GREATER MEKONG SUBREGION
ECONOMIC COOPERATION PROGRAM

Global and Regional Development
and Impact of Biofuels:

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GLOBAL AND REGIONAL DEVELOPMENT AND IMPACT OF BIOFUELS

A FOCUS ON THE GREATER MEKONG SUBREGION

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Printed in the Philippines.

ISBN 978-971-561-846-5
Publication Stock No. RPT090356

Cataloging-In-Publication Data

Asian Development Bank.
Global and Regional Development and Impact of Biofuels: A Focus on the Greater Mekong Subregion
Mandaluyong City, Philippines: Asian Development Bank, 2009.

1. Biofuels. I. Asian Development Bank.

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Abbreviations

CNY	–	yuan
EU	–	the European Union
FAO	–	Food and Agriculture Organization of the United Nations
GMS	–	the Greater Mekong Subregion
GMS-5	–	Cambodia, the Lao People’s Democratic Republic, Myanmar, Thailand, and Viet Nam
GTAP	–	Global Trade Analysis Project
Lao PDR	–	the Lao People’s Democratic Republic
mt	–	million ton
OECD	–	Organisation for Economic Co-operation and Development
PRC	–	the People’s Republic of China
US	–	the United States

Acknowledgment

The study "Strategy for Integrating Biofuel and Rural Renewable Energy Production in Agriculture for Poverty Reduction in the Greater Mekong Subregion" is a successful result of the close collaborative work among affiliates and friends of the Greater Mekong Subregion Economic Development Initiative. The study was made possible by funding from the Asian Development Bank (ADB) and the International Fund for Agricultural Development (IFAD). Special thanks are also due to the Food Agriculture Organization of the United Nations (FAO); and to its Regional Office for Asia and the Pacific (FAO RAP) in Bangkok for its assistance in organizing and hosting a number of workshops and meetings that brought together collaborators and partners to discuss the emerging issues confronting the development of the Greater Mekong Subregion (GMS).

The study was led and coordinated by Mercedita A. Sombilla of the Southeast Asian Center for Graduate Study and Research in Agriculture (SEARCA) and could not have been completed without the strong support of the governments of the GMS countries, particularly the national biofuel assessment teams composed of the following eminent experts and technical personnel:

Luyna Ung, Hay Sovuthea, and Sophiak Siek of the Supreme National Economic Council; and Sar Chetra of the Ministry of Agriculture, Forestry and Fisheries for the assessment study "Status and Potential for the Development of Biofuels and Rural Renewable Energy: Cambodia";

Jikun Huang, Huanguang Qiu, and Jun Yang of the Center for Chinese Agricultural Policy, Chinese Academy of Sciences; Yuhua Zhang and Yanli Zhang of the Institute of Rural Energy and Environmental Protection, Chinese Academy of Agricultural Engineering; and Yahui Zhang of the Center of International Cooperative Service, Ministry of Agriculture for the assessment study "Status and Potential for the Development of Biofuels and Rural Renewable Energy: the People's Republic of China";

Kham Sanatem of the Forestry and Agriculture Promotion Center, Ministry of Agriculture and Forestry; Bouathep Malaykham of the Electric Power Management Division, Department of Electricity, Ministry of Energy and Mines; Phouvong Phommabouth, Department of Trade Promotion, Ministry of Industry and Commerce; Sounthone Ketphanh, National Agriculture and Forestry Research Institute, Ministry of Agriculture and Forestry; and Keophayvan Insixiengmai, Technology Research Institute, Science and Technology Agency for the assessment study "Status and Potential for the Development of Biofuels and Rural Renewable Energy: the Lao People's Democratic Republic";

U Hla Kyaw of the Department of Agriculture and Planning, Ministry of Agriculture and Irrigation; Thandar Kyi of Yezin Agricultural University; San Thein, Myanma Industrial Crop Development Enterprise, Ministry of Agriculture and Irrigation; U Aung Hlaing, Department of Agricultural Planning; and U Tin Maung Shwe, Myanmar Academy of Agriculture, Forestry, Livestock and Fishery Sciences for the assessment study "Status and Potential for the Development of Biofuels and Rural Renewable Energy: Myanmar";

Suthiporn Chirapanda, independent consultant; Sudarat Techasriprasert, Office of Agricultural Economics; Somjate Pratummin, Ministry of Agriculture and Cooperatives; Samai Jain, Ministry of Science and Technology; and Prapon Wongtarua, Ministry of Energy, for the assessment study "Status and Potential for the Development of Biofuels and Rural Renewable Energy: Thailand";

Nguyen Do Anh Tuan, Nguyen Anh Phong, Nguyen Nghia Lan, and Ta Thi Khanh Van of the Institute of Policy and Strategic Agricultural and Rural

Development, Ministry of Agriculture and Rural Development (MARD); Tran The Tuong of the Department of Crop Production, MARD; Phan Dang Hung, Department of Forestry, MARD; Vi Viet Hoang, Department of Cooperation and Rural Development, MARD; and Ha Van Chuc, Department of Livestock Production, MARD, for the assessment study "Status and Potential for the Development of Biofuels and Rural Renewable Energy: Viet Nam"; and

Jikun Huang, Jun Yang and Huanguang Qiu of the Center for Chinese Agricultural Policy, Chinese Academy of Sciences; Scott Rozelle of Stanford University; and Mercedita A. Sombilla of SEARCA, for the projection study "Global and Regional Development and Impact of Biofuels: A Focus on the Greater Mekong Subregion".

The country reports were consolidated in the report entitled "Integrating Biofuel and Rural Renewable Energy Production in Agriculture for Poverty Reduction in the Greater Mekong Subregion: An Overview and Strategic Framework for Biofuel Development" by Mercedita A. Sombilla of SEARCA; and Urooj S. Malik, A. K. Mahfuz Ahmed, and Sarah L. Cueno of the Southeast Asia Department, ADB.

During the course of this study, the team received valuable advice and guidance from many individuals and agencies. Special thanks are due to Urooj Malik, Director, Christopher Wensley, Officer-in-Charge, and Mahfuz Ahmed, Senior Agricultural Economist of the Agriculture, Environment, and Natural Resources Division, Southeast Asia Department, ADB; Thomas Elhaut, Director, Asia and the Pacific Region, IFAD; Hiroyuki Konuma of FAO RAP, Bangkok, Thailand; and the members of the GMS Working Group on Agriculture: San Vanty, Under Secretary of State, Ministry of Agriculture, Forestry and Fisheries, Cambodia; Tang Shengyao, Director of Asia and Africa Division, Department of International Cooperation, Ministry of Agriculture, the People's Republic of China; Phouangpharisak Pravongviengkham, Director General, Department of Planning, Ministry of Agriculture and Forestry, the Lao People's Democratic Republic; U Than Thay, Deputy Director, Department of Agricultural Planning, Ministry of Agriculture and Irrigation, Myanmar; Dounghatai Danvivathana, Director, Foreign Relations Division, Office of the Permanent Secretary, Ministry of Agriculture and Cooperatives, Thailand; and Le Van Minh, Director General, International Cooperation Department, MARD, Viet Nam.

Technical and logistical support was provided by the GMS Working Group on Agriculture Secretariat based at ADB headquarters, composed of Marilou Drilon, Sununtar Setboonsarng, and Sarah Cueno. Thanks go also to the ADB Resident Offices for facilitating the workshops and team meetings in the GMS countries.

The initial editing of the reports was done by Mercedita A. Sombilla. The manuscript editor was Caroline Ahmad, and the copy editors were Corazon Desuasido and Toby Miller. The final review of the studies was done by Urooj Malik.

Financial management and accounting support was provided by Oscar Badiola. Imelda Batangantang and SEARCA's accounting unit monitored the project's financial flow.

Finally, many thanks are due to the numerous other colleagues, partners, and stakeholders who provided valuable comments and information which added to the richness of the documents.

Introduction

Global production of biofuels has been growing rapidly. While the motivation for this expansion is complex, the most important rationale is to enhance national energy security. Due to the growing demand for fossil fuels and their relatively limited supply, governments of many energy-short countries are searching for any and all means to increase their energy production.[1] A continued rise in oil prices and/or rapid improvements in biofuel production technology will encourage private firms and individuals to invest in biofuel enterprises for profit. Governments are also interested in biofuels because they offer a means to increase energy consumption without increasing the amount of carbon dioxide (CO_2) released into the atmosphere. Crops that produce feedstock for biofuel production essentially take CO_2 from the air, so when biofuel is burned and CO_2 is again released there is no net gain. However, there are arguments about whether or not the outcome really is a zero sum game (footnote 1).[2] Some governments also see biofuels as a way to support the politically powerful—and, depending on the country, politically sensitive—farm sector. Promoting this source of energy can raise farm prices and improve the incomes and welfare of those involved in farming.

Biofuels offer the potential to spur rural development, but there are concerns regarding their impact on food security and poverty. Biofuels may facilitate agricultural and rural development by fostering greater investment in agriculture and creating jobs in feedstock production, biofuel manufacturing, and in the transport and distribution of feedstock and products.[3] Since feedstock accounts for more than half of the cost of biofuels production, biofuel development will promote the production of feedstock crops significantly. However, the potential effects on food security and poverty should not be overlooked.[4] If there is a major rise in the price of staple foods worldwide, or if the demand for crops for processing into fuels increases substantially, the age-old concern of governments and development practitioners—food security and poverty—may become a major issue.

The countries of the Greater Mekong Subregion (GMS), like many other countries in the world, have made plans or are planning to develop strong national biofuel programs.[5] The level of biofuels development varies greatly among countries, but by 2007 every country had set out a biofuel development plan.[6]

1 Food and Agriculture Organization (FAO). 2008. *Soaring Food Prices: Facts, Perspective, Impacts and Actions Required*. High-Level conference on World Food Security. FAO, Rome; Organisation for Economic Co-operation and Development (OECD). 2007–2008. *Economic Assessment of Biofuel Support Policies.* Paris: Directorate for Trade and Agriculture, OECD.

2 Crutzen, P. J., A. R. Mosier, K. A. Smith, and W. Winiwarter. 2007. N_2O Release from Agrobiofuel Production Negates Global Warming Reduction by Replacing Fossil Fuels. *Atmospheric Chemistry and Physics Discussion.* 7. 11,191–11,205; Von Blottnitz, H., and M.A. Curran. 2007. A Review of Assessments Conducted on Bio-Ethanol as a Transportation Fuel from a Net Energy, Greenhouse Gas, and Environmental Life Cycle Perspective. *Journal of Cleaner Production.* 15. 607–619.

3 United States Department of Agriculture, Natural Resources Conservation Service (USDA-NCRS). 2006. *Soil Erosion.* NCRS Conservation Resource Brief, No.0602. Washington, D.C.: USDA; Fischer, G., and R. Schrattenholzer. 2001. Global Bio-Energy Potentials through 2050. *Biomass and Bioenergy.* 20. 151–159.

4 International Food Policy Research Institute (IFPRI). 2008. High Food Prices: *The What, Who, and How of Proposed Policy Actions: IFPRI Policy Brief.* Washington, D.C.; Rosegrant, M. W. 2008. *Biofuel and Grain Prices: Impacts and Policy Responses.* Testimony for the United States Senate Committee on Homeland Security and Governmental Affairs, May 7, 2008; Tangermann, S. Food Price Inflation: Biofuels, Speculators or Emerging Market Demand? www.voxeu.org/index.php?q=node/1437; World Wildlife Fund. 2007. *Rainforest for Biodiesel? Ecological Effects of Using Palm Oil as a Source of Energy.* Frankfurt.

5 In this report, Cambodia, the Lao People's Democratic Republic, Myanmar, Thailand, and Viet Nam are referred to as the GMS-5. Yunnan Province and Guangxi Zhuang Autonomous Region in the People's Republic of China (PRC) also fall within the GMS. When discussions in this report also include the PRC, this will be pointed out.

6 Sombilla, A. M. 2008. *Strategies and Options for Integrating Rural Renewable Energy Production into Rural Agriculture for Poverty Reduction in the GMS.* A project report submitted to the Asian Development Bank. Manila.

