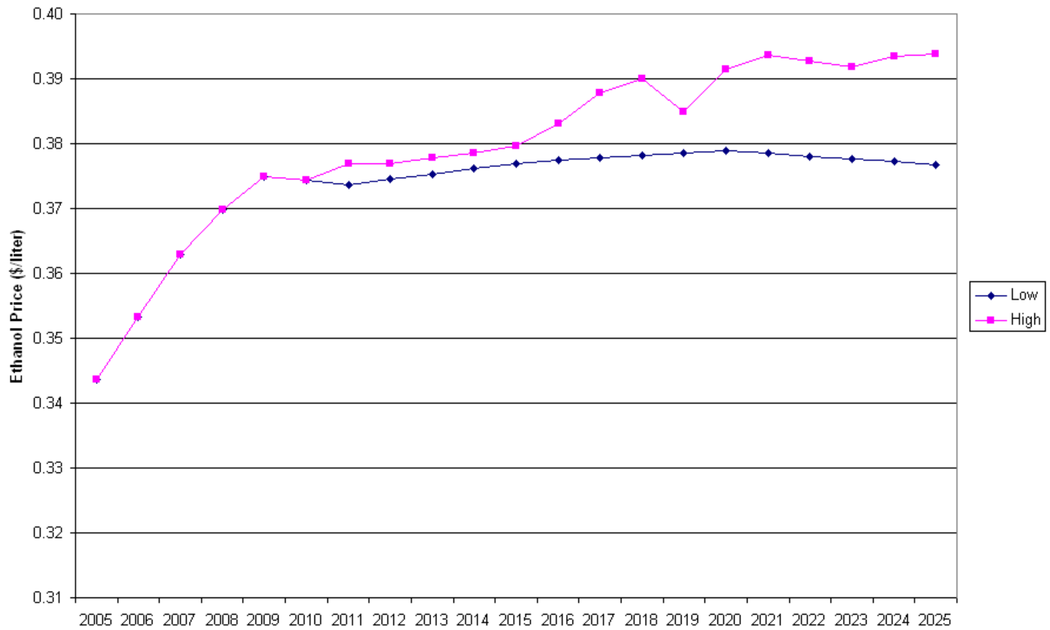


Source: Authors calculations.

4.53 Figure 4.9 also shows the steady and increasing demand for imports of ethanol from other regions like the United States, which is likely to be the case into the future, given that the US is not likely to take up large-scale sugarcane production for ethanol production, and will only be able to sustain production from maize for as long as the policy environment makes it sustainable. The steadily increasing demand for transportation fuel is also unlikely to abate in future, which will make it continually dependent upon energy imports for its domestic needs. The monotonic increase in the demand for transportation fuel across all regions is also reflected in the regional energy projections of the International Energy Association (IEA, 2006), which show steady growth for all of Latin America in domestic, industrial and transportation uses of energy. The transportation energy demand scenarios that we show here do not explicitly account for improvements in the efficiency of energy use in vehicle technologies – and, essentially, assume that motor vehicle transportation technologies are still based upon the principal of internal combustion, and that no major shifts to electric-driven technologies have been made[26].

[26] While there are an increasing amount of hybrid technologies that combine both combustion and electric motors for propulsion, there have been no studies to show their rate of diffusion across various regions of the world that we can draw from, in order to estimate rates of efficiency improvement.

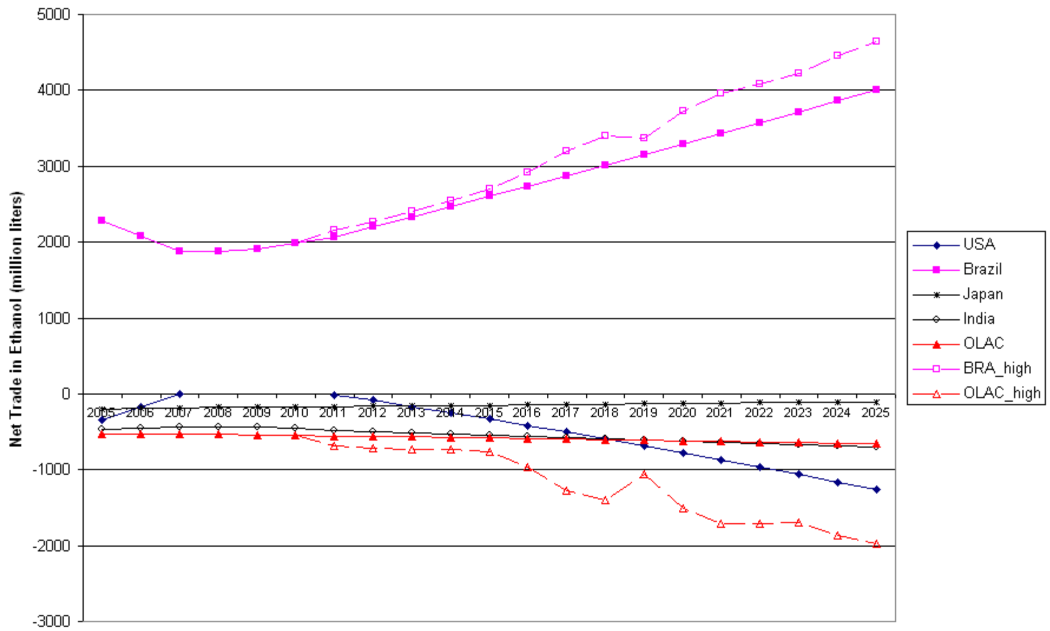
Figure 4.8 Projection of Ethanol Market Prices over Time ($/liter)



Source: Authors calculations.

4.54 Indeed it could very well be the policy-driven shifts in consumer adoption of alternative transportation technologies, or the imposing of required mandates on vehicle efficiency and fuel composition that will likely prove to be the most significant "shifters" of transportation energy demand. While there has been a considerable amount of attention given to the consequences of imposing higher vehicle fuel efficiency standards within the United States, in recent months, there has not been clear discussion of these issues within the Latin American region, although it is well-recognized that Brazil leads the region in the adoption of alternative vehicle technologies, such as 'Flex-Fuel' vehicles, which can tolerate high blends of ethanol with fossil fuels. The implication of these facts may be the further strengthening of efforts to modernize vehicular fleets ongoing in several countries in the region as well as introduce additional market incentives for the use of next generation fuels and fuel alternatives that have been driven mostly by environmental and public health concerns, predominantly efforts to reduce contamination levels in different countries in the region.

Figure 4.9 Projection of Ethanol Net Trade over Time (million liters)



Source: Authors calculations.

Key Policy Implications from the Quantitative Analysis

4.55 Drawing from the results that have been presented from the model-based analysis, we can infer some of the key implications that are of policy relevance. We list them in summary form, below:

- Brazil will continue to remain the 'mainstay' of the global ethanol economy and trade balance into the foreseeable future, and provide needed exports that will be demanded, increasingly, from other countries, including a number within other parts of Latin America.
- While some Latin American countries like Argentina and Colombia have set into place programs for biofuels production, based on internal policy mandates and goals, they will likely not be able to meet all their demands for biofuels through internal, domestic production, even with increased cereal and root crop imports.
- Countries like Brazil will also remain net exporters of sugar to the world market, for the foreseeable future, although the size of net exports might decline considerable over time, if demands for ethanol exports are to continue along the lines that have been projected in this study.
- The food security and malnutrition impacts under the ethanol-driven scenarios are likely to be significant in regions like Mexico, where cereals like maize are important in the local diets, and should be addressed through the appropriate social protection programs. Supplementary food assistance programs might be necessary, at the country-level, for some regions which are likely to be more heavily affected. The management of national cereal stocks might also be adjusted to compensate for wide price fluctuations and to ensure adequate local supplies. While such kinds of impacts are likely to be felt more

keenly in regions like Africa, which depend on maize as staples, there is still cause for concern in Latin America, as well.

- While the biodiesel scenarios did not present major implications for food security, there might be implications for land use, if relatively low yielding oilseed crops are used as feedstock, rather than more higher-yielding plantation oil products. Attention, however, would need to be paid as to how extensification of land area is carried out – especially under plantation agriculture or agro-forestry – so as not to impact upon important ecosystems and sensitive land areas.

4.56 While we were not able to do an extensive analysis of land use, in this study, there are some clear implications for both agricultural and non-agricultural land use that come from the change in agricultural crop area under the scenarios. The extensification of cereal lands will, most likely, entail the re-organization of cropping patterns to accommodate more intensified production of the desired crops, perhaps spreading into less fertile or more fragile lands. As one can almost surely assume that the areas that are best suited for cereal production are already in use, especially in regions that depend on them as staples – then the added area will have to come at the expense of other crops that are in adjacent lands, or from the use of lands that are less well-suited to intensive crop cultivation.

4.57 In the case of sugarcane, there are likely to be different tradeoffs for land use that might come with the extensification of cultivated area to meet the increased demand for biofuel feedstock. Sugarcane, unlike maize, is not intercropped or grown in close rotation with other crops (as occurs in the case of wheat and maize). While there might likely be rangeland areas that can be extensified for production of sugarcane in Brazil, for example, there might be a displacement of livestock activities into areas that might have "knock-on" effects for other land uses, such as forestry. If the expansion of cropland for cultivation of oil-based feedstock crops (for biodiesel) is combined with that for sugar or starch-based (for ethanol), then the land use implications might be even stronger than each measured individually.

4.58 Without doubt, many countries will rely on global markets for biofuel products in order to meet internal demands, and in the face of both land and natural resource constraints to domestic production. For this reason, the state of trade policies towards biofuels products will have to be examined, to see the benefits that could come from increased liberalization of these markets – both in terms of the benefits to fuel and food markets.

5. RELEVANT POLICY ISSUES FROM BIOFUEL EXPANSION IN LATIN AMERICA AND CARIBBEAN COUNTRIES

5.1 In this study, we touch upon a number of important policy issues that are relevant to the countries within Latin America and the Caribbean. Policy decisions start from deciding on the appropriate crop to base biofuels expansion and continue to those related directly to both human well-being as well as the quality of the environment, and the overall ecosystem. The most important issue touching on human well-being is that of food security and nutrition[27], while those of immediate relevance to the environment are those of land and water use. One of the main lessons learned from the Brazil experience (in Box 8) is that targeted policies can be successful in selecting the best course of action in the long run. Furthermore, these programs can accomplish their goals without having and overtly intrusive (sometimes expensive) public sector intervention in the market. The right policies and incentives can work in promoting biofuels development within the agricultural context.

What crop or crops?

5.2 One of the first decisions that need to be made is the crop (or crops) in which a nascent biofuels program will be based. As described in these report, crops have inherent oil content, coupled with a variable output yield per unit of land that responds to environmental conditions, therefore the yield of biofuels per unit of land varies significantly between crops and production zones.

Box 8. Lessons from Brazil

Brazil has the world's second largest ethanol program and is capitalizing on plentiful soybean supplies to expand into biodiesel. More than half of the nation's sugarcane crop is processed into ethanol, which now accounts for about 20 percent of the country's fuel supply. Initiated in the 1970s after the OPEC oil embargo, Brazil's policy program was designed to promote the nation's energy independence and to create an alternative and value-added market for sugar producers. The government has spent billions to support sugarcane producers, develop distilleries, build up a distribution infrastructure, and promote production of pure-ethanol-burning and, later, flex-fuel vehicles (able to run on gasoline, ethanol-gasoline blends, or pure hydrous ethanol). Advocates contend that, while the costs were high, the program saved far more in foreign exchange from reduced petroleum imports.

