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Biofuels and Rural Economic Development in Latin America and the Caribbean

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Acronyms

CIAT = The International Center 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

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

Abstract

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. Very little discussions have been focused on Latin America, except for Brazil. Potential negative impacts re-enforce the need of performing more in depth analysis of the potential impact of biofuels expansion in Latin America and the Caribbean (LAC). Paper estimates biofuels production potential based on current production situation and develops a forward-looking analysis of the long-term impact of biofuels expansion in Latin America and its effects on prices, trade, food security, malnutrition and other indicators using the IMPACT-WATER model developed by IFPRI. The analysis conducted for this paper of potential crops in the region show that from a technical and productivity standpoint in which to base biofuels expansion continues to be sugarcane and palm oil trees. 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 biofuels expansion. Our analysis, and those made in other studies, show that biofuels expansion is not likely to have a binding land production constraint in Latin America, with a few exceptions. The forward-looking estimations from the IMPACT-WATER model show that Brazil will continue to be the major player in the ethanol market. Brazil will expand its ethanol exports to meet growing demand in other countries including some in Latin America. Other countries such as Argentina and Colombia will likely continue their biofuels expansion plans, although our estimate show that they will not likely meet their demand based on current production potential. The IMPACT-WATER simulations also show that biofuels impacts on food security and malnutrition will likely happen in those countries where the feedstock used for biofuels 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. The extent to which biofuels efforts can contribute towards addressing or affecting all 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.

Introduction

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 reducing dependence on fossil fuels, minimize negative environmental impacts, and increase the use of alternative energy sources for transportation and other uses. The accumulating 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.

This paper is divided into five sections. Section two introduces the background, rationale, and substantive issues relating biofuels generation to agriculture in Latin America. Section three provides an overview of the capacity and policy issues related to agricultural and biofuels production 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 using IFPRI IMPACT-WATER model 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. Section five discusses policy issues related to biofuels expansion in Latin America and the Caribbean while section six concludes with some final thoughts.

Objectives and Scope

This paper has two 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 biofuels 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.

In this paper we assume that the most likely use in the LAC region 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.

There are several 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 paper is on production of ethanol and biodiesel from agricultural feedstocks. Given the available feedstock conversion technologies, the most viable feed stocks for ethanol production for transportation in Latin America are sugarcane and maize/sorghum, while those for biodiesel are oilseed crops like palm oil and coconuts. 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 Table 1 contains a list of countries included in this study.

Diagnostic of the Current Crop Situation in LAC: An Indicator Approach

Data collected for this section served as a foundation to derive the scenarios and estimations in section 4. More sophisticated approaches to the indicator approach pursued in this section are the studies conducted by Ludeña, Razo and Saucedo (2007), Razo, Astete-Miller, Saucedo, and Ludeña 2007. We pursued in addition to the analysis included in this paper a separate indicator analysis of supply and demand factors that may affect biofuels production in Latin America. This analysis is available upon request.

Regional Potential for Latin American Feedstock Production

Table 2 presents current production summaries for potential target feedstock for ethanol and biodiesel and data on the relative shares for the largest producers of the 30 countries in LAC region. 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 biofuels production in the region. As can be seen in Table 2, LAC countries have significant production share relative to world's total production only in the case of sugarcane and soybeans, 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.

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 biofuels production in Latin America.

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.

Table 3 introduces yield of potential crops that may be considered as target for biofuels production in LAC countries. Of all the crops listed in Table 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 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.

Estimating potential biofuels production using current production area and yield

We use current area and yield in order to estimate the potential production of ethanol and biodiesel in each LAC country, for those crops with significant area harvested and production in those countries to answer two questions below including meeting mandatory blending requirements (See Table 4 for production data). 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. The basic formulas to estimate maximum production of ethanol and biodiesel are presented in Annex 2 of the supplemental document to this paper (found in AGECON Search).

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

Table 5 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.

Table 6 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 6.

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?

Results in Table 7 show that the best alternative to produce ethanol is sugarcane, followed by maize and then cassava. Not surprisingly Brazil has the highest potential for biofuels 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 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. Results in Table 7 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.

Results in Table 8 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.

Assessment of Potential and Impacts Biofuels Growth in LAC Countries

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.