However, the ability to develop and sustain the rapid expansion of biofuel production is hindered by a lack of information and understanding of the economics of its market. It has been observed in the GMS and elsewhere that no country has been able to launch a domestic biofuels industry without government support beyond the normal regulatory role.[7]

Biofuel development in the GMS must therefore take into account the full spectrum of market and social values, such as foregone food production and other agricultural outputs, environmental impact, and improvements in the welfare of the rural poor. Economic analysis is needed to evaluate the social costs and benefits of biofuels and to decide when, where, and how to embark on a biofuel program. Economic analysis can also help reshape planned or existing programs to maximize their efficiency and their net benefits to society.

This study is one of the first steps to try to improve understanding of the global and regional impacts of biofuel development on agriculture and on the rest of the economy, with specific focus on the GMS. The analysis aims to provide preliminary answers to the following questions:

(i) How will the rise in demand for biofuels affect global food prices?

(ii) How will global and GMS biofuel development programs affect national and regional agricultural production and trade?

(iii) What are the implications on household food security, poverty, and the use of land and water resources in the GMS?

Answers to these questions could feed into policy recommendations to help ensure the development of economically and socially sound biofuels programs in the countries of the GMS.

[7] ADB. 2007. *Bioenergy Development for Rural Poor in the Greater Mekong Subregion: Issues, Challenges, and Opportunities.* Consultant's report. Manila (TA 6324-REG).

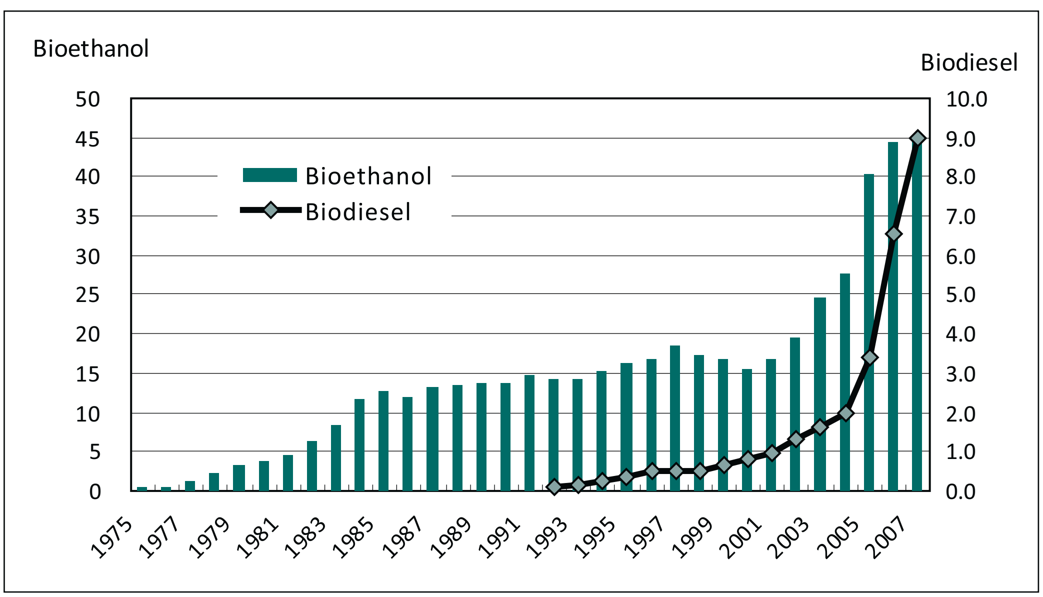
Emerging Biofuel Development

Overview of the Global Development of Biofuels

Global biofuels production rose sharply after 2000 (Figure 1). Although some countries, such as Brazil and the United States (US), started their biofuel development programs in the mid-1970s when the oil price reached its record peak, the expansion of biofuel development programs accelerated only after 2000. In 1975, worldwide production of bioethanol was 0.42 million tons (mt) and biodiesel production was negligible; but by 2000, annual production of bioethanol was 15 mt and biodiesel production reached 0.8 mt (Table 1). Since 2000, growth in global biofuel production in many countries has been stimulated by strong government support and by the oil price surge in 2008. By 2007, global biofuel production had risen to 44 mt of bioethanol and 9 mt of biodiesel (Table 1), or 1.8% of total global transport fuel consumption in energy terms.[8]

Motives for the recent expansion of biofuel programs are numerous and vary from country to country. They can be grouped into three broad categories as (i) national energy security concerns, particularly crude oil supply; (ii) environmental concerns, specifically increased emission of CO_2 as one of the

Figure 1: World Biofuel Development, 1975–2007
(million tons)



Note: The world total is composed of data from Brazil, Canada, the People's Republic of China, Colombia, the European Union, India, Pakistan, Paraguay, Thailand, and the United States.

Sources: Renewable Fuels Association. 2008. *Ethanol Industry Outlook*. www.ethanolrfa.org/industry/outlook, Earth Policy Institute. 2006. *World Ethanol Production and World Biodiesel Production*. www.earthpolicy.org/index.php?/plan-b-updates/2006/update55, and BIODIESEL 2020. 2008. *Global Market Survey, Feedstock Trends and Forecasts*. www.emerging-markets.com/biodiesel

[8] F.O. Licht. 2007. *World Ethanol and Biofuels Report*. Various issues. Tunbridge Wells. United Kingdom.

main causes of climate change; and (iii) development of new markets for agricultural produce, hence, increased revenues for farmers.

In 2007, Brazil and the US together accounted for almost three-quarters of global biofuel production. In both countries, ethanol accounts for almost all biofuel output, although biodiesel production in the US also increased substantially after 2006. The production of bioethanol in the US, derived mainly from maize, surged after 2000 as a result of the rising world oil price, tax incentives, and mandates for ethanol as a gasoline blending component. In 2007, the country produced a total of 21.3 mt of bioethanol (Table 1), accounting for 48.2% of the global output. Demand for maize as a feedstock for ethanol has been rising rapidly, and by 2007, about one-third of maize produced in the US was used to produce bioethanol. In 2007, US biodiesel production was 2.1 mt (Table 1), and it consumed 20% of the country's total soybean output.[9]

Brazil was the world's largest producer of biofuels until 2006, when it was overtaken by the US. The volume of Brazil's biofuel production and its future growth may have a significant impact on the world food market, particularly for sugar, as bioethanol production in Brazil is based entirely on sugarcane. Production peaked in the 1980s, then declined as international oil prices fell, before resuming rapid growth in 2000 (Table 1). Falling production costs, higher oil prices, and the introduction of vehicles that allow switching between ethanol and conventional gasoline have contributed to the renewed surge in output. Bioethanol production in Brazil in 2007 reached 16.5 mt (Table 1), accounting for 37.2% of the world's total bioethanol production. The share of biofuels in Brazil's total transport fuel demand in 2007 was about 20%.[10]

The production of biofuels in Europe is also growing rapidly. The bulk of production in the European Union (EU) is biodiesel. According to the Organisation for Economic Co-operation and Development (OECD), the EU's biodiesel production in 2007 reached 5.7 mt, which accounted for more than 63% of world biodiesel output (Table 1). The major feedstock used in the EU is rapeseed. Germany is the leading producer of biodiesel with an output of 3.8 mt in 2007 (42% share

Table 1: Biofuel Production in Major Countries, 1996 and 2000–2007
(million tons)

Location	1996	2000	2001	2002	2003	2004	2005	2006	2007
Ethanol: World	**16.2**	**15.0**	**16.2**	**18.8**	**23.7**	**26.5**	**35.3**	**39.8**	**44.2**
US	3.6	5.3	5.8	7.0	9.2	11.1	12.8	15.9	21.3
EU	—	0.2	0.2	0.4	0.4	0.5	0.8	1.5	1.6
Brazil	12.5	9.2	10.0	10.9	1 2.8	13.1	13.9	14.7	16.5
PRC	0*	0*	0*	0	0.1	0.2	0.8	1.3	1.4
Diesel: World	**0.5**	**0.8**	**1.0**	**1.3**	**1.6**	**2.0**	**3.4**	**6.6**	**9.0**
US	—	—	—	—	—	0.1	0.2	0.8	2.1
EU	—	—	0.9	1.1	1.4	1.9	3.2	4.9	5.7

— = data not available, EU = European Union, PRC = People's Republic of China, US = United States.

Note: * = almost zero.

Sources: World data: the Renewable Fuels Association, Earth Policy Institute, and BIODIESEL 2020; US data: the Renewable Fuels Association and BIODIESEL 2020; EU data: Beyond Petroleum and the European Biodiesel Board; Brazil data: the Renewable Fuels Association; the PRC's data: Qiu and Huang, 2008.

[9] *Renewable Energy Policy Network for the 21st Century*. 2007. Renewables 2007 Global Status Report. www.ren21.net/pdf/RE2007_Global_Status_Report.pdf

[10] Nass, L., P. Pereira, and D. Ellis. 2007. Biofuels in Brazil: An Overview. *Crop Science*. 47. 2,238–2,237.

of world market), followed by the US (20%), France (11%), and Italy (7%) (footnote 1).

In 2007, the People's Republic of China (PRC) was the world's fourth-largest biofuel producer and fourth-largest bioethanol producer. Its bioethanol production reached 1.4 mt in 2007 (Table 1), and its biodiesel production was 0.2 mt.[11] Four large-scale bioethanol production plants in Heilongjiang, Jilin, Henan, and Anhui provinces were constructed in 2001. Their total annual bioethanol production capacity is about 1.5 mt with maize as the main feedstock. In 2007, the PRC set up another bioethanol company in Guangxi Zhuang Autonomous Region with annual production capacity of 0.2 mt. The plant began operating in early 2008 using cassava as its major feedstock.[12]

Targets for Biofuel Development and Support Policies in the Major Biofuel-Producing Countries

Many countries follow the practice of setting indicative targets for biofuel development with strong policy support. To promote biofuel development and ensure that targets can be achieved, various support policies have been adopted or considered in the major biofuel-producing countries. These measures support various stages in the production–use chain, from agricultural feedstock production, feedstock conversion, biofuel distribution and marketing, to final consumption. Given their high production costs compared with fossil-based alternatives, and the need to modify existing logistics for infrastructure, transport, and delivery equipment, biofuels generally are not economically viable. They are unlikely to prosper in most countries (except in Brazil) in the absence of public support.

The United States

The US has adopted a series of policies to promote biofuel development since the 1970s. The federal government provides tax incentives to promote ethanol production, and a number of bioethanol-producing states provide additional incentives. Tax exemptions for biofuel were initially established by the Energy Tax Act of 1978, with full exemption for 10% blended gasoline of the then $0.04/gallon (gal) federal gasoline excise tax, which translates into an effective subsidy of $0.40/gal of bioethanol (or $122/ton [t]). A 1980 law added an alternative blender's credit of $0.40/gal, applicable to other blend levels including E85 (an ethanol-gasoline blend including 85% ethanol in volume terms). In 2007, the US provided a $0.51/gal (or $156/t) tax refund for blenders of bioethanol. Some states also provide support, and the federal government exempted the income taxes of small biofuel plants whose annual bioethanol production is lower than 60 million gal (or 196,000 t). Tax credit is also applied to biodiesel production, $1.00/gal (or $306/t) tax rebate applied to biodiesel made from virgin oil or $0.50/gal if made from recycled oil such as cooking oil.[13]

Import restrictions are also used to promote the emerging US biofuel industry. Ethanol imports from countries outside the North American Free Trade Agreement face a primary tariff of 1.9%–2.5% plus an "other duty or charge", often referred to as the secondary ethanol tariff, of $14.27 per hundred liters (hl). Using the 2007 average price for Brazilian bioethanol of $0.42/hl as a benchmark, the secondary ethanol tariff was equivalent to an ad valorem of 33.9%. However, imports under the Caribbean Basin Initiative[14] enter the US tariff-free, with increasing import quotas. The tariff applied to biodiesel is 4.6%—substantially lower than that for ethanol.