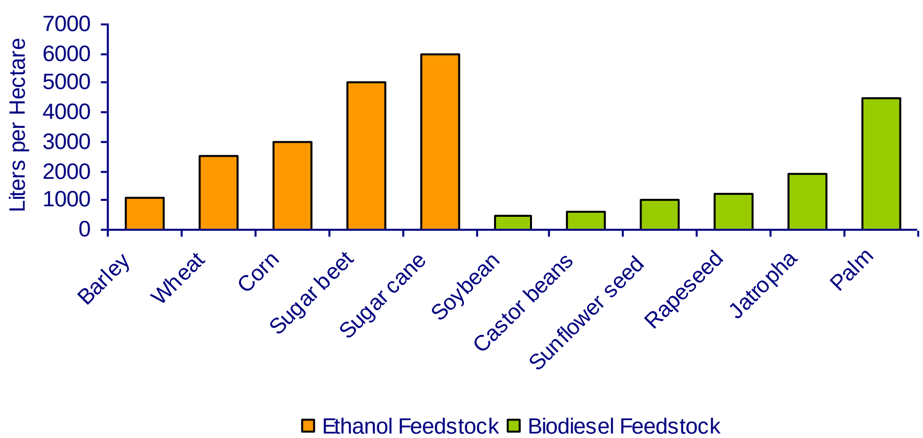
In the mid- to late 1990s, Brazil eliminated direct subsidies and price setting for ethanol. It pursued a less intrusive approach with two main elements—a blending requirement (now about 25 percent) and tax incentives favoring ethanol use and the purchase of ethanol-using or flex-fuel vehicles. Today, more than 80 percent of Brazil's newly produced automobiles have flexible fuel capability, up from 30 percent in 2004. With ethanol widely available at almost all of Brazil's 32,000 gas stations, Brazilian consumers currently choose primarily between 100-percent hydrous ethanol and a 25-percent ethanol-gasoline blend on the basis of relative prices. Approximately 20 percent of current fuel use (alcohol, gasoline, and diesel) in Brazil is ethanol, but it may be difficult to raise the share as Brazil's fuel demand grows. Brazil is a middle-income economy with per capita energy consumption only 15 percent that of the United States and Canada. Current ethanol production levels in Brazil are not much higher than they were in the late 1990s. Production of domestic off- and on-shore petroleum resources has grown more rapidly than ethanol and accounts for a larger share of expanding fuel use than does ethanol in the last decade.

Source: Amber Waves, November 2007, The Future of Biofuels: A Global Perspective

[27] Poverty and food security issues could not be addressed directly in this report, without making use of a general equilibrium model and detailed household-level information.

5.3 The scenarios in Section 3.4 introduce estimations that address both yield of biofuels per ton of feedstock and the yield per unit of land of the crop that produce feedstock. Based on that exercise we indicated that the best option, from a biofuels yield standpoint, where sugarcane for ethanol production and palm oil for biodiesel. This result is illustrated in Figure 5.1 below. Note that the ethanol yield per hectare of sugar beet is almost comparable to that of sugar cane. As described in this report, the production of sugar beet is relatively small in Latin America and the Caribbean, although more important in temperate climate countries. Interestingly enough, the yield of Jatropha spp., although lower than palm oil, is higher than that of rapeseed and sunflower seeds, crops that are heavily used in industrialized countries for the production of oil.

Figure 5.1 Biofuel yield per crop (in liters per hectare)



Source: OECD report (2006).

Irrigated and rain fed crop production: Implications for land and water use policies

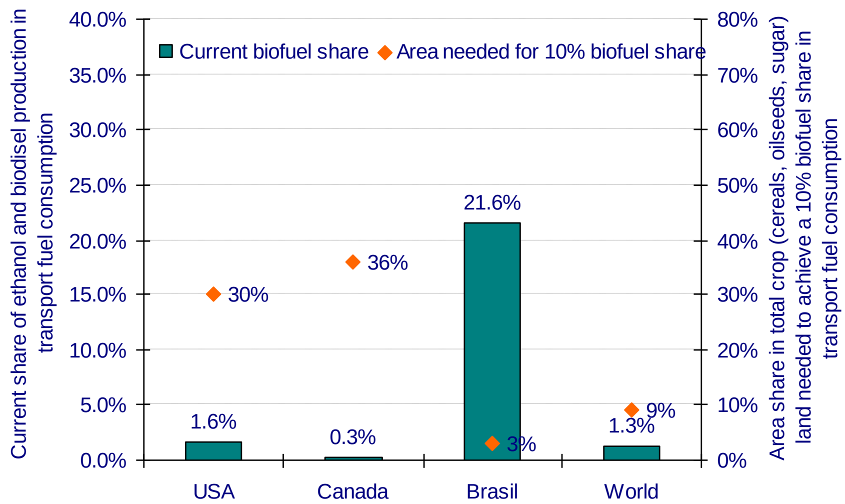
5.4 While we have not addressed specific impacts on non-agricultural land uses within this report, there are important consequences to be recognized from the expansion of agricultural area (in either irrigated or rain fed form). While many parts of Latin America do not have the types of land availability constraints that are seen in South, Southeast and East Asia, there are still fragile lands and vulnerable ecosystems in need of protection that need to be taken into consideration, when evaluating the implications of biofuel-driven expansion of cultivated crop area. As described in section 3.4 of this report, several countries in Latin America have significant slack agricultural area for the potential expansion of biofuels and may not have a significant constraint to meet relatively modest blending requirements, such as the 10% technical maximum of ethanol that current combustion engines can use without a modification

5.5 As seen in Figure 5.2, if there is a global need to meet the requirement of substituting 10% of total fuels' share with biofuels, there will be a need for a nine fold expansion in total area planted to meet that requirement. Whereas for some countries, like Brazil, they are already producing above the minimum threshold needed for a 10% biofuel substitution and may even have significant more area to produce biofuels. Contrast this situation with that of the USA and Canada that would

need to dedicate roughly one third to their total land area, just to fulfill the 10% substitution threshold.

5.6 Figure 5.3 shows used and unused available farm land area. The most striking example is that of Brazil which has used so far only 12% of its total farm land area. Argentina is another example of a country with significant land is available for food or biofuels expansion. The possibilities for expansion of wheat and maize area, as an example, are subjected more strongly to soil quality and terrain suitability limits, than would be the expansion of area for rain fed oilseeds or plantation-oriented agro-forestry of oil-bearing trees[28]. Being that wheat and maize are annual crops which do not have the permanence of perennial plantation trees, or even sugarcane, there are more substitution possibilities with other crops, and even the possibility of reverting to other types of food or fodder crops, altogether, that would not be possible within plantation-style systems.

Figure 5.2 Current biofuels area and area needed for a 10% biofuels share



Source: von Lampe (2006).

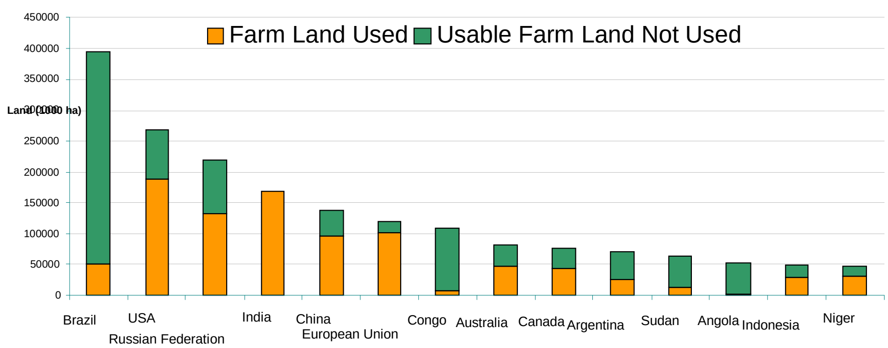
5.7 But there are other pathways that policy makers should consider, besides the raising of staple food prices, through which biofuel growth can produce 'losers'. Poorer families, with insecure land tenure status, might also be displaced from land that is converted into higher yield-producing, plantation-style modes of production, that depend on extensive holdings to create attractive economies of scale. While social disruption may be inevitable in any setting of rapid economic and technological change, there can still be a dampening of negative impacts well-being of humans through well-designed programs that are targeted to mitigate welfare losses and protect against livelihood losses. In regions where land tenure has been weak, historically, closer attention should be

[28] Plantation crops have problems of their own. For example, the possibility exists that biodiesel derived from palm trees may be produced from new or existing plantations. The implication of new plantations is that tropical forest may be cleared to make room for plantations and thus destroy natural habitats (i.e. orang utans in Indonesia). The Netherlands has started discussing certification programs implemented using segregation, traceability and in some cases identity preservation contained in labeling schemes that would guarantee consumers that biodiesel was produced in existing plantations.

paid to the impact that biofuels can have on the human landscape, and not just only to purely environmental criteria.

5.8 As we have described in different sections in this report, the expansion of biofuels will have distinct and critical implications for water use and consumption in agriculture. Water requirements to produce crops that serve as feedstock for biofuel production vary significantly. If we add the critical development of urbanization and the increased competition for water sources in most countries in Latin America and the Caribbean, in tandem with the expected increased variability of climate in the foreseeable future, we can only conclude that water will be the most critical non-renewable resource, and will in many cases determine the success of biofuels and agriculture. Expansion of sugarcane and even palm oils will be directly affected and in some cases limited by water availability.

Figure 5.3 Farm land used and not used in several countries



Source: Kojima 2006.

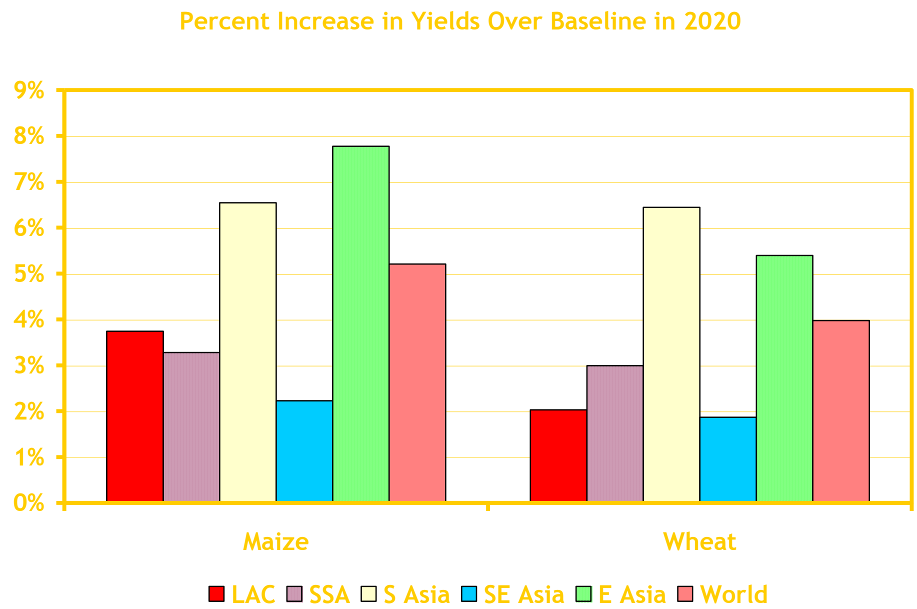
The Food for Fuels Tradeoff

5.9 One of the most critical questions to answer is whether there will be a "food & water for fuels" tradeoff. Msangi et al. (2007) explores this question by exploring scenarios contrasting a status quo baseline with biofuels expansion using conventional technologies, 2nd generation technologies and a combined 2nd generation plus increased crop productivity/enhancement scenario.

5.10 Results from this exercise show that there will be a "food & water-versus-fuel" trade-off if innovations and technology investments in crop productivity are slow and reliance is placed solely on conventional feedstock conversion technologies. The implication of this result is that there is the urgent need for the development of 2nd generation technologies coupled with increased crop productivity compared to the current baseline. An increased investment in biofuel conversion and crop productivity improvements reduces the competition between food & water and biofuels. Furthermore, to provide and incentives for countries to invest in scientific capacity, biofuel expansion increases the value of crop breeding for productivity improvements in wheat, maize,

cassava, and sugar; therefore showcasing potential synergies and multiplier effects of investments innovation and scientific capacity.

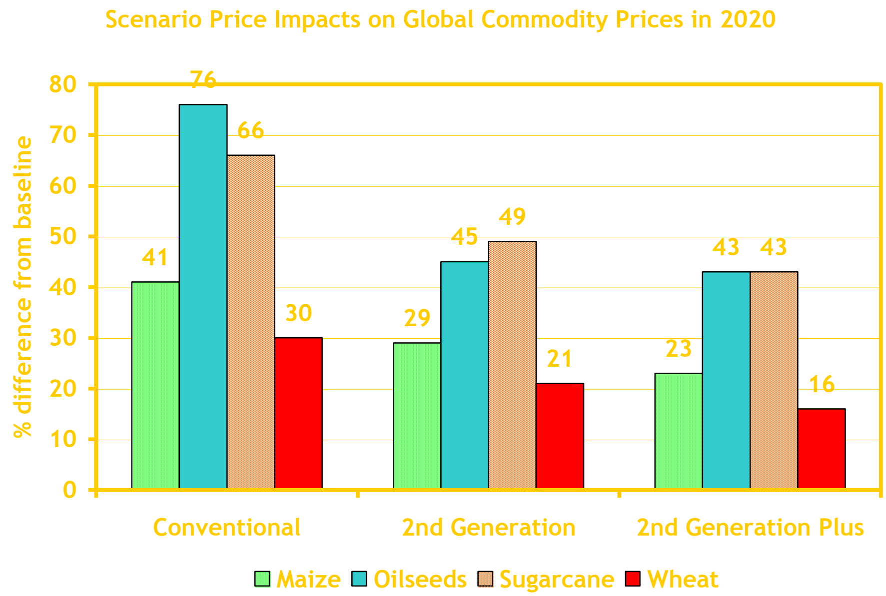
Figure 5.4 Yield Enhancements in "2nd Generation Plus"



Source: Msangi *et al.*, 2007.

