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Promotion of Climate Resilience in Rice and Maize

Thailand National Study

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ASSOCIATION OF SOUTHEAST ASIAN NATIONS (ASEAN) and the GERMAN-ASEAN PROGRAMME ON RESPONSE TO CLIMATE CHANGE (GAP-CC), DEUTSCHE GESELLSCHAFT FÜR INTERNATIONALE ZUSAMMENARBEIT (GIZ) GMBH. IN PARTNERSHIP WITH THE SOUTHEAST ASIAN REGIONAL CENTER FOR GRADUATE STUDY AND RESEARCH IN AGRICULTURE (SEARCA)

List of Acronyms

AFCC	ASEAN Multi-Sectoral Framework on Climate Change: Agriculture, Fisheries, and Forestry towards Food Security
AFET	Agricultural Futures Exchange in Thailand
AFSIS	ASEAN Food Security Information System
AMS	ASEAN Member States
ASEAN	Association of Southeast Asian Nations
AWD	Alternate Wetting and Drying
BAAC	Bank for Agriculture and Agricultural Cooperatives
CF	Continuous Flooding
CIAT	Centro International de Agricultura Tropical (International Center for Tropical Agriculture)
CIMMYT	International Maize and Wheat Improvement Center
CP	Charoen Pokphand
CRU	Climatic Research Unit
CSI	Consortium for Spatial Information
DIVA-GIS	DIVA – Geographic Information System
DOA	Department of Agriculture
FAO	Food and Agriculture Organization
FOB	Free on Board
GAP	Good Agricultural Practices
GCM	Global Climate Model
GHG	Greenhouse Gas
GIS	Geographic Information System
GISTDA	Geo-Informatics and Space Technology Development Agency
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
GMO	Genetically Modified Organisms
GMP	Good Manufacturing Practices
HRD	Human Resource Development
HYV	High-yielding Variety
IRRI	International Rice Research Institute
KDML	Khao Dawk Mali
MOF	Market Organization for Farmers
NESDB	National Economic and Social Development Board
OAE	Office of Agricultural Economics
OPV	Open Pollinated Varieties
PWO	Public Warehouse Organization
R&D	Research and Development
RD	Rice Department
RIICE	Remote Sensing-based Information and Insurance for Crops in Emerging Economies
SAR	Species-Area-Relationship
SEARCA	Southeast Asian Regional Center for Graduate Study and Research in Agriculture

Table of Contents

Table of Contents

List of Tables

List of Figures

Foreword

Climate change poses a serious threat to Thailand's agriculture sector in which its severity and occurrence becomes more intense and frequent compared in the past. Flood and drought, extreme and uncertain climate events, outbreak of pests and diseases are just some of the climate change related hazards that continue to impact Thailand. Climate variability introduces risks and uncertainty into the agricultural systems which is a major concern for marginalized smallholder farmers. In the promotion of climate resilience in rice, Thailand has identified three good practices, namely: crop calendar, Alternate Wetting and Drying (AWD) technique; and the Remote Sensing Based Information and Insurance for Crops in Emerging Economies (RIICE) technology using combination of Synthetic Aperture Radar (SAR) remote sensing and crop modeling for government policy intervention and crop insurance programme. Whereas for maize, two climate resilience good practices identified namely the establishment of maize seed villages in major maize producing areas and breeding for drought tolerant varieties.

Thailand through the Department of Agriculture, Ministry of Agriculture and Cooperatives hereby endorses the National Study on Climate Change Adaptation Good Practices for Rice and Maize/Cassava in Thailand for submission to the Senior Officials Meeting of the ASEANMinisters on Agriculture and Forestry (SOM-AMAF).