Quantifying Growth Potential for Biofuels in Latin America

Outline of the Quantitative Scheme

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 include: 1) a global agricultural production and trade model, 2) A quantitative representation of future crude oil prices on the world market, 3) A quantitative relationship between energy demand for transport and the socio-economic growth patterns of income and population, over time and 4) a simplified spatial equilibrium model of ethanol and biodiesel trade

A schematic which illustrates how the various modeling components are linked together in order to provide the overall quantitative framework of analysis as well as a complete description of the simulation methodology and approach is included in Annex 6 of the supplemental paper (available in AGECON search). 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.

From the Figure 4.1, 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 biofuels products themselves. 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. Policies affecting energy markets and trade of energy products could also be interventions, but are not explored in this study.

Modeling Assumptions

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

1. That markets for both agricultural and biofuels commodities are competitive, and amenable to analysis with a straightforward equilibrium-driven approach;
2. All agricultural and biofuels commodities will be treated as homogenous in quality and characteristics (for consumption), and are not differentiated by quality from countries of origin;
3. 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;

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 6 of the supplemental paper (available AGECON search).

Scenario Analysis of Biofuels Growth

Among the key simulation-based indicators that we will bring out in this section include changes with respect to baseline of agricultural prices, irrigated and rain fed crop area and production, implications for land use, shifts in trade patterns within agricultural feedstock markets, trade movements within the markets for the biofuels products, impacts on consumptive water use in agriculture, as differences from baseline, implications on food security and malnutrition status, and impacts on gross agricultural revenue, as differences from baseline

In all these cases, the 'baseline' is a reference run, in which there is no accelerated growth in agricultural commodity demand due to biofuels usage – but, rather, a smooth pattern of proportional growth in the 'other' demand category, according to movements in food and feed utilization levels[1]. Baseline schematics of scenarios and baseline data are included in Appendix 7 of the supplemental paper. 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 biofuels 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

We characterize the baseline situation for our quantitative assessment by describing the allocation of production characteristics for the key biofuels crops in the Latin American region. As irrigated and total harvested area, are significant towards explaining the results of our scenarios, we describe them in greater detail below.

The distribution of irrigated area used as a baseline is given in Table 9. 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.

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.

If we look at the growth of total maize area, under baseline model assumptions, in Figure 2a, 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. 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 biofuels production. The basic "baseline" trajectories will be compared with those under two specific biofuels 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 A6.1 in Annex 6 of supplemental paper.

The area expansion trajectory for sugarcane growth (Figure 2b) 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.

Ethanol, Biodiesel and Combined Scenarios

Given the prominence of ethanol in global biofuels 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.

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.

In the biodiesel 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.

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. Finally, the combined biodiesel and ethanol scenarios adds up the previous scenarios into one composite scenario happening in tandem.

Scenario Results

Table 10, 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, biofuels-driven expansion utilizing cassava as a feedstock tends to cause much stronger impacts on price.[2] 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.

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 such as Colombia (CGIAR 2007; IPS 2007).

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 biofuels feedstock in tropical regions, such as Brazil. As has also been expressed in other global assessments of biofuels potential (OECD, 2007; FAPRI, 2007), the current biofuels 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.

The impacts observed on irrigated area in the scenario considering a 'stable' trajectory of ethanol growth in LAC, in Table 11, 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 10) 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 9), 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.

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.

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 biofuels 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.

Examining the impacts on total feedstock crop area under the 'stable' ethanol growth scenario, as shown in Table 12, 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 10) 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 12, since most of it is realized in the expansion of rainfed area.

In parallel with Table 12, the percentage increases in irrigated production under a stable trajectory of ethanol production growth in LAC (Table 13), 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 m^3/ton for sugarcane, compared with 1900 m^3/ton for maize and 1500 m^3/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. 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.

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 14 shows the 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[3]. Results in Table 14 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[4].

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).

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.

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.

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.

The results in Table 15, 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[5].

Table 15 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 15 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.

Table 16 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 availability, as it responds to changes in food production, prices and the market-level consumer demand response[6]. Results shown in Table 16, are closely parallel to those given previously in Table 15, and describe an important indicator of food security – namely, per capita calorie availability[7]. 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 16, 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.

From the results shown in Table 16, 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 15. 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.

Results from both Tables 15 and 16, 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 biofuels 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. 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.

