CHAPTER 1

INTRODUCTION

As concerns about global greenhouse gas emissions and a desire for clean energy sources mount, many countries are exploring bioenergy developments as a possible solution. The Food and Agriculture Organization (FAO) of the United Nations has set up the Bioenergy and Food Security (BEFS) project to assess how bioenergy developments can be implemented without hindering food security.

Thailand has a rapidly developing biofuels sector. As Thailand has traditionally benefited from a robust agricultural sector, biofuels present new opportunities for Thai farmers who have long been able to produce enough food to feed the country and plenty more for export and other uses. With its Alternative Energy Development Plan (AEDP), the Thai Government aims to leverage its strong agricultural sector to expand biofuels production six-fold to five billion litres by 2022.

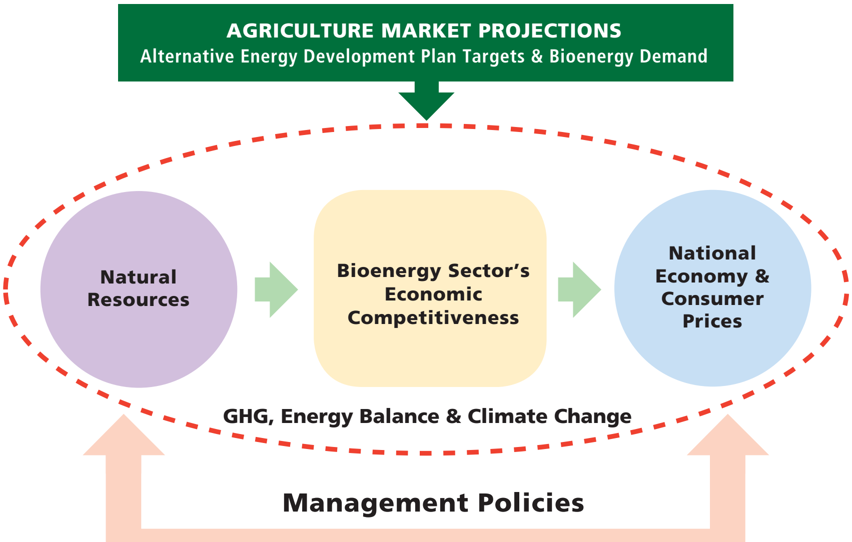
There are strong arguments for promoting biofuels and the Thai Government cites a number of them as justification for implementation of the AEDP including enhanced fuel energy security, reduced greenhouse gas emissions and new opportunities for rural development. But there are also potential risks associated with expanding biofuel production to the scale anticipated by the AEDP. Biofuel production systems compete with food production for land and agricultural resources which can potentially jeopardize food security. The precise impact on food security depends on a range of factors including the land used for bioenergy production, feedstock, agricultural management practices, the industrial set-up of the sector and developments in global agricultural and energy markets.

In the case of Thailand the key crops for biofuel production are sugar cane, cassava and oil palm. In some instances the Thai Government is anticipating that the effect of the AEDP on the production of these crops will be considerable. For example, between 2010 and 2022, cassava production is expected to increase from 2.27 million tons to more than 15 million tons, while crude palm oil output is expected double from 1.8 million tons to 3.4 million tons.

Ultimately, the long-term sustainability of the biofuels sector in Thailand depends on careful management of the country's natural resources. With the BEFS project, FAO has worked with Thai technical organizations to provide the knowledge and analysis to help guide future decisions regarding the expansion of the biofuels sector and management of the necessary natural resources. Essentially FAO wants to strengthen the capacity of the Thai Government to balance the trade-offs associated with the AEDP including potential risks to food security.

The BEFS analysis, as illustrated in Figure 1.1, is underpinned by the AEDP. The AEDP targets will affect Thailand's future agricultural market and will involve increased use of Thailand's natural resources. The efficiency of the Thai bioenergy sector in managing these resources will determine the economic competitiveness of the sector and its effect on climate. The sector will affect the national economy and households through the price of food made from the biofuel feedstock crops and from the price of biofuels, but also through a presumed increase in returns for farmers. The future sustainability of biofuels and bioenergy as alternative energy sources will depend on how the Thai Government manages the pressures that the bioenergy sector will place on its natural resources and agricultural markets.

FIGURE 1.1
BEFS Analytical Framework in Thailand



The BEFS analysis in Thailand does not only assess the feasibility of the bioenergy sector per se, but rather recognizes that biofuels and, to a large extent, bioenergy development is an extension of the agricultural sector. While the findings of the BEFS analysis indicate that Thailand is capable of meeting its ambitious targets, strategies will be necessary to improve agricultural productivity. Farming communities in Thailand will need more support if they are to bring about such improvements in productivity. Most of this investment will need to be directed toward Thailand's north and north-east regions, which, while the areas with the most potential for future expansion of cassava and oil palm production, are also home to most of Thailand's remaining poor.

But overcoming this challenge could unlock multiple dividends for Thailand. More productive farms, investment and improved farming techniques will increase farmers' incomes and reduce GHG emissions per unit of transport fuel produced. Greater income for Thailand's farmers will also have flow-on benefits to rural communities that will aid in continuing Thailand's progress over the past 20 years in reducing poverty and increasing food security.

The BEFS analysis for Thailand is structured as follows:

Chapter 2 sets the context against which the bioenergy sector is developed in Thailand. This section illustrates the macroeconomic performance of the country, the agriculture and energy sector, the socio-economic conditions, poverty, rural development and environmental issues. It also presents the status of bioenergy policy in Thailand.

Chapters 3 to 8 are the technical chapters of the analysis that contain the results of the main analytical components that constitute the BEFS Analytical Framework.

The main findings are then recapped in a separate volume entitled "BEFS Thailand - Key results and policy recommendations for future bioenergy development". The results are used to provide information and recommendations for policy-makers how to achieve the envisaged biofuel targets in a sustainable way without impacting food security.

CHAPTER 2

THAILAND CONTEXT

Thailand occupies the western half of the Indochinese peninsula and the northern two-thirds of the Malay Peninsula in Southeast Asia. It is delimited by Myanmar (Burma) to the west, Laos to the north and east, Cambodia to the southeast, and Malaysia to the south.

The National Research Council divides Thailand into six geographical regions, based on natural features including landforms and drainage, and into human cultural patterns. These divisions provide a clear basis for economic, social and ecological discussions. The northern region is mountainous and was traditionally the most heavily forested area of the country. The north-eastern region (Isarn) constitutes approximately one-third of the area of the Kingdom and almost one third of the population of Thailand lives in this region. The central region (including Bangkok Metropolitan Region) includes the basin of the Chao Phrya river which runs from north to south and, after crossing Bangkok, flows to the Gulf of Thailand. The geography of the western region of Thailand bordering with Myanmar, like the North, is characterized by high mountains and steep river valleys. The region hosts much of Thailand's less-disturbed forest areas. Water and minerals are also important natural resources; the region is home to many of the country's major dams, and mining is an important industry in the area. The eastern region, which comprises the hilly countryside from Bangkok to the Cambodian border, is characterized by higher rainfall and poorer soils than the adjoining central region. It is an important area for growing fruit, maize and cassava, and its coastline offers extensive opportunities for fisheries and tourism. The southern region, part of a narrow peninsula, is distinctive in climate, terrain and resources, and is the principal rubber-growing area. The forests of the south, as elsewhere in the Kingdom, have been seriously overcut. In recent years, the region has suffered from severe flooding, which is worsening because of deforestation and the subsequent soil erosion.

The Thai economy is one of the most robust in Asia. In the 1960s, the economy was predominantly based on agriculture and largely dependent on its abundant produce such as rice, cassava, maize, rubber and sugar cane, along with its production of seafood, primarily shrimp. In that period, Thai GDP depended heavily on the agriculture sector (37 percent of GDP) and the majority (more than 80 percent) of the labour force worked in the sector. The 1980s to mid-1990s marked the boom years in Thailand and saw the country develop into a diverse, modern and industrialized economy. Thailand used its strong agricultural sector to initiate a shift into industrialization. The availability of cheap local labour, enabled the country to shift into manufacturing and processing products for export purposes, starting with simple agri-based manufacturing and steadily progressing to more sophisticated industries. This led to the rapid expansion of the manufacturing sector and a marked increase in exports. Since this time the contribution of the agriculture sector to Thailand’s GDP has declined. In 2008 agriculture accounted for less than nine percent of GDP, while services and industry made up around 45 percent each.

Thailand's real GDP growth in 2008 was 2.6 percent, falling below previous Thai Ministry of Finance growth estimates due to the emerging global economic crisis. Falling global demand associated with the onset of the crisis put particular pressure of Thailand’s export sector, which accounts for around 60 percent of GDP

– a trend that continued into 2009. During the first quarter of 2009, total exports declined by 23.1 percent year-on-year, which contributed to a 7.1 percent contraction in total GDP. Headline inflation in January 2009 was -0.4 percent. The Thai Government adopted a two-stage fiscal stimulus response to address the effects of the crisis. The first phase, introduced in February 2009, was aimed at stimulating domestic purchasing power through cash handouts. The second phase, worth around US $57 billion, will be implemented over the 2010-12 period and is targeted at stimulating a range of large scale infrastructure projects.

Thailand is a member of the World Trade Organization (WTO) and the Cairns Group of agricultural exporters. Thailand is also part of the ASEAN Free Trade Area (AFTA). Thailand has actively pursued free trade agreements with: China commencing in October 2003, but limited to agricultural products, with a more comprehensive FTA to be agreed upon by 2010; India in 2003 when it began a limited agreement; Australia in January 2005 when it commenced a full agreement; and, Japan in February 2004 when Thailand began free trade negotiations, and in September 2005 when they made an in-principle agreement. Negotiations for a USA-Thailand Free Trade Agreement began in 2004 but were suspended in 2006 following the dissolution of the Thai Parliament and the subsequent military-led coup. The United States and Thailand held informal consultations and had a formal dialogue on trade and investment issues in June 2008, and held informal meetings in March 2009.

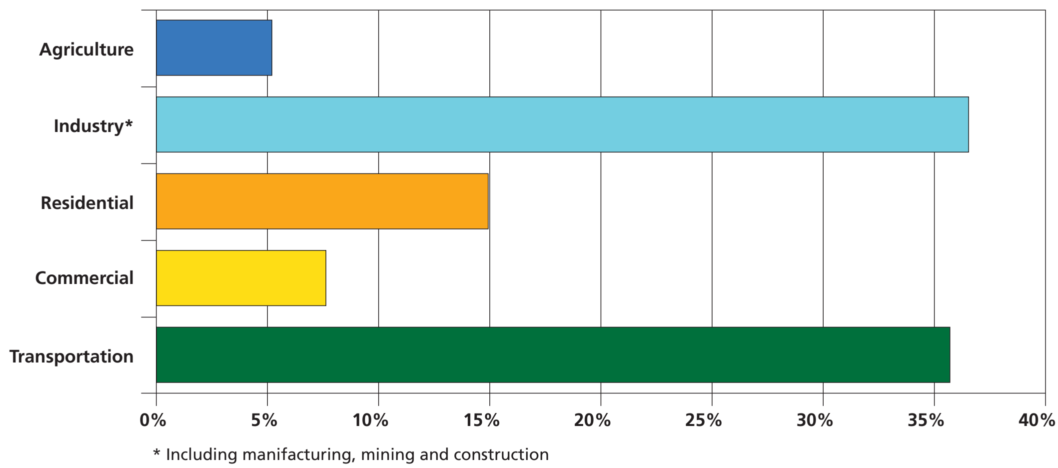
2.1 THE ENERGY SECTOR

Thailand's energy consumption has remarkably increased at pace with the recovery that began after the 1997 economic crisis. Thailand's strong economic performance since this time is reflected in the increasing growth of industrial output and energy consumption.

According to preliminary data provided by the Department of Alternative Energy Development and Efficiency (DEDE) of the Ministry of Energy (MoE), in 2009 the industrial and transport sectors were the largest consumers of energy accounting for 36.6 percent and 35.7 percent of final energy consumption respectively. In contrast, the agriculture sector accounted for only 5.2 percent of final energy consumption (Figure 2.1). These shares have remained relatively constant over the past five years.

FIGURE 2.1

Final energy consumption by economic sector in 2009



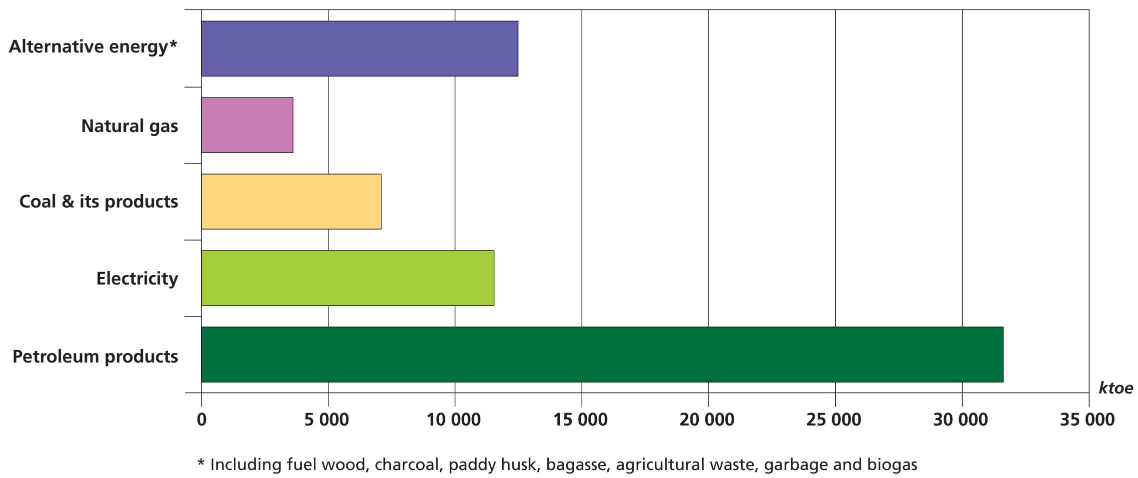
Source: DEDE.

In 2009, commercial energy, which consists of petroleum products, natural gas, coal, lignite and hydro, accounted for 66.5 percent of total energy produced and 80.6 percent of energy consumed. Renewable energy, which consists of fuel wood, paddy husk, bagasse, agricultural and municipal waste, biogas, solar, wind and geothermal accounted for 31.8 total domestic energy production and 18.4 percent of energy consumed. Biofuels accounted for 1.3 percent of total energy production and 0.8 percent of domestic energy consumption.

Over the past five years the commercial energy sector's share of domestic primary energy production has fallen slightly due to small increases in use of agricultural wastes, biofuels and biogas as energy sources. However, as indicated above, in terms of consumption Thailand is still largely dependent on fossil fuels to power its economy. To meet continued growth for energy Thailand has expanded domestic production of energy and supplement domestic supplies with imports. In the last two decades, Thailand has increased its production of crude oil more than seven fold while production of natural gas has increased more than five fold. Interestingly, the next largest domestically produced energy source is fuel wood. Figure 2.2 presents final energy consumption by fuel type in 2009. While natural gas is the main locally produced energy source it still only accounts for 5.4 percent of final energy consumption.

FIGURE 2.2

Final energy consumption by type in 2009



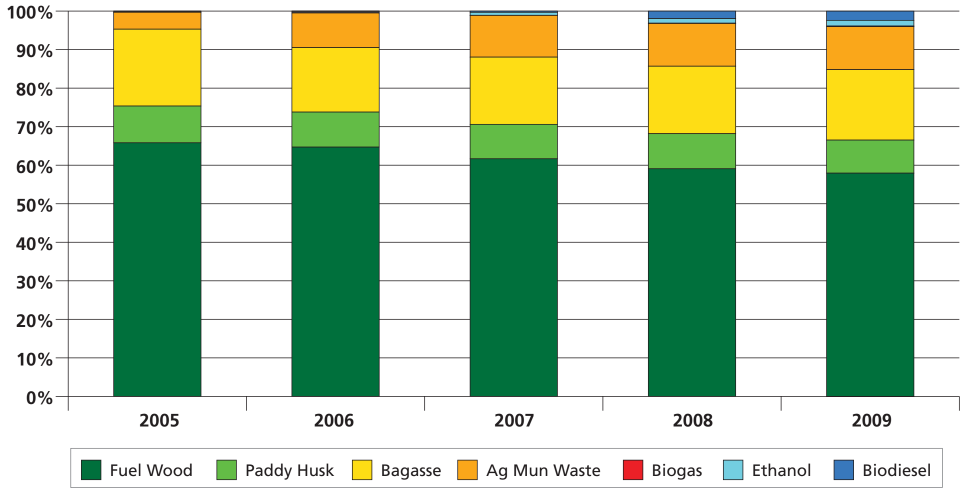
Source: DEDE.

In terms of exposure to international energy markets, practically all of Thailand's energy imports are from commercial fossil energy sources with crude oil accounting for the vast majority. National policies aimed at reducing oil imports through energy efficiency measures and increased domestic energy production have aided to reduce energy imports over the past decade – particularly of petroleum products. However, the reduction in consumption of petroleum products has been relatively small and has not been matched by a corresponding decrease in expenditures on energy imports. In fact, expenditures on energy imports have grown dramatically. For example, between 2002 and 2006 the value of crude oil imports increased from $6.67 billion to $19.77 billion, which was equivalent to 200 percent increase expenditure over the course of just five years. Since this time the global oil market has been characterized by ever increasing volatility.

While renewable energy is a domestically produced source of energy that already constitutes a large share of total final energy production and consumption in Thailand, inefficient fuel wood sources still constitute the largest share (Figure 2.3). Despite the perceived benefits of more efficient modern renewable energy systems, there are still a number of obstacles in the way of mainstreaming these new energy technologies including lack of consumer confidence and higher costs when compared to prevailing commercial energy sources. However, Thailand is particularly well placed to take advantage of new developments in the renewable energy sector; particularly with regard to bioenergy.

FIGURE 2.3

Alternative and renewable energy mix



Source: DEDE.

Thailand is traditionally an agriculture-based society. It currently produces a wide range of agricultural crops such as rice, sugar cane, rubber sheets, palm oil and cassava. Part of the harvest is exported each year, generating billions of baht revenues for the country. In processing these agricultural products, a large amount of residues are also generated. Some of these residues have been used as energy sources for industry; particularly in the agricultural processing sector. For instance, rice mills burn paddy husks to produce steam to power electricity generators, sugar mills and ethanol plants use bagasse to co-fire refinery operations, and palm oil refineries use residues to produce steam and electricity. Private industry is also developing biogas technology generated from animal manure and landfill for power generation and waste management purposes.

The major financial resource for these activities is the Energy Conservation Promotion Fund (ENCON Fund) established by the government under the Energy Conservation Promotion Act in 1992 to provide financial support to government agencies, state enterprises, non-government organizations, individuals and businesses that wish to implement measures to increase energy efficiency. Several biogas projects have been supported by the ENCON Fund, such as biogas from animal manure for generating power on livestock farms, and R&D on the feasibility of generating biogas from wastewater treatment.