Dr. Suwit Chaikiattiyos
Deputy Director-General
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Ministry of Agriculture and Cooperatives

Executive Summary

In 2013, Thailand endorsed a project proposal entitled Production System Approach for Sustainable Productivity and Enhanced Resilience to Climate Change at the 8th Association of Southeast Asian Nations (ASEAN) Technical Working Group Meeting held in Singapore. The primary objective of the proposal is to promote food security through the sustainable and efficient use of land and water resources by minimizing the impacts of and contributions to climate change. This goal is in line with the ASEAN vision on food security as well as climate protection in agriculture and forestry within the ASEAN Member States (AMS), and cross-sectoral initiatives within the ASEAN cooperation framework. The German-ASEAN Programme on Response to Climate Change: Agriculture, Forestry, and Related Sectors supported the project and designated Thailand as the Lead Country. After the project proposal was further developed to make the scope more comprehensive, the title was changed to Promotion of Climate Resilience of Rice and Other Crops. Through the technical assistance of the Southeast Asian Regional Center for Graduate Study and Research in Agriculture (SEARCA), the project results will be synthesized to develop policy guidelines for ASEAN adoption.

This project is also related to other ASEAN subsidiary bodies, namely, the ASEAN Climate Change Initiative, an ASEAN comprehensive and cross-sectoral platform for coordination and cooperation; ASEAN Integrated Food Security Framework, a regional umbrella for food security-related initiatives, including emerging threats of climate change; and ASEAN Multi-Sectoral Framework on Climate Change: Agriculture, Fisheries, and Forestry towards Food Security (AFCC).

The project has three specific objectives:

(1) To promote common understanding and facilitate the exchange of experiences in climate change and agriculture, focusing on selected crops such as rice, maize, and cassava;
(2) To identify successful practices and policies at AMS level for tackling these climate change-related threats that can be promoted and scaled up; and
(3) To identify common concerns and capacity needs, and propose regional support strategies and instruments to address these coherently

Seven AMS are participating in the project: Cambodia, Indonesia, Lao PDR, Myanmar, the Philippines, Thailand, and Vietnam. This report, which is Thailand's contribution, covers rice and maize. These crops are two of the most important commodities in Thailand because they serve as staple food and major foreign exchange earners of the country.

This report reviews current statistics and cites previous research to capture the potential impacts of climate change on rice and maize production value chains. Ekasingh et al. (2004), in cooperation with the International Maize and Wheat Improvement Center (CIMMYT), compiled research data to complete the analysis of rice and corn production value chains in Thailand. The Office of Agricultural Economics (OAE), Centro International de Agricultura Tropical (CIAT), and Deutsche Gesselschaft fur Internationale Zusammenarbeit (GIZ) GmbH (2012) conducted a joint study on agriculture and climate change in Thailand. The study presented temperature and rainfall patterns in the four regions of the country, forecasted the temperature and rainfall scenarios for the next 10 years, and analyzed the vulnerability and suitability of rice and maize.

Potential regional collaborations could be developed from five research thrusts: (1) research network programs on climate change assessment, mitigation, and adaptation; (2) technology transfer; (3) human resource development (HRD) programs; (4) institutional support; and (5) ASEAN regional cooperation on climate resilience and food security.

The following good practices in promoting climate resilience were identified: for rice, (1) crop calendar, (2) alternate wetting and drying (AWD) technique, and (3) Remote sensing-based Information and Insurance for Crops in Emerging Economies (RIICE) technology using a combination of species-area-relationship (SAR) remote sensing and crop modeling for government policy intervention and crop insurance programs; and for maize, (1) establishing maize seed villages in major maize-producing areas and (2) breeding drought-tolerant varieties.

I. INTRODUCTION

Located at the center of the Southeast Asian peninsula, Thailand covers an area of 51.31 million hectares (ha). It borders Myanmar and Lao PDR to the north, Malaysia to the south, Lao PDR and Cambodia to the east, and Myanmar to the west. The four major regions have different geographic features: (1) the mountainous northern region is the forest area of the country; (2) the northeastern region, where the major crops are non-irrigated rice, sugarcane, and cassava, occupies approximately one third of the whole country area; (3) the central region, which is the major area for irrigated rice production, is dominated by the Chao Phraya River basin; and (4) the southern region, where the major crops are rubber and oil palm, has a tropical rainforest climate.