Demand for Biofuels and Market Implications

We now present the implications for trade in biofuels products, themselves, under the scenarios developed in the previous sections. In the projected demands for transportation energy 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 biofuels production, we can project the demand trend for biofuels products over time, such as is shown for ethanol in Figure 3a. 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.

Figure 3b, 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. 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). 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 respect, the plantation palm oils would be highly advantageous, and would provide much more favorable cost economies for biodiesel production.

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 biofuels products. Figure 4a 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.

In the case of biodiesel, we also see a steady trend for biofuels imports to meet internal demands in those countries (Figure 4b). 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[8], 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.

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 5a 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. 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. Looking more closely at global biofuels 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.

Figure 5a, 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, depicted as negative net exports in the graph, 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.

Figure 5a 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.

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.

Relevant Policy Issues from Biofuel Expansion in LAC Countries

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, 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 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?

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.

The scenarios in Section 3 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. Figures presented by OECD (2006) show that different crops have different ethanol/biodiesel yields.

Land and water use policies

A paper by von Lampe (2006) showed that 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% biofuels 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. A paper Kojima (2006) described, used and unused available farm land area, in relevant countries. 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.

But there are other pathways that policy makers should consider, besides the raising of staple food prices, through which biofuels 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 paid to the impact that biofuels can have on the human landscape, and not just only to purely environmental criteria.

As we have described in different sections in this paper, 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 biofuels 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.

The Food for Fuels Tradeoff

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. 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 biofuels 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, biofuels 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.

Agricultural income and prices

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 (von Braun 2008). 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.

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).

The downward trend in commodity prices seems to be reversing. Von Braun (2008) indicates that 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 bio-energy.

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 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.

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.

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.

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.

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.

Food security, malnutrition and social protection

From the forward-looking analysis done in this paper, 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[9], 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.

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[10].

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.

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.

Development and business plans for biofuels expansion

In the LAC region, 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. 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.

Final reflections

In this paper we analyze important biofuels expansion issues that have implications for the agricultural and energy economies within the Latin America and the Caribbean region. 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. 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.

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, and thus may have an impact on livelihoods and vulnerability.

Yet, 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. The Brazil case study is worthwhile exploring by other Latin American countries as there may be important lessons to be learned, in terms of how environmental concerns can be addressed and land use policies more effectively implemented.

At the core of the biofuels 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 biofuels 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.

We have shown in this paper 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 note 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.

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. 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.

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.

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.

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.

Footnotes

[1] 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).

[2] 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.

[3] 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.

[4] 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.

[5] 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).

[6] 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.

[7] 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.

[8] 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.

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

[10] 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.

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Tables

Table 1 List of Latin American and Caribbean Countries and their associated groupings

Regional definitions in model	Countries within aggregate regions in IFPRI's IMPACT-WATER model and 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.

Table 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 author's 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 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.

Table 4 Current Production of Crops that may serve as Feedstock for Biofuel Expansion, by Country (tons)

Country	Cassava	Cotton seed	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
E.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	1,975	90,387	8,830	12,152	93,848	581,572	285,855	234

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

Table 5 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 required (1,000 lts)	100% production from targeted crop destined for ethanol (1,000 lts)	% of current production to meet blending standards	100% production from targeted crop destined for ethanol (1,000 lts)	% of current production to meet blending standards	100% production from targeted crop 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

Note: Author estimations

Table 6 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 / projected standards (as %)	Biodiesel requirements (Million lts/year)	100% production from targeted crop destined for biodiesel (Million lts)	% of current production to meet blending standards	100% production from targeted crop destined for biodiesel (Million lts)	% of current production to meet blending standards	100% production from targeted crop 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
Dom. Rep.		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

Note: Author estimations

Table 7 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 100% production from targeted crop was destined for ethanol (1,00 lts)	% of current ethanol demand potentially met with current production	100% production from targeted crop was destined for ethanol (1,00 lts)	If % of current ethanol demand potentially met with current production	100% production from targeted crop was destined for ethanol (1,00 lts)	If % 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%

Note: Author estimations

Table 8 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 100% production from targeted crop was used for biodiesel (Million liters)	% of current biodiesel demand potentially met with current production	If 100% production from targeted crop was used for biodiesel (Million liters)	% of current biodiesel demand potentially met with current production	If 100% 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%
E. 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%