The Thai biofuel sector is relatively small but developing rapidly. The key biofuel crops are sugar cane (molasses) and cassava for ethanol and palm oil for biodiesel. However, other feedstocks are used to produce biodiesel such as waste cooking oil and stearine, which is a by-product from refining palm oil.

The production of ethanol for transport purposes in existing alcohol refineries and sugar milling operations began in 2004. Since this time the number of ethanol refineries has expanded with total production capacity now at 2.575 million litres per day (MLPD) or 940 million litres per year (MLPY). Actual ethanol demand is around one MLPD meaning that there is currently excess production capacity. Thai Government policies aimed at expanding the market for ethanol have encouraged new entrants into the ethanol sector with a number of refineries planned or under construction. However, unlike existing facilities most new production facilities are expected to use cassava as their key feedstock. Once these facilities are complete, it is expected production capacity will increase to 3.24 MLPD or 1 180 MLPY.

Large-scale biodiesel production for blending into fossil diesel began in 2007. In 2008 biodiesel consumption increased to 1.2 MLPD (438 MLPY) and around two MLPD (730 MLPY) in 2009. Refineries planned or under construction are expected to bring total production capacity to 4.5 MLPD or 1 640 MLPY. Large-scale biodiesel refineries are concentrated in the south of Thailand near oil palm plantations and around Bangkok near fossil fuel refineries and fuel distributors. Biodiesel production at small-scale facilities is currently not included in national statistics, but is thought to be minimal.

2.1.1 The Alternative Energy Development Plan

Thailand's policy framework for bioenergy and biofuels is underpinned by the Alternative Energy Development Plan, which will be implemented over the period from 2008 to 2022. The plan has three phases (short-term 2008 to 2011, medium-term 2012 to 2016 and long-term 2017 to 2022) and aims to increase the share of Thailand's energy supply delivered by alternative energy sources to 20.3 percent by the final year of implementation. DEDE is the Thai Government agency responsible for implementing the AEDP.

The objectives of the AEDP are to:

- use alternative energy as the main source of energy, thus replacing oil imports;
- increase the country's energy security;
- promote the use of integrated green energy communities;
- enhance alternative energy technology industry development; and
- research, develop and encourage high efficiency alternative energy technologies.

The AEDP's three phases are:

Short term (2008–2011). During this phase DEDE will focus on promoting commercial alternative energy technologies and energy sources with high commercial potential such as biofuels, co-generation from biomass and biogas.

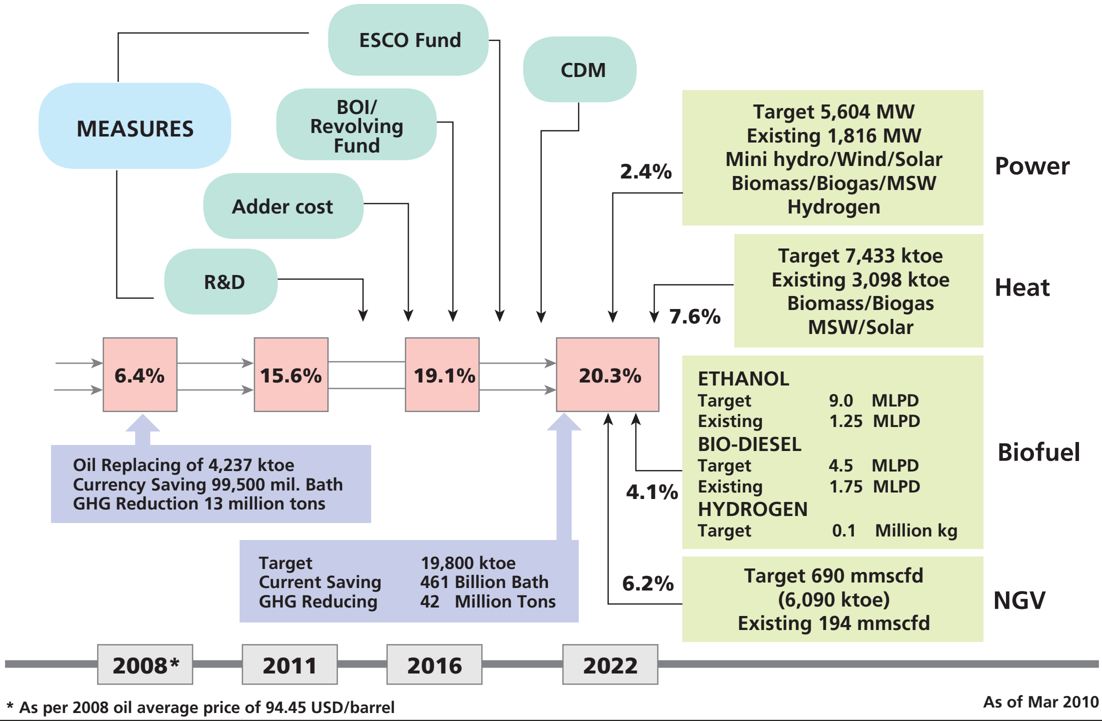
Medium term (2012 –2016). During this phase DEDE will encourage the development a viable alternative energy technology industry with targeted R&D activities in areas such as new technologies for biofuels production and models for development of green cities.

Long term (2017–2022). During this phase focus will shift toward utilizing potential new alternative energy technologies such as hydrogen and bio-hydrogenated diesel (BHD). DEDE will also look for ways to extend green city models throughout Thai communities and to encourage biofuel and alternative energy technology exports in countries in the ASEAN region.

The plan includes volume targets for a wide range of alternative energy sources including electricity and thermal energy from renewable resources and alternative transport fuels including biofuels and natural gas (Figure 2.4).

FIGURE 2.4

Alternative Energy Development Plan

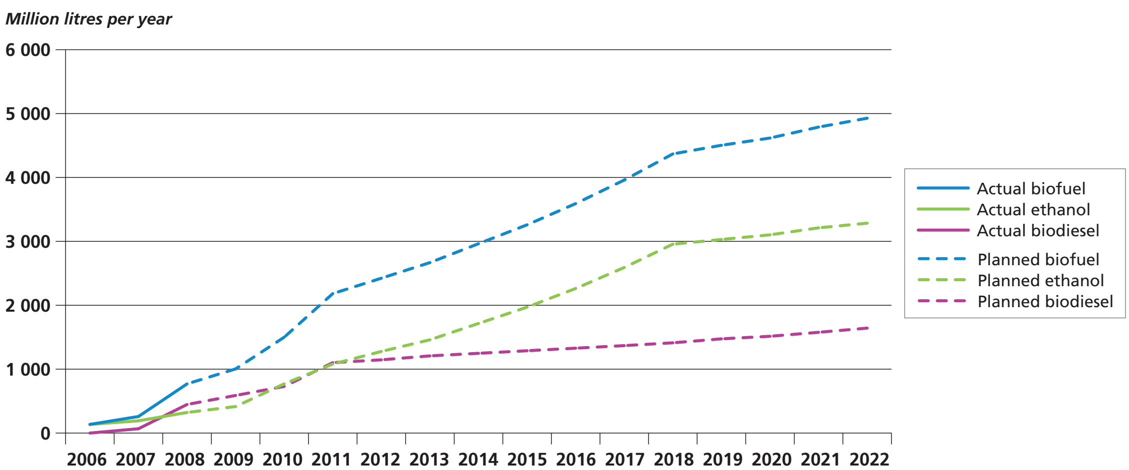


Source: MoE.

In Thailand, the BEFS project focused its analysis on the biofuel sector. The AEDP predicts that Thailand's biofuel output will increase five times by 2022 to almost 5 000 MLPY as illustrated in Figure 2.5. As previously indicated, the biofuel crops envisaged for ethanol production are cassava and sugar cane and oil palm for biodiesel.

FIGURE 2.5

Actual and planned biofuel production under AEDP



Source: MoE.

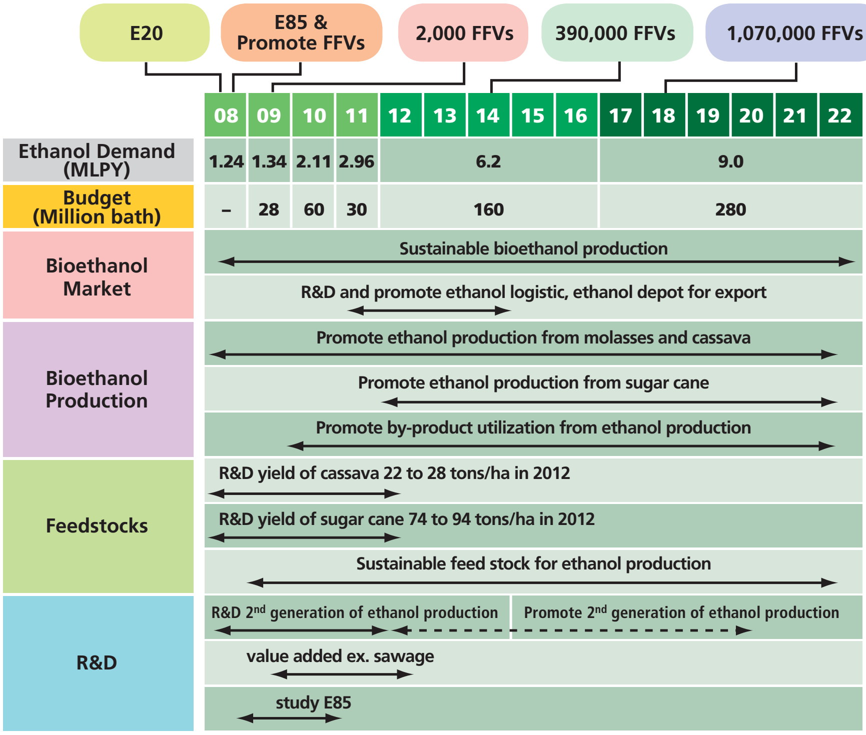
To achieve the anticipated growth in biofuels output the Thai Government has adopted detailed roadmaps for both the ethanol and biodiesel sectors, which are detailed in the next section.

2.1.2 Ethanol sector

Under the roadmap illustrated in Figure 2.6, the increased demand for biofuel crops will be met mainly through increases in yields for both cassava and sugar cane (i.e. molasses). The roadmap also includes provisions for the use of sugar juice harvested from contaminated lands as ethanol feedstock.

FIGURE 2.6

AEDP roadmap for ethanol



Source: MoE.

The Thai Government's plan to expand the market for ethanol has encouraged new entrants into the sector with a number of new refineries planned or under construction. However, unlike existing facilities most new production facilities are expected to use cassava as their key feedstock. Once these facilities are complete, production capacity will increase to 3.24 MLPD or 1 180 MLPY.

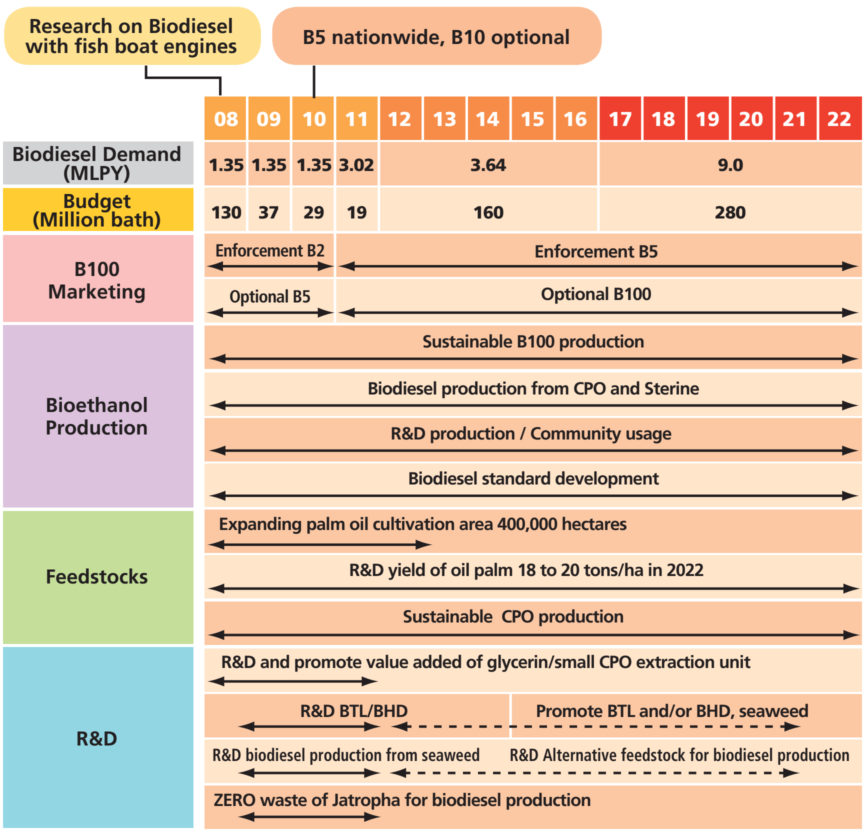
To facilitate the long-term development of the ethanol sector, the Thai Government plans to support research in areas including investigating ligno-cellulosic ethanol and to promote flexible-fuel vehicles. The gasoline market is small compared to diesel in Thailand, so promoting flexible fuel vehicles will be an important way to expand the domestic market for ethanol in the later years of the AEDP.

2.1.3 Biodiesel sector

A similar roadmap has been developed for the biodiesel sector. A prominent feature of the biodiesel roadmap (Figure 2.7) is the phased introduction of mandatory blending targets – biodiesel blending mandate at 2 percent (B2) in 2008 and at 5 percent (B5) in 2011. To meet the future anticipated demand for biodiesel the roadmap calls for an increase in yield as well as an increase in plantation area for oil palm. The additional land required to meet the target is expected to be as much as 400 000 hectares by 2022, which will double the current harvested area. The Thai Government will conduct research to identify opportunities for algae-based biodiesel, for using jatropha plants as feedstock and for using biomass-to-liquid operations.

FIGURE 2.7

AEDP roadmap for biodiesel



Source: MoE.

Large-scale biodiesel production for blending into fossil diesel began in 2007. In 2008, biodiesel consumption increased to 1.2 MLPD (438 MLPY) and around two MLPD (730 MLPY) in 2009. Refineries planned or under construction will bring the total production capacity to 4.5 MLPD (1 640 MLPY). Large-scale biodiesel refineries are concentrated in the south of Thailand near oil palm plantations and around Bangkok near fossil fuel refineries and fuel distributors. Biodiesel production at small-scale facilities is currently not included in national statistics, but is thought to be minimal.

2.2 THE AGRICULTURE SECTOR

Agriculture has been instrumental in Thailand's economic development and to some degree continues to shape Thai identity, support Thai lifestyles and is strong element of the image the country presents to the world. About one-third of Thailand's total land area of about 51 million hectares is dedicated to agricultural production. Rice is the country's largest crop, but the main cash crops are sugar cane and cassava. There are several annual crops including maize and also perennial crops such as oil palm, rubber, coconut and various fruits.

Expansion of the sector over the past 30 years has been the result of a number of changes both within and outside the sector. The emergence of large-scale food processing, agribusiness and commercial agriculture has had a particularly strong impact on the recent development of the sector and the introduction of new technology and methods has accelerated the production of new crop varieties, use of fertilizer, pesticides and herbicides.

At first, technologies associated with the Green Revolution combining irrigation, fertilizer, high yielding varieties and pest control in a closely managed production environment, were adopted slowly in Thailand. However, by the 1990s, Thailand had become a significant importer of fertilizer and pesticides and developed small local production capacity. Increased use of machinery has also accompanied this transformation in Thailand's agricultural sector.

Although Thai agriculture evolved from wet rice systems, modern irrigation systems were generally imported. Large dam projects were implemented with the aim of increasing rice area and production. Additional dams have become a common policy response to perceived need for additional water resources both in agriculture and hydro-power sectors. In addition, the increased availability of credit for farmers and the creation of the Bank of Agriculture and Agricultural Cooperatives (BAAC) facilitated the types of investment necessary to realize the benefits of technological progress within the sector.

Thailand is now one of the world's leading suppliers of sugar, rice and cassava. Modern mechanization, chemical pesticides and fertilizers in association with large scale irrigation facilities have been crucial in facilitating the regular cycle of agricultural output required to meet the needs of export markets. At present, 77 percent of the value-added in crop agriculture arises from the production of traded goods. Exports of agricultural products amounted to almost 10.5 percent of the total Thai exports in 2004.

Despite expansion of Thai agricultural output over the past three decades, in the last five years the agricultural sector contribution to GDP has declined. However, the sector still continues to be important in terms of employment accounting for approximately 39 percent of the Thailand's labour force (NSO, 2007). The agriculture sector is also an important source of crisis resilience, self-sufficiency and rural social support for poorer rural communities.

Continued development within the sector is necessary to preserve rural livelihoods. The rapid expansion of agriculture was generally made possible by the conversion of forest land to agriculture. Continuation of this practice is no longer practical. As new land for agricultural cropping is now extremely scarce, future increases in production must arise from increases in yield.

However, compared to international standards the average yield per hectare for key crops is at low to medium levels. This has been attributed to a number of factors including:

- physical, chemical and biological deterioration;
- cultivation on steep sloping land without soil conservation practices;
- inappropriate farming systems for increasingly intensive agriculture;
- poorly defined land ownership with associated restrictions of access to fair credit;
- a poorly developed farm credit sector;
- poorly developed agricultural infrastructure;
- irregular rainy seasons.

Government intervention in the sector has been high. The Thai Government is involved in nearly every stage of the agriculture production chain including regulation of agriculture foreign trade, taxation, exchange rates, trade restrictions and the provision of public resources for infrastructure and support of services for agricultural producers. How the Thai Government adapts future policies to address the challenges identified above will have a substantial impact on the future of the sector and its capacity to generate income for future generations of Thai farmers.

2.2.1 Agricultural policy

The development of agricultural policy in Thailand is strongly linked to the Thai Government's national planning process, which began in 1959. From the 1960s through the 2000s the Thai Government has implemented nine five-year National Economic Development Plans each with different implications for the agriculture sector.

Early plans focused on expanding agricultural production to satisfy the demands of the rapidly industrializing economy. A strong focus on industrial development in urban centres led to rural migration. With the arrival of the Green Revolution in the 1970s the national plans looked to rectify long standing issues regarding land title. This was necessary to create the necessary credit in the agriculture sector to encourage the increases in inputs, irrigation and mechanization heralded by the Green Revolution.

By the time of the fourth national plan in 1977 Thai Government policy had started to take greater account social issues arising from issues such as high population growth, low average incomes for farmers, rising unemployment among agricultural workers, low agricultural productivity, low rates of technology adoption by farmers and resistance to new technologies and limited availability of agricultural land. However, due to slow implementation and little progress on these national priorities for the agriculture sector, subsequent plans focused on trying to reverse growing poverty in rural Thailand.

By the commencement of the 1990s agriculture policy became more closely aligned with objectives regarding rural development and exports. At this time particular surplus crops were highlighted for export potential. Subsequent plans aimed to improve the productivity of the agricultural sector while also preserving the environment through the creation of a more sustainable agriculture sector.