5.11 This exercise shows that the expansion area is stronger for sugarcane, which has both land use and water use implications. Sugarcane has the highest yield in liters of ethanol per hectare – which makes expansion attractive. However, countries need to look closely at water use implications, as it might be a serious constraint in drier zones of the regions in the world. This result also has implications for land policy and the possibility for deforestation. Even if area does directly encroach on protected environments – there could be a "knock-on" effect that causes the displacement of something else that does (e.g. pasture and livestock).

Figure 5.5 Price Impacts Across Scenarios



Source: Msangi *et al.*, 2007.

Agricultural Income and Prices

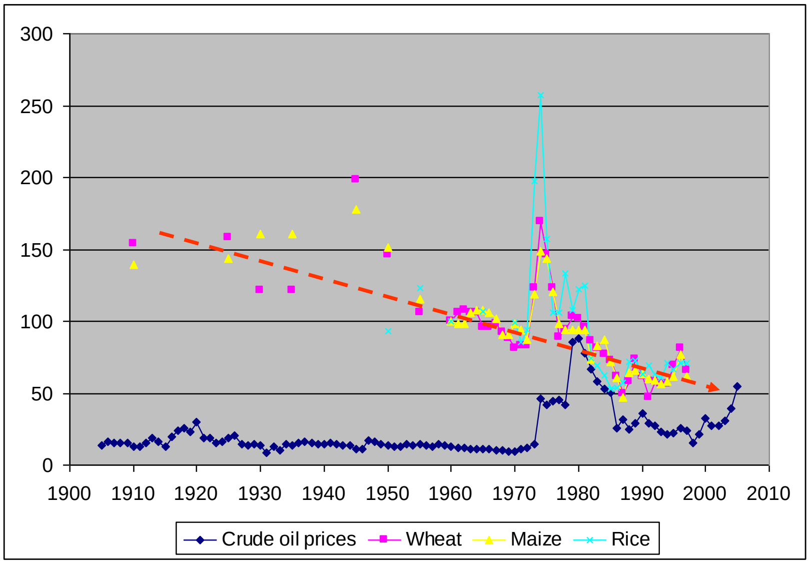
5.12 One of the remarkable outcomes from advances in modern agriculture has been the fact that during the second half of the 20th century, food prices have declined (See Figure 5.6). In many cases the decline in food prices has been true in both absolute terms and relative to other prices in the economy. The decline in food prices during this period is a direct outcome from technical change in the agricultural sector in most countries, amongst other issues. Technical change included such advances as the use of improved plant and animal genetic resources, crop rotations, fertilizers and pesticides, improved agronomic management and other innovations. Although there had been a relatively small slowdown in the rate of total factor productivity globally, enough to warrant calls for additional investments in agricultural R&D, new technologies became available that have the potential to guarantee increased productivity in the long run.

5.13 Productivity is not the only explanatory as there are other supply, demand and trade considerations that may help explain depressed agricultural commodity prices. A major explanatory variable for depressed prices were the subsidies given by industrialized countries to their domestic agricultural production. For example the World Bank (2003) estimated that OECD subsidies depressed agricultural prices 10-50% below long term trend depending on the specific commodity. US farm policies have similar negative impacts on food prices, especially since those crops that are more heavily subsidized under existing Farm Bills, are also those exported significantly (Schnepf and Womach, 2007).

5.14 The downward trend in commodity prices seems to be reversing. In Figure 5.7, monthly commodity prices for rice, corn, and wheat in the United States seem to show an upward surge in commodity prices which has already been reflected in international commodity prices. What has changed over time and how will this affect Latin America and the Caribbean countries? These two

questions will be extremely relevant to LAC countries policy formulation and implementation environments especially with regard to bioenergy.

Figure 5.6 Cereal and Crude Oil Price Index 1905-2000 (For all series 1960=100)

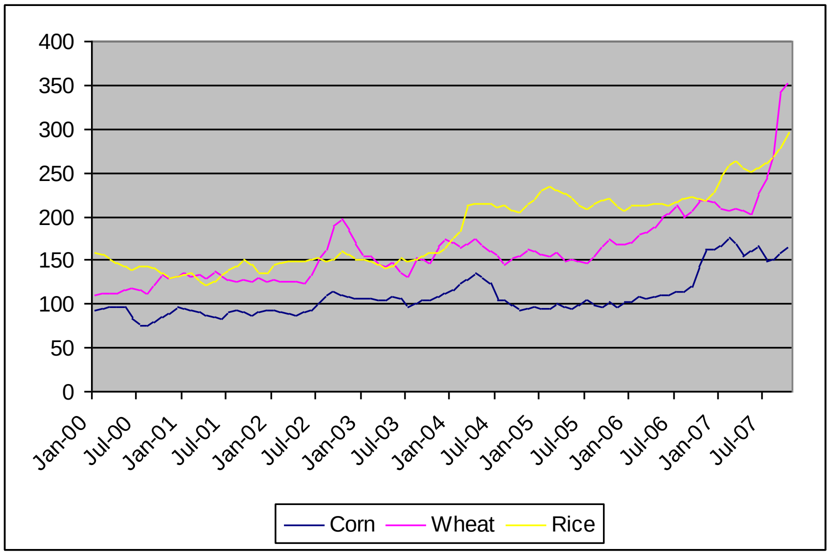


Source: Author's construction based on a presentation by Von Braun (2008).

5.15 The surge in agricultural commodity prices can be traced back to changes in many of the supply, demand and trade considerations and new factor that changed agricultural markets in developed and developing countries. From the supply (production) side, agriculture is now facing increased pressures on land, water, inputs and changes in workforce patterns, especially towards urban and international migrations. Increased pressures induced by abrupt and unpredictable climate change patterns will likely become even more serious in the near future. Furthermore, LAC countries will face the impact of policy decisions by other developed and developing countries as they address the issue of climate change. The LAC policy milieu becomes even more complex once these countries' agrarian structure, technology and policy gaps and limitations are taken into consideration.

5.16 From the demand side, income growth in countries such China, India, Brazil and Russia, implied a change in food consumption patterns, including a shift towards a higher demand for animal products. The change in consumption patterns has been reinforced by demand changes originating from energy security policies that promoted Bioenergy and Biofuels production in several countries. Not surprisingly, a well known result from economic theory and experience is that as a demand increase (a rightward shift to the demand curve) for feedstocks used to produce a particular product (biofuels) increases, price of the input (feedstock) increases *ceteris paribus*. Even if production increases (a rightward shift of the supply curve), if the relative shift of the demand curve dominates, prices and quantity will still increase.

Figure 5.7 Monthly Prices for Three Commodities in the United States (US$/ton)



Notes: a) Source FAO(2008), b) Corn is US No.2, Yellow, U.S. Gulf (Friday), $US/ton, Wheat is US No.2, Hard Red Winter ord. Prot, US Fob Gulf (Tuesday) $US/ton, and Rice is Rice (White Broken Rice, Thai A1 Super, f.o.b Bangkok (Friday closing price)).

5.17 How will the surge in commodity prices impact stakeholders in LAC countries? Increases in the price of commodities used as feedstock favors net producers as agricultural income increases for this segment of the population. In industrialized countries, net agricultural producers are typically a very small proportion of total population and thus they are able to capture much of the additional income from price increases. However, in many developing countries, a significant proportion of their population are still agricultural producers, who themselves may be net consumers as in many cases they are subsistence farmers that do not produce enough food to eat every year. Other net consumers include non-farm rural and the urban poor. Therefore, commodity price increases affect negatively poor consumers and/or net consumers, particularly those in urban areas. Poor consumers are affected negatively as they spend a greater proportion of their income for food expenditures. In this sense, price increases affect the vulnerability of poor producers and consumers as it increases their food insecurity.

5.18 For example, in the United States and OECD countries, food accounts to roughly 10% of total consumer spending in average. The share of food in some developing countries can be as high as 60-70% of total consumer spending. A 30% increase in the price of food in a 5 year period, reduces the standard of living in the USA and OECD countries by roughly 3% per year. In contrast the same price increase would decrease living standards in poor countries by 18-21%, maintaining other prices and income constant. The specific impact of food price increases will thus become a trade-off between the gains obtained by net producers and losses by net consumers in a country or region. The tradeoff will of course be directly affected by the relative share of each stakeholder group affected by food price increases.

5.19 The net effect on society of the expansion for biofuels is not clear-cut and easy to predict, particularly in those economies distorted by taxes, tariffs, and subsidies. In addition, a well known cross market effect is when a price increase of a particular feedstock will affect those

industries that use the feedstock as an input. For example in the case of increases in the price of maize, we will expect to see increases in the price of pork, poultry, beef, and the beverage industry that use high sugar syrups derived from maize. The income and cross market effects can only be captured through detailed household and/or community budget analysis, or general equilibrium models that allow for income changes as part of the economic system.

5.20 What are the lessons for LAC countries of food price increases? As we continue discussing in other sections of this report, one of the most important policy lessons for LAC countries is the need to carefully evaluate all the potential gains and benefits from the expansion of biofuels both domestically and by other countries. The policy challenge is to identify alternatives in terms of crops and technologies, as well as understand the specific supply, demand and trade considerations that will affect energy and food consumption patterns in the near future. This process will help ensure that potential negative issues such as food insecurity and uneven income effects, or positive impacts such as alternative small business and food production opportunities for economically depressed areas are indeed evaluated in order to ensure maximizing the benefits, minimizing the cost and risks of biofuel expansion.

Food security, malnutrition and social protection

5.21 From the forward-looking analysis done in this report, we observed that there were significant implications for food security in regions and/or countries like Mexico which depend heavily on cereal-based staples for food. As Mexico has a very high rate of urbanization[29], and a large number of urban poor who cannot substitute market purchases of staples with their own household production or on-farm grain storage, there is considerable risk of vulnerability to price shocks. Given the expenditures for schooling and housing are typically quasi-fixed in the short-term, increases in food prices will invariably result in adjustments in food consumption, and likely compromises in nutritional quality. For this reason, adequate attention should paid to social protection programs that can mitigate the effects of these shocks through direct nutritional interventions or cash transfers, once the recipients are appropriately targeted.

5.22 More attention could also be paid to the management of commodity storage programs that can supplement the role of private grain traders and distribution networks, in providing a dampening effect on prices, in times of high volatility, through the control and release of cereal stocks. For households to rely purely on their own ability to store grain and provide longer-term consumption smoothing through private stocks would be largely inefficient, and subject to the usual problems of spoilage and lowered efficiency of household asset management[30].

5.23 On a global level, regions like Sub-Saharan Africa are more likely to feel the welfare effects of biofuels expansion in the Americas more keenly than other regions (or even Latin America itself), through food prices. Nonetheless, there is still scope for implementation of social protection programs within the Americas that can mitigate the worst effects of energy-driven increases in staple prices.

[29] The urban share of population is 75% according to data from the UN Statistics Division (*World Population Prospects*, 2004 revision).

[30] The loss of efficiency arises when a larger share of a household's income is tied up due to higher cost of maintaining sufficient food stocks. Additional income needed to maintain a minimum amount of food for the household's survival could otherwise be put into more productive assets or towards other household uses.

5.24 Results obtained in our forward looking exercise, are qualitatively similar to those presented in report from USDA-ERS (2007) on overall food insecurity in 70 countries around the world. This report found that the most food insecure region in the world is Sub-Saharan Africa. As a region, 44% of Latin America is consuming food below its minimum nutritional requirements in 2006. This is higher than the 28% estimate of 2005. The number of persons below minimum nutritional requirements is expected to drop to 16% by 2016 as food consumption is expected to rise in the future. However, the regional averages mask significant country (and regions within a country) differences in terms of food insecurity and are heavily influenced by the severely skewed income distribution. For example, in terms of food insecurity, Haiti and Nicaragua remain most vulnerable to food production and price changes.

Trade policies

5.25 The role of global markets in biofuels will likely be to relieve some of the pressure for internal production of fuel products, and allow the larger and more efficient producers, like Brazil, to supply the needs of other countries, as it is already doing. This will result in "intra-American" trade of biofuels, both between Brazil and the rest of the Latin American countries, as well as between North and South America, given the insatiable demands for transport fuel in the US, and it's increasing awareness of the need for 'clean' technologies.