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[11] Qiu, H., and J. Huang. 2008. The Impacts of Biofuel Developments on World Food Price and Implications for China's Agriculture. *China Agricultural Trade Development Report 2008.* Chinese Agricultural Press, Beijing. www://bioconversion.blogspot.com

[12] Chinese Academy of Agricultural Engineering. 2007. Bioenergy Development in China. Internal report. Beijing.

[13] Yacobucci, B.D. 2008. Biofuels Incentives: A Summary of Federal Programs. Congressional Research Service report to the US Congress.

[14] The Caribbean Basin Initiative was a unilateral and temporary US program initiated by the 1983 Caribbean Basin Economic Recovery Act. The initiative came into effect on 1 January 1984 and aimed to provide several tariff and trade benefits to many Central American and Caribbean countries.

The Energy Independence and Security Act, passed in 2007, set the target for US biofuel production at 15.2 million gal in 2012, 30 million gal in 2020, and 36 million gal in 2022. Maize-based bioethanol and cellulosic bioethanol will be the major biofuels in the US in the future. For example, the Act prescribed that of the total 36 billion gal biofuel production in 2020, 15 billion gal will be produced from maize (42% of total biofuel production), 10.5 billion gal will be based on cellulosic technologies (29% of total biofuel production), 3.5 billion gal will come from other energy crops such as sweet sorghum and sugarcane, and 1 billion gal will consist of biodiesel.

Brazil

Brazil is the world's second largest producer of biofuels. It produces mainly bioethanol from sugarcane, and it is currently the only country to promote biofuel use beyond minimal blending levels by allowing consumers to choose it as a fuel substitute. The government promotes the availability of ethanol at almost every gasoline station in the country and has encouraged the manufacture of flexible fuel cars, which are capable of using pure gasoline, E25 (a mixture of 75% gasoline and 25% ethanol), and pure bioethanol. In the 1970s, the government established a National Fuel Ethanol Program to increase the use of domestically-produced biofuel in transport. This program received considerable government support and was successful in helping fuel ethanol to gain a larger market share than gasoline as a transport fuel. The program was eliminated in the 1990s with the liberalization of bioethanol prices; however, the government still provides some support to ethanol production through a combination of market regulation and tax incentives. Support through market regulation takes the form of official blending of bioethanol with gasoline in transport fuel. Additional support is given by providing credits for storing bioethanol, by setting a lower excise tax on ethanol use than on gasoline, and by periodic purchases and sales from its strategic reserves. Brazil applies an ad valorem duty of 20% to imports of ethanol (footnote 10).

The government's target for bioethanol production is 9.5 billion gal in 2012 (31.0 mt), and 11.5 billion gal in 2016 (37.7 mt). The government also enacted a law establishing a biodiesel obligation of 2% by the end of 2007 (800 million liters per year [l/year]), 5% by 2013 (2 billion l/year), and 20% by 2020 (12 billion l/year). To produce the vegetable oil required for the biodiesel feedstock, in February 2005, the Government of Brazil made $41.9 million available for loans to several thousand families to produce oil from castor oil plants.

European Union Countries

In the EU, major support for the production and use of biofuels is provided by the member states. Directive 2003/30/EC of the European Parliament and of the Council of the European Union (the 2003 Biofuel Directive on the promotion and use of biofuels or other renewable fuels for transport) directs member states to set target minimum shares of biofuels in their total gasoline and diesel for transport use. As a reference value for these targets, the 2003 Biofuel Directive states that a minimum share of 5.75% is to be achieved by the end of 2010. The EU explicitly mandated member states to set up the necessary legislation to ensure compliance, and allowed tax concessions to promote the use of biofuels.[15]

The EU provides support in the form of tariffs and payments. It applies a tariff of €10.20/hl (33.2%) on denatured ethanol imports and €19.20/hl (62.4%) on undenatured ethanol imports,[16] while a tariff of 6.5% is levied on biodiesel imports. The EU also provides "Energy Crop Aid", which is a payment per unit area of crops grown for energy generation. The sum of €45 per hectare (/ha) is paid for the cultivation of feedstocks used for biofuel production to generate heat and/or power. The use of fallow land for cultivation of non-food crops is also permitted.

A number of EU member states have legislated minimum rates for the incorporation of biofuels into transport fuels sold. Rates differ from country to country. Tax concessions are another measure which is widely applied. These concessions either reduce or

[15] Schnepf, R. 2006. European Union Biofuels Policy and Agriculture: An Overview. Congressional Research Service (CRS). The Library of Congress CRS Report for Congress. RS22404.

[16] Ad valorem terms were calculated based on average prices and exchange rates in 2007.

eliminate excise tax on biofuels in some countries. A distinction is made between biofuels used in low-level blends with fossil fuels, and pure biofuels. On average, the tax for ethanol and biodiesel is about 50% lower than the rates for gasoline and fossil diesel. Countries with legislated biofuel mandates often apply a normal excise tax to biofuels, while most countries that do not have a biofuel mandate stimulate biofuel use through reduced rates of excise tax.

A directive on bioenergy, published as a Commission proposal in early 2008, includes an increased and mandatory target of 10% of transport fuels to be replaced by biofuels by 2020 (footnote 1). The proposal makes a clear reference to second-generation biofuels, which are expected to represent an important portion of this target share.

The People's Republic of China

The PRC has set up a series of support policies to facilitate bioethanol production and marketing. The first policy—Special Development Plan for Denatured Fuel Ethanol and Bioethanol Gasoline for Automobiles in the Tenth Five-Year Plan, 2001–2005—was announced in early 2001. Its goal was to experiment with bioethanol production, marketing, and support measures. To achieve this goal, two policy documents were jointly issued by the National Development and Reform Commission and seven relevant ministries in 2002 and 2004. These are the Pilot Testing Program of Bioethanol Gasoline for Automobiles in 2002, and the Expanded Pilot Testing Program of Bioethanol Gasoline for Automobiles in 2004.[17] Under these policies, four bioethanol plants were set up, and nine provinces were selected to pilot the use of E10 (a mixture of 90% gasoline and 10% ethanol).

Incentive policies were implemented to encourage the expansion of the biofuels industry. It is mandatory to mix 10% bioethanol in gasoline in nine provinces to secure the biofuel market; the 5% consumption tax on bioethanol is waived; the 17% value-added tax is refunded to the bioethanol production plants; and a direct subsidy is given to bioethanol plants to ensure that they can make a reasonable profit. There is still no clear support policy for the marketing of biodiesel in the PRC, but in 2008 the government began to pay CNY200 per mu ($425/ha) for biodiesel feedstock production.

In 2005, the PRC issued the Renewable Energy Law, which took effect on 1 January 2006. This law makes clear that the PRC will forcefully push for the development of renewable energy. In June 2007, under the guidelines stipulated by the Renewable Energy Law, the National Development and Reform Commission (2007) formulated the Middle- and Long-Term Development Plan for Renewable Energy. The plan aims to lower the PRC's petroleum imports to less than 50% of total domestic consumption by 2020, while annual production of biofuels is targeted at 10 mt for bioethanol and 2 mt for biodiesel for the same year. In response to food price increases and the mounting concern over food—especially grain—security, the government announced a regulatory policy on biofuel expansion in mid-2007, which prohibited any further grain-based biofuel expansion. Instead, it encouraged the use of sugarcane, cassava, sweet potato, sweet sorghum, and other non-grain crops as the major biofuel feedstocks (footnote 11).

Canada

Canada has introduced mandatory blending requirements for ethanol in gasoline and for biodiesel in fossil diesel (footnote 1). At the federal level, gasoline must contain at least 5% bioethanol by 2010, while diesel fuels must contain at least 2% biodiesel by 2012. In addition to the mandates, the Government of Canada has provided Can$2.2 billion for programs to boost domestic production. This funding supports direct producer incentives, programs to support farmer participation in the biofuel industry, and a fund to help commercialize cellulosic biofuels. Biofuels also benefited from federal and provincial excise tax exemptions, but federal tax exemptions of biofuels were eliminated since 1 April 2008. Canada applies a Can$0.05/l tariff on bioethanol imports from outside North American Free Trade Agreement. In addition to federal contributions, several provinces support biofuels through measures such as capital grants, direct subsidies, and tax credits.

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[17] National Development and Reform Commission and seven other ministries. 2002. The Pilot Testing Program of Bioethanol Gasoline for Automobiles; and Detailed Regulations for Implementing Pilot Testing Program of Bioethanol Gasoline for Automobiles.

Biofuel Development and Policies in the Five Countries of the Greater Mekong Subregion

Thailand is the only country in the Greater Mekong Subregion (GMS)—apart from the PRC—that has commercialized the production of biofuel. Biofuel production is undertaken on a very limited scale in Myanmar and Viet Nam, and on an experimental level in Cambodia and the Lao People's Democratic Republic (Lao PDR). The production of bioethanol in Thailand is dependent on two major raw materials: molasses and cassava. At present, most ethanol plants use molasses to produce ethanol. Nine ethanol plants are operating in the country, with a combined annual production capacity of 0.4 mt and an actual production of about 0.3 mt (footnote 6).

Although most countries in the GMS are interested in developing biofuels, only the PRC, Thailand, and Viet Nam have set well-defined targets for future biofuel development and have provided supportive policies. Myanmar's target is to plant jatropha on 2.3 million ha for biodiesel production by 2009, but it has not established any mid- and long-term targets for biofuel development.[18] At the time of writing, Cambodia and the Lao PDR have not set clear targets.

Thailand

Thailand has initiated a large biofuel program. The country's major feedstocks for bioethanol are molasses and cassava (Table 2). Most ethanol plants use molasses to produce ethanol, except the Thai Nguan Plant, which produces 130,000 l/day (112 t/day) from cassava feedstock. Nine ethanol plants are in operation, with a combined capacity of 1.26 million l/day. Actual production, however, is 0.98 million l/day.[19] By the end of 2008, more bioethanol plants became operational and feedstock demand is expected to gradually shift to cassava. The government encourages the use of bioethanol and E20 gasoline to substitute for methyl tertiary butyl ether. It is projected that by 2011, annual bioethanol production in Thailand will reach 0.71 mt (Table 2).

Oil palm is the only crop used as a feedstock for biodiesel. The government has mandated the use of B2 (diesel blended with 2% biodiesel) starting in 2008. By 2011, B2 will be replaced by B5 (diesel blended with 5% biodiesel), and biodiesel production is projected to rise to 0.89 mt (Table 2).

Table 2: Planned Biofuel Production and Feedstock Demand in Thailand, 2008–2011
(million tons)

Feedstock	2008	2009	2010	2011
Biofuel production (million tons)				
Bioethanol	0.37	0.47	0.57	0.71
Biodiesel	0.34	0.39	0.41	0.89
Demand for feedstocks (million tons)				
Molasses	1.48	1.62	1.69	1.75
Cassava	0.54	1.02	1.66	2.57
Palm oil	0.39	0.45	0.47	1.02

Source: Chirapanda. 2008.

18 Tin Maung Shwe. 2008. Country Assessment on Bio-fuel and Renewable Energy: The Union of Myanmar. Presentation at the 6th Asian Society of Agricultural Economists (ASAE) International Conference, 28–30 August 2008, Manila.

19 ADB. 2008. *Status and Potential for the Development of Biofuels and Rural Renewable Energy*: Thailand. Consultant's report. Manila (TA 6324-REG).

Viet Nam

Viet Nam is in the initial stages of biofuel development. It plans to develop three types of biofuel in the future: bioethanol from starch and molasses, biodiesel from catfish oil and plant oil, and biogas from animal waste. The first two biofuels were prioritized due to their potential for commercial production, which could help spur further economic growth. Biogas has been valuable in promoting environmental protection and in promoting rural development, though primarily on a small scale.

Based on the Government of Viet Nam's Decision 177/QD-TTg, biofuel will account for 1% of the total fuel demand in the transport sector in 2015 (an estimated 0.25 mt), and 5% in 2025 (about 1.8 mt) (Table 3). Production of biodiesel is targeted at 0.15 mt in 2015 and 1.20 mt in 2025. A lower target for bioethanol is set at 0.10 mt in 2015 and 0.60 mt in 2025.[20] Jatropha and catfish oil will be the major feedstocks for biodiesel production in Viet Nam. The major feedstock for bioethanol will be sugarcane, and sweet sorghum will be developed to provide about 10% of the feedstock for bioethanol.