With the inception of the Thai biofuels industry in the early 2000s the Thai Government has responded by designing and implementing policies specifically for biofuel crops. Under the 2008 – 2010 action plan for cassava development, the Ministry of Agriculture and Cooperatives (MOAC) adopted a number of measures to improve cassava yields. Also, under the 2008 – 2012 Oil Palm Industrial Development Plan, MOAC is implementing initiatives to encourage expansion of oil palm plantings including low interest loans from BAAC.

In March 2010 a new Memorandum of Understanding was executed between the MoE and MOAC. This is an important measure to ensure that the AEDP is implemented uniformly across all relevant branches of government.

2.3 SOCIAL AND ENVIRONMENTAL ISSUES

2.3.1 Poverty and smallholder farmers

Thailand is a middle-income country that has seen remarkable progress in human development in the last twenty years. The Human Development Index (HDI) for Thailand is 0.783, which ranks the country at 87 out of 182 countries (UNDP, 2009). It will achieve most, if not all, of the global Millennium Development Goals well in advance of 2015. Thailand has reduced the incidence of poverty from 27 percent in 1990 to 11.3 percent in 2004 (UNDP, 2007), and the proportion of underweight children has fallen by nearly half. Most children are in school, and universal primary school enrolment is achievable. Malaria is no longer a problem in most of the country. Annual new HIV infections have been reduced by more than 80 percent since 1991, the peak of the epidemic. Strides are being made toward gender equality.

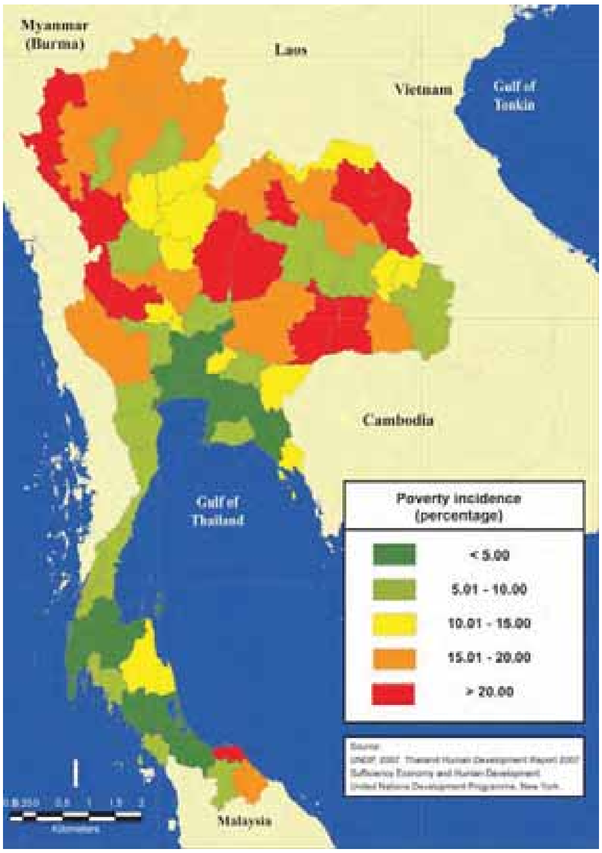
Thailand's success in reducing poverty has been attributed to a mixture of astute policy making, strong democratic governance, an industrious population, public investment in social services, advantageous historic and geopolitical circumstances and, not least, economic growth.

However, despite this success, progress has not benefited everyone equally. Those Thais more closely linked to the international economy have tended to realize the benefits of development much more quickly than others. Meanwhile those Thais who remained in the domestic economy, such as small scale farmers, have generally received fewer benefits, proportionately. As a result, a number of development challenges persist, particularly for certain groups and geographical regions.

Income inequality and lack of social protection and access to services continue to be significant human development concerns. Thailand's cities have grown faster than its countryside. Farmers constitute about 30 percent of the total population of Thailand (i.e. around 20 million) and their numbers are declining by about four percent per year. Their choices and incomes are increasing, but they remain among the poorest part of the population. In fact 87 percent of the poor are farmers and farm workers in rural areas, mainly in the rural northeast, far north and far south of the country (UNDP, 2007) (Figure 2.8).

FIGURE 2.8

Poverty incidence in 2004



Source: UNDP, 2007.

Growing inequality between urban and rural populations will pose threats to future social and political stability in Thailand. Thailand's national development plans have noted that social inequities arising from greater industrialization could be addressed through measures to ensure that greater national wealth benefits the whole populace. However, while Thai agriculture is still dominated by poor smallholder producers, plans to develop the wealth generating capacity of Thai agriculture tend to focus on technological enhancement of commercial agriculture and agribusiness methods. Advanced farm technologies may not necessarily be within practical reach of poor, smallholder farmers.

Despite growing inequality, agriculture in Thailand is both a major source of income through exports and a social welfare system. Smallholders produce the majority of agricultural products including the raw materials utilized by commercial agriculture and agribusiness, while also contributing most of the labour. Labour productivity in agriculture is still low when compared to other sectors. Productivity improvements in the agriculture sector could present the most effective strategy to improve agricultural development that will benefit the poorer rural communities.

Ongoing challenges include higher rates of maternal mortality in the Muslim south, enduring child malnutrition in remote northern hill tribe areas and unsustainable use of natural resources. Additionally, there are warning signs of a resurgence of HIV/AIDS. Women still have fewer career advancement opportunities and display low participation in electoral politics. Domestic violence against women is also a concern among poorer communities. While education reform has been greatly advanced in the last few years, yet gaps remain in terms of quality of education and adaptability to the needs of the economy.

A variety of ongoing and new government policies seek to address these problems. The Cabinet of Thailand's strong endorsement of the UN Millennium Development Goals (MDGs) Report 2004 was a promising step which provided a clear mandate to transform these goals into government policy. This progress will hopefully continue with the integration of additional national development targets outlined in the MDG "Plus" Agenda.

2.3.2 Soil degradation, deforestation and water management

As indicated previously, Thailand's economic growth over the last three decades has been fuelled by rapid industrialization and intensified agricultural production. But this growth, which has relied extensively on the country's abundant and diverse natural resources, has come at a price in terms of land degradation and loss of natural habitats, reduced water quality and increased levels of pollution.

Thai agriculture has significantly changed the natural environment. Departure from traditional farming practices and intensification has degraded soils, while fertilizer and pesticide use have increased without sufficient environmental or health regulatory controls. Fertile, deep, relatively flat, well-drained soils of high natural organic matter have been degraded, and strategies to encourage regeneration are required. Expanding agriculture by opening new lands can now only access marginal and fragile soils, including steep, shallow and skeletal soils, with limited nutrients and moisture.

Water use and availability problems in Thailand may also be underestimated. Open access to irrigation systems has increased strain on some water systems, which could be rectified by appropriate resource pricing schemes. Continued use of chemical herbicides also presents issues in terms of soil and water contamination.

Issues of irreversible changes to the Thai landscape from rice and rubber agriculture, upland deforestation and coastal prawn aquaculture among other activities, changes in water regimes from agriculture and logging, as well as irrigation and uncontrolled groundwater extraction, are now compounded by environmental concerns relating to pollution from agriculture and agribusiness. The long term future of Thailand's natural resources continues to require both the attention of planners and the public.

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CHAPTER 3

AGRICULTURE MARKET PROJECTIONS

As discussed in the previous chapter, Thailand is one of the world's major agricultural producers and is also a food exporting country. For some goods such as cassava, sugar and rice, Thailand is one of the top five exporters globally. This connection to global markets means that many Thai farmers depend on export markets for their livelihood. The share of exports as a proportion of total production is as high as 70 percent. This dependence on export markets implies some risks for Thai farmers; particularly during times of market imbalance. For example, excess supply of agricultural products on global markets put downward pressure on prices, which negatively impacts on the income and livelihoods of Thai farmers. The AEDP and its provisions for development of the biofuel sector provide an option for farmers to stabilize farm incomes in times of high price volatility.

Agricultural markets are continuously reacting to changes in supply and demand. It's essential to understand the likely effects that biofuels might have on commodity markets in order to evaluate the effect of biofuel development in Thailand. Policy needs to be based on detailed assessments of the future supply and demand conditions that might arise in response to biofuel development. Such an assessment will assist policy makers to understand how biofuel demand for feedstocks might affect the commodity market within their country over time and deliver more effective policy responses to benefit Thai farmers.

The objective of this chapter is to present an assessment of how Thailand's agricultural market could possibly be affected by implementation of the AEDP targets for biofuels. Detailed agricultural projections will be developed for each key biofuel feedstock crop as well as other key agricultural crops over a ten year time period. The value of the analysis is not so much the precision of projected values in any one year, but the dynamics of how markets are expected to evolve over the time period assessed.

3.1 COSIMO METHODOLOGY

The agricultural market projections are based on the Commodities Simulation Model (COSIMO) developed by FAO. COSIMO provides projections of production, consumption (i.e. in the form of food, feed, fuel or fibre), imports, exports, stocks and prices. The results can highlight important challenges or opportunities in agricultural markets and provide a picture of how agricultural markets could evolve over time with respect to a set of macroeconomic conditions, trends and current agricultural/biofuel policies.

COSIMO is a partial equilibrium simulation model. The model is determined by elasticities, technical parameters and policy variables. Data inputs for the model come from information provided by national statistics sources and supplemented by external sources such as the United Nations (UN) and World Bank and include:

- Macroeconomic variables, such as population estimates derived from the UN Population Prospects, real GDP, GDP deflator, crude oil price and exchange rates from OECD and World Bank; and
- Agricultural data in terms of quantities produced, consumed and traded from the Trade and Markets Division of FAO.

The model produces a global equilibrium and analyses the effects of international policies on specific country's agricultural markets. All of the major agricultural sectors, including the biofuel sector, are connected and are integrated within the model so that all the main characteristics of the crops and livestock sectors influence the final equilibrium. The extension of the model to include the biofuel sector required technical data that came mainly from country specific information. The technical data were used to generate a world commodity database for ethanol and biodiesel, along with country specific baseline data on different biofuel crops and their processing costs.

In the case of Thailand, the model was used in standalone version, which means that the country information were extrapolated and the projections were generated once country's equilibrium was achieved. This was possible because Thailand is a major supplier of agricultural commodities to the international market and it is assumed that international biofuel policies will have minimal effect on the Thai agricultural market. On the other hand the standalone version allowed the Office Agriculture of Economics (OAE) of the Ministry of Agriculture to revise the basic information with country specific data, without re-balancing the overall global model.

3.1.1 Macro-economic assumptions

The general and country specific assumptions considered in the baseline are as follows:

General assumptions:

- Oil prices are expected to decrease substantially from $97 in 2008 to $62 per barrel in 2009. The oil price then increases with the economic recovery and it is estimated that it fluctuates in the $77-$94 range from 2010-2018. These projections are from the reference scenario reported by the International Energy Agency (IEA, 2009). The projections have the oil price resuming an upward trend and by the end of the period will equal the previous peak in nominal terms. The world oil price will remain well above historical levels. The oil price is an important factor for developments in agricultural markets as it impacts upon energy, transport, fertilizer cost while also setting the basis for the competitiveness of biofuel as an alternative energy source.
- The projections are produced for the period 2009-2018.

Thailand specific assumption:

- Average annual GDP growth is assumed to be 9.3 percent over the whole period, which is consistent with the estimate used by the Thai National Economic and Social Development Board (NESDB);
- The average annual GDP deflator is 4.4 percent (NESDB) and according to the Thai Ministry of Commerce CPI growth is 4.2 percent;
- The domestic currency depreciates in nominal terms against the US dollar at an average rate of -2.4 percent annually. The real exchange rate depreciates by -4.23 percent annually;
- Based on these macro assumptions, real food expenditure, after an initial decrease in 2009 from 2010, increased afterwards. By 2018 the real food expenditure is almost double the 2008 level, and therefore the annual average growth rate is 7.6 percent over the period; and
- Population increases at a 0.52 percent annual rate.

3.1.2 Biofuel assumptions

The purpose of the analysis is to show how Thailand's agricultural market could evolve over time as a result of the implementation of the AEDP biofuel targets. The main assumption is that the AEDP targets, until 2018, will be achieved. Table 3.1 reports the detailed ethanol targets.

TABLE 3.1

Ethanol targets

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Gasoline total consumption	7 811	7 928	8 034	8 154	8 271	8 388	8 503	8 620	8 736	8 853
Anticipated ethanol demand	415	770	1 080	1 278	1 460	1 716	1 971	2 263	2 592	2 957
Potential ethanol mandate (%)	5	10	13	16	18	20	23	26	30	33

Note: the consumption and demand are expressed in million litres per year.
Source: OAE and MoE.

The proportion of the AEDP ethanol targets expected to be produced using either molasses or cassava feedstock are reported in Table 3.2. Whether these proportions can be met depends on the crop production and the existing capacity and configuration of available ethanol production plants. In 2009, there were 17 ethanol plants with total capacity of 2.57 million litres per day. Over half of these facilities are equipped to use only molasses as a feedstock. However, a number of new cassava ethanol facilities are expected to come online in the near future. Based on this assumption cassava production is supposed to increase substantially; mainly through increases in yield. This policy was reflected in the model was reflected by increasing the yield trend coefficient starting from 2010.

In Thailand sugar cane is one of the major cash and export crops the industry is well established. Over the last ten years the average area of harvested sugar cane has remained stable at around one million hectares. The yield in Thailand is generally lower than other major sugar producing countries, especially Brazil and Mauritius, because only a small area of sugar cane is produced on irrigated lands; the rest relies on natural rainfall.

Cassava, like sugar, is another major crop in Thailand with the high potential for export. Fresh cassava roots are either processed directly into cassava starch and then used locally or exported as starch, or the fresh roots are converted into cassava chips and then stored locally and eventually exported as dried chips (called tapioca chips on the international market). The harvested area of cassava has grown slightly by around one million hectares over the last few years, because of increased prices for cassava root. The price increase was mainly attributed to higher world demand for food and fodder.

TABLE 3.2

Share of ethanol targets by feedstock

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Molasses	70%	50%	35%	35%	30%	30%	30%	25%	25%	20%
Cassava	30%	50%	65%	65%	70%	70%	70%	75%	75%	80%

Source: OAE and MoE.

Table 3.3 provides a detailed description of future biodiesel demand anticipated by the AEDP. Palm oil is clearly the feedstock with the most potential to meet future demand for biodiesel in Thailand, accounting for roughly 90 percent of Thailand's crude vegetable oil production.

TABLE 3.3

Biodiesel targets

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Diesel total consumption	15 968	16 284	16 538	16 785	17 028	17 267	17 505	17 745	17 985	18 225
Anticipated biodiesel demand	589	730	1 102	1 146	1 208	1 248	1 288	1 329	1 369	1 413
Potential biodiesel mandate (%)	4	4	7	7	7	7	7	7	8	8

Note: consumption and demand are expressed in million litres.
Source: OAE and MoE.

3.2 THAI AGRICULTURAL MARKET PROJECTIONS

3.2.1 Thailand baseline

Baseline projections on production and consumption trends are presented in Figure 3.1. In presenting the data, coarse grains, roots and tubers and vegetable oil are represented by maize, cassava and palm oil respectively. Sugar cane is presented in terms of molasses and sugar.

The production profile indicates that overall oilseeds will continue to have a small share in the agricultural sector and that wheat is almost zero. Meat, eggs and fresh dairy also account for a small share. On the other hand, rice, roots and tubers and sugar cane will be the most important agricultural crops in terms of production, followed by maize and palm oil.

FIGURE 3.1

Thai projections for production and consumption profile

Source: OAE.

The consumption profile trends indicate that rice and cassava in particular will dominate Thai consumption patterns. Rice remains the largest commodity for food consumption over the period. Cassava increases its share predominantly due to the AEDP and its increased use as a biofuel feedstock. However, it is also anticipated that demand for starch from the sweetener industry will increase. Due to high maize price over the past few years cassava will become an attractive alternative as feed. Throughout the baseline, income growth results in an increased share of food expenditure on meat (i.e. pork and poultry) and vegetable oils, namely palm oil. Maize consumption remains relatively stable and it is mainly due to feed consumption, while wheat consumption increases over the period following growth in GDP.

Table 3.4 shows the production, consumption and net trade projections for the main commodities in the base period (average of the three-year period 2007-2009) and 2018. The full trend of the projections over the ten-year period and the area and yield of the major commodities can be found in Appendix.

Rice

Total consumption is determined only by rice food consumption as a very limited quantity of rice is used as feed, while crushing (milling) rice is not considered in the baseline. Total domestic use is projected to increase on average by 4.5 percent annually following a linear positive trend. Production is expected to decline at the average annual rate of 0.3 percent starting from 2010. This is mainly due to a decrease in the harvested area accompanied by small growth in yields. While the harvested rice area decreases at an annualized rate of almost two percent, yields remain at around 2.3 tons/ha with very small annual growth of around 1.5 percent. Although the country is a net exporter, exports are expected to decline considerably at an average annual rate of 15 percent.

Roots and tubers (cassava)

As discussed above, in Thailand the roots and tubers aggregate category is comprised exclusively of cassava. It is Thailand's second most important crop with an average crop area share of 18 percent. In response to the AEDP, the total area covered by cassava is expected to grow by two percent annually increasing by 350 000 hectares by the end of the period. Yields are expected to grow by two percent annually and reach almost 27 tons/ha by 2018. Consequently production will rise by 15 million tons by 2018. Total consumption is projected to increase more than three-fold over the entire period with a high peak in 2011 when cassava will surpass molasses in the biofuel targets. As noted above, consumption will be driven by increased ethanol production. The country will remain a net exporter of cassava (i.e. chips, pellets and starch) from 2008 to 2018 but the production will be mainly absorbed by greater internal demand. As a result, exports are expected to decline by more than half over the period.

Sugar cane (molasses & sugar)

The harvested area of sugar cane is projected to increase slightly at an average annual rate of around 2.6 percent. Yields are projected to grow from 70 ton/ha in 2009 to almost 80 ton/ha in 2018 resulting in overall growth in national molasses and sugar production. The increase in molasses production will be largely consumed for ethanol production. Sugar production is projected to increase two-fold in-line with GDP growth. Contrary to the situation for cassava, molasses and sugar will continue to be largely exported.

Vegetable oil (palm oil) and oil seeds

As indicated above, vegetable oil in Thailand is mostly comprised of palm oil. Production is expected to double with an average annual growth rate of 8.5 percent throughout the projection period. This increase is due to a projected doubling of oil palm plantations by 2018. The increased consumption is mostly driven by demand for biodiesel. Consumption as food will also increase up to 1.5 million tons by the end of the period largely due to growth in GDP. Thailand remains a net exporter of palm oil but after a positive trend until 2013 it is anticipated that exports of palm oil will decline.

The oil seeds category consists mainly of soybean. Production and consumption are projected to increase over the period. However, consumption will exceed production resulting in increased imports.