5.26 While there is a natural tendency to erect national trade barriers, in the form of tariffs, to protect nascent national industries from competing imports of ethanol from outside countries – this may serve to exacerbate country-level price impacts for food and feed products that could otherwise be relieved through trade in ethanol (or biodiesel), itself. As has been cited in the case of US ethanol policy (Sumner and Lee, 2007), there can be policy inconsistency between efforts to promote domestic biofuels usage in transportation – thereby encouraging the substitution of oil imports for ethanol imports – and erecting barriers to the importation of ethanol itself through tariffs.

5.27 Tariff policies, therefore, that are aimed at protecting domestic biofuels industries should be carefully (and periodically re-) evaluated, so as to determine a reasonable schedule for the 'phasing-out' of support over time, so as to avoid distortions that can work against longer-term goals of efficiency gains, at the industry-level, and unintended welfare losses to consumers. While the US tariff policies towards ethanol have not been explicitly cited in recent complaints of Brazil to the WTO, there remain questions that need to be resolved, and which are of relevance to the national policies of all countries within Latin America and the Caribbean.

Development and business plans for biofuels expansion

5.28 In this report we have discussed different policy development and implementation alternatives available for governments in terms of crops, investments, legal frameworks and biofuels expansion capabilities. We have also discussed potential effects and impacts, of biofuels expansion on different sectors of the economy. We have pointed out that there are relatively few countries have explicit legislation, laws and regulations related to biofuels expansion. In fact, few countries have defined which, where and how they are focusing biofuels. That is defining, for example, whether biofuels policies will be directed towards producers with minimal resources in marginal areas versus intensive (commercial) producers, or different combinations of both. What is (somewhat) worrisome is that even fewer countries have policies, strategies and/or the "business model or models" that will

drive biofuels expansion in the near or long term future, particularly when some of these countries have initiated or promoted cultivation of crops with the intention of producing biofuels.

5.29 In essence there is the need to define from the start if biofuels expansion will be part of "Energy vs. Agriculture vs. Economic Development" policies or combinations thereof. This process will be critical to avoiding many of the pitfalls described in this report, while at the same time securing all the potential benefits that biofuels expansion may bring to different countries in Latin America and the Caribbean.

Policy tools and instruments

5.30 As discussed in this report the most used policy tool for promoting biofuel expansion has been mandatory blending requirements, although it is not the only tool available for policy makers. Table 5.1 presents a set of policy tools described by Rajagopal and Zilberman (2007). The breadth of policy options available to countries in Latin America and the Caribbean is significant as many LAC countries may have achieved the degree of good governance that will allow the appropriate application of such policies. The appropriateness and the likely impact of each policy tool needs to be examined however on a country by country basis.

5.31 The same authors provide a set of qualitative measurements of likely impact of a set of policy instruments that may be implemented by governments in developing countries, as shown in table 5.2. The main purpose of this table is to showcase the likely direction of such policies in developing countries. The net effect to society will be determined by the relative weight of each individual impact with respect to others in the country policy portfolio. Our review of existing policies showed that Latin American countries need to assess, develop and implement alternative policies well in advance before starting major biofuel expansion projects.

Table 5.1 Policy tools available to provide incentives for biofuels expansions

Type of policy	**Some examples**
Incentive - Tax or Subsidy	Excise tax credit for renewable energy, Carbon tax, Subsidies for flex fuel vehicles, Price supports and deficiency payments, Tariffs or subsidies on imports/exports
Direct control	Renewable fuel standards, Mandatory blending, Emission control standards, Efficiency standards, Area control, Quotas on import/export
Enforcement of property rights and trading	Cap and trade
Educational and informational programs	Labeling
Improving governance	Certification programs
Compensation schemes	Payment for environmental services

Source: Rajagopal and Zilberman (2007).

Table 5.2 Policy instruments and impacts for biofuels expansion

	Potential impacts on:						
Policy Instrument	**Oil use reduction**	**Green house gases reduction**	**Farm income**	**Ethanol producers**	**Consumer surplus (Food)**	**Consumer surplus (Energy)**	**Govt. Budget**
Energy and fuel policies							
Biofuel tax credit	+	<>	+	+	-	<>	-
Biofuel mandate	+	<>	+	+	-	-	<>
Carbon/Gasoline tax	+	+	<>	<>	<>	-	+
Efficiency standard	+	+	<>	<>	<>	+	<>
Vehicle subsidy	<>	<>	<>	<>	<>	<>	-
Ag and trade policies							
Price support	+	<>	+	<>	+	+	-
Cultivation area control	<>	<>	+	-	-	-	-
Import tariff	+	<>	+	+	-	-	+
Export subsidy	<>	<>	+	+	-	-	-
Export quota	+	<>	-	+	+	+	<>

Notes: 1) Source is Rajagopal and Zilberman (2007), 2) Type of impact: + = positive, - = negative, <>= ambiguous.

5.32 This need becomes more acute, particularly if biofuels expansion happens in those crops that have a direct bearing on food security (i.e. maize in Mexico and Central America) and/or where the potential exist for expansion in environmental sensitive areas. These assessments need to consider the social, economic and environmental impacts and implications of biofuels expansion. These policy analyses efforts are critically lacking in Latin America, especially as some countries have already started biofuel expansion projects, in some cases even initiated cultivation of crops for feedstock, without a clear business model and plan for further integration of biofuels within a production chain, or by considering broader development and poverty alleviation goals undertaken by governments in the region.

6. FINAL REFLECTIONS

6.1 While this study does not completely exhaust the discussion of the many issues that surround the growth potential of biofuels in Latin America and the Caribbean, we elucidate some important issues that have implications for the agricultural and energy economies within the region. These implications are also highlighted in the 2008 World Development Report (See Box 9). We recognize that the future trajectory of biofuels production growth is heavily driven by the policies that will be adopted in these countries. Given the uncertainty about how policies will evolve into the future, we must proceed with our analysis based on current decisions that have been announced to date.

6.2 Other future trends may be somewhat less uncertain – such as the general trajectory of population growth (within a reasonable range), and the likely availability of land, as pressures of urbanization and land conversion occur. We have tried to base our analysis around the best estimates of this that we could find – although more detailed work can be done on the land use analysis, to better examine the quality of land, and its likely productivity under different production systems, as well as the income and cross market effects which will determine net benefits to households, communities and society.

Box 9. Biofuels: The Promise and the Risks, World Bank's 2008 World Development Report, Agriculture for Development

Public policies for biofuels must be defined.

To date, biofuel production in industrial countries has developed behind high protective tariffs on biofuels, in conjunction with large subsidies paid to biofuel producers. Such policies are costly to developing countries that are, or could become, efficient producers in profitable new export markets. Poor consumers also pay higher prices for food staples as grain prices rise in world markets, a rise that is largely induced by distortionary policies.

Can developing countries, apart from Brazil, benefit from developing biofuel industries?

The favorable economic conditions and the large environmental and social benefits that justify significant subsidies are probably uncommon for first-generation technologies. In some cases, such as with landlocked countries that import oil and that could become efficient producers of sugarcane, the high costs of transport could make biofuel production economically viable even with current technologies. The much higher potential benefits of second-generation technologies, including technologies for small-scale biodiesel production, justify substantial privately and publicly financed investments in research.

The challenge for governments in developing countries is to avoid supporting biofuels through distortionary incentives that might displace alternative activities with higher returns—and to implement regulations and to devise certification systems that will reduce environmental and food security risks from biofuel production. Governments need to carefully assess economic, environmental, and social benefits and the potential to enhance energy security.

Reducing potential environmental risks from large-scale biofuels production could be possible through certification schemes to measure and communicate the environmental performance of biofuels (for example, a green index of GHG reductions). But the effectiveness of certification schemes requires participation from all major producers and buyers as well as strong monitoring systems.

Source: http://go.worldbank.org/UK40ECPQ20

6.3 A clear trend emerges from our analysis is that an increasing demand for transportation energy will increasingly manifest itself in the form of demand for alternative fuel products, such as

biofuels. This demand for transport energy will co-exist with the increasing demand for food products to feed growing populations that are also increasing (generally, albeit unequally) in income levels, and are therefore increasing their intake of meat products, which also depend on the same grain crops that were are considering as feedstocks for biofuels production. This combination of demands for agricultural products will continue to put pressure on agricultural markets and lead to the inevitable increases in food prices that were shown in our analysis.

6.4 This situation opens a tremendous opportunity to both Brazil and the rest of the Latin American region to re-visit their own internal energy programs, and put in place the necessary investments that will lead to more efficient and highly productive food and energy systems. This 'packaging' of policy to address both the food and energy sector is a strategy that was followed by Brazil, since the early 1970s, which has resulted in its position as a net exporter of both major energy and food commodities. There is an example in that, to be followed by other Latin American countries – as well as important lessons to be learned, in terms of how environmental concerns can be better protected, and land use policies more effectively implemented.

6.5 At the core of the biofuel expansion issue in Latin America and the Caribbean lays the need for countries to have explicit and well defined business models that will help drive and shape biofuel expansion. From economic development opportunities that support increasing income to net producers, to community development projects that help agriculture support sustainable livelihoods and development; there is the need to examine tradeoffs and opportunities at all levels in the region.

6.6 We have shown in this report that production and productivity gaps continue to exist in LAC countries. Although not limited to LAC countries, long standing limitations are still present in the region which has yield lags and less than ideal input use. These productivity constraints may become even more critical with increased pressures for multiple uses. We noted that biofuels deployment will be closely related to biotechnology, plant breeding and plant genetic resources utilization. Therefore discussions related to innovation, education and S&T gaps will be critical in shaping the future of biofuels expansion in the region. As biofuels will be closely tied to biotechnology and biosafety policy issues, as well as R&D investments in general; increased examination of these issues is warranted. As crop productivity is critical to the success of biofuels expansion, further activities that examine seed systems and plant genetic resources improvement mechanisms –which are lacking in some countries- is also warranted. Therefore; limitation, gaps and trade-offs in terms of land, water and crops will need to be analyzed carefully in the future.

6.7 While this study represents only a first attempt to work on this topic, within Latin America, it will help to lay the groundwork for more extensive studies that can examine more specific and detailed aspects of the linkages between food and energy markets within the region. Future work should aim to bring the food and energy modeling components closer together, so that a broader array of technologically- and policy-focused research questions can be asked. By doing so, we hope to be in a better position to answer more of the pressing questions that surround the future growth possibilities of the biofuels sector within Latin America, and to better inform policy makers of the options that are available to them.

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Annex 1

Estimation of ethanol/biodiesel potential based on current area and yield

Formula for Ethanol

The current maximum ethanol production achievable in crop i and country j (CPE_{ij}) is defined as:

$$CPE_{ij}^{max} = \left(\frac{Aij \times Yij \times C}{1+E} \right)$$

where, A_{ij} is the area harvested to crop i in country j, Y_{ij} is the yield per hectare of crop i in country j, C is the ethanol yield per ton of feedstock. E is a variable that measures the volume displacement of ethanol compared to gasoline. We used a value of 15% based on our review of literature. Values used in our estimations for variable C is presented in Table A1-1.

Formula for Biodiesel

The current maximum biodiesel production achievable in crop i and country j (PB_{ij}) is defined as:

$$CPB_{ij}^{max} = \left(Aij \times Yij \times OC \times BY \times F \right)$$

where A_{ij} is the area harvested to crop i in country j, Y_{ij} is the yield per hectare of crop i in country j, OC is the oil content of the feedstock expressed as a percent are presented in Table A1-1. BY is the biodiesel yield from oil, equivalent to 80%. F is a conversion factor converting Kilograms of oil per hectare to liters of oil per hectare equivalent to 1.19.

Table A1-1 Ethanol and Biodiesel Yields per Ton of Feedstock Used in Estimations

Feedstock	Ethanol yield per ton of feedstock (lt/ton)	Value range for ethanol yields	Oil content of feedstocks for biodiesel production (% Oil)	Value range for oil content of feedstocks	Biodiesel yield per ton of feedstock (lt/ton)
Cassava	200	200-280			
Maize	400	396-400			
Sorghum	359				
Sugar Cane	75	75-85			
Wheat	362				
Sugar beet	98				
Cottonseed			18	18-22	274
Soybeans			20	18-22	304
Rapeseed			40	38-45	608
Oil palm fruit			22	18-22	334

Notes: a) C=Ethanol yield per ton of feedstock, b) OC= Oil content of feedstocks for biodiesel.