Situated in the tropical monsoon climate zone, Thailand has two distinct seasons: the rainy season from May to October and the dry season from November to April. The average minimum and maximum temperatures are about 12°C and 40°C, respectively. The average annual rainfall is 1,540 millimeters (mm) in the northern region; 1,627 mm in the northeastern region; 1,574 mm in the central region; and 2,669 mm in the southern region (Luanmanee and Lertna 2013).

Thailand's total area is 51.31 million ha, of which about 40 percent is allocated to crop production. Rice, maize, cassava, sugarcane, and palm oil are the most important crops grown in the country. In 2001–2007, rice constituted nearly 60 percent of the total cultivated area. Other grains and upland crops, tree crops, and vegetables accounted for 20.84 percent, 19.31 percent, and 0.32 percent, respectively. Crop structure had adjusted slightly due to a declining trend in rice area and an increasing trend in tree crop areas because of better net returns compared to rice. The share of upland crops increased during the 1980s due to high production cost and low output price (Isvilanonda and Bunyasiri 2009).

II. VALUE CHAIN MAPPING

2.1 Rice

According to Luanmanee and Lertna (2013), rice cultivation in Thailand is divided into two groups: non-irrigated and irrigated. Rice cultivation in the northeastern region is under rainfed conditions wherein rice is cultivated once a year. After harvesting rice, some farmers leave the paddy field for grazing. This differs from the paddy field in the irrigation system of the central region wherein rice is cultivated with about five crops within two years. The farmers' common practice is to burn the rice straw to shorten the time for soil preparation. It was estimated that the rice straw burning area was about 7.90 million ha. Burning rice straw causes carbon dioxide emission and ecosystem imbalance.

2.1.1 Rice Production Area, Harvested Area, Production Volume, and Yield per Rai

Data on the planted area, harvested area, production volume, and yield per rai for rice were presented in the Agricultural Statistics of Thailand 2013 (OAE 2013) (Table 1).

The two major rice cropping seasons are major rice and second rice (Yoovatana 2013). The production areas and volume for both cropping seasons were higher in 2013 than in 2005. In 2013, the country's total planted area for major rice was 64.99 million rais, whereas the harvested area was 61.37 million rais. The production volume was 28.02 million tons (t) at the country's average yield of 457 kilograms (kg) per rai. Comparing rice production by region, the northeastern region had the highest planted area at 39.43 million rais. The planted area in the northern, central, and southern regions was 14.99 million rais, 9.60 million rais, and 0.96 million rais, respectively. The harvested area had a similar trend: 36.52 million rais in the northeastern region, 14.66 million rais in the northern region, 9.24 million rais in the central region, and 0.94 million rais in the southern region.

Table 1. Major rice and second rice production

Region	Planted area (million rais)		Harvested area (million rais)		Production volume (million t)		Yield per rai (kg/rai)	
	2005	2013	2005	2013	2005	2013	2005	2013
Major rice								
Country Total	53.39	64.99	53.89	61.37	23.31	28.02	433	457
North	12.78	14.99	11.98	14.66	6.61	8.66	552	591
Northeast	32.77	39.43	30.71	36.52	10.38	13.19	338	361
Central	9.80	9.60	9.31	9.24	5.52	5.73	592	620
South	2.02	0.96	1.89	0.94	0.81	0.44	592	471
Second Rice								
Country Total	12.80	16.09	12.79	15.96	8.79	10.77	687	674
North	4.48	7.09	4.47	7.59	3.06	4.75	685	675
Northeast	1.26	1.68	1.26	1.62	0.69	0.84	543	514
Central	6.73	6.91	6.72	6.9	4.88	4.96	725	719
South	0.34	0.40	0.34	0.39	0.17	0.22	502	549

The second rice production was higher in 2013 than in 2005 (OAE 2013). In 2013, the country's total planted area for second rice was 16.09 million rais, whereas the harvested area was 15.96 million rais. The production volume was 10.77 million t at the country's average yield of 674 kg/rai, which was higher than the production volume of major rice.