Coarse grains (maize)

The maize area is assumed to remain stable over the baseline period and the yield to increase slightly from 3.6 to 4.2 ton/ha by 2018. Better yields explained 80 percent of the projected improvement in production. Maize produced in Thailand is mainly used as feed. Despite a projected increase in production of livestock, maize production is not expected to increase in step due to the substitution of cassava for maize as a principal source of feed. While consumption is expected to exceed supply over the period, little change in Thailand's net trade situation for maize is anticipated in 2018.

Meat

Poultry production is expected to be less than consumption, which is expected to double by 2018. In fact, Thailand's net exports are projected to decrease by 13.2 percent annually. Pork production is expected to meet demand. Thailand is expected to remain a net importer of beef by the end of the outlook period.

TABLE 3.4

Main commodity highlights

	Average 2007-2009	2018	Average annual growth rate [(a)]		Average 2007-2009	2018	Average annual growth rate
Rice				Oil seeds (soybean)			
Production	21 014	19 981	-0.3%	Production	427	484	1.1%
Consumption	11 751	17 931	4.5%	Consumption	2 079	2 549	2.2%
Net trade	8 947	1 728	-14.9%	Net trade	-1 639	-2 068	2.5%
Root and tuber (cassava)				Coarse grain (maize)			
Production	27 387	42 260	4.4%	Production	4 379	4 855	0.9%
Consumption	9 926	35 257	13.0%	Consumption	4 111	4 471	1.1%
Net trade	17 460	7 003	-8.4%	Net trade	267	377	0.1%
Molasses				Poultry			
Production	3 014	5 913	7.0%	Production	1 166	1 374	1.5%
Consumption	2 294	3 626	5.6%	Consumption	615	1 222	8.0%
Net trade	720	2 287	10.0%	Net trade	576	150	-13.2%
Sugar				Pork			
Production	7 884	14 963	6.8%	Production	895	1 336	4.7%
Consumption	2 620	6 267	9.9%	Consumption	879	1 323	4.8%
Net trade	4 586	8 998	11.1%	Net trade	16	13	-3.1%
SugarVegetable oil (palm oil)				Beef			
Production	1 880	4 066	8.5%	Production	241	388	5.8%
Consumption	1 265	3 267	10.0%	Consumption	262	410	5.5%
Net trade	584	782	4.6%	Net trade	-21	-22	0.6%

Note: the values are expresed in thousand tons.
[(a)] The average annual growth rate is calculated by the least square growth rate. It is estimated by fitting a linear regression trend line to the logarithmic annual values of the variable in the relevant period. In the case of negative values it is calculated on absolute values.
Source: OAE.

3.2.2 Low GDP growth rate scenario

The global economic meltdown has impacted Thailand's economy more severely than earlier projected, forcing the World Bank in 2009 to revise its previous annual growth forecast of around two percent to a contraction of 2.7 percent in 2009. In response the World Bank suggested that Thailand accelerate its economic stimulus programs. Based on this information, an alternative scenario was developed incorporating the GDP contraction in 2009 and a revised annual average GDP growth rate of around four percent in the out years as opposed to the NESDB official forecast of 9.3 percent.

The main differences between the baseline and the low GDP growth scenario are as follows:

- area and yield trends of the main commodities are similar to the reference case with high annual GDP growth rate;
- the average annual growth rates of production for each commodity are very similar to the baseline except for pork and beef which were shown to reduce by half;
- consumption is expected to grow at a rate slower than that expected in the baseline. The average annual growth rates of consumption are significantly lower for commodities with high share in food consumption like sugar, rice, palm oil and soybean. In the case of meat the rate of growth in consumption is half that observed in the baseline with production almost matching consumption by 2018;
- for the commodities used as feed, biofuel feedstock or for other industrial uses growth in consumption contracts less than other commodities. The only exception is maize, which is projected to be completely replaced by cassava as a source of feed; and
- Thai economy will tend to reduce exports of rice and cassava considerably less than the baseline over the period; the doubled production of sugar will be absorbed largely by the external market. Overall the international price and demand for Thai commodities will be more favourable compare to the domestic ones.

3.3 CONCLUSIONS

- *Meeting the AEDP biofuel targets will require sizable increases in the production of key biofuel crops: sugar cane, cassava and oil palm*. The agriculture projections indicate that the increase in production will come largely from yield improvements in the case of sugar cane and cassava and expansion of the land area used for oil palm and cassava. The projections seem to indicate that to accommodate the increase in the harvested area of cassava and oil palm, the area of land under rice cultivation may decline by almost two million hectares. The implications of this will be investigated further in the following chapters;
- *To fulfil the targets a reduction in Thailand's exports of rice and cassava are expected*. In the case of rice the decline in exports is the result of the decline in production resulting from reduced harvested area of rice. In the case of cassava the reduction in exports is in response to increases in domestic demand for cassava in the ethanol industry and other domestic uses;
- *Reduction of exports implies that the returns from domestic production of biofuels are assumed to be greater than from exporting the feedstock commodities*. There is a risk that in times of weaker domestic demand and high world prices for biofuel feedstock crops, producers may be tempted to look for opportunities in export markets. The Thai Government will need to ensure that the policy environment for biofuels encourages feedstock producers to supply the biofuel industry;
- *Strong income growth in Thailand translates into increases in food demand and expenditure for sugar, vegetable oil, meat, egg and wheat*. Only in the case of beef and wheat there will be a need to rely on

more imports to meet domestic demand. Although recent economic conditions have put some downward pressure on agricultural commodity prices, they are expected to remain at higher price levels than historic averages. While Thailand's economy remains strong despite the world economic downturn and domestic political instability, it is unlikely that the Thai Government's projections for economic growth will be met. If this is the case, Thailand will tend to export more agricultural produce due to the availability of better prices on international markets. As noted above, whether this will also apply to biofuel feedstock crops depends on the policy environment and incentives provided to producers.

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3.5 APPENDIX

TABLE A3.1

Crop projections

Year	Average 2007-2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	Average annual growth rate[(a)]
Rice											
Production	21 014	20 811	19 023	18 740	18 729	19 033	19 304	19 554	19 758	19 981	-0.3%
Consumption	11 751	12 836	13 478	14 084	14 673	15 237	15 863	16 435	17 190	17 931	4.5%
Net trade	8 947	5 759	5 328	4 986	4 577	3 608	3 055	2 702	2 199	1 728	-14.9%
Root and tuber (cassava)											
Production	27 387	31 120	32 290	33 705	34 993	36 178	37 565	39 031	40 622	42 260	4.4%
Consumption	9 926	14 618	17 431	19 043	21 163	23 246	25 383	28 532	31 257	35 257	13.0%
Net trade	17 460	16 503	14 859	14 662	13 830	12 932	12 182	10 499	9 365	7 003	-8.4%
Molasses											
Production	3 014	4 073	4 265	4 542	5 016	5 577	5 897	5 937	5 869	5 913	7.0%
Consumption	2 294	2 584	2 595	2 896	2 886	3 200	3 535	3 477	3 820	3 626	5.6%
Net trade	720	1 489	1 669	1 646	2 130	2 377	2 363	2 460	2 049	2 287	10.0%
Sugar											
Production	7 884	10 334	10 652	11 325	12 641	14 135	14 802	14 860	14 685	14 963	6.8%
Consumption	2 620	3 066	3 476	3 875	4 301	4 548	5 043	5 581	5 904	6 267	9.9%
Net trade	4 586	3 981	3 545	4 515	8 121	10 959	7 892	7 011	9 217	8 998	11.1%
Vegetable oil (palm oil)											
Production	1 880	2 480	2 698	2 925	4 065	4 065	4 065	4 065	4 066	4 066	8.5%
Consumption	1 265	1 686	1 875	2 069	2 282	2 476	2 671	2 866	3 067	3 267	10.0%
Net trade	584	772	837	829	1 748	1 575	1 383	1 186	980	782	4.6%
Oil seeds (soybean)											
Production	427	447	455	447	447	453	459	469	477	484	1.1%
Consumption	2 079	2 141	2 178	2 225	2 246	2 301	2 357	2 417	2 481	2 549	2.2%
Net trade	-1 639	-1 710	-1 728	-1 779	-1 796	-1 850	-1 901	-1 952	-2 007	-2 068	2.5%
Coarse grains (maize)											
Production	4 379	4 695	4 609	4 646	4 613	4 679	4 751	4 857	4 847	4 855	0.9%
Consumption	4 111	4 124	4 065	4 150	4 201	4 271	4 325	4 362	4 442	4 471	1.1%
Net trade	267	517	537	492	424	403	422	479	394	377	0.1%

Note: the values are expresed in thousand tons.
[(a)] The average annual growth rate is calculated by the least square growth rate. It is estimated by fitting a linear regression trend line to the logarithmic annual values of the variable in the relevant period. In the case of negative values it is calculated on absolute values.
Source: OAE.

TABLE A3.2

Livestock projections

Year	Average 2007-2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	Average annual growth rate[(a)]
Poultry											
Production	1 166	1 225	1 274	1 297	1 320	1 327	1 339	1 338	1 354	1 374	1.5%
Consumption	615	653	713	773	844	898	974	1 042	1 137	1 222	8.0%
Net trade	576	571	561	523	474	428	363	294	214	150	-13.2%
Pork											
Production	895	914	952	1 009	1 060	1 122	1 162	1 221	1 268	1 336	4.7%
Consumption	879	896	935	992	1 043	1 105	1 146	1 206	1 254	1 323	4.8%
Net trade	16	18	17	17	17	17	15	15	13	13	-3.1%
Beef											
Production	241	244	248	257	273	293	317	340	363	388	5.8%
Consumption	262	264	269	278	294	314	338	361	385	410	5.5%
Net trade	-21	-20	-21	-21	-21	-21	-21	-21	-22	-22	0.6%

Note: the values are expresed in thousand tons.
[(a)] The average annual growth rate is calculated by the least square growth rate. It is estimated by fitting a linear regression trend line to the logarithmic annual values of the variable in the relevant period. In the case of negative values it is calculated on absolute values.
Source: OAE.

TABLE A3.3

Area and yield projections for the major commodities

Year	Average 2007-2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	Average annual growth rate[(a)]
Rice											
Area	10 629	10 192	9 272	9 023	8 897	8 906	8 908	8 902	8 877	8 857	-1.7%
Yield	1.98	2.04	2.05	2.08	2.11	2.14	2.17	2.20	2.23	2.26	1.4%
Root and tuber (cassava)											
Area	1 228	1 347	1 371	1 404	1 431	1 451	1 478	1 507	1 539	1 571	2.3%
Yield	22.29	23.10	23.55	24.00	24.46	24.93	25.41	25.90	26.40	26.90	2.0%
Sugar cane											
Area	962	941	964	1 006	1 094	1 186	1 210	1 188	1 140	1 117	2.7%
Yield	69.44	73.41	73.52	74.03	74.73	75.52	76.74	77.50	78.30	79.58	1.3%
Vegetable oil (palm oil)											
Area	506	675	730	786	1 107	1 090	1 074	1 058	1 042	1 027	7.7%
Yield	3.00	3.09	3.14	3.19	3.23	3.28	3.33	3.38	3.43	3.49	1.6%
Oil seeds (soybean)											
Area	300	303	305	296	292	291	291	293	295	295	-0.4%
Yield	1.42	1.47	1.49	1.51	1.53	1.55	1.58	1.60	1.62	1.64	1.5%
Coarse grains (maize)											
Area	1 201	1 238	1 204	1 196	1 171	1 171	1 172	1 182	1 165	1 152	-0.6%
Yield	3.65	3.79	3.83	3.89	3.94	4.00	4.05	4.11	4.16	4.21	1.5%

Note: the area refers to harvested area and is expresed in hectares; the yield is expressed in tons/ha.
[(a)] The average annual growth rate is calculated by the least square growth rate. It is estimated by fitting a linear regression trend line to the logarithmic annual values of the variable in the relevant period. In the case of negative values it is calculated on absolute values.
Source: OAE.

CHAPTER 4

NATURAL RESOURCE ANALYSIS: LAND

It isn't completely clear how bioenergy crops affect food production and consequently food security. In order to monitor any changes, it is important to have a clear picture of Thailand's staple food crops and their primary growing regions. Any plan for bioenergy production must be managed carefully to ensure that it does not have a negative effect on food production. Thailand currently produces an adequate amount of its main bioenergy crops – oil palm for biodiesel and sugar cane and cassava for ethanol – for its domestic use and for export. But, demands for both food and energy are increasing. Thailand must increase considerably its productivity and expand its cultivation of land for bioenergy crops if it is to meet the AEDP targets, but not at the expense of staple food crops or of forests and other environmentally vulnerable areas. It is essential to conduct scientifically sound assessments of the natural resources – in particular assessments of land and water – that are necessary for such an ambitious plan.

As previously discussed, agriculture is a key sector of Thailand's economy. Greater recognition of the importance of agriculture and improved planning are essential to continued economic growth and continued poverty reduction. It is possible to increase the agricultural production in order to accommodate the bioenergy and the food market but it should be managed sustainably while respecting protected areas and biodiversity.

The main objective of this chapter is to assess the potential of biofuel crop production to fulfil the AEDP from a land perspective. Land is one of the natural resources that should be considered carefully in order to evaluate which areas are better suited to which crops and which ones are available for bioenergy crops, taking environmental and food security issues into account.

There are three main crops indicated in the AEDP: sugar cane, cassava and palm oil. An analysis of these three main crops follows the brief description of the methodology.

4.1 THE METHODOLOGY OF LAND ASSESSMENT

The methodological framework of the land assessment is composed of two main elements: the land suitability assessment and the availability of suitable land. The land suitability assessment (LSA) is based on a zoning approach developed and used by FAO since 1978. LSA considers a range of climatic (i.e. temperature and rainfall) and soil related geo-referenced (i.e. pH, nutrients, slope) elements to identify the most suitable areas for growing the key biofuel crops and to understand how much of each crop can be produced given specific agricultural practices and levels of inputs. The suitability of a given portion of land is expressed as a percentage of the maximum attainable yield for each crop.

Once the suitable land is identified, an analysis of the availability of such land helps to draw a more realistic picture of the potential land area and biofuel crop production; and, it makes clearer the trade-offs among bioenergy development, food production and environmental protection.

In Thailand the Land Development Department (LDD) of the Ministry of Agriculture is responsible for the land assessment. It is also responsible for training farmers to improve the use of soil resources, promoting better agricultural management in terms of water and soil conservation, and for supporting and expanding the use of organic fertilizers. The main objective is to accelerate agricultural development and to increase productivity in terms of both quality and quantity while also reducing production costs especially in poor areas. With this in mind, LDD developed a tool to support farmers called Thai Soil Management Simulation Farming (TSM_SIMFARM).

4.1.1 Land Suitability Assessment

The LSA is used to evaluate the suitability of a specific location for producing a particular crop under a well-defined agricultural management system based on the agro climatic, soil and landform conditions. The LSA then evaluates the potential production and return for such areas. There are three steps to this analysis:

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

The criteria are formulated by interpreting climate and soil related information as limiting factors to achieve the maximum attainable yield for a specific LUT.

A detailed flowchart of the LSA methodology (Figure A4.1) and the specific suitability assessment criteria (Tables A4.1-2-3) used for defining the suitability of palm oil, sugar cane and cassava in Thailand can be found in Appendix.

To define the maximum attainable yield, LDD has collected yield information through field visits and interviews with farmers, who were selected through a multi-stage, stratified, random sampling technique. Figure 4.1 shows the locations of 380 farmers working on sugar cane, 281 on cassava and 211 on oil palm.

The suitability index is defined as the potential of a specific location to achieve a certain percentage of the maximum attainable yield for a specific crop because of its agro-climatic and soil conditions. In Thailand the suitability index has four classes that are defined slightly differently from the ones identified in the FAO methodology, but are still comparable. Table 4.1 describes the suitability classes and the corresponding achievable yields for the biofuel crops analyzed in the Thai context. It could be worst to clarify that the information on yield and area by crop reported in this chapter is referred to planted area as the objective of this study is the land assessment. Conversely the information provided by OAE and in the AEDP refers to harvested area.

TABLE 4.1

Attainable yield by suitability class for the key biofuel crops

Suitability Class	Achievable yield* (%)	Sugar cane (ton/ha)	Cassava (ton/ha)	Oil palm (ton/ha)
Very suitable	95 – 100	69.6 – 73.3	27.6 – 29.0	26.6 – 28.0
Suitable	60 – 95	44.0 – 69.6	17.4 – 27.6	16.8 – 26.6
Moderately suitable	40 – 60	29.3 – 44.0	11.6 – 17.4	11.2 – 16.8
Marginally suitable	0 – 40	< 29.3	< 11.6	< 11.2

* Of the maximum attainable yield.
Source: LDD.

LDD also collects much more information at the farmer level. Based on a Logistic Regression Analysis (LRA), this information is used to calibrate and adapt the LSA results to the reality on the ground.

FIGURE 4.1

Sampling points for sugar cane, cassava and oil palm

Source: LDD.

4.1.2 Availability of suitable land

The suitability assessment considers all the land as potential area for expanding each crop. However, not all the land is available for agricultural expansion and bioenergy development for various reasons. The availability of suitable land is closely related to political needs and priorities. Areas designated for other use, such as urban areas, or areas assigned by law to commercial activities, such as forestry concessions, cannot be considered even if their suitability is very high. Areas with environmental concerns or areas already under agricultural food production should be analyzed carefully.

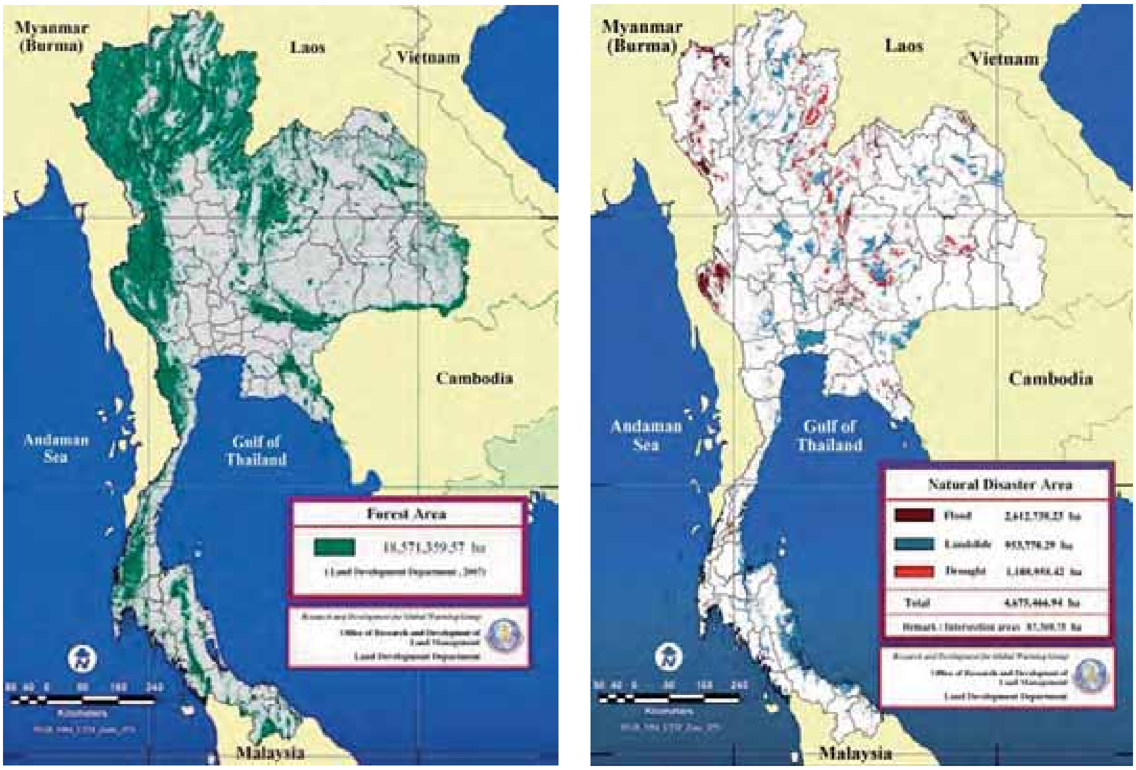
Over the last 20 years, deforestation has become a serious concern in Thailand. Designating particular areas as forest reserves has not protected these lands from agricultural expansion. Forest land, national parks, conservation area, wildlife and sanctuaries account for about 36 percent of the total land area, equivalent to more than 18 million hectares. Such areas have been subtracted from the potential area suitable for bioenergy crop production in order to ensure that bioenergy crops do not encroach upon protected lands.