Table A1.2 Current Area Harvested of Potential Target Crops by Country

Country	Cassava	Cotton	Maize	Oil palm fruit	Sorghum	Soybean	Sugar Cane	Wheat	Sugar Beet
Argentina	17	258	2,481	0	522	13,595	302	7,453	0
Bolivia	36	80	315	0	64	841	107	110	0
Brazil	1,758	632	12,324	54	826	21,006	5,598	2,576	0
Chile	0	0	124	0	0	0	0	419	29
Colombia	178	70	645	159	76	40	426	22	0
Costa Rica	21	0	0	0	0	0	49	0	0
Dom. Rep.	15	0	27	10	2	0	90	0	0
Ecuador	22	4	449	133	6	52	90	13	1
El Salvador	2	2	237	0	90	1	62	0	0
Guatemala	5	1	603	21	43	12	189	5	0
Honduras	4	1	318	45	41	81	75	2	0
México	2	93	7,272	14	1,801	3	638	586	0
Nicaragua	12	2	368	2	48	0	45	0	0
Panamá	2	0	68	6	2	1,772	33	0	0
Paraguay	293	244	428	13	13	1	67	302	0
Perú	88	36	469	11	0	0	70	131	0
Uruguay	0	0	48	0	17	201	3	151	0
Venezuela	45	17	639	24	250	1	138	0	1
TOTAL	**2,500**	**1440**	**26,815**	**492**	**3,801**	**37,606**	**7,982**	**11,770**	**31**

Source: Area Harvested (Av. 2003-5, 1,000 ha) in FAOSTAT (2007).

Table A1.3 Yields of Potential Target Crops by Country

Country	Cassava	Cotton seed	Maize	Oil palm fruit	Sorghum	Soybeans	Sugar Cane	Wheat	Sugar Beet
Argentina	10.0	0.8	6.7	-	4.9	2.6	64.5	24.0	-
Bolivia	10.1	0.6	2.1	-	2.6	1.9	46.8	10.0	-
Brazil	13.6	2.0	3.4	10.1	2.2	2.6	72.2	19.0	-
Chile	0.0	-	10.8	-	-	-	-	43.0	-
Colombia	10.9	0.9	2.6	18.7	3.6	2.1	88.7	20.0	-
Costa Rica	15.0	0.5	1.9	14.5	1.4	-	75.6	-	-
Dominican Republic	6.8	-	1.4	15.3	2.1	-	47.7	-	-
Ecuador	4.1	0.4	1.8	13.5	1.8	1.8	73.9	7.0	58.0
El Salvador	11.6	0.7	2.8	-	1.6	2.3	76.4	-	-
Guatemala	3.2	1.1	1.8	28.5	1.2	2.9	93.6	21.0	-
Honduras	3.7	1.1	1.5	25.3	1.0	1.9	71.3	5.0	-
Mexico	15.0	1.9	2.8	15.9	3.5	1.5	73.5	48.0	427.0
Nicaragua	8.8	1.2	1.4	24.6	2.0	2.0	88.1	-	-
Panama	12.5	-	1.3	10.4	3.4	0.8	49.0	-	-
Paraguay	17.0	0.6	2.3	9.6	1.9	2.4	42.0	17.0	-
Peru	10.9	1.1	2.7	18.4	2.8	1.6	114.5	13.0	-
Uruguay	-	-	4.6	-	4.1	2.1	52.2	22.0	-
Venezuela	11.7	0.7	3.2	12.0	2.1	2.8	67.2	3.0	190.0
AVERAGE	8.7	0.8	3.1	12.0	2.3	1.7	72.4	14.0	37.5

Notes: a) Source is FAOSTAT (2007), b) Yield is estimated as the average for years 2003-5, c) Yield units are ton/ha.

Annex 2

Estimates of Maximum Production and Share of Production to Meet Ethanol and Biodiesel Demand for Selected Target Countries and Crops

Table A2-1 Maximum Production and Share of Production to Meet Ethanol Demand for Selected Target Countries and Crops Using Fixed per Hectare Yield of Ethanol

Ethanol	**Mandatory or projected ethanol standard (% of motor gas)**	**Ethanol required to meet mandatory or projected standard (1000 lts /year)**		**If all targeted crop area was used for ethanol (1,000 lts)**	**% current production to meet standards**		**If all targeted crop area was used for ethanol (1,000 lts)**	**% current area to meet standards**		**If all targeted crop area was used for ethanol (1,000 lts)**	**% current area to meet standards**
Argentina	0.05	246,493		1,960,833	13		85,000	290		7,690,697	3
Bolivia	0.20	137,797		695,998	20		179,667	77		977,678	14
Brazil	0.23	3,704,658		36,388,192	10		8,791,450	42		38,205,630	10
Chile		0		0	0		0	0		385,020	0
Colombia	0.10	538,032		2,765,923	19		888,700	61		1,998,746	27
Costa Rica	0.07	55,065		316,788	17		105,300	52		22,031	250
Dominican Republic	0.05	67,746		585,195	12		75,050	90		84,454	80
Ecuador		0		584,567	0		110,833	0		1,390,732	0
El Salvador	0.09	50,657		399,750	13		7,933	639		733,925	7
Guatemala	0.10	106,874		1,230,667	9		25,000	427		1,869,300	6
Honduras	0.30	129,795		490,187	26		21,167	613		987,267	13
Mexico	0.10	3,411,838		4,148,863	82		8,000	42,648		22,542,001	15
Nicaragua		0		293,388	0		60,400	0		1,141,162	0
Panama	0.10	54,658		213,352	26		11,267	485		211,875	26
Paraguay	0.20	45,028		436,497	10		1,467,300	3		1,325,446	3
Peru	0.08	86,430		455,260	19		440,033	20		1,455,088	6
Uruguay		0		20,518	0		0	0		149,265	0
Venezuela	0.10	1,209,386		894,205	135		226,967	533		1,981,365	61

Table A2-2 Maximum Production and Share of Production to Meet Biodiesel Demand for Selected Target Countries and Crops Using Fixed per Hectare Yield of Biodiesel

				Palm oil			**Soybeans**			**Cotton seed**	
Biodiesel	**Mandatory or projected biodiesel standards (as % of diesel)**	**Biodiesel required to meet mandatory or projected standard (Million lts/year)**		**If all targeted crop area was used for biodiesel (Million lts)**	**% current area to meet standards with palm oil**		**If all targeted crop area was used for biodiesel (Million lts)**	**% current area to meet standards**		**If all targeted crop area was used for biodiesel (Million lts)**	**% current area to meet standards**
Argentina	0.05	332		0	0		9,517	3		144	230
Bolivia	0.10	46		0	0		589	8		45	104
Brazil	0.05	1,366		287	476		14,704	9		354	386
Chile		0		0	0		0	0		0	0
Colombia	0.05	103		843	12		28	365		39	264
Costa Rica		0		247	0		0	0		0	0
Dominican Republic		0		55	0		0	0		0	0
Ecuador		0		703	0		37	0		2	0
El Salvador		0		0	0		1	0		1	0
Guatemala		0		110	0		9	0		1	0
Honduras		0		239	0		57	0		1	0
Mexico		0		74	0		2	0		52	0
Nicaragua		0		12	0		0	0		1	0
Panama		0		33	0		1,240	0		0	0
Paraguay		0		70	0		1	0		136	0
Peru		0		56	0		0	0		20	0
Uruguay	0.05	26		0	0		141	19		0	0
Venezuela	0.05	84		129	65		1	8,144		10	875

Annex 3

Technical and Methodological Issues Related to IMPAC-WATER Approach

In this technical annex, we discuss the methodological approach that was used in the forward-looking modeling analysis of biofuel growth impacts, in more detail. We describe the partial-equilibrium modeling framework of IMPACT-WATER, itself, as well as the quantitative approach that is taken to assess malnutrition impacts that are associated with each of the scenarios.

Given the importance of assessing the potential impacts of large-scale expansion of bio-fuel production on food security and poverty both globally as well as in Latin America and the Caribbean, we make use of a global modeling framework that can capture important linkages between regions of high demand growth in energy and those with rapidly developing potential in bio-energy supply and agricultural growth. While a simplified representation of ethanol and biodiesel trade are embedded into the model framework, a land use modeling component could not be integrated with the market equilibrium modeling of agricultural supply and demand within the short timeline of this study. Nevertheless, we feel that the results that are presented in this desk study are adequately representative of the types of impacts that might be expected under the scenarios presented.

Description of Impact Water Model

In this section we describe the main features of the IMPACT-WATER model, which represents a central component of the quantitative approach used in this study. In particular, we highlight the way in which it is adapted to study the growth potential of biofuel production within Latin America.

IFPRI developed the global food projection model: the International Model for Policy analysis of Agricultural Commodities and Trade or IMPACT, in the beginning of the nineties. Its development was motivated by a lack of a long-term vision and consensus about the actions that are necessary to feed the world in the future, reduce poverty, and protect the natural resource base. In 1993, these same long-term global concerns launched the 2020 Vision for Food, Agriculture and the Environment Initiative. This initiative created the opportunity for further development of the IMPACT model, and in 1994 the first results from the IMPACT model were published as a 2020 Vision discussion paper: World Supply and Demand Projections for Cereals, 2020 (Agcaoili-Sombilla and Rosegrant, 1994).

Since then, the IMPACT model has been used for a variety of research analyses which link the production and demand of key food commodities to national-level food security. For example, the paper Alternative Futures for World Cereal and Meat Consumption (Rosegrant, Leach and Gerpacio, 1999), examines whether high-meat diets in developed countries limit improvement in food security in developing countries, while the article Global Projections for Root and Tuber Crops to the Year 2020 (Scott, Rosegrant and Ringler, 2000) gives a detailed analysis of roots and tuber crops. Livestock to 2020: The next food revolution (Delgado et al., 1999) assesses the influence of the livestock revolution, which was triggered by increasing demand through rising incomes in developing countries the last decade.

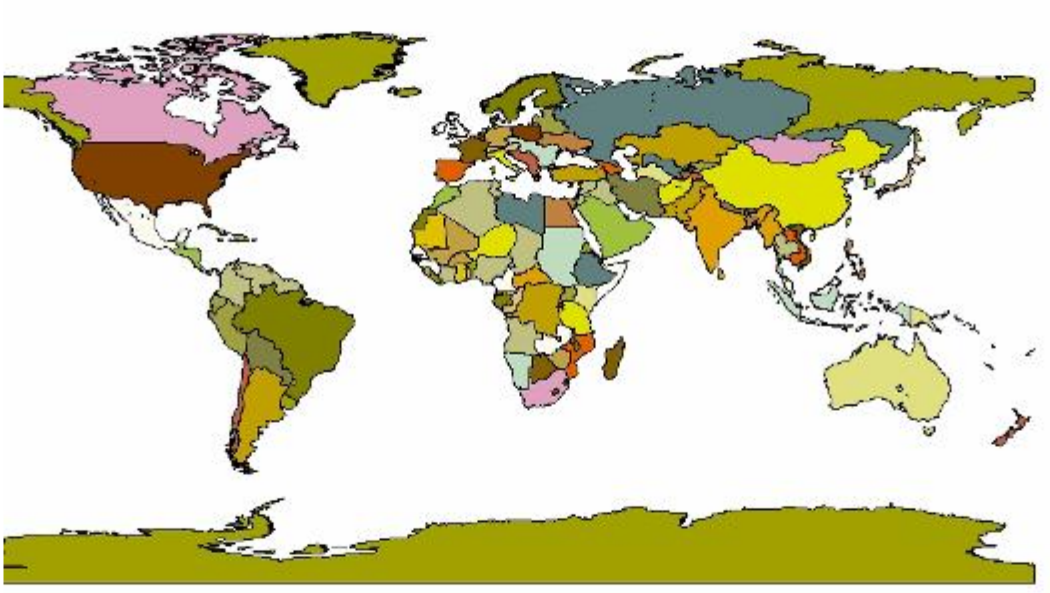
IMPACT also provided the first comprehensive policy evaluation of global fishery production and projections for demand of fish products in the book Fish to 2020: Supply and Demand in Changing Global Markets (Delgado, Wada, Rosegrant, Meijer and Ahmed, 2003). Besides these global projections, regional studies have also been completed such as Asian Economic Crisis and the Long-Term Global Food Situation (Rosegrant and Ringler, 2000) and Transforming the Rural Asian Economy: the Unfinished Revolution (Rosegrant and Hazell, 2000). These studies were a response to the Asian financial crisis of 1997 and analyzed the impact of this crisis on future developments of the food situation in that region.

More recently, the IMPACT model has been applied to looking at scenario-based assessments of future food production and consumption trends, under both economic and environmentally-based drivers of change. The most comprehensive set of results from the IMPACT model were published in the book Global Food Projections to 2020 (Rosegrant et al., 2001), which gives a baseline scenario under which the best future assessment of production and consumption trends are given, for all IMPACT commodities. In addition to the baseline, alternative scenarios are also offered, based on differing levels of productivity-focused investments, lifestyle changes and other policy interventions. These scenarios describe changes that are both global as well as regional in nature – such as those which are specific to meeting the MDG goals in Sub-Saharan Africa (Rosegrant et al., 2005). Policy analyses based on alternative scenarios that are more environmentally-focused were published in an IFPRI book titled World Water and Food to 2025: Dealing with Scarcity (Rosegrant, Cai and Cline, 2002). The version of IMPACT that was used to generate the results for this study (IMPACT-WATER) will be used to discuss the scenarios examined in this study.