Myanmar

Ethanol derived from sugarcane is produced on a limited commercial scale in Myanmar. A plant yielding 36,000 t/year of bioethanol is located in Maunggone, Sagaing Division. In 2008, the Myanmar Economic Corporation—a military-based industrial conglomerate—established two large bioethanol plants with a total capacity of 1.8 million gal/year of ethanol (footnote 7). Commercial production, distribution, and use began in April 2008. A large private company—Great Wall—established and expected to complete in 2008 an alcohol-processing plant yielding 3,700 gal/day. Another new factory will be constructed by the associate company of Great Wall in Katha town. This company applied for a license to distribute, deliver, and market its bioethanol.

Besides sugarcane, the other crops with potential for bioethanol production in Myanmar are maize, cassava, and sweet sorghum. Sugarcane is the most appropriate feedstock for ethanol production, given the available technology in the country. Sweet sorghum is being investigated as a potential alternative.

Biodiesel production is being piloted, and its expansion to a commercial scale is not yet in the pipeline. The unit cost of biodiesel is still high compared with that of bioethanol due to the high price of jatropha seeds for planting. The government plans to cultivate jatropha to help meet future energy requirements, and planting has been in progress since 2006. Based on this plan, the area planted to jatropha will expand from 2.53 million ha in 2007 to 3.23 million ha in 2010 (footnote 18). In 2008, the country still did not have a large-scale biodiesel processing plant due to the limited availability of technology and investment.

Table 3: Projected Biofuel Production in Viet Nam
(million tons)

	Decision No 177/2007/QD-TTg				VCAP			
Year	Total (mt)	Ethanol (mt)	Diesel (mt)	in Gasoline %	Total (mt)	Ethanol (mt)	Diesel (mt)	in Gasoline %
2010	0.01	0.01	0.03	0.04	—	—	—	—
2015	0.25	0.10	0.15	1.0	—	—	—	—
2020	—	—	—	—	1.63	0.54	1.09	5.0
2025	1.8	0.60	1.20	5.0	2.88	0.96	1.92	8.0

— = no data, mt = million tons, VCAP = Vietnam Center for Agricultural Policy.

Source: Vietnam Center for Agricultural Policy. 2008.

[20] ADB. 2008. *Status and Potential for the Development of Biofuels and Rural Renewable Energy: Viet Nam*. Consultant's report. Manila (TA 6324-REG).

Cambodia and the Lao People's Democratic Republic

Biofuel production in Cambodia and in the Lao PDR is still in the pilot project stage or at an experimental level. Because food security remains a primary concern, these countries are cautious about biofuel development. So far, there is no clear biofuel development policy or program. In central Cambodia, a village-level biofuel project in Kompong Chang provided the communities with small oil expellers to process jathropa seeds. Funded by the Government of Canada, the project ended in 2006 but is being continued by a private company. Training and dissemination of the technology used in the project are conducted by various nongovernment organizations, academic institutions, and private enterprises.

Biofuel production in the Lao PDR is recognized by the government as a priority area. Development is being initiated by Kolao—the biggest agriculture company in the country—using jatropha as the major feedstock.

Methodology and Scenarios

Although biofuels are being developed in many countries, including those of the Greater Mekong Subregion (GMS), little quantitative assessment had been done on the impact of global and regional biofuel development on agriculture and food security. This section presents the methodology and scenarios used in this study to assess the likely implications for agriculture and the rest of the economy of biofuel development in the GMS and the rest of the world.

Methodology

To understand the likely impact of biofuel development on agriculture and on other areas of the economy, an analytical framework was built based on the Global Trade Analysis Project (GTAP) platform.[21] As the GTAP model allows multiple features (i.e., multiple commodities and multiple countries), it is possible to model the linkages among biofuels production, energy, and global agricultural markets. Since it is a global trade model, the impact of world markets can be tracked to specific countries or regions, including the GMS.

To tailor the standard GTAP modeling platform to this analysis, three modifications were made:[22]

(i) Because the GTAP database does not have a biofuels sector, production activities that produce biofuels were created and added into the GTAP model as a separate sector.

(ii) Since agriculture is linked with energy markets through the biofuel sector, the parameters that allow for the substitution between capital and energy (that are embodied in GTAP-E [Energy] model) were updated, and a set of parameters was added to capture the substitution between biofuels and gasoline.[23]

(iii) Efforts were made to refine and determine the elasticity of substitution in land allocation among different crops—those that produce biofuels (e.g., maize) and those that do not (e.g., cotton).

Introducing Biofuels into the Global Trade Analysis Project Database

Version 6 of the GTAP database is used in this study. The standard GTAP database has 57 sectors, of which 20 represent agriculture and processed food. Despite this level of disaggregation, many of the biofuel feedstock crops are aggregated with non-feedstock crops. The standard GTAP database does not have a sector for the biofuels industry.

The model for this study modifies the standard database by disaggregating and explicitly including the key biofuels feedstock crops in the model's database.

[21] The Global Trade Analysis Project is a well-known multi-country, multi-sector computable general equilibrium model (see Hertel, T.W. 1997 *Global Trade Analysis, Modelling and Applications.* Cambridge University Press. New York). The model is based on the assumption that producers minimize their production costs and consumers maximize their utility subject to a set of common constraints. Supplies of and demands for all commodities balance by adjusting prices in perfectly competitive markets. On the production side, firms combine intermediate inputs and primary factors (e.g., land, labor, and capital) to produce commodities with constant-return-to-scale technology. Intermediate inputs are composites of domestic and foreign components, with the foreign component differentiated by region of origin (this is known as the Armington assumption).

[22] The modelling undertaken for this study received most of its funding from the Bill & Melinda Gates Foundation.

[23] The GTAP-E model introduces energy–capital substitution to the standard GTAP model and is widely used for analyzing policy on energy and climate change.

Using trade data from the United Nations database, UN Comtrade, and production data from the Food and Agriculture Organization of the United Nations (FAO), maize was disaggregated from cereal grains and soybean was disaggregated from oilseeds. This was done by using a splitting program known as SplitCom.[24] In a second modification to the standard database, new production activities were built for four biofuel industry subsectors—sugar ethanol, corn ethanol, soybean diesel, and rapeseed diesel. These were introduced into the GTAP database using a method similar to that developed by Taheripour et al.[25]

Linkage between Agriculture and Energy Markets through Biofuel Sectors

Agriculture can be linked with energy markets through the model's biofuel sectors as there are substitutions between biofuel and gasoline. To capture the effects of the emergence of biofuels production, the standard GTAP model was extended by introducing the energy–capital substitution relationships described in the GTAP-E model.[26] In addition to the standard assumptions, the substitutions between biofuels and petroleum products are accounted for. To introduce the possible substitution of biofuels and petroleum products, a nested constant elasticity of substitution function between biofuels and petroleum products is incorporated into the GTAP-E capital–energy commodity nested structure. The method used was similar to the approaches taken by others who also add this sector to the GTAP-E model.[27] The elasticity of substitution between crude oil and biofuels is crucial in this research since it will be an important element that ties the price of energy to the price of food. In past research on biofuels in Brazil, the European Union (EU), and the United States (US), almost all values of the elasticity of substitution are similar to those used by Hertel et al. (footnote 27), who set the substitution parameter for Brazil at 3.0, the EU at 2.75, and the US at 1.0. This work uses the default value of 2.0, which is the value of the parameter used by Birur et al. (footnote 27).

Allocation of Agricultural Land

The biofuels boom—especially for first-generation biofuels—will increase the demand for feedstock crops. However, the feasibility of changing land use from one crop to another may differ significantly according to the type of land. The standard version of GTAP allocates land using a constant elasticity of transformation structure. While this assumption means that different types of land use are imperfect substitutes for each other (a plausible assumption), all uses have the same degree of substitutability. This land use structure makes it difficult to capture differences in substitutability that will almost surely emerge with the rapid expansion of feedstock crops.

To overcome this problem, different types of new land use modules are being incorporated into the standard GTAP model. One approach is explored in Hertel et al. (footnote 27) where the authors use different agro-ecological zones, following the methodology outlined in Lee et al.[28] Banse et al. developed a stylized demand structure for land by producers of different crops that allows for different degrees of substitutability among the cultivated land for different crops.[29] To implement this, they embed within the GTAP framework a land supply curve equation that allows for the expansion of land. This paper uses the approach of Banse et al to model the land use structure. This approach helps capture

[24] Horridge, M. 2005. *SplitCom: Programs to Disaggregate a GTAP Sector.* Preliminary draft. Centre of Policy Studies, Monash University, Melbourne, Australia.

[25] Taheripour, F., D.K. Birur, T.W. Hertel, and W.E. Tyner. 2007. Introducing Liquid Biofuels into the GTAP Database. *GTAP Research Memorandum No.11*, Center for Global Trade Analysis, Purdue University, West Lafayette, Indiana; Note: The version of the model used does not account for dry distillers grains.

[26] Burniaux, J.M., and T.P. Truong. 2002. *GTAP-E: An Energy-Environmental Version of the GTAP Model*. GTAP Technical Paper No.16. Center for Global Trade Analysis, Purdue University, West Lafayette, Indiana.

[27] Birur, D.K., T.W. Hertel, and W.E. Tyner. 2007. *The Biofuel Boom: Implications for World Food Markets*. Paper presented at the Food Economy Conference, The Hague; Hertel, T.W., W.E. Tyner, and D.K. Birur. 2008. *Biofuel for All? Understanding the Global Impacts of Multinational Mandates.* GTAP Technical Paper No.51. Center for Global Trade Analysis, Purdue University, West Lafayette, Indiana.

[28] Lee, H., T. Hertel, B. Sohngen, and N. Ramankutty. 2005. *Towards an Integrated Land Use Data Base for Assessing the Potential for Greenhouse Gas Mitigation*. GTAP Technical Paper No. 25. Center for Global Trade Analysis, Purdue University, West Lafayette, Indiana.

[29] Banse, M., H.V. Meijl, A.Tabeau, and G. Woltjer. 2008. *Will EU Biofuel Policies Affect Global Agricultural Markets?* Research Report, Agricultural Economics Research Institute. The Hague.

the different degrees of substitutability between agricultural land uses. In this paper, the land use allocation structure is created by adding a three-level constant elasticity of transformation nested structure to the standard GTAP model, which takes into account the different degrees of substitutability among different land use types.[30] Unlike in the Banse study, however, no endogenous adjustment of total land supply is allowed as there was not enough information on the availability of new land for agricultural production and on the responses of land supply to land and agricultural prices.

Despite these modifications, some limitations to the use of the GTAP framework for assessing the impact of biofuel development were noted. The production of the GTAP model adopts the assumption of constant returns to scale technology and perfect competition. The intermediate inputs and primary factors (i.e., land, labor, and capital) are combined together through a nested constant elasticity of substitution function. The land is a sluggish factor, there is imperfect mobility among crops, and the constraints of water and land are still not fully represented in the GTAP model. Moreover, the rapid expansion of some feedstock crops such as maize, oil crops, sugarcane, and cassava may result in more intensive cultivation and monocropping, which have negative environmental effects and lead to lower productivity. However, such effects could not be captured and evaluated by the GTAP model.

Formulation of Scenarios

Five scenarios were developed, including one reference scenario and four alternative scenarios. The main aim of this study is to assess the impact of global and regional biofuel development on the GMS, with special consideration of the region's development strategies. The first three alternative scenarios simulate the possible effects of fulfilling the targets in

(i) other regions, i.e., Brazil, the EU, and the US—scenario 1 (S1);

(ii) GMS-5 countries, excluding the People's Republic of China (PRC)—scenario 2 (S2); and

(iii) all countries in the GMS, including the PRC—scenario 3 (S3).

The fourth alternative scenario assesses the effects of global biofuel development determined by market mechanisms under the assumption of high biofuel-gasoline substitution elasticity and high oil price—the "high-high" scenario (or "H-H" scenario). The reference scenario assumes that world biofuel production levels do not expand beyond 2006, and therefore there is no emergence of biofuels in the future.