Thailand is affected periodically by natural disasters such as floods, landslides and droughts that, in turn, affect the country's agricultural production. Floods affect about 9.2 percent of arable land, landslides about 3.4 percent and drought about 3.9 percent.

Areas prone to natural disasters are also subtracted from suitable land because of the high risk of losing crops. Almost five million hectares of land are affected by natural disasters and this represents nine percent of the total land area. Figure 4.2 shows where forest and natural disasters occur.

FIGURE 4.2

Forests and natural disaster area



Source: LDD.

4.1.3 A tool to support farmers

Increasing the use of fertilizer has played a major role in increasing the supply of food to a continually growing world population. Similarly, higher demand for specific crops, as is occurring with biofuel crops, could lead farmers to follow the same path. However, focusing attention on the most important nutrients, such as nitrogen, has in some cases led to nutrient imbalances, to excessive applications of nitrogen, to inefficient use of nitrogen fertilizer causing large environment damage such as lower air and water quality, decreased biodiversity and human health concerns. Better management of all essential nutrients in conventional production systems is required if a more sustainable agriculture that maintains the necessary increases in crop production while minimizing waste, economic loss and environmental impacts is to be developed. More extensive production systems such as conservation agriculture and organic farming may prove to be sustainable. Increasingly, land managers will need to conform to good agricultural practices to achieve production targets and to conform to environmental targets as well. Soil information has become a necessary part of any decision involving a specific site.

TSM_SIMFARM, LDD's computer-based decision support tool, determines the best-bet fertilizer strategies for a range of target yields for a specific crop, given soil nutrient supplying capacity, potential yields and nutrient recovery rates. Based on detailed site-specific information, this tool can provide quick and cost effective answers for the crop under investigation to such questions as:

- how much fertilizer should be applied;
- which is the best composition of chemical and organic fertilizer;
- how much can the inputs' cost be reduced based on appropriate application of the inputs; and
- how much to irrigate, calculating the minimum amount of water available to an individual farm.

With this tool, the LDD supports farmers with clear information to increase their yields for each specific crop and, as a consequence, helps them to improve the suitability of the land. TSM_SIMFARM also helps them to reduce their production costs, which increases their returns.

LDD provides a cost-benefit analysis to help farmers identify which crop could provide the highest return, and whether or not to consider a potential crop change (Table A4.4 in Appendix). However, the behaviour of Thai farmer's is dictated by the market. They seek higher returns and therefore change crops according to commodity prices. This is the main reason for increased supplies and lower prices for some commodities.

4.2 RESULTS

In order to meet AEDP targets, the productivity of existing lands under cultivation must be improved and eventually biofuel crops must expand cultivation to new areas. The following looks at the three main bioefuel crops in detail.

The suitability classification of existing lands under cultivation is applied based on the yield information collected in the field. The suitability assessment as described in Section 4.1.1 is carried out on total land.

4.2.1 Sugar cane

The actual area that is currently used to produce sugar cane is only a little more than 1.6 million hectares. More than 90 percent of sugar cane in Thailand is cultivated under rainfed conditions. The maximum potential yield is around 70–75 tons/ha. Currently, 45 percent of sugar cane plantation is being grown with yields of less than 29 tons/ha classifying the land as marginally suitable land. The next biggest area of sugar cane cultivation is classified suitable land since higher yields are achievable (Table 4.2).

TABLE 4.2

Area under sugar cane cultivation by suitability class

Suitability Class	Irrigated ha & %	Rainfed ha & %	Total ha & %
Very suitable	8 885 8.9	96 894 6.4	105 779 6.5
Suitable	60 264 60.7	519 407 34.4	579 671 36.0
Moderately suitable	4 623 4.7	209 106 13.8	213 729 13.3
Marginally suitable	25 458 25.7	687 333 45.5	712 791 44.2
Total	99 230 6.2	1 512 740 93.8	1 611 970

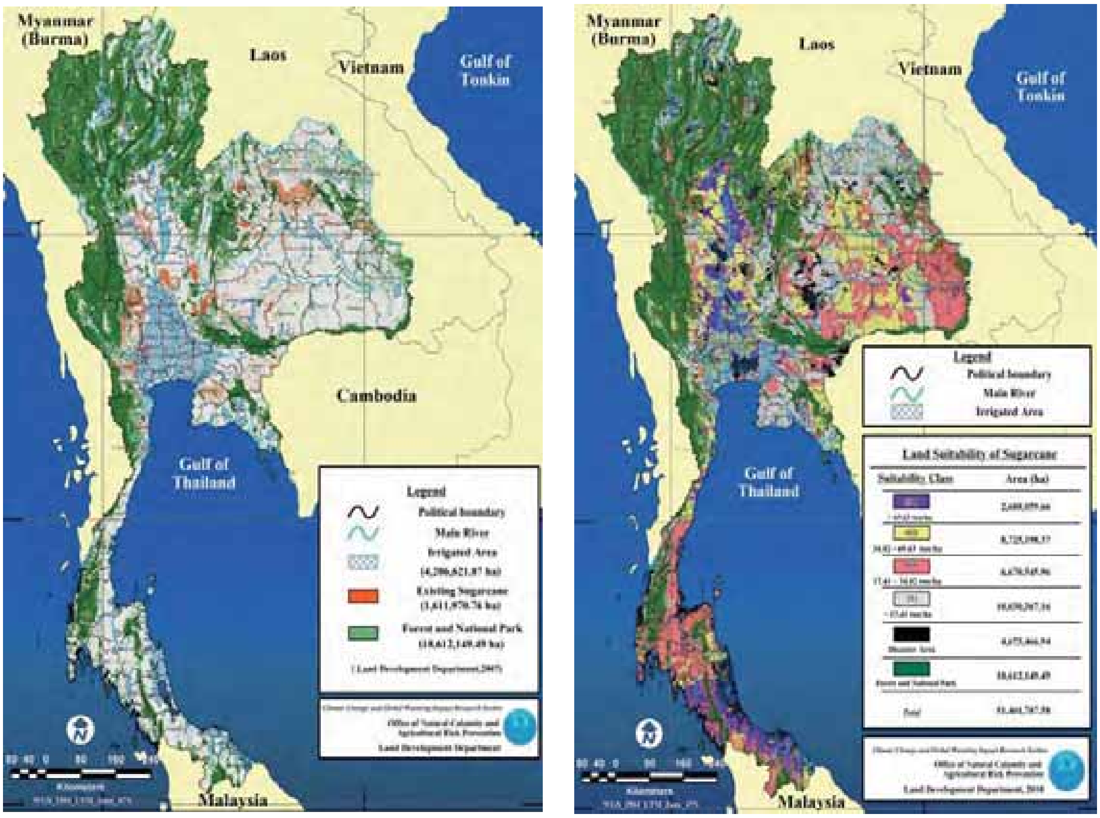
Source: LDD.

Better agricultural management, such as appropriate use of fertilizers or best combination of chemical and organic fertilizer based on the soil profile and efficient use of irrigation, could improve the suitability of these areas. In particular, it could help to raise the suitability of the largest area up to moderately suitable with an increase of the yields up to 44 tons/ha. Furthermore, TSM_SIMFARM provides farmers with a cost analysis of the improvements so they can evaluate potential costs or benefits connected to upgrading.

The suitability assessment shows almost 2.7 million hectares of very suitable land and 8.7 million hectares of suitable land available for sugar cane cultivation in Thailand (excluding forests, protected areas and areas prone to natural disasters). The very suitable areas are concentrated mainly in the central provinces and also in Phatthalung and Songkhlain in the south. Suitable areas are located around the central provinces and in the north-eastern region. Figure 4.3 shows the location of the actual area under sugar cane production and the potential land by suitability class. In particular, the area in purple corresponds to very suitable land and the suitable land is indicated in yellow.

FIGURE 4.3

Actual versus potential area for sugar cane by suitability class



Source: LDD.

The suitable land identified as available after having excluded areas for environmental reasons could be already partly under agricultural production. In terms of crop promotion, the suitable land could be used for other crops, mainly cash crops with higher values and returns for farmers. Table 4.3 shows that the area where sugar cane could achieve the maximum yield (very suitable) is already almost 70 percent under rice and rubber production, and another ten percent of the land cannot be used because it consists of urban area and water bodies.

TABLE 4.3

Actual use of available suitable land for sugar cane

	Irrigated					Rainfed				
	ha					ha				
	1	2	3			1	2	3		
Very suitable	Rice	Urban	Rubber	...	Sugar cane (4)	Rice	Rubber	Water body	...	Sugar cane (5)
	473 685	87 416	66 767		8 885	738 421	587 792	139 955	...	96 894
Suitable	Rice	Urban	Sugar cane	...	...	Rice	Maize	Sugar cane	...	...
	881 184	178 148	60 264	...	...	3 301 311	597 465	519 407	...	...
Moderately suitable	Rice	Maize	Urban	...	Sugar cane (8)	Rice	Rubber	Oil palm	...	Sugar cane (8)
	182 929	38 886	37 738	...	4 623	2 353 699	1 301 923	410 965	...	209 106
Marginally suitable	Rice	Urban	Cassava	...	Sugar cane (6)	Rice	Cassava	Maize	...	Sugar cane (4)
	498 507	134 884	79 531	...	25 45	3 520 417	731 486	709 978	...	687 333
	Total sugar cane plantation				99 230	Total sugar cane plantation				1 512 740

Source: LDD.

Fifty-five percent of the suitable land is already under rice and maize production, and another four percent cannot be used. Considering the area already under sugar cane production described above, the very suitable and suitable land available for expanding sugar cane is respectively around 300 000 hectares where the maximum yields could be achieved and two million hectares where sugar cane yields could reach 40 to 70 tons/ha.

The potential land expansion and resulting crop changes will be feasible for farmers only from the perspective of the cost/benefit analysis. Based on the information in Table A4.4 in Appendix, farmers could look at the costs and benefits of a portfolio of crops to evaluate the most appealing situation.

4.2.2 Cassava

About 1.6 million hectares of land is currently being used for cassava. Cassava production is currently produced under rainfed conditions. Fifty-five percent of the area under cassava cultivation is classified marginally suitable due to yields below 12 tons/ha. Most of the remaining area is moderately suitable with yields between 12 and 17 tons/ha, which is about half of the yields in very suitable land (Table 4.4).

Cassava is usually considered to be a low-value crop with minimal returns for farmers, which contributes to its current low yield. Yields can be increased with the use of improved varieties, pest and disease control and with better practices such as appropriate use of nutrients to restore soil nutrients and fertility. But, such practices require investments. An increased demand and higher prices for cassava might provide enough incentive to encourage farmers to adopt some of these better practices. This should help to improve the cassava suitability in particular of the largest area actually classified as marginally suitable due to the low yields.

TABLE 4.4

Area under cassava cultivation by suitability class

Suitability Class	Irrigated	Rainfed	Total
	ha & %	ha & %	ha & %
Very suitable	2 822	151 003	153 825
	16.0	9.3	9.4
Suitable	2 052	162 518	164 570
	11.7	10.1	10.1
Moderately suitable	8 767	413 527	422 294
	49.8	25.6	25.8
Marginally suitable	3 954	889 120	893 074
	22.5	55.0	54.7
Total	17 595	1 616 168	1 633 763
	1.1	98.9	

Source: LDD.

Based on the suitability assessment such land is classified as moderately suitable and the improvements described above could lead to increase the yield on average of five tons/ha. Similar upgrading toward the suitable class it is feasible for the moderately suitable land.

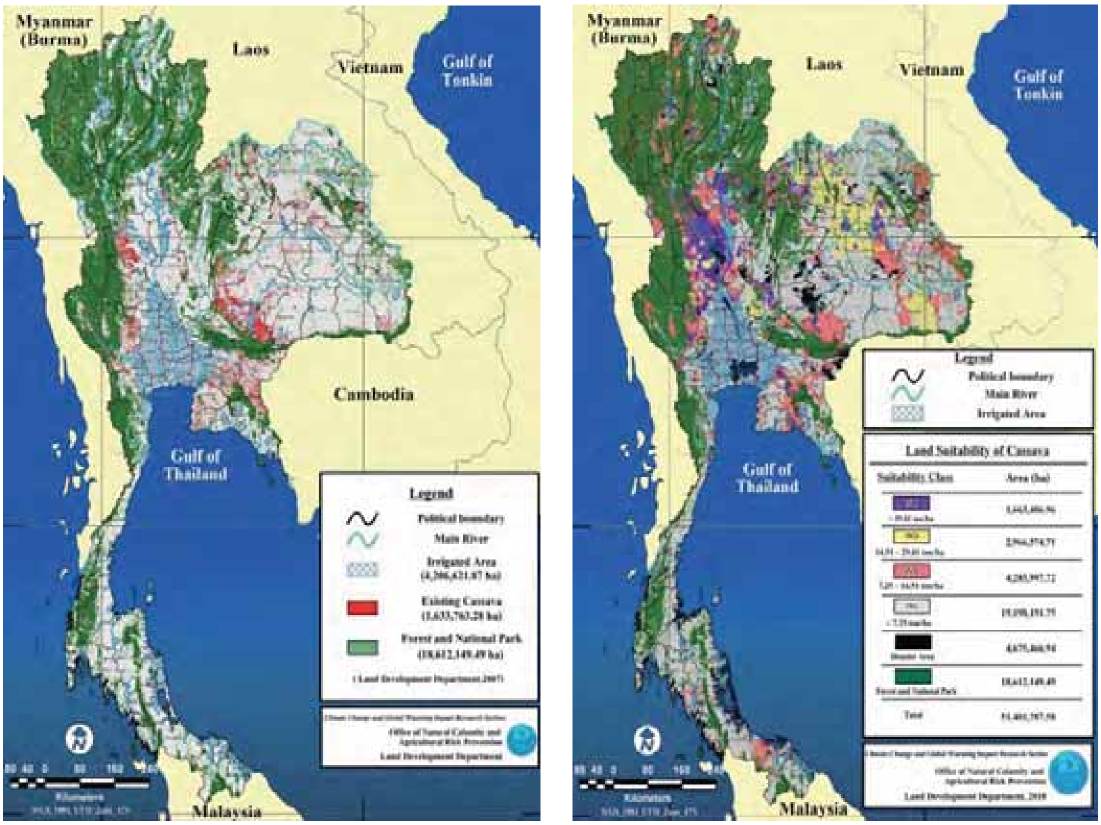
The AEDP expects a large increase in the demand for cassava bioethanol to meet its targets. The increased demand is expected to be met by increasing the average yield of cassava from 23 to 28 tons/ha. It does not expect land cultivation for cassava to expand.

The suitability assessment indicates that such an increase in yields is feasible, but it will not be possible to maintain the existing export markets and meet the additional demand from the cassava ethanol industry. Raising the productivity, and consequently the suitability, of existing cassava crop land will require considerable effort to be achieved in short term.

Crop expansion could be another way to increase production if yields are not sufficiently high. The actual production is largely located in the north-east in Nakhon Ratchasima province, in the centre in Kampaeng Phet and in the east in Chachoengsao. The suitability assessment shows 1.6 million hectares of very suitable land and 2.9 million hectares of suitable land for cultivating cassava after having excluded the environmental areas. The most suitable areas are mostly located in the central and north-eastern regions as shown in Figure 4.4.

FIGURE 4.4

Actual versus potential area for cassava by suitability class



Source: LDD.

Looking at the most suitable land after having excluded environmentally sensitive areas and at the actual land use (Table 4.5), ten percent of this land is already under cassava production and 65 percent is under other agricultural production. Mainly the area is under rice and sugar cane cultivation leaving 400 000 hectares available for expanding cassava without affecting other crops. The suitable land for cassava is mainly cultivated with rice, sugar cane and mixed crops. The potential area for expansion is around 900 000 hectares.

TABLE 4.5

Actual use of available suitable land for cassava

	Irrigated					Rainfed				
	ha					ha				
	1	2	3			1	2	3		
Very suitable	Rice	Sugar cane	Urban	...	Cassava (6)	Rice	Sugar cane	Cassava	...	...
	128 692	15 324	9 800	...	2 822	747 363	184 697	151 003	...	...
Suitable	Rice	Urban	Mixed crops	...	Cassava (13)	Rice	Mixed crops	Sugar cane	...	Cassava (5)
	112 133	25 272	14 154	...	2 052	1 253 858	241 689	213 063	...	162 518
Moderately	Rice	Rubber	Urban	...	Cassava (7)	Rice	Cassava	Maize	...	...
suitable	195 636	45 037	34 634	...	8 767	1 753 914	413 527	332 282	...	...
Marginally	Rice	Urban	Mixed orchard	...	Cassava (45)	Rice	Rubber	Maize	...	Cassava (5)
suitable	1 599 543	350 435	157 900	...	3 954	6 105 233	413 527	332 282	...	889 120
	Total cassava plantation				17 595	Total cassava plantation				1 616 168

Source: LDD.

As already discussed cassava delivers minimal returns for farmers. Promotion for expansion, improvement and crop change will require a great deal of effort, mainly to assure the highest and competitive returns. Particular attention should be paid to the possibility of a crop change that could have a negative effect on GHG balance as described more in-depth in Chapter 7.

4.2.3 Oil palm

Oil palm is being cultivated on nearly 630 000 hectares of land, largely in the south and classified as suitable and moderately suitable area (Table 4.6). Suitable land can produce yields as high as 28 tons/ha, but the maximum yield for moderately suitable land is only about half that amount.

Oil palm yields have been shown to increase through better management practices and by limiting chemical fertilizers in favour of organic methods and products, which also reduces production costs. Such practices can also raise the suitability of the land that is already being cultivated.