The Modeling Methodology of IMPACT

IFPRI's IMPACT model offers a methodology for analyzing baseline and alternative scenarios for global food demand, supply, trade, income and population. IMPACT coverage of the world's food production and consumption is disaggregated into 115 countries and regional groupings (see figure A3-1 below), and covers 32 commodities, including all cereals, soybeans, roots and tubers, meats, milk, eggs, oils, oilcakes and meals, vegetables, fruits, sugarcane and beet, and cotton. Most importantly, it now incorporates key dry land crops such as millet, sorghum, chickpea, pigeon pea and groundnuts.

Figure A3-1 Economic Regions within IMPACT-WATER Model



IMPACT models the behavior of a competitive world agricultural market for crops and livestock, and is specified as a set of country or regional sub-models, within each of which supply, demand and prices for agricultural commodities are determined. The country and regional agricultural sub-models are linked through trade in a non-spatial way, such that the effect on country-level production, consumption and commodity prices is captured, through the net trade flows in global agricultural markets. The model uses a system of linear and nonlinear equations to approximate the underlying production and demand relationships, and is parameterized with country-level elasticities of supply and demand (Rosegrant et al., 2001). World agricultural commodity prices are determined annually at levels that clear international markets. Demand is a function of prices, income and population growth. Growth in crop production in each country is determined by crop prices and the rate of productivity growth. Future productivity growth is estimated by its component sources, including crop management research, conventional plant breeding, wide-crossing and hybridization breeding, and biotechnology and transgenic breeding. Other sources of growth considered include private sector agricultural research and development, agricultural extension and education, markets, infrastructure and irrigation.

A wide range of factors with potentially significant impacts on long-term, future developments in the world food situation can be used as exogenous drivers within IMPACT. Among these drivers are: population and income growth31, the rate of growth in crop and livestock yield and production, feed ratios for livestock, agricultural research, irrigation and other investment, price policies for commodities, and elasticities of supply and demand. For any specification of these underlying parameters, IMPACT generates long-term projections for crop area, yield, production, demand for food, feed and other uses, prices, and trade; and livestock numbers, yield, production, demand, prices, and trade. The version of the model used for this paper has a base year of 2000 (a three-year average of 1999-2001 FAOSTAT data) and makes projections out to the year 2025.

[31] Projections of population are taken from those of the UN Statistics Division (medium variant projections, 2004 revision), while those of income are consistent with the *Technogarden* scenario of the Millennium EcoSystem Assessment (MA, 2005).

Incorporating Water Availability into IMPACT

The primary IMPACT model simulates annual food production, demand, and trade over a 25-year period based on a calibrated base year. In calculating crop production, however, IMPACT assumes a "normal" climate condition for the base year as well as for all subsequent years. Impacts of annual climate variability on food production, demand, and trade are therefore not captured in the primary IMPACT model.

In reality, however, climate is a key variable affecting food production, demand, and trade. Consecutive droughts are a significant example, especially in areas where food production is important to local demand and interregional or international trade. More importantly, water demand is potentially increasing but supply may decline or may not fully satisfy demand because of water quality degradation, source limits (deep groundwater), global climate change, and financial and physical limits to infrastructure development. Therefore future water availability—particularly for irrigation—may differ from water availability today. Both the long-term change in water demand and availability and the year-to-year variability in rainfall and runoff will affect food production, demand, and trade in the future. To explore the impacts of water availability on food production, water demand and availability must first be projected over the period before being incorporated into food production simulation. This motivates an extension of IMPACT using a simulation model for inter-sectoral water allocation that operates at the global scale.

The Water Simulation Module (WSM) simulates water availability for crops accounting for total renewable water, nonagricultural water demand, water supply infrastructure, and economic and environmental policies related to water development and management at the river basin, country, and regional levels. Crop-specific water demand and supply are calculated for the eight of the key crops modeled in IMPACT—rice, wheat, maize, other coarse grains, soybeans, potatoes, sweet potatoes and yams, and cassava and other roots and tubers—as well as for crops not considered (which are aggregated into a single crop for water demand assessment). Water supply in irrigated agriculture is linked with irrigation infrastructure, permitting estimation of the impact of investment on expansion of potential crop area and improvement of irrigation systems.

IMPACT-WATER—the integration of IMPACT and WSM—incorporates water availability as a stochastic variable with observable probability distributions to examine the impact of water availability on food supply, demand, and prices. This framework allows exploration of water availability's relationship to food production, demand, and trade at various spatial scales—from river basins, countries, or regions, to the global level—over a 25-year time horizon.

Although IMPACT-WATER divides the world into 115 spatial units, significant climate and hydrologic variations within large countries or regions make large spatial units inappropriate for water resources assessment and modeling. IMPACT-WATER, therefore, conducts analyses using 126 basins, with many regions of more intensive water use broken down into several basins. China, India, and the United States (which together produce about 60 percent of the world's cereal) are disaggregated into 9, 13, and 14 major river basins, respectively. Water supply and demand and crop production are first assessed at the river-basin scale, and crop production is then summed to the national level, where food demand and trade are modeled. By intersecting the 115 economic regions with the 126 river basins, we get a total of 281 spatial units that are represented within the current

IMPACT-WATER modeling framework. An graphical depiction of the estimation process is presented in the following diagram.

Descriptive Outline of Analytical Modeling Components

1 Computation of Socio-Economic trajectories of national income and population growth, using exogenous assumptions

↓

2 Generate various demand parameters from trajectories of socio-economic growth →

- Demand for gasoline and diesel, for transport
- Demand for agricultural food commodities
- Generate trajectory of crude oil prices, based on estimated empirical relationship

↓

3 Generate demand for agricultural feedstocks from implied demand for biofuel products →

- Implied feedstock demands are calculated from ethanol and biodiesel demand, using implied fuel-to-feedstock ratios and requirements
- Growth of feedstock demand is driven by future blending and replacement requirements for biofuels for each region

↓

4 **TRADE SIMULATION MODELS** →

- IMPACT-WATER model takes generated agricultural feedstock demands and simulates impacts on agricultural markets , water use and food security, and crop area
- Implications of feasibility of biofuel growth on import demands for biofuel products is explored with spatial equilibrium models

↓

5 Computation of →

- Agricultural market prices
- Implied ethanol and biodiesel trade patterns and prices

→ **Generated according to alternative scenarios**

Representation of Crude Oil Prices

In this study, we represent the world market prices of oil exogenously, and driven purely by a relationship fitted to average historical prices and with an ‘error’ term that represents market-level ‘noise’ in price movements. Using data that is freely available, on international oil prices (BP, 2005), we fit the following relationship over time

$$P_t = a + b\left[\tfrac{1}{3}\sum_{t-1}^{t-4} P_t\right] + c\left[\tfrac{1}{3}\sum_{t-1}^{t-4} P_t - \tfrac{1}{3}\sum_{t-2}^{t-5} P_t\right]^d$$

Where P is the price of crude oil at time t, and the constants a, b, c and d, are parameters to be estimated from the data. This relationship maintains the ‘inertia’ of past prices, and uses a non-linear relationship to capture the shape of the historical profile. While world energy prices are, clearly, driven by more than just ‘memory’, and are subject to a number of socio-economic and geo-political factors. However, given the scope of this study, we were not able to fully capture those dynamics and inter-linkages within the global oil market, and rely on this ‘reduced-form’ relationship.

This relationship gave a fit to the observed data that is shown in figure A3-2, below, and shows a reasonable degree of congruence to the historical record of global market prices for crude oil. Using this relationship, to which we add randomly generated ‘noise’, we are able to project a forward-looking trajectory for crude oil prices that is used within our modeling framework, to determine the economic feasibility of domestic biofuel production. The future profile of prices is shown below and relies upon the specification of the random term, which is specified with a uniform distribution. The selected interval determines the shape and trajectory of the outward trend shown in Figure A3-3, and can be subjected to alternative assumptions.

Figure A3-2: Fit of Oil Price Relationship to Observed Data

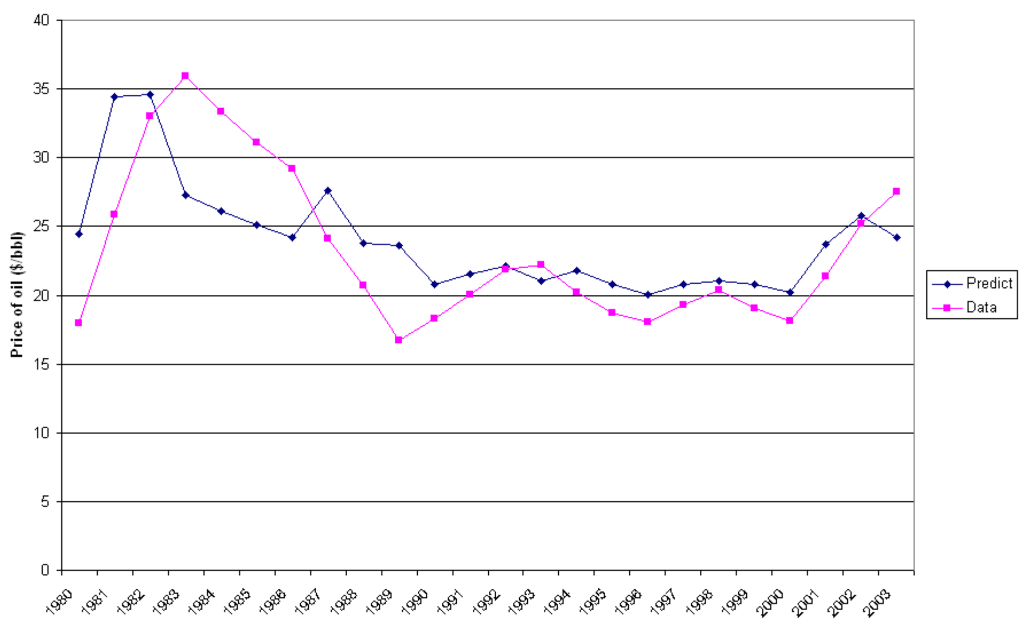
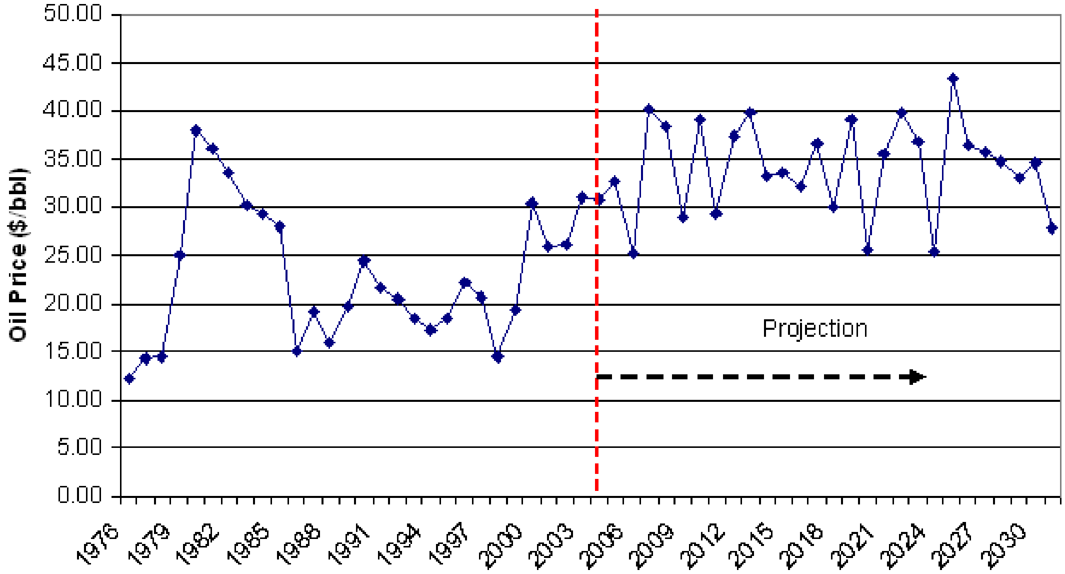


Figure A3-3: Projection of Crude Oil Prices in Future



Measures of Malnourishment in IMPACT

To determine how the aforementioned scenarios affect food security within Sub-Saharan Africa, we project their nutritional impacts, namely the resultant percentage and number of malnourished children under the age of five. Any child whose weight-for-age is more than two standard deviations below the weight-for-age standard set by the U.S. National Centre for Health Statistics/ World Health Organization is considered malnourished. The IMPACT-WATER model is able to project this number for each scenario, thereby allowing us to compare the relative abilities of various scenarios to foster improvements in food security. The percentage of malnourished children under the age of five is estimated from the average per capita calorie consumption, female access to secondary education, the quality of maternal and child care, and health and sanitation (Rosegrant et al., 2001). The precise relationship used to project the percentage of malnourished children is based on a cross-country regression relationship of Smith and Haddad (2000), and can be written as follows:

$$\Delta_{t,t-1}MAL = -25.24 \cdot \ln\left(KCAL_t / KCAL_{t-1}\right) - 71.76 \cdot \Delta_{t,t-1}LFEXPRAT \quad 0.22 \cdot \Delta_{t,t-1}SCH - 0.08 \cdot \Delta_{t,t-1}WATER$$

where *MAL* = percentage of malnourished children
KCAL = per capita kilocalorie availability
LFEXPRAT = ratio of female to male life expectancy at birth
SCH = total female enrollment in secondary education (any age group) as a percentage of the female age-group corresponding to national regulations for secondary education, and
WATER = percentage of population with access to safe water.