In the first three alternative scenarios, the reference scenario assumes that the static nature of biofuels production is relaxed. Biofuel production will meet the target level of individual countries as shown in Table 4. The difference between the three alternative scenarios is that different countries are taken into account. Only the three most important biofuel-producing countries or regions (i.e., Brazil, the EU, and the US) are considered in S1, which models global biofuel development outside the GMS-5. In S2, data on biofuel development in GMS-5 countries (i.e., excluding the PRC) are added to S1. S3 considers the PRC and shows the effects of biofuel development in all GMS countries, in addition to the three main biofuel-producing countries (Table 4).

As biofuels development may be affected significantly by the world oil price and the extent of substitution between biofuel and gasoline, the fourth alternative scenario (H-H) is also formulated. This scenario is constructed to assess the possible impact of the market response under the assumption of high biofuel-gasoline substitute elasticity and high world oil price. In this scenario, the oil price is allowed to rise to a level of about $120 per barrel—the level reached in mid-2008. An elasticity of 20 is adopted between biofuel and gasoline, which indicates a situation of flexible use of gasoline and biofuel by vehicles.

This study assumes that only first-generation biofuel production technology is used during 2006–2020. Although second-generation technology is being developed, it has not been incorporated in the analysis due to lack of information and because it is not economically feasible.

[30] Huang, H., F. Van Tongeren, F. Dewbre, and H. Van Meijl. 2004. *A New Representation of Agricultural Production Technology in GTAP*. Paper presented at the Seventh Annual Conference on Global Economic Analysis, Washington, D.C.

Table 4: Biofuel Production in the Base Year (2006) and Targeted Production in 2020 in Major Countries and Regions under Different Scenarios

		2020			
Item	2006	Reference Scenario	Scenario 1 (3 producers: Brazil + EU + US)	Scenario 2: (3 producers + GMS-5)	Scenario 3: (3 producers + GMS-5 + the PRC)
Ethanol (million tons)					
US	15.9	15.9	117.8	117.8	117.8
EU	1.5	1.5	21.0	21.0	21.0
Brazil	14.7	14.7	43.2	43.2	43.2
GMS-5 countries	0.5	0.5		5.3	5.3
The PRC	1.3	1.3			10.0
Diesel (million tons)					
US	0.8	0.8	6.9	6.9	6.9
EU	4.9	4.9	46.4	46.4	46.4

EU = the European Union; GMS-5 = Cambodia, the Lao People's Democratic Republic, Myanmar, Thailand, and Viet Nam; PRC = the People's Republic of China; US = United States.

Source: Data for production in 2006 are actual figures, and data in 2020 in the last column are governments' targeted levels, as presented in the section on Emerging Biofuels Development in this report.

Results of the Impact Assessment

Impact on World Prices and Agricultural Production

Impact on World Prices

Biofuel development in Brazil, the European Union (EU), and the United States (US) (Scenario1 [S1]) will have a pronounced impact on world food prices. The prices of all agricultural commodities will increase with great variation. Prices of biofuel feedstock crops will also rise significantly. Compared with the reference scenario, under S1 the world average export price of maize will rise by 17.7%, soybean by 13.6%, other oilseeds by 27.6%, and sugarcane by 11.3% (Table 5, column 1).

In the land-use structure, it is assumed that the land-use mobility of wheat, other grains, fibers, and other crops with feedstock commodities is higher than that of rice, vegetables, and animal pastures. As a result, the price of wheat increases by 7.5%, other grains by 7.9%, fibers (mainly cotton) by 7.7%, and other crops by 11.1% (Table 5). Results also indicate modest increases in the price of other crops that have less land use mobility with feedstock crops. These

Table 5: Impact on World Average Export Price of Agricultural Commodities, Compared with the Reference Scenario in 2020

(%)

Commodity	Scenario 1 (3 producers: Brazil + EU + US)	Scenario 2: (3 producers + GMS-5)	Scenario 3: (3 producers + GMS-5 + PRC)
Rice	4.1	4.5	4.6
Wheat	7.5	7.6	7.8
Maize	17.7	17.8	18.2
Other grains	7.9	7.9	14.4
Cassava	5.5	6.6	8.2
Vegetables and fruits	5.5	5.6	5.5
Soybean	13.6	13.8	13.9
Other oilseeds	27.6	27.8	28.0
Sugarcane	11.3	12.2	12.3
Fibers	7.7	7.8	7.9
Other crops	11.1	11.3	11.5
Beef and mutton	2.5	2.5	2.5
Pork and poultry	2.6	2.7	2.7
Milk	0.7	0.8	0.8
Processed food	1.2	1.2	1.2

EU = European Union; GMS-5 = the five countries of the Greater Mekong Subregion: Cambodia, the Lao People's Democratic Republic, Myanmar, Thailand, and Viet Nam; PRC = the People's Republic of China; US = the United States.

Source: Authors.

include rice, which increases in price by only 4.1%, and vegetables and fruits, which increase in price by 5.5% in 2020.

The price of processed food and animal products will also increase mainly due to the rising cost of inputs such as maize and other feeds. However, their price increases are relatively less than those of crops. As shown in column 1 of Table 5, the price of beef, mutton, pork, poultry, dairy products, and processed food will increase by 2%–3%.

The impact of biofuel development on the world price of agricultural commodities in GMS-5 countries is very minor and much smaller than the effects in Brazil, the EU, and the US. The impact of GMS-5 countries' biofuel development on world prices is measured by the difference between Scenario 2 (S2) and S1 in Table 5. The impact on prices of all agricultural commodities, except cassava and sugarcane, is minor. The world price of cassava rises by 1.1% and sugarcane by 0.9%, in 2020. These results are consistent with the much smaller target level of biofuel production in the GMS-5 countries relative to Brazil, the EU, and the US, and the choice of feedstock crops used (mainly cassava and sugarcane).

Even taking the PRC's biofuel development into account (Scenario 3 [S3]), the impact on the world price of the main agricultural commodities is still very limited. Compared with S1, the world price of other agricultural commodities—except other grains, cassava, and sugarcane—rises only by 0.1%–0.5% in S3 (Table 5, column 3). However, world price of other coarse grains and cassava will increase substantially because future biofuel development in the PRC will depend heavily on sweet sorghum (included in "other coarse grains") and cassava as feedstock. As a result, the world price of other coarse grains will increase by about 6%, and the world price of cassava will increase by 3% (comparing S3 and S2). Although the biofuel development target in the PRC is much lower than that of Brazil, the EU, and the US, the impact on the world price of other coarse grains is still significant as the world market of these commodities is very small. The limited supply capacity of those commodities will lead to a steep rise in their world price. Meanwhile, it should be noted that the mobility of feedstock among countries affects the world price. If mobility is low (e.g., cassava), the increase in the world price may be small, but its domestic price will rise dramatically. Such effects are further demonstrated in the regional analysis.

Impact on World Agricultural Production

Price changes due to global biofuel development will affect world agricultural production significantly. The production of feedstock crops will increase substantially at the expense of other agricultural commodities (Table 6). For example, under S1, US production of maize in 2020 will increase by 59.4%, other oilseeds by 89.4%, and sugarcane by 11.2% compared with the reference scenario. In contrast, production of many "other crops", animal products, and processed food will decrease, especially for those crops with higher mobility of land use with feedstock crops. Production of wheat will decline by 14.5%, other grains by 13.9%, cotton by 13.5%, and other crops by 8.3% (Table 6, column 1). Similar declines in crop production are also seen in Brazil and the EU.

The production of feedstock commodities will increase significantly in S1, even in regions without further biofuel expansion (e.g., the PRC and the GMS-5 countries). As shown in Table 6, maize production in the PRC will increase by 18.0%, soybean by 14.3%, other oilseeds by 71.4%, and sugarcane by 5.4%. In the GMS-5 countries, maize production will increase by 14.3%, soybean by 10.9%, other oilseeds by 12.1%, and sugarcane by 3.2% in 2020 compared with the reference scenario. A minor difference is that the reduction in production of other agricultural commodities in the PRC and in the GMS-5 countries is less than in Brazil, the EU, and the US. This is mainly due to the effect of the large drop in production in Brazil, the EU, and the US, which will create some space for other countries to fill.

Similar to the effects on world prices, the impact of biofuel development on world agricultural supplies in the GMS-5 is very limited and is concentrated only in the feedstock crops used in these countries. Under S2 and S3, compared with biofuel development in Brazil, the EU, and the US, (S1), more production resources will be allocated to produce feedstock crops used by the GMS-5 countries (Table 7). Therefore, the

Table 6: Impact on World Agricultural Production in Scenario 1, Compared with the Reference Scenario in 2020
(%)

Commodity	US	EU	Brazil	PRC	GMS-5	Rest of World	World Total
Rice	(13.6)	(1.2)	(7.0)	(0.2)	(0.5)	(1.8)	**(1.4)**
Wheat	(14.5)	(16.9)	(6.8)	(0.5)	(0.8)	4.2	**(0.4)**
Maize	59.4	(12.5)	(6.3)	18.0	14.3	28.6	**27.8**
Other grains	(13.9)	(9.4)	(5.1)	(5.2)	(3.0)	5.1	**(0.6)**
Cassava	(12.5)	(13.9)	(1.1)	(3.9)	(0.9)	(1.0)	**(0.9)**
Vegetables and fruits	(5.2)	(8.1)	(1.7)	(0.2)	(0.5)	0.3	**(1.0)**
Soybean	(5.3)	(21.4)	6.1	14.3	10.9	10.9	**1.5**
Other oilseeds	89.4	219.5	180.1	71.4	12.1	30.0	**60.8**
Sugarcane	11.2	(1.1)	64.6	5.4	3.2	0.7	**8.1**
Fibers	(13.5)	(37.6)	(6.7)	4.8	6.0	4.6	**(0.9)**
Other crops	(8.3)	(11.5)	(2.7)	(6.7)	6.7	4.9	**(0.9)**
Beef and mutton	(1.5)	(0.4)	(4.0)	(0.2)	(0.2)	(0.3)	**(1.0)**
Pork and poultry	0	(2.9)	(3.1)	(0.8)	(0.1)	(0.5)	**(1.1)**
Milk	(1.4)	0.1	(0.2)	(0.8)	(0.5)	(0.6)	**(0.6)**
Processed food	(0.5)	(1.4)	(2.4)	(0.7)	(0.7)	(0.5)	**(0.8)**

( ) = negative number; EU = European Union; GMS-5 = the five countries of the Greater Mekong Subregion: Cambodia, the Lao People's Democratic Republic, Myanmar, Thailand, and Viet Nam; PRC = the People's Republic of China; US = the United States.

Note: Scenario 1 consists of three producers: Brazil, the EU, and the US; the reference scenario assumes biofuel production does not expand beyond 2006 levels.

Source: Authors.

production of agricultural commodities not used as feedstocks in the region will be reduced. However, the diversion effect is small, especially in S2 (i.e., not considering biofuel development in the PRC). Compared with S1, world production of cassava will increase by 4.1%, while that of sugarcane will increase by 0.8% (the difference between S2 and S1 in Table 7).

Under S3, which takes into account the PRC's biofuel development, the supply of other coarse grains will rise by 13.6%, cassava by 9.2%, and sugarcane by 0.7% relative to S1 (the percentage change in S3 minus the percentage change S1 in Table 7). The impacts of biofuel development in the PRC are relatively more pronounced than those of the GMS-5 because the target level of the PRC's biofuel production is almost double that of the GMS-5 countries combined.