TABLE 4.6

Current area under oil palm cultivation by suitability class

Suitability Class	Irrigated	Rainfed	Total
	ha & %	ha & %	ha & %
Very suitable	16 0.1	889 0.1	905 0.2
Suitable	10 203 32.0	318 586 53.5	328 789 52.4
Moderately suitable	21 038 66.0	275 585 46.3	296 623 47.3
Marginally suitable	622 1.9	282 0.1	904 0.1
Total	31 879 5.1	595 342 94.9	627 221

Source: LDD.

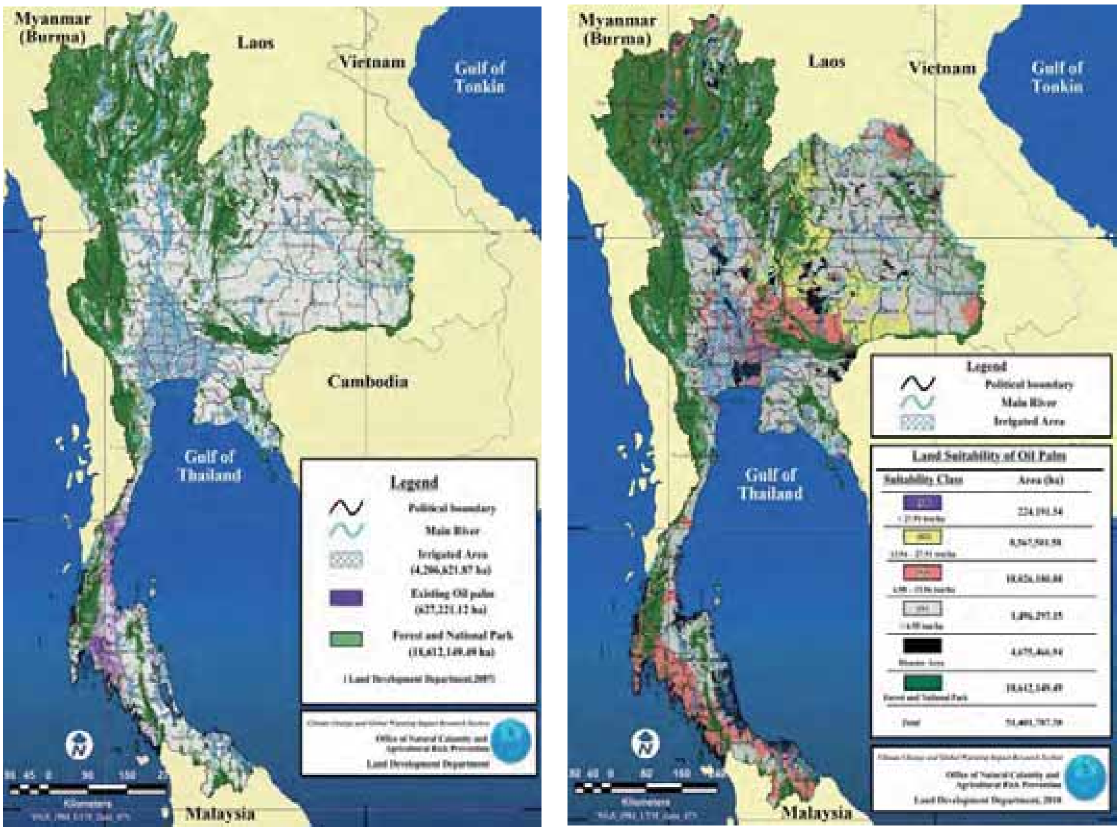
The AEDP predicts that oil palm plantations could increase by as much as 400 000 hectares in an effort to meet Thailand's biodiesel targets. Based on the assessment, there are an additional 200 000 hectares of very suitable land in the south and about 8 million hectares of land considered suitable for oil palm production mainly located in the north-east, as shown in Figure 4.5.

In terms of competition with other crop production, oil palm production is very suitable in the south in areas largely already under rice and rubber production. There is very limited opportunity for expansion in the rubber area because of its high returns. More than half of the suitable land is already in use with again rice and rubber plus maize leaving available around three million hectares, mainly located in the north-eastern region (Table 4.7 and Figure 4.5).

Oil palm could produce better returns for farmers in these areas than some of the key crops currently under cultivation such as rice and maize. Expanding oil palm production into the north-east could provide improved financial returns for farmers in the region and have a positive effect on rural development.

FIGURE 4.5

Actual versus potential area for oil palm by suitability class



Source: LDD.

TABLE 4.7

Actual use of available suitable land for oil palm

	Irrigated ha					Rainfed ha				
	1	2	3			1	2	3		
Very suitable	Rubber 6 040	Rice 5 582	Mixed orchard 1 324	... ...	Oil palm (13) 16	Rice 128 035	Water body 54 381	Rubber 40 629	... ...	Oil palm (25) 889
Suitable	Rice 372 190	Urban 105 283	Rubber 98 438	... ...	Oil palm (16) 10 203	Rice 2 051 504	Rubber 1 362 343	Maize 606 734	... ...	Oil palm (6) 318 586
Moderately suitable	Rice 990 765	Urban 169 508	Rubber 100 392	... ...	Oil palm (13) 21 038	Rice 6 639 615	Rubber 1 564 312	Cassava 1 051 262	... ...	Oil palm (12) 275 585
Marginally suitable	Rice 667 934	Urban 142 157	Sugar cane 39 203	... ...	Oil palm (46) 622	Rice 1 093 567	Cassava 362 603	Maize 240 016	... ...	Oil palm (78) 282
	Total oil palm plantation				31 879	Total oil palm plantation				595 342

Source: LDD.

4.3 CONCLUSIONS

- *The required expansion of biofuel crop production is feasible but should be carefully planned to avoid deforestation, biodiversity loss, expansion into areas affected by natural disasters and excessive harmful crop changes*. In the short-term, the targets envisaged by the AEDP are achievable, but, as noted below, will require strong improvement in yields. As discussed in Chapter 3, over the long-term, achievement of the AEDP targets will require an expansion of the land area allocated to biofuel crops. If not managed correctly, such an expansion could result in a number of negative environmental externalities such as increased GHG emissions and loss of biodiversity and soil organic matter. Issues associated with GHG emissions from potential land use and crop changes arising from the expansion of biofuel feedstock crop production are examined in more detail in Chapter 7.
- *Potential yield improvements of the key biofuel crops are feasible through more efficient and sustainable agriculture management*. Sustainable agricultural management techniques such as conservation agriculture, organic farming methods and careful use of organic rather than chemical fertilizers could help the farmers to achieve yield improvements while also respecting the environment and providing higher returns through reduced costs for equipment, labour and fuel. a As noted in Chapter 2, the declining productivity of agricultural land is a growing problem for Thai farmers. Sustainable agriculture practices will help to improve the long-term productivity of the land resulting in more stable yields and reduced the soil erosion. Sustainable agricultural practices are also more likely to reduce GHG emissions from farming as discussed in Chapter 7 and enhance the resilience of the natural resource base required for agricultural production. To realize yield improvements and take advantage of more sustainable agricultural practices the provision of assistance in terms of agricultural extension services is necessary. Thailand is producing its agricultural products under rainfed condition, except for rice. Irrigation could be another way to improve yields. Potentials and implications of the use of water resource are described in detail in Chapter 5.
- *Technical support and extension services for farmers will be required to increase biofuel crop production and fulfill the short-term targets of the AEDP*. Farmers require technical support and up-to-date information to optimize yield and returns. A wealth of agronomic information is available from the Thai Government that will be essential to encourage the yield improvements necessary to meet the AEDP biofuel targets. Action is required to bridge the gap between farmers, farmer's organizations and government to improve the delivery of agricultural extension services and relevant information regarding land productivity, yield

and price. The role of farmers' organizations in facilitating the transfer of agricultural technology and techniques between farmers and the Thai Government will need to be strengthened.

- *Monitoring of the AEDP targets over the long-term is required to prevent the risk of any harmful land and/or crop use changes*. The AEDP targets must be monitored over the long-term to ensure that efforts to raise agricultural production and productivity to meet the targets do not cause environmental harm or threaten food security. While policy certainty will be crucial in overcoming a number of the challenges inherent in the AEDP, the Thai Government must retain the ability and capacity to regularly assess progress toward the targets and re-evaluate policy in the face of changing circumstances.

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4.5 APPENDIX

FIGURE A4.1
Land Suitability Assessment flowchart

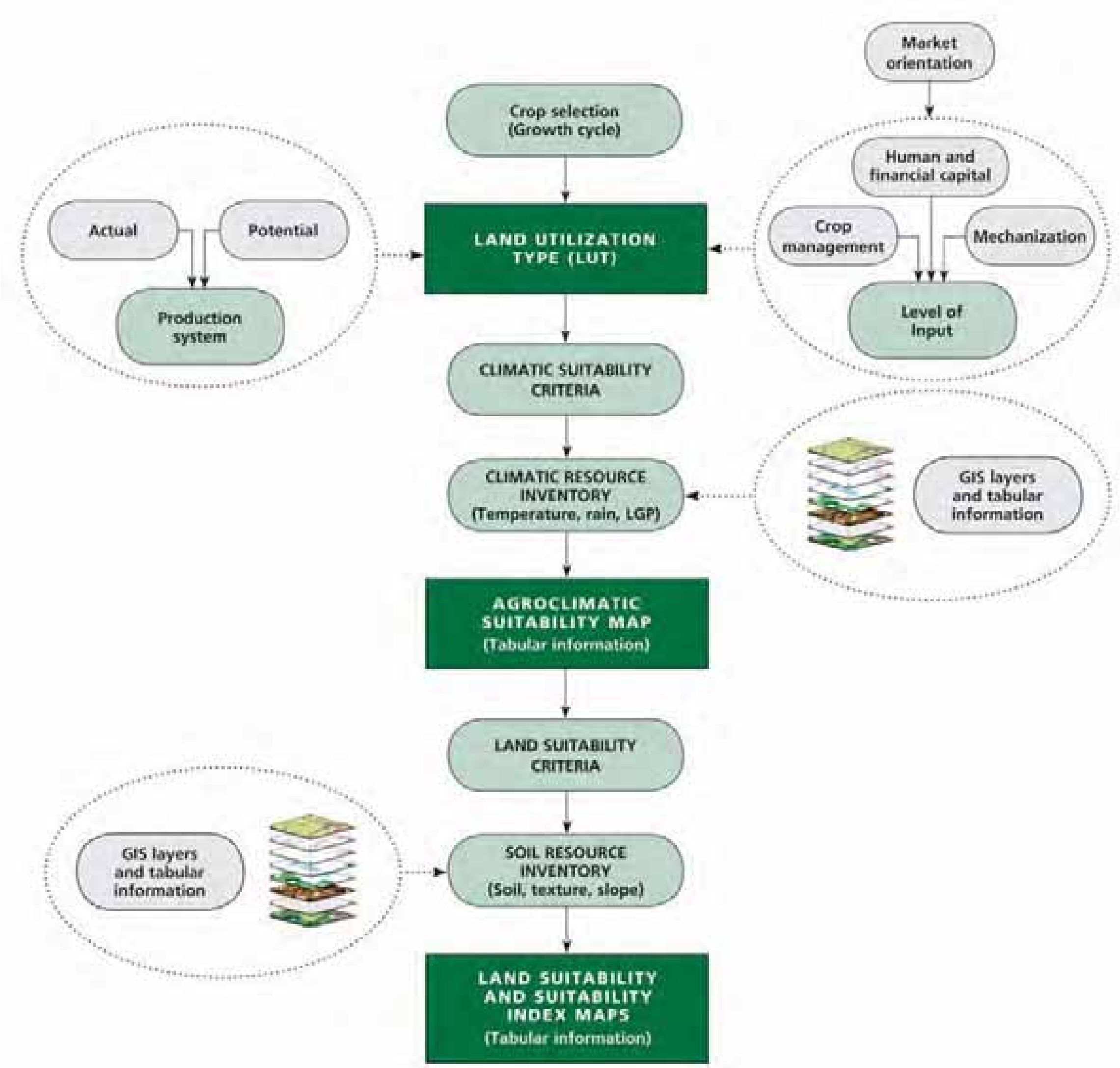


TABLE A4.1

Suitability Assessment Criteria for sugar cane

Factors			Suitability Assessment Criteria			
Attribute	Diagnostic	Unit	Very Suitable	Suitable	Moderately Suitable	Marginally Suitable
	Temperature	°C	>24	< 24	–	–
Moisture	Rainfall	Mm	1200 – 2500	2500 - 3000 900 - 1200	3000 - 4000 –	> 4000 < 900
Oxygen	Soil drainage	Class	5, 6	3, 4	2	1
Nutrient availability	Nutrient status P K Organic matter	Class ppm Ppm %	VH, H > 25 > 60 > 2.5	M, L 6 – 25 30 – 60 1 – 2.5	– 0 – 6 0 – 30 0 – 1	– – – –
Nutrient retention	C.E.C. subsoil B.S. subsoil	meq/100g %	> 15 > 35	5 – 15 < 35	< 5 –	– –
Rooting condition	Soil and Water depth Root penetration	Cm Class	> 100 1, 2	50 – 100 3	25 – 50 4	< 25 –
Salt excess	EC. of saturation	dS./m	< 2	2 – 4	4 – 8	> 8
Soil toxicity	Depth of jarosite Reaction	Cm pH	>150 5.6 – 7.3	100 – 150 7.4 – 7.8 4.5 – 5.5	50 – 100 7.9 – 8.4 4.0 – 4.4	< 50 > 8.4 < 4.0
Flood hazard	Frequency	Yrs./time	10 Yrs./1	6-9 Yrs./1	3-5 Yrs./1	1-2 Yrs./1
Soil workability	Workability class topsoil	Class	1, 2	3	4	–
Mechanization	Slope Rockout crop Stoniness	% Class Class	0 – 2 1 1	2 – 5 2 2	5 – 20 3 3	> 20 4 4
Erosion hazard	Slope	Class	AB	C	D	> D

Source: LDD.

TABLE A4.2

Suitability Assessment Criteria for cassava

Factors			Suitability Assessment Criteria			
Attribute	Diagnostic	Unit	Very Suitable	Suitable	Moderately Suitable	Marginally Suitable
	Temperature	°C	>25	< 25	–	–
Moisture	Rainfall	Mm	1000 – 1500	1500 - 2500 900 - 1000	2500 - 4000 500 - 900	> 4000 < 500
Oxygen	Soil drainage	Class	5, 6	4	–	1, 2, 3
Nutrient availability	Nutrient status N P K Organic matter	Class % ppm Ppm %	VH, H, M > 0.1 > 10 > 30 > 1	– < 0.1 < 10 < 30 < 1	– – – – –	– – – – –
Nutrient retention	C.E.C. subsoil B.S. subsoil	meq/100g %	> 10 > 35	< 10 < 35	– –	– –
Rooting condition	Soil and Water depth Root penetration	Cm Class	> 100 1	50 – 100 2	25 – 50 3	< 25 4
Salt excess	EC. of saturation	dS./m	< 2	2 – 4	4 – 8	> 8
Soil toxicity	Depth of jarosite Reaction	Cm pH	>100 6.1 – 7.3	50 – 100 7.4 – 7.8 5.0 – 6.1	25 – 50 7.9 – 8.4 4.0 – 5.0	< 25 > 8.4 < 4.0
Flood hazard	Frequency	Yrs./time	10 Yrs./1	6-9 Yrs./1	3-5 Yrs./1	1-2 Yrs./1
Soil workability	Workability class topsoil	Class	1, 2	3	4	–
Mechanization	Slope Rockout crop Stoniness	% Class Class	0 – 12 1 1	12 – 23 2 2	23 – 38 3 3	> 38 4 4
Erosion hazard	Slope Soil loss	Class Ton/rai/yr	AB < 2	C 2 – 4	D 4 – 12	> D > 12

Source: LDD.

TABLE A4.3

Suitability Assessment Criteria for oil palm

Factors			Suitability Assessment Criteria			
Attribute	Diagnostic	Unit	Very Suitable	Suitable	Moderately Suitable	Marginally Suitable
	Temperature	°C	>29	25 – 29	22 – 25	< 22
Moisture	Rainfall	Mm	2000 - 3000	3000 - 4000 1800 - 2000	4000 - 5000 1500 - 1800	>5000 <1500
Oxygen	Soil drainage:					
	Trenching	Class	4, 5	3	2, 6, 7	1
	Non-trenching	Class	3, 4, 5	1, 2	–	–
Nutrient availability	Nutrient status	Class	VH, H, M	L	–	–
	P	ppm	> 45	15 – 45	10 – 15	< 10
	Organic matter	%	> 4.5	2.5 – 4.5	1.5 – 2.5	< 1.5
Nutrient retention	C.E.C. subsoil	meq/100g	> 15	3 - 15	< 3	–
	B.S. subsoil	%	> 35	< 35	–	–
Rooting condition	Soil depth	Cm	> 150	100 – 150	50 – 100	< 50
	Root penetration	Class	1, 2	3	4	–
Salt excess	EC. of saturation	dS./m	< 2	2 – 3	3 – 6	> 6
Soil toxicity	Depth of jarosite	Cm	>150	100-150	50-100	
	Reaction	pH	5.1-6.0	6.1-7.3 4.5-5.0	7.4-8.4 4.0-4.4	> 8.4 < 4.0
Flood hazard	Frequency	Yrs./time	10 Yrs./1	6-9 Yrs./1	–	3-5 Yrs./1
Soil workability	Workability class topsoil	Class	1, 2	3	4	–
Mechanization	Slope	%	0 – 12	12 – 23	23 – 38	> 38
	Rockout crop	Class	1	2, 3	4	5
	Stoniness	Class	1	2	3	4
Erosion hazard	Slope	Class	ABC	D	E	> E

Source: LDD.

TABLE A4.4

Return on investment analysis for crop type

Order	Type	Benefit $/ton	Cost $/ton	B/C	Margin %
1	Orange	419.7	193.0	2.17	217.46
2	Shallot	429.7	280.2	1.53	153.36
3	Rubber	1 500.1	1 182.2	1.27	126.89
4	Oil palm	62.9	68.8	0.91	91.45
5	Pepper	2 180.8	2 414.8	0.90	90.31
6	Irrigated rice	162.5	205.2	0.79	79.21
7	Corn	107.3	135.7	0.79	79.05
8	Soybean	220.5	323.7	0.68	68.12
9	Cassava	22.1	33.1	0.67	66.82
10	Pineapple	47.5	84.8	0.56	56.01
11	Coffee	623.9	1 208.5	0.52	51.63
12	Durian	148.7	484.6	0.31	30.68
13	Rainfed rice	77.5	259.5	0.30	29.85
14	Mung bean	78.6	473.8	0.17	16.59
15	Longkong	93.0	709.7	0.13	13.1
16	Longan	61.8	501.6	0.12	12.32
17	Sugar cane	2.0	19.4	0.10	10.41
18	Peanut	13.9	506.9	0.03	2.75
19	Potato	-0.55	267.7	0.00	-0.21
20	Garlic	-14.61	560.3	-0.03	-2.61
21	Rambutan	-47.89	338.9	-0.14	-14.13
22	Lychees	-191.64	666.5	-0.29	-28.75
23	Mangosteen	-272.18	645.7	-0.42	-42.16
24	Onion	-81.19	186.3	-0.44	-43.59

Source: LDD.