Note: Author estimations

Table 9 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

Table 10 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

Table 11 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

Note: IMPACT-WATER projections

Table 12 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

Note: IMPACT-WATER projections

Table 13 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

Note: IMPACT-WATER projections

Table 14 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

Note: IMPACT-WATER projections

Table 15 Baseline Child Malnourishment levels in year 2025 and Differences from Baseline under Scenarios

Countries	Baseline (000 children)	Ethanol expansion (%)	Biodiesel Expansion (%)	Combined Ethanol + Biodiesel expansion (%)
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

Note: IMPACT-WATER projections

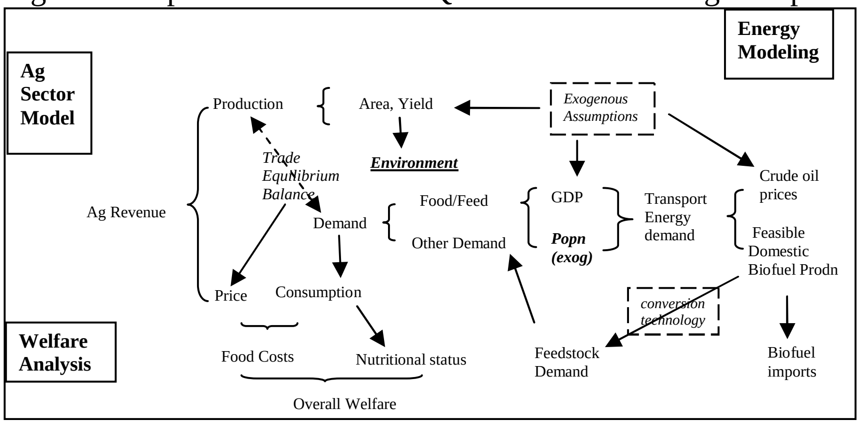
Table 16 Baseline per capita calorie availability in year 2025 and percentage difference from baseline under scenarios

Countries	Baseline (Kcal/cap/day)	Ethanol expansion (%)	Biodiesel expansion (%)	Combined Ethanol + Biodiesel expansion (%)
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

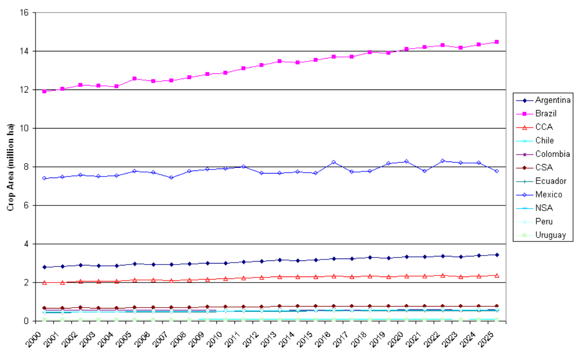
Note: IMPACT-WATER projections

Figures

Figure 1 Graphical Schematic of Quantitative Modeling Components



Figures 2a and 2b Projection of Maize and Sugarcane Area in Latin America (Baseline Growth



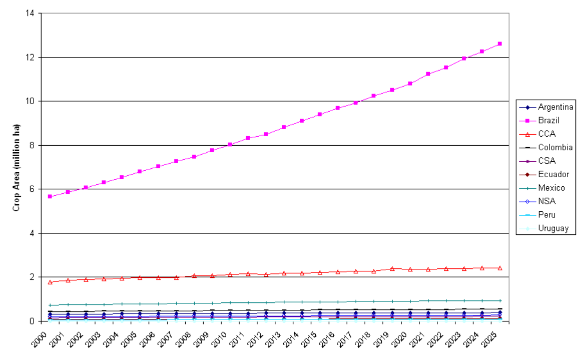
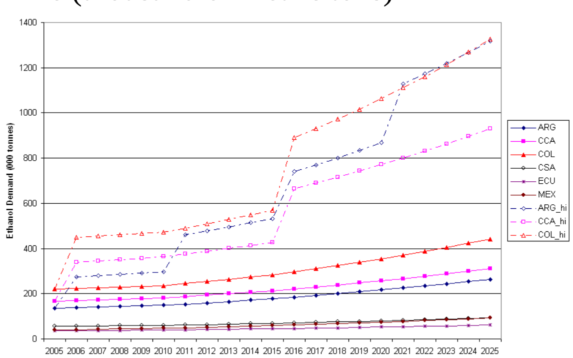