Impact on Agricultural Prices and Production in the Five Countries of the Greater Mekong Subregion

Impact on Agricultural Prices

The development of biofuels by Brazil, the EU, and the US would significantly increase agricultural prices in the GMS-5 countries. Although it is assumed that there is no further biofuel development in the GMS-5 in S1, rising world agricultural prices also impact the GMS through international trade. Table 8 shows that the supply price of all agricultural commodities in GMS-5 countries increases, especially for commodities used as feedstocks in Brazil, the EU, and the US. The

Table 7: Impact on World Supply of Agricultural Commodities, Compared with the Reference Scenario in 2020
(%)

Commodity	Scenario 1 (3 producers: Brazil + EU + US)	Scenario 2: (3 producers + GMS-5)	Scenario 3: (3 producers + GMS-5 + PRC)
Rice	(1.4)	(1.5)	(2.0)
Wheat	(0.4)	(0.4)	(0.6)
Maize	27.8	27.8	27.7
Other grains	(0.6)	(0.6)	13.0
Cassava	(0.9)	3.2	8.3
Vegetables and fruits	(1.0)	(1.0)	(1.3)
Soybean	1.5	1.5	1.4
Other oilseeds	60.8	60.8	60.7
Sugarcane	8.1	8.9	8.8
Fibers	(0.9)	(0.9)	(1.3)
Other crops	(0.9)	(0.9)	(1.0)
Beef and mutton	(1.0)	(1.0)	(1.1)
Pork and poultry	(1.1)	(1.0)	(1.6)
Milk	(0.6)	(0.6)	(0.6)
Processed food	(0.8)	(0.8)	(0.9)

( ) = negative number; EU = European Union; GMS-5 = the five countries of the Greater Mekong Subregion: Cambodia, the Lao People's Democratic Republic, Myanmar, Thailand, and Viet Nam; PRC = the People's Republic of China; US = the United States.

Note: the reference scenario assumes biofuel production does not expand beyond 2006 levels.

Source: Authors.

Table 8: Impact on Price of Agricultural Commodities in the Five Countries of the Greater Mekong Subregion, Compared with the Reference Scenario in 2020
(%)

Commodity	Scenario 1 (3 producers: Brazil + EU + US)	Scenario 2: (3 producers + GMS-5)	Scenario 3: (3 producers + GMS-5 + PRC)
Rice	3.8	6.5	6.5
Wheat	8.9	9.6	9.8
Maize	11.1	12.5	12.7
Other grains	5.1	6.4	13.3
Cassava	4.2	21.7	25.8
Vegetables and fruits	4.0	6.9	6.9
Soybean	10.3	11.1	11.2

continued on next page

Table 8 *continued*

Commodity	Scenario 1 (3 producers: Brazil + EU + US)	Scenario 2: (3 producers + GMS-5)	Scenario 3: (3 producers + GMS-5 + PRC)
Other oilseeds	12.4	14.1	14.2
Sugarcane	4.8	27.6	27.5
Fibers	8.1	9.1	9.1
Other crops	8.6	9.9	10.0
Beef and mutton	0.6	1.4	1.3
Pork and poultry	1.7	3.0	3.0
Milk	0.2	0.4	0.4
Processed food	1.5	3.1	3.2

EU = European Union; GMS-5 = covers the five countries of the Greater Mekong Subregion: Cambodia, the Lao People's Democratic Republic, Myanmar, Thailand, and Viet Nam; PRC = the People's Republic of China; US = the United States.

Source: Authors.

price of maize rises by 11.1%, soybean by 10.3%, other oilseeds by 12.4%, and sugarcane by 4.8% in 2020. Significant price rises are seen in commodities with high mobility of land use with feedstock crops and which are highly dependent on the world market to satisfy domestic demand in the GMS-5. For example, the price of wheat increases by 8.9% and fibers by 8.1%.[31]

Biofuel development in the GMS-5 countries would also have an impact on the price of agricultural products. However, this is likely to be concentrated in several feedstock commodities because future biofuel development in those countries is mainly based on two commodities: cassava and sugarcane. If the targeted biofuel production is realized in 2020, the domestic price of these two commodities would increase significantly. As shown in column 2, Table 8, the price of cassava rises by 21.7% compared with the reference scenario, while the price of sugarcane rises by 27.6%. Meanwhile, as more resources are switched to the production of cassava and sugarcane, the prices of other commodities in the GMS-5 countries increase further, compared with those in S1.

Interestingly, biofuel development in the GMS-5 countries has less effect than S1 on the price of many other agricultural commodities. For example, the price of wheat rises by 0.7%, maize by 1.4%, other grains by 1.3%, soybean by 0.8%, other oilseeds by 1.7%, fibers by 1.0%, and other crops by 1.3% in 2020 (the difference between S2 and S1 in Table 8). These changes are much smaller than the increase driven by biofuel development in Brazil, the EU, and the US. However, vegetables and fruits, pork and poultry, and processed food, experience relatively significant impacts compared with S1. This is because biofuel development in S1 has less effect on these commodities due to the low mobility of land use between feedstock crops; and these four commodities are very important in the GMS-5 countries, where they make up 74.9% of total agricultural production.[32] Therefore, biofuel development in the GMS-5 countries would have a more marked effect on these key commodities. The absolute change in price is, nevertheless, small; e.g., compared with S1, the price of rice increases by 2.7%, vegetables and fruits by 2.9%, pork and poultry by 1.3%, and processed food by 1.6%.

[31] Self-sufficiency in the five GMS countries is only 0.6% for wheat and 24.4% for fiber in 2001, according to the GTAP-6 database. The authors predict that self-sufficiency in fiber will be further reduced to 14.9% in 2020. Hence there is high dependence on the world market to meet domestic demand for these two commodities.

[32] In the total agricultural production data, rice accounts for 12.3%, vegetables and fruits for 10.9%, pork and poultry for 14.9%, and processed food for 36.8% in the reference scenario in 2020.

The impact of the PRC's biofuel development on agricultural prices in GMS-5 countries is also minimal, except in the case of cassava and other grains (Table 8). This is due to the assumption that cassava and sweet sorghum will be two major feedstock crops for future biofuel development in the PRC. The high price of cassava, caused by the rapid rise in demand from the PRC's biofuel industries, would be transmitted to neighboring countries, such as those of the GMS-5. Correspondingly, under the simulation, the price of cassava rises by 4.1% in the GMS-5 countries, compared with S2 (the difference between S3 and S2 in Table 8), but the impact of biofuel development in the PRC on the price of other agricultural commodities in the GMS-5 would be very limited (the difference between S3 and S2 in Table 8).

Impact on Agricultural Production and Land Use

In response to these price changes, the production structure and use of land by different agricultural commodities would also change significantly in the GMS-5 countries. Although S1 assumes no further biofuel expansion in the GMS-5 countries during 2006–2020, the production of crops used for feedstock in Brazil, the EU, and the US would still increase in GMS-5 countries. According to the simulation, the production of maize will increase by 14.3%, soybean by 10.9%, other oilseeds by 12.1%, and sugarcane by 3.2% (Table 9, column 1). The production of fiber and other crops (mainly horticultural commodities such as coffee) will also rise by 6%–7%, and there will be slight decreases in the production of other agricultural commodities.

However, a different picture emerges for fibers (chiefly cotton) and other crops. The GMS-5 countries are heavily dependent on the world market to satisfy their domestic demand for fibers. In 2001, self-sufficiency in cotton in the GMS-5 countries was only 24%, and will decline to 16% in 2020 according to the simulation for the reference scenario. When the world supply of cotton drops due to the biofuel boom in Brazil, the EU, and the US, the demand must

Table 9: Impact on Agricultural Production in the Five Countries of the Greater Mekong Subregion, Compared with the Reference Scenario in 2020
(%)

Commodity	Scenario 1 (3 producers: Brazil + EU + US)	Scenario 2 (3 producers + GMS-5)	Scenario 3 (3 producers + GMS-5 + PRC)
Rice	(0.5)	(2.7)	(2.8)
Wheat	(0.8)	(1.9)	(2.2)
Maize	14.3	10.4	10.7
Other grains	(3.0)	(4.6)	12.8
Cassava	(0.9)	47.4	55.1
Vegetables and fruits	(0.5)	(2.6)	(2.7)
Soybean	10.9	6.9	6.1
Other oilseeds	12.1	8.3	8.2
Sugarcane	3.2	30.8	30.7
Fibers	6.0	1.5	1.5
Other crops	6.7	2.8	2.7
Beef and mutton	(0.2)	(0.5)	(0.5)
Pork and poultry	(0.1)	(1.2)	(1.2)
Milk	(0.5)	(0.7)	(0.7)
Processed food	(0.7)	(3.0)	(3.1)

( ) = negative number; EU = European Union; GMS-5 = the five countries of the Greater Mekong Subregion: Cambodia, the Lao People's Democratic Republic, Myanmar, Thailand, and Viet Nam; the PRC = the People's Republic of China; US = the United States.

Source: Authors.

be met domestically, so domestic cotton production would increase in GMS-5 countries. Meanwhile, the export of other crops (mainly horticulture) in GMS-5 countries would rise significantly due to the projected decline in horticulture supply in the rest of the world.

While biofuel expansion in the GMS-5 would have only a limited effect on world crop prices and production, agricultural production within the region would change significantly. The model shows that the production of cassava, which is used as a biofuel feedstock in GMS-5 countries, rises by 48.3% in S2 compared with S1, and sugarcane production increases by 27.6% (Table 9). As more resources are converted to produce these feedstock crops, the output of other agricultural commodities declines slightly in S2 compared with S1 (Table 9, column 2).

Impact on Agricultural Prices and Production in the People's Republic of China

Impact on Agricultural Prices

In general, the impact on the PRC of biofuel development in the rest of the world is broadly similar to its impact on the GMS-5 countries. However, due to the differences in the agricultural production structure and their feedstocks for biofuel production, slight difference exists in some commodities. Simulation results show that the PRC's agricultural prices would rise significantly in S1, and that prices of agricultural commodities used as feedstock in Brazil, the EU, and the US would rise significantly in the PRC. In S1, the price of maize increases by 11.8%, soybean by 10.9%, other oilseeds by 22.3%, and sugarcane by 6.0% in 2020 (Table 10, column 1).

Table 10: Impact on the Price of Agricultural Commodities in the People's Republic of China, Compared with the Reference Scenario in 2020

(%)

Commodity	Scenario 1 (3 producers: Brazil + EU + US)	Scenario 2 (3 producers + GMS-5)	Scenario 3 (3 producers + GMS-5 + PRC)
Rice	2.7	2.9	3.7
Wheat	2.7	2.8	3.0
Maize	11.8	11.9	12.4
Other grains	6.3	6.4	56.7
Cassava	2.9	4.7	61.2
Vegetables and fruits	2.2	2.4	2.9
Soybean	10.9	11.1	11.2
Other oilseeds	22.3	22.5	22.8
Sugarcane	6.0	7.3	7.7
Fibers	5.0	5.2	5.8
Other crops	7.1	7.3	7.4
Beef and mutton	1.5	1.7	1.7
Pork and poultry	2.0	2.2	2.4
Milk	1.2	1.3	1.3
Processed food	1.5	1.6	1.6

EU = European Union; GMS-5 = the five countries of the Greater Mekong Subregion: Cambodia, the Lao People's Democratic Republic, Myanmar, Thailand, and Viet Nam; PRC = the People's Republic of China; US = the United States.

Source: Authors.

As expected, the model shows that biofuel development in the GMS-5 countries would have a very limited impact on the PRC's agricultural prices. Although agricultural prices in the PRC increase in S2 compared with the reference scenario, the differences between agricultural prices in S1 and S2 are very small (Table 10).

However, while the PRC's biofuel program may have little effect on the rest of the world, it would have a marked effect on the domestic prices of the feedstocks used (other coarse grains and cassava). Instead of rising by 4.7% in S2 (Table 10, column 1), the PRC's cassava price rises by 61.2% under S3 (Table 10, column 3). Similarly, the prices of other coarse grains (sweet sorghum and others) rise by 50.3% compared with their price in S2 (56.7% minus 6.4%, row 4, Table 10). As more resources shift to the production of biofuel crops, the prices of other agricultural commodities also increase. However, compared with the effects of biofuel development in Brazil, the EU, and the US, the price impact on other agricultural commodities is small.

Impact on Agricultural Production

The simulation shows that agricultural production in the PRC would change significantly in response to a world biofuel boom. In S1, the PRC's production of maize increases by 18.0%, soybean by 14.3%, other oilseeds by 71.4%, and sugarcane by 5.4% (i.e., feedstock crops used by Brazil, the EU, and the US) compared with the reference scenario in 2020 (Table 11, column 1). Production of fibers also rises by 4.8%, while that of other crops, livestock, and processed food declines slightly.