$\Delta_{t,t-1}$ = the difference between the variable values at time t and t-1.

Most of this data comes from the following sources: the World Health Organization's Global Database on Child Growth Malnutrition, the United Nations Administrative Committee on Coordination- Subcommittee on Nutrition, the World Bank's World Development Indicators, the FAO FAOSTAT database, and the UNESCO UNESCOSTAT database. The per capita calorie consumption variable is derived from two components; these include the amount of calories obtained from commodities included in the model as well as calories from commodities outside the model. Knowing this percentage, the projected number may be calculated using the following equation:

$$NMAL_t = MAL_t \times POP5_t,$$

where *NMAL* = number of malnourished children, and
POP5 = number of children 0–5 years old in the population.

Observed relationships between all of these factors were used to create the semi-log functional mathematical model, allowing an accurate estimate of the number of malnourished children to be derived from data describing the average per capita calorie consumption, female access to secondary education, the quality of maternal and child care, and health and sanitation.

Modeling

As was explained , the quantitative framework used in this study does not completely integrate the agricultural and energy modeling components. The IMPACT-WATER model is a stand-alone model into which we input crop feedstock requirements that are driven by the scenarios for crop-based biofuel production. The supply side of the model, responds to the additional 'other' demand for crop tonnage that is consistent with the amounts needed for biofuel conversion, as is shown in Figure 1. The portion of biofuel demand that cannot be met through domestic, feedstock-based production is 'passed' to the energy model as a 'demand' for imports. The trade model then adjusts to the implied demand to give the corresponding spatial trade patterns that correspond to the implied import demands. In a more integrated framework, there would be a biofuel demand 'function' that would be embedded as part of the IMPACT-WATER model, itself, such that it responds to and adjust to available levels of feedstock, and induces additional production or international trade of the biofuel product, itself, if needed. While this is not a part of the modeling framework, currently, we hope to integrate this functionality more closely into the main model in the near future.

Modeling Energy Demand for Biofuels

Given the close inter-connections between the demand for energy products and the demand for agricultural products that are consumed as feedstocks, in the production of biofuels, we have included some key quantitative relationships that tie the socio-economic growth trajectories to the demand for energy products[32]. We have used available data to construct a population and income-

[32] Given the limited scope of this desk study, we were unable to construct a model that fully captures the interactions between socio-economic growth and energy demand for all uses and for all economic sectors. While this could be done with an economy-wide, computable general equilibrium model, there is a global-level model, which has sufficient spatial disaggregation to adequately represent the Latin American region – neither do such

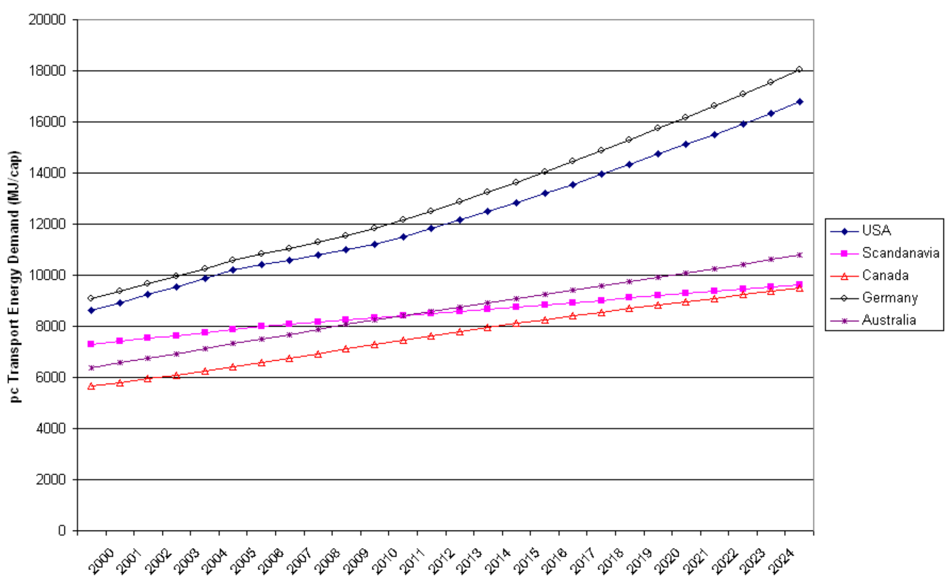
driven representation of transport energy demand growth across time, and have linked that with projections of oil prices and scenario-driven blending requirements with renewable energy sources, to quantify the demand for biofuel products.

Numerous empirical studies have attempted to link the long-term trends in socio-economic growth to the demand for energy products and the intensity of energy use within national economies, such as that of Galli (1998), which looked at trends within Asia, and the global study of Price *et al.* (1998). In these studies, a quantitative relationship between per-capita income and the demand for energy were used to describe likely long-term trends for energy production, and the implied economic and environmental consequences. For the purposes of this study, we focus specifically on energy for transportation, as it provides the primary motivation for biofuel production and utilization, globally, and is the central focus of most biofuels studies. We draw on the empirical relationship between per-capita energy demand for transport and per-capita GDP (income) that was estimated across 122 countries, by Price et al. (1998), and use the exogenous projections of population and national income within IMPACT-WATER, to drive this relationship over time. The equation linking energy demand and income, estimated by Price *et al.*, is given below.

$$Energy = 154.1\left(pcGDP\right)^{1.16} \qquad R^2 = 0.8$$

where Energy is in units of Mega Joules per capita and per capita GDP is in thousands of dollars. Using the socio-economic drivers within our model database, and this empirical relationship, we are able to derive projections of per-capita transportation energy demand shown in figure 4.2, below.

Figure 4.2: Projections of Per-Capita Transport Energy for Selected Countries



This figure shows a comparable trajectory of per-capita energy growth among the top industrialized countries, and represents a range of overall average annual growth from 1.1% for the

models typically have the kind of disaggregation among the agricultural commodities that allows one to look at the impacts on the specific feedstocks of interest.

Scandinavian region to an average rate of 2.8% for Germany. Looking more specifically at the Latin American Region, we see the growth trajectories shown in Figures 4.3a and 4.3b below.

Figure 4.3a: Projections of Per-Capita Transport Energy for LAC region

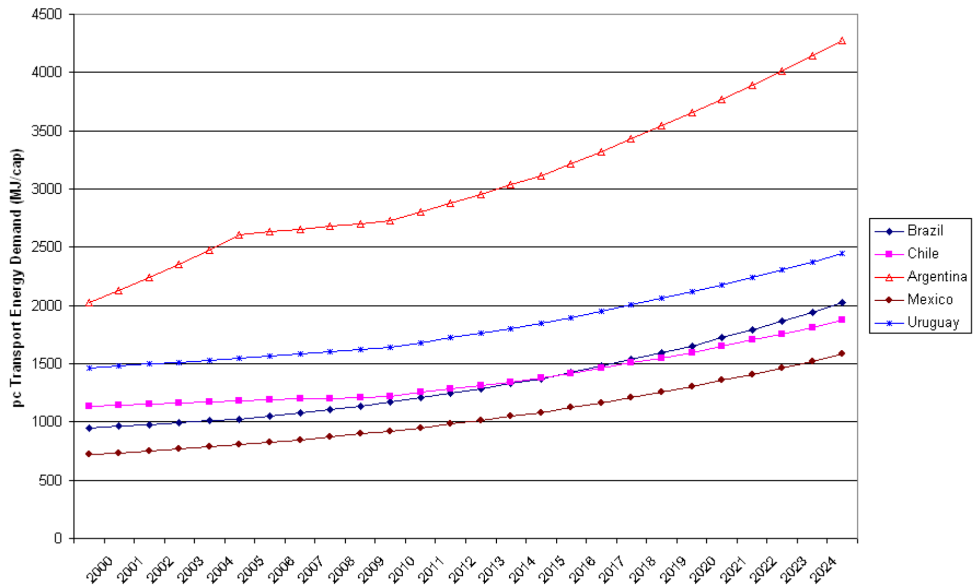
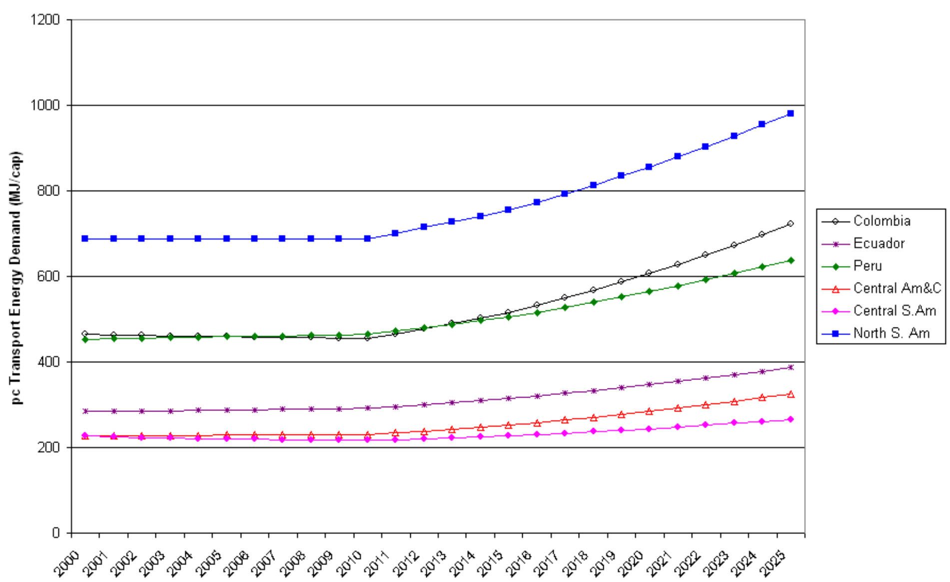


Figure 4.3b: Projections of Per-Capita Transport Energy for LAC region



Figures 4.3a and 4.3b show the distinction between the 'high growth' regions and those which show a steady, but lower profile of energy demand growth. It should be noted, again, that these are per-capita measures, which must be multiplied by national population to give the total domestic demand for transportation energy. Therefore, the relative ranking among countries will likely appear quite different, when expressed in terms of total demand terms. Undoubtedly, there are technological and policy-driven factors that might very well change the trajectory of these energy

trends – necessitating other variables to be present within the empirical relationship. The inclusion of these factors, such as transportation technology and national energy policy are beyond the scope of this desk study, and will be explored further in future work. In the following section, we discuss the design of the modeling component which captures international trade in energy products.

Modeling Trade in Biofuel Products

Based on the inferred demand for transport fuel, and the feasibility of domestic biofuel production that is possible within each region, any deficit that cannot be met by own-production must be satisfied through international trade in biofuel products. Given that the IMPACT-WATER model only treats international trade in agricultural commodities, at present, we construct a separate spatial equilibrium model to represent the adaptation that is plausible within international biofuel markets.