CHAPTER 5

NATURAL RESOURCE ANALYSIS: WATER

There is global consensus that the competition for scarce water resources is intense and that the world faces unprecedented challenges in using water sustainably (CA, 2007). Today, agriculture requires about 86 percent of the fresh water available worldwide (Hoekstra and Chapagain, 2007). In many parts of the world, agriculture has to compete for water with urban centres and industries (Falkenmark, 1997; Postel et al., 1996; UNESCO, 2006). Competition occurs where urban centres expand into formerly rural areas and water demand for households and industry grows, often leaving agriculture with insufficient water. There is also competition between upstream and downstream users. The large-scale introduction of biofuels to mitigate the effects of climate change may establish another competitor for water resources.

However, the current discourse pays limited attention on the effects of biofuel production on water use and on local water systems. More than 1.2 billion people already live in water scarce areas (CA, 2007). With increasing demand for irrigation from the domestic and industrial sectors, people at risk of water shortages will increase to one-third of the world's population by 2050 (de Fraiture et al, 2007). The stress on land and water resources could accelerate with increasing demand for biofuel.

This chapter assesses the effect biofuel production has on water, in particular the effect of molasses and cassava ethanol production. It is also an assessment of the effects of increasing biofuel demand due to the AEDP on local water systems in Thailand. The water footprint is a geographically explicit indicator because it depends on a location-specific set of factors such as hydrology, climate, geology, topography, agriculture management and yields. The water footprint for biodiesel was not assessed for the BEFS project.

5.1 THE METHODOLOGY OF WATER FOOTPRINTS

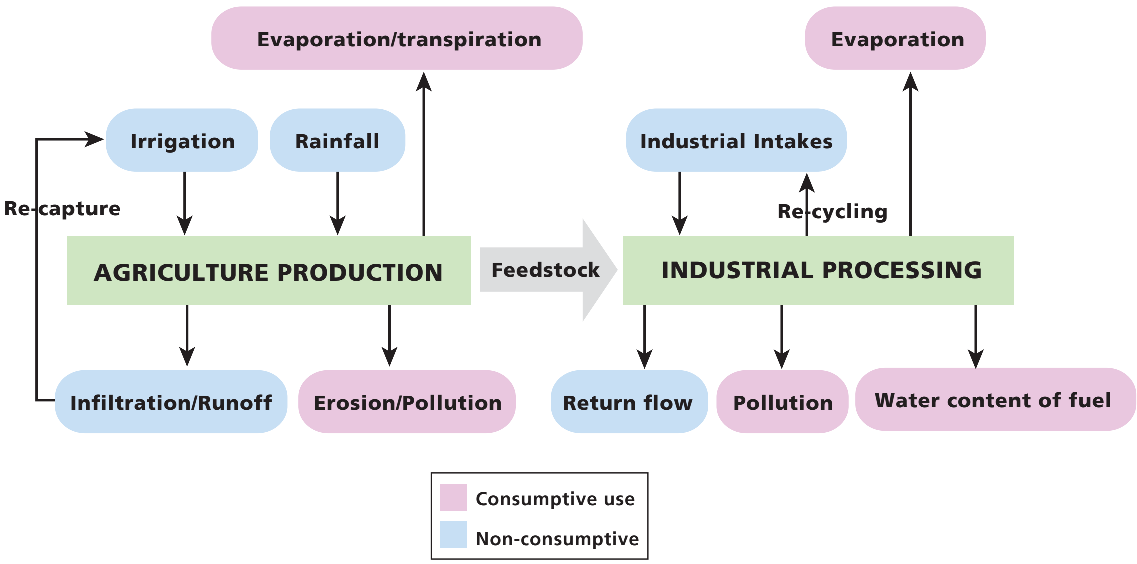
The water footprint (WF) is a concept introduced to address the issue of freshwater used to produce the goods and services related to a certain consumption pattern. In the biofuel supply chain water is consumed in both the agricultural and industrial phases.

The WF has three components: green, blue and grey. The green component is the volume of rainwater that evaporates during the production process. It refers to the total evapotranspiration during crop growth from fields and plants. The blue component refers to the volume of surface and groundwater that evaporates during crop growth. It is defined as the sum of the evaporation of irrigation water from the field and the evaporation of water from irrigation canals and artificial storage reservoirs. In industrial production and services, the blue component is defined as the amount of water withdrawn from ground or surface water that does not return to the system from which it came. The grey component is the volume of water that becomes polluted during production. The grey component is defined as the amount of polluted water associated with the production of goods and services. It is the amount of water needed to dilute pollutants that enter into the natural water system during the production process to the extent that the quality of the ambient water remains

above agreed water quality standards (UNESCO, 2008). The first two are related to water use, the latter to water pollution.

Water is used in the overall biofuel life cycle and its depletion can be distinguished in consumptive water use (CWU) and non-consumptive water use (N-CWU). CWU is water that has been used up permanently, e.g. depletion through evaporation and transpiration. N-CWU is the return flow of water that may or may not be captured for further use (Figure 5.1).

FIGURE 5.1
Land Suitability Assessment flowchart



Source: Fingerman et al, 2010.

This analysis estimates the total WF for sugar cane and cassava ethanol in terms of water depleted per unit of biofuel (m^3/litre) and total water depleted per year (m^3/year).

5.1.1 Water footprints of ethanol production

The WF for sugar cane, specifically molasses, ethanol will be estimated first and then the same process applied to cassava ethanol. Water depletion in ethanol production occurs in three stages (Figure 5.2): first, agricultural water use during sugar cane crop growth (A); second, industrial water uses in the production of sugar and molasses from sugar cane (B); and third, industrial water used in producing ethanol (C).

In the first stage, rainwater, which is stored in soil moisture, is one form of direct water use. Irrigation withdrawals, either through canal or groundwater, and wastewater application are other forms of direct water use. Seeds contribute to indirect water use. However, the quantity of water use in seeds is generally negligible compared to direct water use. In this stage water pollution occurs when fertilizer and pesticide leach into the groundwater or enter local river systems. At the crop production stage, the green WF is the minimum between effective rainfall and crop-specific evapotranspiration, in this specific case sugar cane. If the crop is irrigated, the blue WF is the net evapotranspiration requirement, which is the minimum between the difference of the crop-specific evapotranspiration and the effective rainfall and 0. In Appendix equations 5.1 and 5.2 define the green and blue WF for a generic crop.

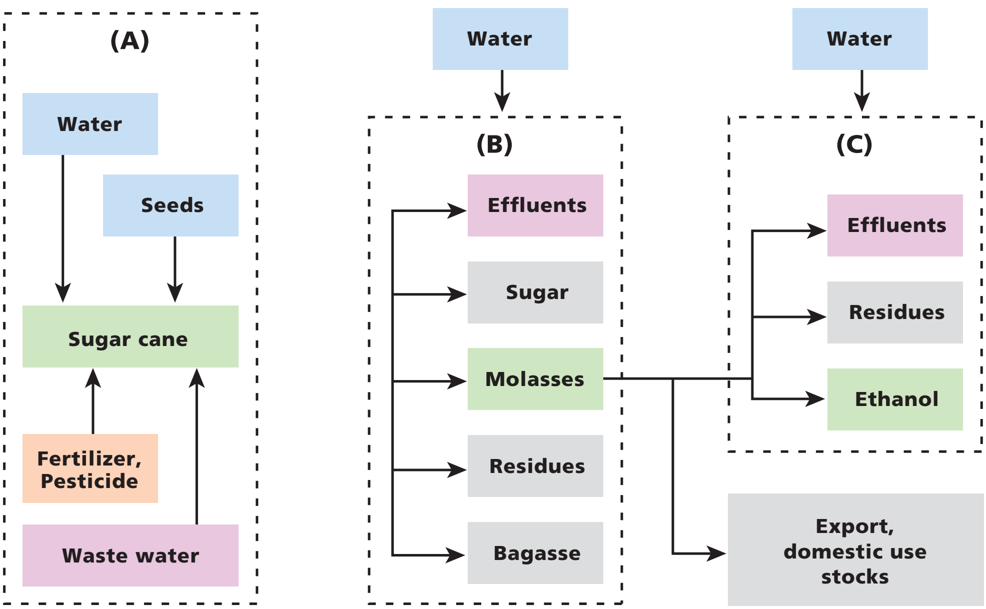
In the second stage, sugar cane is processed to obtain sugar as the main product, and molasses and bagasse as by-products (B in Figure 5.2). Thus, only a part of the sugar cane production WF can be attributed to molasses production. To estimate the coefficient of attribution the conversion rates and the export prices of sugar, molasses and bagasse are used. Moreover, direct water use in the industrial production process B is considered to contribute to the blue WF. Effluents generated in this process contribute to water pollution. In Appendix equations 5.3 and 5.4 define the green and blue WF for molasses.

In the third stage an industrial process converts molasses into ethanol (C in Figure 5.2). The green WF of ethanol is a share of the green WF of molasses, where the share is the conversion rate of molasses to ethanol. Industrial water use for producing ethanol is treated as blue WF. Technical details can be found in the equations 5.5 and 5.6 in Appendix. Also in this industrial process, the wastewater is the water polluter. Wastewater stored in ponds is first treated to bring its quality parameters to an acceptable level, and next reapplied to crop fields primarily as fertilizer. During this process, part of the wastewater stored in ponds can leach into groundwater systems, and part of the wastewater applied to fields can reach local river systems with rainfall or irrigation return flows.

The estimation of WF of cassava ethanol is similar to that of sugar cane, except that there is only one stage of industrial production. First, water use is in cassava production. Next, a part of the cassava production is directly used for ethanol production and the rest for food and feed use. In Appendix equations 5.1 and 5.2 estimate the green and blue WF of cassava crop production; equations 5.5 and 5.6 estimate the green and blue WF for the process of converting cassava to ethanol.

FIGURE 5.2

Process of sugar-based ethanol production



Notes: A – Sugar cane production; B – Sugar/molasses production; C – Ethanol production.

5.2 WATER FOOTPRINTS OF ETHANOL PRODUCTION IN THAILAND

5.2.1 Data and assumptions

The FAOSTAT national and sub-national (FAO, 2010a & b) databases are the source for sugar cane and cassava area and production. The Water and Climate Atlas of the International Water Management Institute (IWMI, 2000) was the source of evapotranspiration. The crop coefficients and the lengths of the growing periods (initial, development, mid-season and late-season) of sugar cane and cassava are taken from the AQUASTAT database (FAO, 2010c).

Water and other input use in crop and ethanol production processes are assessed using a rapid survey. For crop production, five farmers in Baan Pong district (Rajburi province) and five farmers in Chaibadan district (Lopburi province) were interviewed. For the industrial process, the information was collected at the Rajburi sugar factory, the Thai Sugar ethanol plant in Kanchanaburi province and the Sapthip ethanol plant in Lopburi.

The assumption made in estimating the WF of crop production and industrial production of sugar, molasses and ethanol are given below:

- The analysis uses average export prices from 2007 to 2009 for sugar ($277) and molasses ($75) (FAO, 2010a);
- One ton of sugar cane produces 0.045 ton of molasses and 0.11 ton of sugar (FAO, 2010a);
- One litre of ethanol requires four kg of molasses or 5.88 kg of cassava (DEDE, 2010); and
- In the first industrial process related to sugar cane, water is used for cleaning the sugar cane, for juice extraction and for concentration. It is estimated that these steps require 1.22 m^3/ton of sugar cane. The water requirement is again divided using export prices of sugar, molasses and bagasse. The second industrial process mainly requires water for fermentation and distillery. This is assumed to be 8.72 m^3/ton of molasses (Moreira, 2009).

5.2.2 Water footprint of sugar-based ethanol

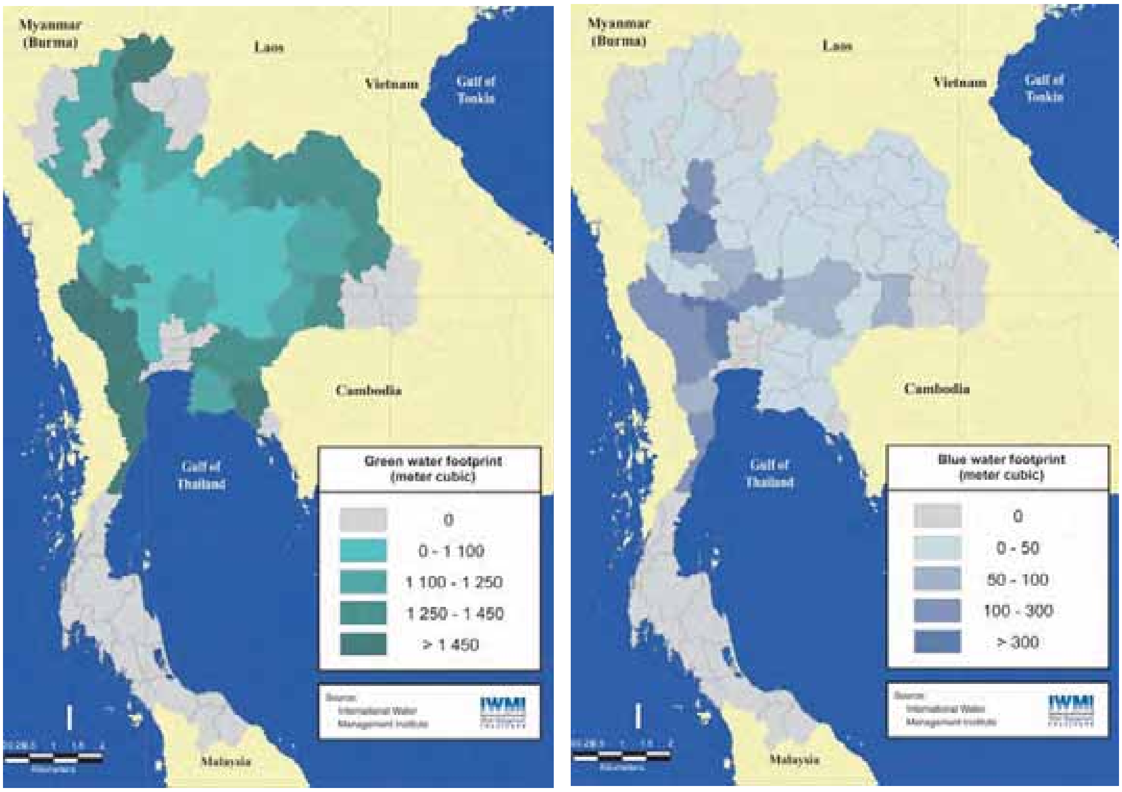
Although effective rainfall meets 57 percent of the crop's water requirements or potential crop evapotranspiration of sugar cane, only 14 percent of the sugar cane plantations are irrigated. In 2004-2006, the average harvested area of sugar cane was 1.047 million hectares.

The total green and blue WF of sugar cane, molasses and molasses-based ethanol are 146, 322 and 1 646 m^3/ton respectively. Alternatively, 1 299 litres of water is consumed during the complete production cycle of one litre of ethanol from molasses. Effective rainfall contributes 90 percent of the total WF of sugar cane production, and 89 percent in molasses ethanol production. This slight reduction is due to water withdrawn for industrial uses. The water consumed in the industrial processes in sugar mills and ethanol production plants — 12.7 litres of water for one litre of ethanol —accounts only nine percent of the total blue WF of 140 litres for one litre of ethanol.

If the sugar cane for ethanol is produced in different districts, then WF could vary from 985 to 2 111 litres of water for one litre of ethanol across districts (Figure 5.3). With 70 percent of the total irrigated area, the central provinces contribute largely to the blue WF, followed by the Northern provinces, which have 26 percent of the total irrigated area.

FIGURE 5.3

Sugar-based ethanol WF by districts



Source: IWMI.

5.2.3 Water footprints of cassava-based ethanol

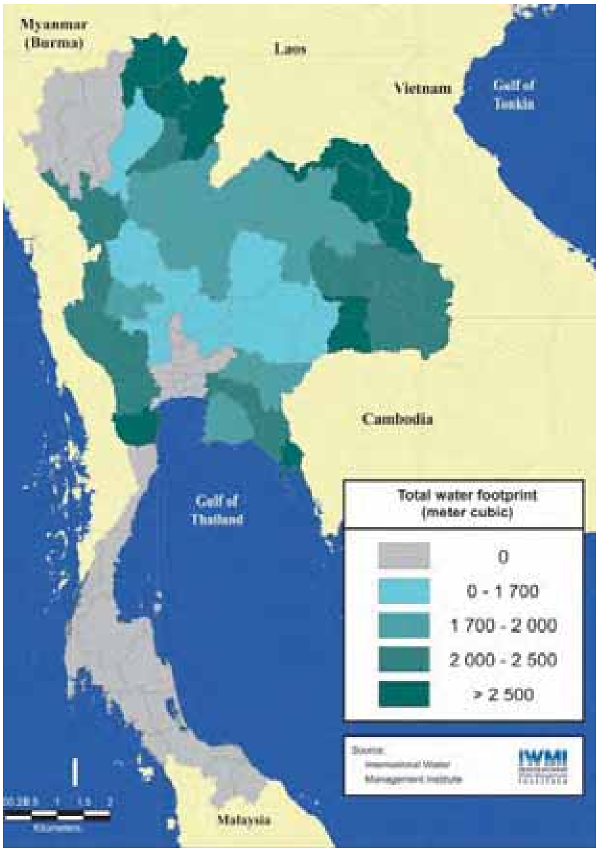
Cassava is the main crop for future ethanol production foreseen in the AEDP. In Thailand, it is mainly a rainfed crop. Effective rainfall share in the evapotranspiration of cassava is 81 percent and no area is irrigated at present. The harvested area under cassava in 2004-2006 was 1.05 million hectares.

The total of green and blue WF of cassava and cassava ethanol production are 307 and 2 304 m^3/ton respectively. Alternatively, 1 817 litres of water is consumed during the complete production cycle of one litre of ethanol from cassava. The blue WF is comprised only of the industrial processes. The calculated blue WF is 12.3 litres for one litre of ethanol.

The WF of cassava ethanol varies from 1 265 to 3 070 litres of water per one litre of ethanol across provinces (Figure 5.4), due to the large variation in cassava yields. Across districts, the evapotranspiration of cassava varies from 726 to 914 mm, while yields vary from 14.0 to 31.5 tons/ha.

FIGURE 5.4

Cassava-based ethanol WF by districts



Source: IWMI.

In terms of blue WF, cassava provides a better feedstock than molasses for ethanol production. While rainfall contributes to almost all the WF of the cassava ethanol production, irrigation meets a part of the water requirement in molasses ethanol production.