Table 11: Impact on Agricultural Production in the People's Republic of China, Compared with the Reference Scenario in 2020

(%)

Commodity	Scenario 1 (3 producers: Brazil + EU + US)	Scenario 2 (3 producers + GMS-5)	Scenario 3 (3 producers + GMS-5 + PRC)
Rice	(0.2)	(0.2)	(0.5)
Wheat	(0.5)	(0.5)	(0.9)
Maize	18.0	17.9	17.0
Other grains	(5.2)	(5.3)	93.6
Cassava	(3.9)	1.5	632.2
Vegetables and fruits	(0.2)	(0.2)	(0.8)
Soybean	14.3	14.3	13.9
Other oilseeds	71.4	71.3	70.6
Sugarcane	5.4	6.9	3.1
Fibers	4.8	4.8	3.8
Other crops	(6.7)	(6.7)	(10.1)
Beef and mutton	(0.2)	(0.2)	(1.3)
Pork and poultry	(0.8)	(0.7)	(2.3)
Milk	(0.8)	(0.8)	(1.6)
Processed food	(0.7)	(0.7)	(1.8)

( ) = negative number; EU = European Union; GMS-5 = the five countries of the Greater Mekong Subregion: Cambodia, the Lao People's Democratic Republic, Myanmar, Thailand, and Viet Nam; PRC = the People's Republic of China; US = the United States.

Source: Authors.

The increase in fiber production (chiefly cotton) in the PRC is mainly caused by the reduced production of cotton in the US and Brazil in S1. The PRC's cotton imports increased rapidly after its accession to the World Trade Organization. Self-sufficiency was only 64.9% in 2006.[33] According to the reference simulation, the PRC's cotton self-sufficiency would fall further to 47.6% in 2020. However, the falling supply of cotton in the rest of the world would raise the world cotton price, shifting demand to domestic supply and raising cotton production in the PRC.

The impact of biofuel development in GMS-5 countries on the PRC's agricultural production would be minimal. The largest changes in production, compared to S1, are seen in cassava and sugarcane. Cassava production rises by 5.4%, and sugarcane production increases by 1.5% in S2 relative to S1 (column 2, Table 11). The impact on the production of other agricultural commodities is marginal.

However, the PRC's own biofuel production would affect its agricultural production significantly. As shown in column 3 of Table 11, the production of other grains rises by 93.6%, and the production of cassava rises by an astonishing 632.2%. Considering the small output of other grains and cassava in the reference scenario, the large demand for these products as feedstocks for the biofuel industry would result in a substantial growth in their production. Meanwhile, because the rapidly rising production of feedstock crops requires more production resources, the production of other commodities declines slightly in S3 compared with S1.

Table 12: Impact on Agricultural Trade of the Five Countries of the Greater Mekong Subregion, Compared with the Reference Scenario in 2020
($ million)

	Export			Import			NetExport		
Commodity	**S1**	**S2**	**S3**	**S1**	**S2**	**S3**	**S1**	**S2**	**S3**
Rice	3	(1)	(1)	(15)	(7)	(7)	18	6	6
Wheat	0	0	0	(10)	(7)	(7)	10	7	7
Maize	9	6	6	(58)	(52)	(53)	67	58	59
Other grains	1	0	2	(1)	0	(3)	2	0	5
Cassava	30	(116)	(63)	(2)	20	18	32	(136)	(81)
Vegetables and fruits	52	(14)	(13)	(13)	6	6	65	(20)	(19)
Soybean	11	8	8	(10)	(2)	(2)	21	10	10
Other oil seeds	13	9	9	(12)	(12)	(12)	25	21	21
Sugarcane	20	(12)	(12)	(1)	6	6	21	(18)	(18)
Fibers	6	3	3	(22)	(18)	(17)	28	21	20
Other crops	367	229	235	(35)	(26)	(27)	402	255	262
Beef and mutton	3	2	2	(6)	(3)	(4)	9	5	6
Pork and poultry	75	9	7	(15)	5	5	90	4	2
Milk	5	0	0	(4)	(6)	(6)	9	6	6
Processed food	(139)	(204)	(212)	9	40	46	(148)	(244)	(258)

( ) = negative number; S1 = Scenario 1 (only three major biofuel producers, Brazil, the European Union, and the United States develop biofuels), S2 = Scenario2 (three major biofuel producers and the five countries of the Greater Mekong Subregion [GMS-5] develop biofuels), S3 = Scenario3 (three major biofuel producers, the GMS-5 and the People's Republic of China develop biofuels).

Source: Authors.

[33] National Bureau of Statistics of China. 2007. *China Statistical Yearbook*. Beijing: China Statistical Press.

Impact on Agricultural Trade in the Greater Mekong Subregion

Impact on Agricultural Trade in the Five Countries of the Greater Mekong Subregion

Biofuel development in the rest of the world would increase the trade surplus in the GMS-5 countries. For example, in S1, the exports of all agricultural commodities—except processed food—increase in these countries (Table 12, column 1) and imports will decrease. This trend is caused mainly by the higher world market price and relatively lower domestic price. The degree of increase in the exports of one commodity depends both on its trade status and on the opportunity created by biofuel development in the rest of the world. For example, the strong comparative advantage of the GMS-5 countries in horticultural crop production, and the high world price of these commodities (Table 5) due to biofuel development in Brazil, the EU, and the US, means that the export of "other crops" increases by $367 million in GMS-5 in 2020 (column 1, Table 12), compared with the reference scenario. Although world prices of maize, soybean, and oilseeds rise more than the prices of horticultural crops, the export of these commodities by the GMS-5 countries would remain very small, as the GMS countries have a low comparative advantage for these commodities. Overall, the net export of agricultural commodities improves by $650 million in S1 compared with the reference scenario in 2020.

The trade status of feedstock crops used in the GMS countries is reversed in S2. Biofuel development in these countries significantly raises the domestic prices of cassava and sugarcane, thus imports of these two commodities rise and exports will decrease significantly. The export of cassava declines from a high of $30 million in S1 to –$116 million in S2, while sugarcane declines from $20 million in S1 to –$12 million in S2. Imports of cassava increase from –$2 million in S1 to $20 million in S2, and sugarcane imports rise from –$1 million in S1 to $6 million in S2 (Table 12). As biofuel production in the GMS-5 countries increases the production cost of other agricultural commodities, the expansion of exports in S2 is much smaller than in S1, while imports increase more in S2. As a result, total net exports in S2 decrease by $25 million compared with the reference scenario.

The GMS-5 countries would have the opportunity to export agricultural commodities to the PRC in S3, but the benefits would accrue mostly to producers of feedstock crops to supply the PRC's biofuel industry. The PRC's biofuel production would increase the price of other coarse grains and cassava significantly, and this would increase the level of imports of these two commodities from neighboring countries.

Impact on Agricultural Trade in the People's Republic of China

Analyses show that biofuel development in Brazil, the EU, and the US would improve the PRC's agricultural trade surplus. The simulation shows that the PRC's exports increase for all agricultural commodities except milk and processed food, while imports of these commodities fall (Table 13). Their trade balances improve significantly, especially for commodities used as feedstocks in Brazil, the EU, and the US. For example, the PRC's net export of maize rises by $946 million, soybean by $196 million, other oilseeds by $1,030 million, and sugarcane by $20 million, compared with the reference scenario in 2020 (column 7 Table 13). The net exports of wheat and fiber also increase significantly. Because the domestic price of milk and processed food rise higher than the corresponding world price, the export of these products decrease and imports rise slightly. Overall, the PRC's total net export of agricultural commodities increase by $4.1 billion in S1 compared with the reference scenario in 2020.

Table 13 also shows that the PRC's own biofuel development program would have marked impact on its agricultural trade. Because of the rapidly rising price of other grains and cassava in S3, the PRC's imports of other grains increase by $174 million, its

Table 13: Impact on Agricultural Trade in the People's Republic of China, Compared with the Reference Scenario in 2020
($ million)

	Export			Import			Net export		
Commodity	**S1**	**S2**	**S3**	**S1**	**S2**	**S3**	**S1**	**S2**	**S3**
Rice	74	71	68	(4)	(4)	(3)	78	75	71
Wheat	5	5	5	(148)	(148)	(136)	153	153	141
Maize	150	154	107	(796)	(797)	(726)	946	951	833
Other grains	79	79	(332)	(3)	(3)	174	82	82	(506)
Cassava	1	47	(3)	0	(3)	138	1	50	(141)
Vegetables and fruits	519	518	479	(94)	(94)	(87)	613	612	566
Soybean	76	75	70	(120)	(118)	(93)	196	193	163
Other oilseeds	1,022	1,022	1,003	(8)	(7)	(5)	1,030	1,029	1,008
Sugarcane	18	27	9	(2)	(15)	(7)	20	42	16
Fibers	2	2	1	(584)	(583)	(552)	586	585	553
Other crops	272	269	277	(44)	(45)	(68)	316	314	345
Beef and mutton	1	1	4	(27)	(21)	(20)	28	22	24
Pork and poultry	46	42	31	(207)	(212)	(116)	253	254	147
Milk	(1)	(1)	0	24	30	37	(25)	(31)	(37)
Processed food	(147)	(171)	(194)	27	28	60	(174)	(199)	(254)

( ) = negative number; S1 = Scenario 1 (only three major biofuel producers, Brazil, the European Union, and the United States develop biofuels), S2 = Scenario 2 (three major biofuel producers and the five countries of the Greater Mekong Subregion [GMS-5] develop biofuels), S3 = Scenario 3 (three major biofuel producers, the GMS-5 and the People's Republic of China develop biofuels).

Source: Authors.

cassava imports increase by $138 million in 2020 (column 6 in Table 13), while its exports of other grains decline by $332 million, and cassava exports decline by $3 million (column 3, Table 13). As biofuel production also increases domestic prices, the net export of other commodities also decreases relative to S1. Although the PRC's agricultural trade position is worse under its own biofuel development program compared with S1, its total agricultural trade balance is still improved relative to the reference scenario. The PRC's net export of agricultural commodities increases to $2.9 billion in S3 compared with the reference scenario, mainly due to the impact of biofuel development in Brazil, the EU, and the US.

Impact of Biofuel Development under the Scenario of High Oil Price and High Elasticity of Substitution between Biofuel and Gasoline

The discussion up to this point has been limited to the impact of biofuel development in three alternative scenarios under assumptions of low oil price ($60 per barrel) and low substitution of biofuel for gasoline (around 2) in 2020. Under these assumptions, substantial subsidies and policy support will be required to achieve the biofuel development targets that the governments have set. However, the situation would be considerably different if the assumptions on oil price and elasticity of substitution between biofuel and gasoline change. This subsection explores the likely impact of biofuel development under high oil prices ($120 per barrel) and high elasticity (20) of substitution between biofuel and gasoline—the H-H scenario. The impacts of biofuel development under the H-H scenario are presented in Tables 14–17.

In the H-H scenario, the production level of biofuels would be much higher than the targets set by the governments of all countries studied. Simulations show that by 2020, ethanol production in Brazil is projected to increase by 5.6 times its level in 2006; by 30.3 times in the PRC; by 21.1 times in the EU; by 29.1 times in the GMS-5 countries; and by 10.3 times in the US (Table 14, column 2). Biodiesel production also increases 20.3 times in the US and 13.1 times in the EU over the same period (column 2, Table 14). Because the growth of biofuel production in each country in the H-H scenario is much greater than any target level set by the different countries in 2020, biofuel production under the H-H scenario would have much stronger impact on world food prices and production.

The world price of agricultural commodities in the H-H scenario would be much higher than in any scenario presented earlier. As shown in Table 15, the world

Table 14: Percentage Changes in Biofuel Production in 2006–2020 under the Planned Target and the H-H Scenario
(%)

Item	Target	H-H Scenario
Ethanol production		
US	640	1,031
EU	713	2,409
Brazil	193	558
PRC	685	3,027
GMS-5	980	2,902
Diesel production		
US	740	2,033
EU	711	1,309

EU = European Union; GMS-5 = the five countries of the Greater Mekong Subregion: Cambodia, the Lao People's Democratic Republic, Myanmar, Thailand, and Viet Nam; H-H = the "high-high" scenario; PRC = the People's Republic of China; US = United States.