Figure 2a. Maize projections

Figure 2b. Sugarcane projections

Note: IMPACT-WATER projections

Figures 3a and 3b Projection of Total Ethanol and Biodiesel Demand in Latin America over Time (thousand of metric tons)



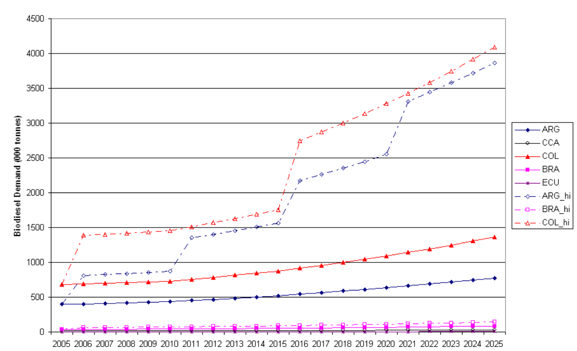
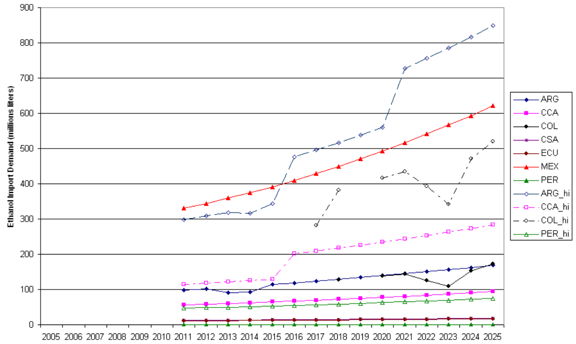


Figure 3a. Ethanol demand

Figure 3. Biodiesel demand

Note: author's calculations

Figure 4a and 4b Projection of Ethanol and Biodiesel Import Demand in Latin America over Time (million liters)



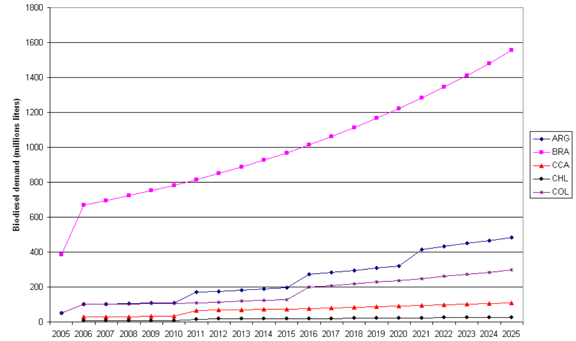
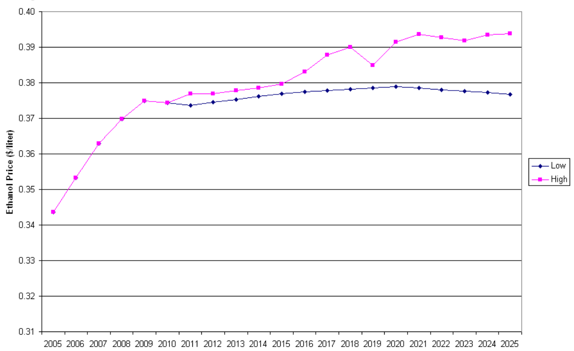


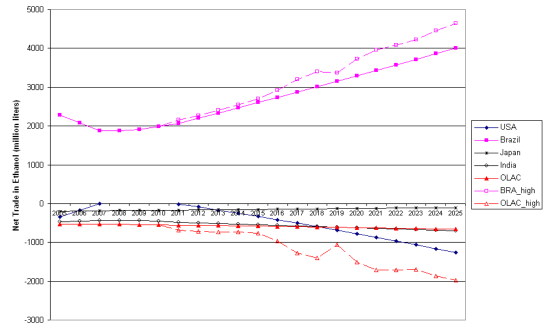
Figure 4a. Ethanol demand

Figure 4b. Biodiesel demand

Source: author's calculations

Figure 5a and 5b Projection of Ethanol Market Prices and Net trade over Time ($/liter)





Ethanol market prices

Ethanol trade

Source: Author's calculations