5.2.4 Future trends of biofuel water footprint

As discussed previously, Thailand projects cassava to be the main feedstock for future ethanol production. Currently, molasses contributes 50 percent of the ethanol production, and this share is expected to decrease to 20 percent by 2018 and remain at that level thereafter.

In 2007-2009, Thailand produced on average 67.8 million tons of sugar cane and consumed 9.9 billion m^3 of water with a 989 million m^3 from irrigation. The blue WF of sugar cane production is only 0.2 percent of the 444 billion m^3 of total renewable water resources (TRWR) in Thailand. More than 70 percent of the blue WF is concentrated in four districts of Kamphaeng Phet province in the north (33 percent) and in three provinces in the central region, namely Suphan Buri (19), Nakhon Pathom (17), Kanchanaburi (7). The proportion of the blue WF when compared to the internal renewable water resources of each of these four locations is four, 13, three and one percent respectively.

Based on the AEDP ethanol targets, ethanol production from molasses is estimated to consume 500 million m^3 of water in 2010. The blue WP in the ethanol production process from molasses is only 0.01 percent of the TRWR. At the rate of current water consumption, the total WP of sugar-based ethanol could reach 853 million m^3 by 2022, including 11 percent from irrigation. The blue WF of sugar-based ethanol will still be only 0.2 percent of the TRWR.

However, this scenario may change due to the projected yield increase. To meet the increasing ethanol demand, Thailand projects the sugar cane yield to increase to 93.8 ton/ha by 2012, from the current level of 53.5 ton/ha in 2006 (DEDE, 2010). If such an increase in sugar cane yields is going to occur, the total irrigated area and hence evapotranspiration from irrigation would inevitably increase. This means higher blue WF and consequently total WF. Since irrigation water consumption in the crop production constitutes the major part of sugar-based ethanol WF, only the sugar cane production WF is considered here.

Three scenarios were tested: a ten, 20 and 30 percent increase in the irrigated area under sugar cane plantation. Detailed information is reported in Table 5.1.

In the absence of information about other inputs, it is assumed that a ten percent increase in sugar cane irrigated area could result in three different yield scenarios; namely possible increases 1.6, 3.2 and 4.8 percent. Under this scenario, the WF of one ton of sugar cane will increase to between 145 to 154-149 m^3 of water. The total blue WF of sugar cane production shall be only 0.3 percent of the TRWR.

A 20 percent increase in total irrigated area is assumed to result in possible yield increases of 3.2, 6.4 and 9.6 percent. Under this scenario, the WF of one ton of sugar cane will increase to between 162-147 m^3/ton. The total blue WF is about 0.43 percent of TRWR.

A 30 percent increase in total irrigated area is assumed to result in possible yield increases of 4.8, 9.6 and 14.4 percent. Under this scenario, the sugar cane WF will actually fall below the base scenario. The total blue WF will reach 0.56 percent of the TRWR.

TABLE 5.1

Sugar cane WF under scenarios of irrigated area and yield growth

Scenarios	Sugar cane irrigated area	Sugar cane yield increase	Sugar cane yield	Sugar cane WF
	% of the total	%	Ton/ha	m^3/ton
Base	14	–	51.46	146
SC1	24	1.6	52.29	154
		3.2	53.11	151
		4.8	53.93	149
SC2	34	3.2	53.11	162
		6.4	55.63	154
		9.6	58.21	147
SC3	44	4.8	56.52	161
		9.6	58.21	157
		14.4	63.64	143

Source: IWMI.

These scenarios show that sugar-based ethanol production, and for that matter even the total sugar cane production, shall consume only a small part of the TRWR. However some concerns need to be addressed to realize the AEDP targets of sugar-based ethanol production in the near future.

The scenarios show the corresponding increase in the sugar cane yield due to the simulated expansion of the irrigated area. The yields calculated fall far short of the yield projections envisioned in the AEDP up to the year 2012. The gap between the irrigated and rainfed sugar cane yields indicates that achieving the growth in yields required to meet the short-term AEDP targets may not be possible; even with substantial growth in irrigated area.

The scenario analysis demonstrates that to improve sugar cane yield more irrigation is necessary. To achieve a 10-30 percent increase in irrigated area will require increased irrigation withdrawals of between 76-222 percent. Realizing this type of growth in the short-term will present a significant challenge.

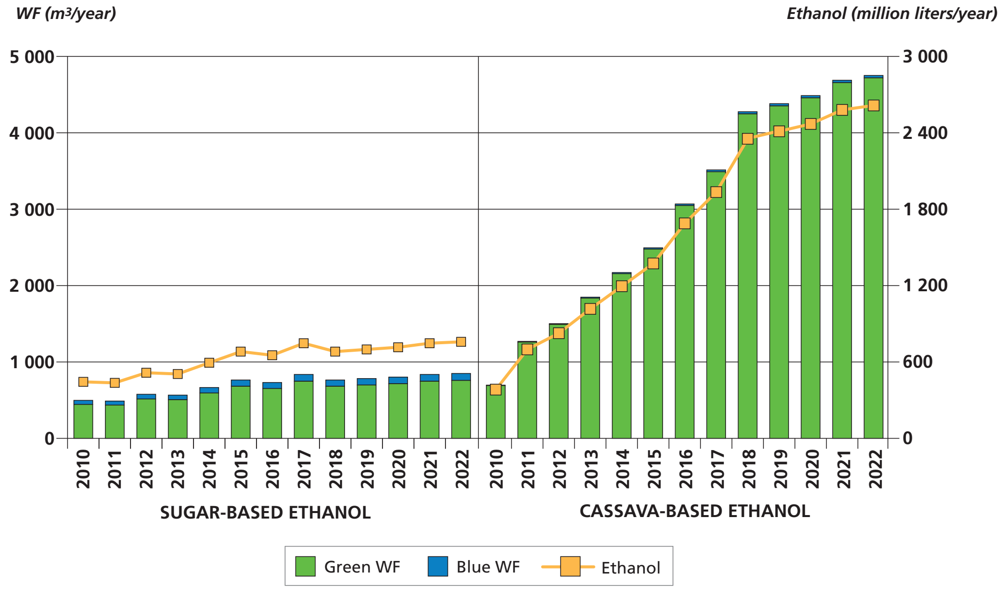
An alternative to new irrigation is reallocation of irrigation from other crops. The other major irrigated crop in Thailand is rice. At present 26 percent of ten million hectares annual rice cropped area is irrigated. A total WF of rice is 1 621– 1 456 m^3/ton from soil moisture and 165 m^3/ton from irrigation. This shows that forgoing one ton of rice could provide irrigation to produce at least ten tons of sugar cane. With 2.56 tons/ha of average rice yield, water consumed in one hectare of rice land could provide irrigation to increase sugar cane production by an additional 20-30 tons. Thus, it seems that reallocation of water from rice to sugar cane production is a possible option for providing the irrigation to increase sugar yields. However, such action may create additional risks to food security.

In the case of cassava ethanol the total WF is 710 million m^3 in 2010. The contribution of the blue WF –15 million m^3 – is negligible in comparison to TRWR. As per the government plans, cassava is expected to be the feedstock for 80 percent of ethanol demand by 2022. At the current rate of WF, the total cassava ethanol WF is expected to reach 4 846 million m^3 by 2022 or one percent of TRWR. Most of it –97.9 percent– is expected to come from effective rainfall. As can be seen in Figure 5.5, unless there is a substantial increase in crop yield or reduction in cassava exports over this period, rainfed crop lands under cassava will have to be increased significantly to meet future ethanol demand.

If cassava exports and area under production is going to remain at the present level, the yield of cassava needs to increase by at least six times to meet anticipated demand for cassava feedstock.

FIGURE 5.5

Total WF of sugar and cassava-based ethanol



Source: MoE.

5.3 WATER QUALITY IMPACTS ON LOCAL WATER SYSTEMS

In addition to withdrawing water from water systems, ethanol production can also affect the water quality of these systems.

Urea fertilizer is a major source of nitrogen leaching into groundwater. In Thailand, sugar cane and cassava production uses about 260 and 200 kg/ha of fertilizers (Table 5.2), but this varies significantly across farms. The nitrogen application alone varies from 65 to 120 kg/ha.

TABLE 5.2

Chemical fertilizer and other inputs for sugar cane and cassava

		Sugar cane	Cassava
Fertilizer (kg/ha)	N	90	90
	P	60	50
	K	110	60
	Total	260	200
Fungicide (kg/ha)		–	620
Insecticide (kg/ha)		60	–
Herbicide (L/ha)		800	–

Source: IWMI based on farm level surveys.

The fertilizer application in sugar cane and cassava crop production currently leaches about 8 680 tons of nitrogen load to groundwater aquifers. Thus, the amount of water required to eliminate the deterioration of water quality during the process of crop production is equivalent to 0.868 billion m^3. However, this is only a small fraction (two percent) of the annual groundwater recharge of 41 billion m^3 at present.

Wastewater generated in mills and ethanol plants is the biggest contributor to water quality deterioration during ethanol production. In sugar-based ethanol production the liquid effluents are molasses and wastewaters. For example, the Rajburi sugar mill generates about 1 500-2 000 m^3 of wastewater per day and produces 650 tons of molasses; Sapthip ethanol distillery generates 1 600 m^3 of wastewater and produces 400-450 tons of molasses per day. A substantial amount of the wastewater, called spent wash, is stored in ponds. The spent wash has high potential for water pollution (Table 5.3). The spent wash generated at the distillery plants is acidic (pH 4.5), has a very high temperature (65-70 °C), contains about 232-1 600 milligrams per litre (mg/L) of nitrogen and has a high content of biochemical and chemical oxygen (43 000 and 80-100 000 mg/L respectively), suggesting a large quantity of organic matter in spent wash. Another 74 000 mg/L of suspended solid are also recorded.

TABLE 5.3

Characteristics of spent wash from sugar and cassava-based ethanol

Parameter	Unit	Spent wash	
		Sugar-based ethanol	Cassava-based ethanol
pH	–	4.5	4.5
Temperature	°C	70	65
Biochemical oxygen	mg/L	n/a	43 000
Chemical oxygen	mg/L	80 000 -100 000	90 000
Total solids		~23% weight	74 000
Organic material	mg/L	n/a	1 600
Total Carbon	mg/L	n/a	n/a
Total Nitrogen	mg/L	232	1 600
Total Phosphorous	mg/L	62	n/a
Total Potassium	mg/L	1 383	n/a

Since Thailand has a zero discharge policy in its wastewater regulation, no direct discharge of wastewaters occurs from the factories into the water systems. Typically, an anaerobic treatment method and infiltration are used for wastewater treatment. Although treatment avoids the negative effect of direct discharge, there is a risk for soil and water pollution in the neighbouring area. High organic loads in these effluents can easily permeate through soil, particularly in areas with high distribution of sandy soil.

According to discussions with factory managers, the infiltration rate of wastewater in storage ponds at Rajburi Distillery is high. Typically it takes a few months for wastewater in a pond (about three to four meters deep, 30 to 40 meters wide) to dry. This is due to the fact that the soil texture in this area is sand and silty. It is well recognized that the coefficient of permeability (k) of sand is higher than that of silt and clay, which means water can penetrate through sand faster than silt and clay. The coefficient of permeability of sand ranges from 1 to 10-5 cm per second, while silt and clay range from 10-5 to 10-9 cm per second. It has been reported that in the area where soil textures are sand and salty sand, wastewater from the pond at the wastewater treatment plant can permeate for about 16 metres within five years. As already noted, some wastewater treatment plants are within one kilometer distance from the Mae Klong river, the surface water supply for people who live in Nakorn Pratom, Rajburi, and Khanchanaburi provinces. Therefore, there is a high risk of soil, surface and ground water contamination in this area.

Spent wash from ethanol distillation, with considerable plant nutrient, is widely used by cane growers with fields closer to sugar mills. According to interviews with farmers, ethanol spent wash is blended with other plant nutrients at 800 TBH per tank with a capacity of 12 m^3 and a 12 m^3 per tank of spent wash mixtures can be used in an area of about 0.6 - 0.8 ha. Spent wash mixture as liquid fertilizer is cost effective and was found to have increased cane yields to a satisfactory level.

It is well known that the application of spent wash, produced in ethanol and liquor distilleries, to agricultural land improves a range of soil properties. These include chemical (carbon, nitrogen and K contents, and nutrient holding capacity) and physical (water stable aggregates, hydraulic conductivity and soil water retention), resulting in enhanced crop productivity. However, evidence of the effect of spent wash application as a fertilizer on crop productivity growth in Thailand is scarce.

Currently, research is being carried out by government departments to assess the impact on soil and ground after applying spent wash. It was proved that the addition of liquor spent wash improves physical and chemical properties of soil and thus crop productivity (LDD, 2000). Similarly, research from Ramkumhang University indicates that applying spent wash from a liquor distillery at the rate of 60 m^3 combined with chemical fertilizer of 20-20-0 at 150 kg/ha of N-P-K per ha significant increased sugar cane yield up to 203 ton/ha in the first year, while applying 20-20-0 alone at 500 kg of a mean formula of N-P-K per ha yielded 75-94 kg/ha. The LDD report recommends applying combined applications of liquor spent wash at 125 -188 m^3/ha and chemical fertilizer of 16-20-0 at 70 kg of a mean formula of N-P-K per hectares for rice cultivation in northern Thailand.

On the other hand, negative effects have also been recorded. Applying liquor spent wash at a rate of more than 250 m^3/ha could result in soil salinity and nutrient imbalance and thus decrease crop productivity. Further research undertaken at the Chulalongkorn University in 2003 to 2004 shows that spent wash can contaminate soil and water with high organic carbon loads (BOD, COD and TOC) — soil and groundwater in surrounding areas of the storage pond at a depth of 20 meters, and surface water bodies at 100 meters away from the pond.

Although the quantity of spent wash generated at present is small, it can increase substantially in the future with more biofuel production. By 2022, the total wastewater generated from sugar-based ethanol would be at least 7.89 million m^3. Given the relatively small area of land currently under sugar-cane cultivation, it would be difficult to use such a quantity of wastewater as fertilizer. Thus storing the remaining wastewater/spent wash in ponds would be an enormous task, and, if stored, its effect on groundwater and surface water systems in and around mills and plants could be very damaging. The actual effects of stored spent wash on local water systems, especially on groundwater, need further assessment.

5.4 CONCLUSIONS

- *The ethanol industry in Thailand uses a relatively small amount of the country's total water resources*. In Thailand sugar cane (i.e. molasses) and cassava are the main feedstocks for ethanol production. The WF of sugar cane, molasses and molasses ethanol in Thailand are 145, 322, and 1 646 m^3/tons, respectively. The blue WF constitutes nine percent of the total WF of sugar-based ethanol. In terms of water use for irrigation, cassava is the better feedstock for ethanol production. Every litre of sugar-based ethanol requires 140 litres of water for the irrigation, while that from cassava requires only 12 litres. Based on ethanol production in 2010 the total blue WF is 69 m^3 and it represents only 0.02 percent of Thailand's TRWR. The WF of cassava and cassava ethanol are 307 and 2 304 m^3/ton respectively, where the blue WF constitutes only 0.7 percent of the total WF of cassava ethanol, mainly related to ethanol processing.
- *Thailand should have sufficient water resources to meet the anticipated expansion of ethanol with the AEDP targets*. At the rate of current water consumption, the total WF of sugar-based ethanol could reach 853 million m^3 by 2022, which represents only around 0.2 percent of Thailand's TRWR. At the current rate of WF, the total cassava ethanol WF is expected to be greater and reach around 4 846 million m^3 by 2022 or one percent of TRWR. However, to meet the feedstock requirements implicit in the AEDP targets, either substantial increases in irrigation or expansion of sugar cane and cassava under rainfed agriculture is required.
- *However, to achieve the improvements in the yield of sugar cane and cassava required by the AEDP irrigation of both crops will need to expand rapidly, which could present challenges in the short-term*. Biofuel demand and production is increasing in Thailand. Ethanol demand in Thailand is set to increase dramatically from 2.1 to nine MLPD, between 2010 and 2022. In the absence of a significant growth in area, a significantly high increase of the yields is the only solution. Given the difference in crop yields between districts and between irrigated and rainfed areas, the planned growth in yields for biofuels crops may not be a realistic goal without expanding biofuel crops under irrigation.
- *While the expansion of ethanol production is not expected to strain water resources in terms of volume, it may have serious impact on water quality near processing facilities*. Biofuel production processes generate a large quantity of wastewater including highly toxic spent wash. Although zero discharge of effluents is the government policy, spent wash is stored in a pond for a long period of time. This can have a significant negative effect on the local groundwater systems and subsequently on the neighbouring streams.

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5.6 APPENDIX

Here below are reported the equations for the definition of the green and blue WF.
For a generic crop, in the specific case sugar cane and cassava:

$$WF^{Green}_{Crop} = Minmun\ (EffRF,\ Et_C) \quad (5.1)$$

$$WF^{Blue}_{Crop} = Minmun\ (Et_C - EffRF, 0) \quad (5.2)$$

where:

WF^{Green}_{Crop} is the green WF.

WF^{Blue}_{Crop} is the blue WF, if irrigation occurs.

$EffRF$ is the effective rainfall.

Et_C is the crop-specific evapotranspiration.

The Et_C of a crop is estimated as the total of crop water requirements in four crop growth periods (initial, development, mid- and late stage). Crop water consumption is estimated by calculating Et_C using the Penman–Monteith model developed by FAO (1998). Et_C is the product of a reference crop evapotranspiration (Et_0) and a crop-specific coefficient (K_C). Et_0 characterizes climate effects and is calculated from temperature, solar radiation, wind speed, and relative humidity. K_C accounts for the effect of characteristics such as crop height, surface coverage, and albedo that distinguish a crop from the reference surface. In the specific case of this analysis the crop is sugar cane.
The green and blue WF for molasses production are estimated by equation 5.3 and 5.4.

$$WF^{Green}_{Molasses} = \beta \left(\alpha\ WF^{Green}_{Sugarcane}\right) \quad (5.3)$$

$$WF^{Blue}_{Molasses} = \beta \left(\alpha\ WF^{Blue}_{Sugarcane} + WF^{Industrial}_{B}\right) \quad (5.4)$$

where:

$$\alpha = \frac{q_2 p_2}{q_1 p_1 + q_2 p_2 + q_3 p_3}$$

$$\beta = \frac{1}{q_2}$$

with $q_1 p_1 + q_2 p_2 + q_3 p_3$ and $p_1 + p_2 + p_3$ respectively the conversion rates and the export prices ($/ton) of sugar, molasses and bagasse respectively;
The green and blue WF of ethanol are estimated using equation 5.5 and 5.6. Feedstocks in the specific case are molasses and cassava.

$$WF^{Green}_{Ethanol} = \gamma \left(WF^{Green}_{Feedstock}\right) \quad (5.5)$$

$$WF^{Blue}_{Ethanol} = \gamma \left(WF^{Blue}_{Feedstock} + WF^{Industrial}_{C}\right) \quad (5.6)$$

Where γ is the conversion factor for molasses into ethanol and $WF^{Industrial}_{C}$ is the water used per every ton of molasses used in the process of converting.