Note: The H-H Scenario assumes that global biofuel development is determined by market mechanisms. High biofuel-gasoline elasticity and high oil price are also assumed under this scenario.

Source: Authors.

Table 15: Impact on World Average Export Price in Scenario 3 and the H-H Scenario in 2020
(%)

Commodity	S3	H-H
Rice	4.6	8.9
Wheat	7.8	24.6
Maize	18.2	69.4
Other grains	14.4	28.7
Cassava	8.2	84.4
Vegetables and fruits	5.5	12.0
Soybean	13.9	46.9
Other oilseeds	28.0	39.7
Sugarcane	12.3	34.7
Fibers	7.9	23.1
Other crops	11.5	23.8
Beef and mutton	2.5	7.2
Pork and poultry	2.7	6.4
Milk	0.8	3.0
Processed food	1.2	4.2

S3 = Scenario 3 (the three major biofuel producers, the five countries of the Greater Mekong Subregion [GMS-5], and the People's Republic of China develop biofuels), H-H = the "high-high" scenario.

Note: The H-H Scenario assumes that global biofuel development is determined by market mechanisms. High biofuel–gasoline elasticity and high oil price are also assumed under this scenario.

Source: Authors.

average export price of maize increases by 69.4% in the H-H scenario compared to the reference scenario in 2020, soybean increases by 46.9%, other oilseeds by 39.7%, and sugarcane by 34.7% (column 2 Table 15). Meanwhile, the prices of other non-feedstock crops also rise significantly. The price of rice increases by 8.9% in 2020, wheat by 24.6%, other grains by 28.7%, vegetables and fruits by 12.0%, fibers by 23.1%, and other crops by 23.8%.

The production of most agricultural commodities would also change dramatically. The production of feedstock crops would increase significantly at the expense of other agricultural commodities (Table 16). Under the H-H scenario, global production of maize increases by 97.9%, soybean by 17.8%, other oilseeds by 73.1%, and sugarcane by 29.1%, compared with the reference scenario in 2020 (column 2, Table 16). In contrast, there is a decrease in production of other crops, animal products, and processed food, especially for crops with a higher mobility of land use with feedstock crops. Compared with the reference scenario in 2020, wheat production drops by 6.3% in 2020, other grains by 13.7%, cotton by 8.9%, and other crops by 7.8% (column 2, Table 16). With the increasing cost of feed and intermediate inputs, the production of beef and mutton, pork and poultry, dairy products, and processed food decrease by 3%–6%.

In the H-H scenario, agricultural prices in the GMS-5 countries also rise significantly. Besides the increasing price of feedstocks used by Brazil, the EU, and the US, the price of feedstocks used in the GMS-5 also rise substantially. Simulations show that the price of maize in the PRC rises by 38.4%, soybean by 41.1%, other oilseeds by 30.2%, sugarcane by 15.6%, other grains by 68.9%, and cassava by 119.3% (column 2, Table 17). Results are similar in the GMS-5 countries (column 4, Table 17). These price increases in both the PRC and the GMS-5 are much higher than those found under S3. Prices of non-feedstock crops and other animal products in the H-H scenario would also rise much more under the H-H scenario than in S3.

Table 16: Impact on World Agricultural Production in Scenario 3 and the H-H Scenario in 2020
(%)

Commodity	S3	H-H
Rice	(2.0)	(6.3)
Wheat	(0.6)	(13.7)
Maize	27.7	97.9
Other grains	13.0	25.7
Cassava	8.3	31.8
Vegetables and fruits	(1.3)	(3.6)
Soybean	1.4	17.8
Other oilseeds	60.7	73.1
Sugarcane	8.8	29.1
Fibers	(1.3)	(8.9)
Other crops	(1.0)	(7.8)
Beef and mutton	(1.1)	(3.5)
Pork and poultry	(1.6)	(5.6)
Milk	(0.6)	(3.5)
Processed food	(0.9)	(3.1)

( ) = negative number, S3 = Scenario 3 (the three major biofuel producers, the five countries of the Greater Mekong Subregion [GMS-5], and the People's Republic of China develop biofuels), H-H = the "high-high" scenario.

Note: The H-H Scenario assumes that global biofuel development is determined by market mechanisms. High biofuel–gasoline elasticity and high oil price are also assumed under this scenario.

Source: Authors.

Table 17: Impact on Agricultural Prices in the Greater Mekong Subregion and The People's Republic of China in Scenario 3 and the H-H Scenario in 2020

(%)

Commodity	The PRC		GMS-5	
	S3	H-H	S3	H-H
Rice	3.7	8.7	6.5	16.6
Wheat	3.0	15.7	9.8	21.9
Maize	12.4	38.4	12.7	38.9
Other grains	56.7	68.9	14.3	18.4
Cassava	61.2	119.3	21.8	108.1
Vegetables and fruits	2.9	5.8	6.9	18.5
Soybean	11.2	41.1	11.2	33.5
Other oilseeds	22.8	30.2	14.2	21.4
Sugarcane	7.7	15.6	27.5	63.9
Fibers	5.8	18.9	9.1	20.0
Other crops	7.4	14.2	10.0	22.8
Beef and mutton	1.7	5.8	1.3	2.3
Pork and poultry	2.4	6.6	3.0	5.2
Milk	1.3	4.3	0.4	2.6
Processed food	1.6	7.6	3.2	8.3

GMS-5 = the five countries of the Greater Mekong Subregion: Cambodia, Lao People's Democratic Republic, Myanmar, Thailand, and Viet Nam; H-H = the "high-high" scenario; PRC = the People's Republic of China; S3 = Scenario 3 (three major biofuel producers, the GMS-5 and the PRC develop biofuels).

Note: The H-H Scenario assumes that global biofuel development is determined by market mechanisms. High biofuel–gasoline elasticity and high oil price are also assumed under this scenario.

Source: Authors.

Conclusions and Implications

Concerns about energy security, climate change, and rural development have prompted many countries to promote national biofuel programs and associated support policies. In common with many developed and developing countries, each of the six countries of the Greater Mekong Subregion (GMS) have also begun to map out ambitious biofuel development plans and strategies, with high production and use targets. There has been much debate on the role of biofuel development in improving national and global energy security, in reducing the amount of CO_2 in the atmosphere, and in agriculture and food security. This study contributes to the debate by modeling the impact of biofuels development—both globally and in the GMS—on agriculture and other parts of the economy.

Based on a modified multi-country, multi-sector computable general equilibrium model, this study reveals that global biofuel development—particularly biofuel programs in Brazil, the European Union (EU), and the United States (US)—would have a substantial impact on world agricultural prices and production. The rise of biofuels development would significantly increase the price of biofuel feedstock crops such as maize, oil crops, sugarcane, and cassava. Because of land substitution effects, prices of other crops would also rise with considerable variation due to the mobility of land substitution between feedstock crops and non-feedstock crops.

In response to price changes due to biofuel development in Brazil, the EU, and the US, the production of biofuel feedstock crops such as maize, rapeseed, and sugarcane would increase in almost all countries, though for different reasons. In Brazil, the EU, and the US, the increased production of maize, oil crops, and sugarcane would be used mostly in their national biofuels production. Exports of these commodities would fall substantially. In the rest of the world, including the countries of the GMS, the production response to world price changes would be positive. The production of feedstock crops used for biofuel production by Brazil, the EU, and the US is expected to rise in the rest of the world, including the five countries of the GMS (GMS-5) and the People's Republic of China (PRC).

An increase in the production of feedstock crops (e.g., maize, oil crops, and sugarcane) in any GMS country due to biofuel production in the rest of the world would raise the supply in that country, increase its exports to (or reduce its import from) the rest of the world, and raise the national self-sufficiency level of these commodities. These results are interesting as current debates have emphasized the negative consequences of biofuel expansion for food security in developing countries. The results of this study indicate that, while importing countries will have to pay higher prices for their imports of maize, soybean, rapeseed, edible oils, and sugarcane, their domestic production and self-sufficiency of these commodities will also increase with rising global food price in the long run. For exporting countries, the expansion of biofuels in the rest of the world will increase their domestic production and exports through higher export prices. In this regard, the GMS countries should welcome the expansion of biofuel development in the rest of the world.

The production of rice, wheat, horticultural crops, and livestock will fall modestly, but agriculture as a whole will expand worldwide, including in the GMS-5 and the PRC. The falling production of rice, wheat, and horticultural crops shown by the simulation is mainly a result of competition for land and other resources used to produce biofuel feedstock crops. Meat production will also decline because the price of its main input (grain) will rise. Because the expansion of feedstock crops is much larger than the reduction of other agricultural commodities, overall agricultural production and income in the world and in the GMS will rise along with biofuel development in Brazil, the EU, and the US.

This study also shows that while biofuel development in the GMS countries, including the PRC, will have little impact on global agricultural prices and production, it will have significant effects on domestic agricultural production and land use. With the exception of a few crops that will be used in biofuel production in the region (e.g., cassava, sweet sorghum, and sugarcane), biofuel development will only raise global prices of other agricultural commodities by 1%–2%. However, domestic land use, feedstock prices, the structure of agricultural production, and trade will change significantly with the expansion of national biofuel production. The rapid expansion of domestic biofuel production will substantially increase feedstock production and reduce the production of other crops and livestock in the subregion. Overall, crop production will become more intensive. This underlines the need for a careful impact assessment as an essential input to the design of each of the GMS countries' biofuel programs. Although environmental issues have not been assessed in this study, it is expected that the expansion of feedstock crops could also result in a monocrop system that could have negative consequences for the environment.

Changes in prices and production in each of the GMS countries brought about by domestic biofuel production will also induce significant changes in their agricultural trade. Overall, the agricultural trade deficit (or surplus) will increase (or decline) modestly in each GMS country. The degree of impact on their national trade deficits will largely depend on the size of their national biofuel programs. Therefore, there are implications for national food security and the trade-offs between food, feed, and fuel. While national biofuels programs can lead to improved national energy security by reducing crude oil imports, they may have adverse effects on national food security as the imports (or exports) of food and feed will rise (or fall). It is also notable that, due to the competition among all crops for land and other resources, these results hold true whether food crops or non-food crops are used for biofuel production in each of the GMS countries.

It must also be pointed out that the extent of the impact of biofuel development on the prices, production, and trade of agricultural and food products is highly dependent on the international oil price and the degree of substitution between biofuel and gasoline. If energy prices rise to a certain level in 2020 (e.g., $120 per barrel in this study), and if ethanol becomes increasingly substitutable for gasoline, the only policy that could ensure food security is to ban biofuels. Eliminating biofuel subsidies and other policies supporting biofuel development would have little effect. For agriculture, biofuels present a huge opportunity for market expansion; however, the growth of biofuel programs in the GMS in the future could disturb land and water allocation and, to some extent, threaten national food security in the subregion.

Biofuel development will be beneficial to agricultural producers who own land and sell crops on the market. Rising agricultural prices and production, and the corresponding rise in land prices and agricultural wages, raise the incomes of farm households and improve household food security. Biofuels may, however, be detrimental to many consumers, particularly the poor who are net food purchasers. It is inevitable that many consumers will suffer, including those in the countries of the GMS. It is thus essential to construct social safety nets or enhance existing social security systems to provide the necessary support for vulnerable citizens. However, higher food prices will encourage state and private investment in agricultural enterprises, and this increased investment will raise agricultural productivity, partly offsetting the rise in agricultural prices from the expansion of the biofuel industry.

Finally, it should be noted that the pathway of biofuels impact through the economy is complex. The methods, results, and implications presented in this paper should be considered preliminary attempts to understand the complicated impact of biofuel development. Further efforts should be made to complete the database on global and regional biofuels, particularly the data for the GMS. Other areas that need further study are the input–output parameters, the link between crops and biofuels and between biofuels and gasoline, and the likely impact of future changes in crops and biofuel processing technology.