The ASEAN Food Security Information System (AFSIS) (2014) reported that for Thailand, the increase in harvested area had compensated for the reduction in yield. In 2014, the country's ratio of production (25,080,125 t) to domestic utilization (10,905,583 t) was 229.98 percent, which was the highest in the ASEAN region. This indicates that Thailand is rice-sufficient. The country carried 24.33 million t or about 70 percent of the total ASEAN stock.

2.1.2 Damaged Area

In June 2014, AFSIS reported that in Thailand, the total damaged area was 669,861 ha (AFSIS 2014). This was caused by flooding (145,164 ha), droughts (348,729 ha), pests (68,066 ha), diseases (94,202 ha), and other factors (13,700 ha).

2.1.3 Production Cost

In 2010–2011, the farmers' production cost was THB 3,929/rai or THB 8,908/t. During the wet cropping season in 2010–2011, the production cost was THB 3,687/rai or THB 9,359/t. During the dry cropping season in 2010–2011, the production cost was THB 4,899/rai or THB 7,776/t (OAE 2011).

2.1.4 Farm Price

The price of paddy with 5 percent moisture content for major rice was THB 7,078/t in 2005 and THB 10,187/t in 2012–2013. The farm value for major rice was THB 168,570 million in 2005 and THB 285,457 million in 2012–2013. For second rice, the price was THB 6,617/t in 2005 and THB 9,764/t in 2012–2013, with farm value recorded at THB 39.42 million in 2005 and THB 105.12 million in 2012–2013 (OAE 2013). The average price for rice in 2014 was USD 422/t, which was slightly lower than the 2013 average (AFSIS 2014).

2.1.5 Rice Farmer Households

In 2009–2010, the total number of rice farmer households was 3,717,360. A total of 836,814 households (22.51%) had an average land holding of 15.47 rais and a rice production area of 10–20 rais; 61,097 households (1.64%) had a rice production area of less than 2 rais; and 8,745 households (0.23%) had a rice production area of more than 100 rais. During the dry cropping season in 2010, the total number of rice farmer households was 665,845. The average land holding per household was 22.86 rais. A total of 136,748 households (20.54%) had a rice production area of 6–10 rais, while 7,766 households (1.17%) had a rice production area of more than 100 rais (OAE 2010).

2.1.6 Rice Value Chain

The major rice cropping season is from May to October, while the second rice cropping season is from November to March, with some delays in the southern region. The major rice, which is planted during the rainy season, usually consists of photosensitive varieties like Khao Dawk Mali (KDML), glutinous, and non-glutinous. The second rice is planted mostly in irrigated lowland areas.

Thailand is one of the leading rice exporters in the world. Its major export destinations are Asia (to Indonesia, Malaysia, the Philippines, Singapore, China, Hong Kong, and Japan), the Middle East (to the Islamic Republic of Iran and Iraq), Africa (to Nigeria, Senegal, and South Africa), and the USA. High-quality rice (e.g., KDML) is exported to Hong Kong, Singapore, Malaysia, the Islamic Republic of Iran, Dubai, and the USA, while middle-quality rice is exported to China and other countries (Yoovatana 2013).

Agrifood Consulting International (2005) created a value chain for rice distribution, which has five major channels. Farmers can either mill their own produce at the local village mill for their own consumption, wherein the husk, bran and broken rice are kept by the mill as payment for the rice milling services. They may also sell the paddies to the primary collectors in the local town or if there are enough surplus paddy, they can sell directly to the central market exchange or to commercial rice mills. In turn, the commercial rice mills can receive paddy from primary collectors, the central market exchange, or the farmers themselves. The value chain for rice in Thailand is presented in Figure 1.