Borrowing on the basic principle of spatial equilibrium models, presented in the seminal paper of Takayama and Judge (1964), we can express the basic framework as follows

$$\max_{x_{i,j}, m_{i,j}, q_i^S, q_i^D, p_i, p_j \geq 0} \sum_{i=1}^{N} \left[\int P^S(q_i^S) dq + \int P^D(q_i^D) dq \right] - \sum_{i=1}^{N} \sum_{j=1}^{N} \tau_{i,j} x_{i,j}$$

$$\begin{aligned}
&s.t. \\
&\quad q_i^S = q_i^D + \sum_{j \neq i} \left(x_{i,j} - m_{i,j} \right) \\
&\quad \sum_i \sum_j x_{i,j} = \sum_i \sum_j m_{i,j} \\
&\quad q_i^D = P^D\left(p_i\right), q_i^S = P^S\left(p_i\right) \\
&\quad p_i \leq p_j + \tau_{i,j}
\end{aligned}$$

Where the quantities of supply and demand for region i are denoted by q_i^S, q_i^D, and where the associated price for region i is embedded in the functional supply and demand relationships $q_i^S = P^S\left(p_i\right), q_i^D = P^D\left(p_i\right)$, which can be integrated to describe the producer and consumer surplus for each region $\int P^S(q_i^S)dq, \int P^D(q_i^D)dq$. The quantities of exported and imported biofuel in region *i* are denoted by x_i and m_i, respectively. The sum of the producer and consumer surplus form the objective function of the problem, from which the costs due to trade tarrifs $\left(\tau_{i,j}\right)$ are subtracted. The trade balance is imposed for each region, in this problem, as well as the 'no arbitrage' constraint on prices – such that the gains in spatial price differences are exhausted by the unit tariff.

This type of model is fairly standard, and can be easily applied to the study of biofuels trade, once it has been parameterized. Using elasticity values from a variety of sources, the model was calibrated for the observed trade in ethanol and biodiesel, and simulated for the scenarios being investigated in this study. The results of the scenario analysis will now be examined in more detail, in the section which follows.

Key Limitations

Data

In carrying out this study, we came across a number of limitations relating to data – mostly relating to the parameterization of the behavioral characteristics of the model. Given the relatively 'thin' economic literature on biofuel production, utilization and trade, there have been very few studies that can provide guidance as to what the long-term response of biofuel supply and demand is to market conditions. While Brazil has been fairly well-studied, compared to most regions of Latin America, and the world, there is not nearly as much empirical evidence for other regions. Most studies are heavily biased toward OECD countries, and tend to leave out much of the developing world, when discussing behavioral response and growth potential.

In this study, we draw upon a number of behavioral parameters used in the OECD study of von Lampe (2006), and adjusted them for other non-OECD regions, according to our best estimate of how such parameters could vary across regions. We also looked for guidance to published studies, to provide some comparison for our forward-looking assessments of biofuels growth, and pulled from a variety of data sources to give reliable starting values for the base year of the biofuels projections – 2005.

Annex 4

Basic scenario schematic and baseline data

Figure A4.1. Scenario schematic for biofuels simulations

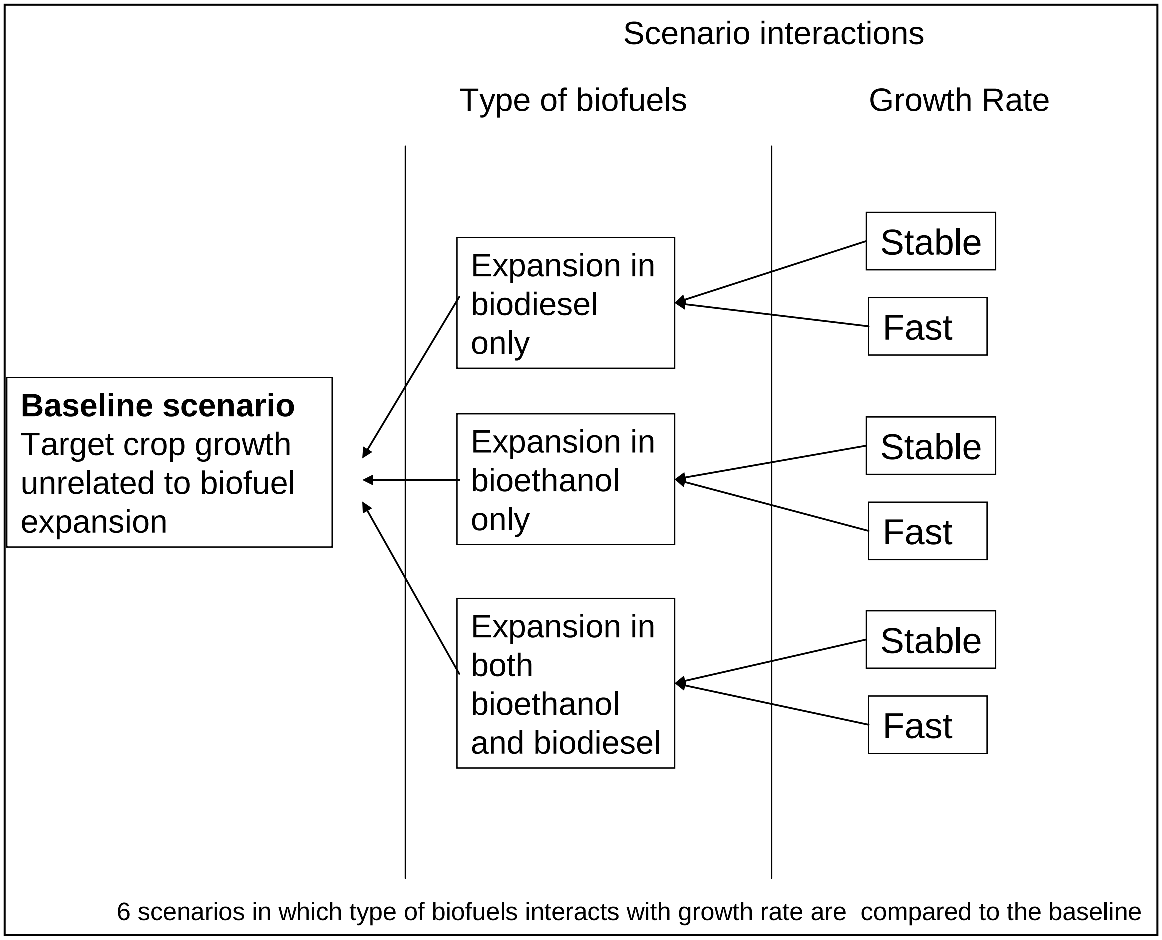


Table A4-1 Baseline Production Levels of Major Biofuels Feedstock Crops (thousands of metric tons)

Countries	***Ethanol***								***Biodiesel***	
	Wheat		**Maize**		**Cassava**		**Sugar**		**Oils**	
	2000	**2025**	**2000**	**2025**	**2000**	**2025**	**2000**	**2025**	**2000**	**2025**
Argentina	15757	23965	15307	28137	168	196	21573	31508	5655	8613
Brazil	2477	4907	35331	53093	22228	28122	445213	2428415	5823	9936
Central America and Caribbean	10	20	3126	7465	1240	1449	97129	156898	537	1054
Central South America	376	765	1415	3503	3886	6954	7599	13079	473	843
Chile	1487	2698	685	1208					275	540
Colombia	37	60	1134	2009	1908	2563	40944	60337	730	1521
Ecuador	15	34	483	1106	89	125	6784	11978	339	665
Mexico	3280	3636	18608	35149	102	112	64506	92131	1205	2082
Northern South America	1	1	1551	3527	753	844	13330	23168	244	479
Peru	180	354	1206	2760	1213	1422	9416	16913	600	1179
Uruguay	284	467	190	445			193	333	82	161

Table A4-2 Baseline Net Trade Levels of Major Biofuels Feedstock Crops (thousands of metric tons)

Countries	***Ethanol***								***Biodiesel***	
	Wheat		**Maize**		**Cassava**		**Sugar**		**Oils**	
	2000	**2025**	**2000**	**2025**	**2000**	**2025**	**2000**	**2025**	**2000**	**2025**
Argentina	10535	16231	9991	18944	-12	56	-135	-216	4689	7289
Brazil	-7606	-8668	-664	-16564	-131	-3326	6839	85191	1189	2342
Central America and Caribbean	-2974	-4524	-2652	-2584	239	56	4413	6778	-739	-944
Central South America	-464	-563	304	1280	-4	1037	20	-2	291	529
Chile	-467	-16	-1165	-2505	0	0	-859	-1179	-172	-118
Colombia	-1183	-1683	-1816	-2791	-7	76	1268	1372	-128	149
Ecuador	-473	-664	-118	-272	13	-113	-14	12	-17	135
Mexico	-2469	-4543	-5567	1080	23	22	2755	2121	-1252	-1705
Northern South America	-1360	-1995	-1095	-473	-35	-210	-162	-287	-346	-407
Peru	-1345	-1751	-921	-1845	-5	-173	-429	-612	80	368
Uruguay	19	-19	-113	54	-4	-4	-93	-125	28	87

Note: positive net trade denotes exports, while negative values denote country imports.

Table A4-3 Baseline Total Demand Levels of Wheat for Ethanol (thousand of metric tons) with utilization shares

Ethanol					
Countries	**Wheat**				
	2000	**2025**	**Food**	**Feed**	**Other**
Argentina	5524	7734	81%	2%	17%
Brazil	9042	13575	89%	4%	7%
Central America and Caribbean	2861	4544	75%	21%	4%
Central South America	786	1327	62%	23%	15%
Chile	1964	2714	85%	8%	6%
Colombia	1199	1743	98%	0%	2%
Ecuador	489	698	99%	0%	1%
Mexico	5713	8179	65%	1%	34%
Northern South America	1311	1996	93%	4%	3%
Peru	1441	2104	96%	0%	4%
Uruguay	378	486	81%	10%	9%

Table A4-4 Baseline Total Demand Levels of Maize for Ethanol (thousand of metric tons) with utilization shares

Ethanol					
Countries	**Maize**				
	2000	**2025**	**Food**	**Feed**	**Other**
Argentina	5344	9193	5%	58%	37%
Brazil	35999	69657	5%	84%	11%
Central America and Caribbean	5620	10049	38%	55%	6%
Central South America	1264	2223	44%	38%	19%
Chile	1854	3713	8%	86%	6%
Colombia	2969	4800	47%	51%	2%
Ecuador	703	1378	16%	75%	9%
Mexico	22525	34069	48%	34%	17%
Northern South America	2300	4000	44%	45%	12%
Peru	2161	4605	10%	86%	4%
Uruguay	235	391	28%	55%	17%

Table A4-5 Baseline Total Demand Levels of Cassava for Ethanol (thousand of metric tons) with utilization shares

Ethanol					
Countries	**Cassava**				
	2000	**2025**	**Food**	**Feed**	**Other**
Argentina	181	141	61%	22%	17%
Brazil	22364	31452	27%	57%	16%
Central America and Caribbean	1097	1489	67%	12%	21%
Central South America	3894	5920	25%	63%	12%
Chile	0	0	8%	0%	92%
Colombia	1921	2493	76%	11%	12%
Ecuador	325	488	27%	67%	5%
Mexico	81	92	90%	0%	10%
Northern South America	776	1043	63%	9%	28%
Peru	1218	1596	73%	0%	27%
Uruguay	4	4	27%	0%	73%

Table A4-6 Baseline Total Demand Levels of Sugar for Ethanol (thousand of metric tons) with utilization shares

Ethanol					
Countries	**Sugar**				
	2000	**2025**	**Food**	**Feed**	**Other**
Argentina	1643	2435	91%	9%	0%
Brazil	10036	16565	84%	3%	13%
Central America and Caribbean	2191	3891	76%	13%	11%
Central South America	471	865	72%	9%	20%
Chile	650	1058	95%	3%	2%
Colombia	1459	2652	81%	6%	13%
Ecuador	476	803	92%	6%	3%
Mexico	4032	7683	81%	7%	12%
Northern South America	1009	1803	83%	4%	13%
Peru	942	1635	83%	0%	17%
Uruguay	82	124	95%	5%	0%

Table A4-7 Baseline Total Demand Levels of Oils for Biodiesel (thousand of metric tons) with utilization shares

Biodiesel					
Countries	**Oils**				
	2000	**2025**	**Food**	**Feed**	**Other**
Argentina	742	1100	85%	1%	15%
Brazil	4729	7688	57%	0%	42%
Central America and Caribbean	1248	1971	59%	2%	40%
Central South America	204	336	80%	0%	20%
Chile	456	667	46%	43%	11%
Colombia	853	1367	64%	0%	36%
Ecuador	354	529	80%	1%	18%
Mexico	2395	3724	53%	0%	47%
Northern South America	502	798	67%	13%	20%
Peru	536	827	51%	0%	49%
Uruguay	57	77	58%	0%	41%

For further information, please contact:

Chief, Latin America and the Caribbean Service
FAO Investment Centre Division
tel +39 06 57053196 – fax +39 06 57054657
TCIO-Service-Chief@fao.org

Or visit the Centre's web site:
www.fao.org/tc/tci/