The value chain matrix for the rice crop system is presented in Table 2.

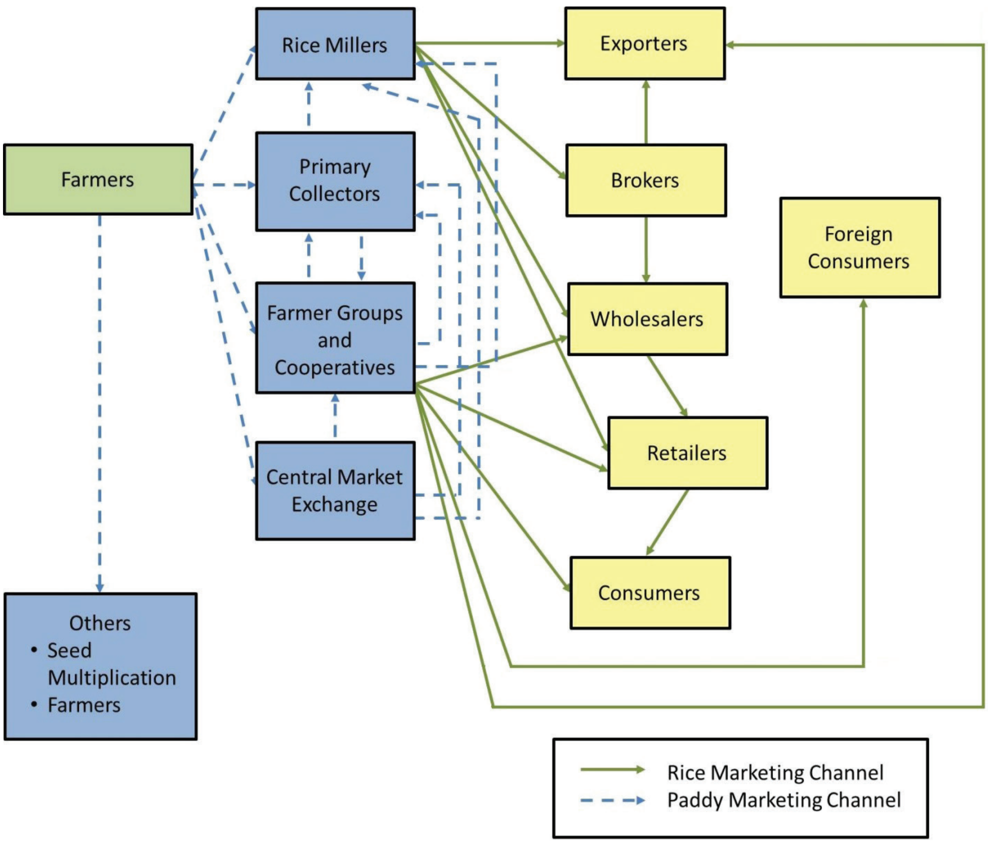

Figure 1. Rice value chain in Thailand.
Source: Agrifood Consulting International (2005)

Table 2. Rice value chain matrix

Production system	Wetland/ lowland rice	• With developed irrigated systems • Follow good agricultural practices (GAPs) for rainfed lowlands in the northeastern region with clay soil, which is planted to the photo-period-sensitive varieties and need fertilizing twice. The first time is for 125 kg/ha of fertilizer (16-20-0, 18-22-0, or 20-20-0) one day before casting or 15–20 days after casting. The second time is for 30 kg/ha of 46-0-0 fertilizer or 62 kg/ha of 21-0-0 fertilizer at the beginning of flowering or 30 days before flowering. Combining chemical fertilizer and manure is good for growing rice. Using 3 t/ha of manure 15-20 days before planting rice is a recommended GAP (Ekasingh et al. 2004).
	Glutinous rice	• In the northeastern and northern region • Some of the photo-period-sensitive varieties (e.g., the glutinous Kor Khor 6 and Sanpatong rice) can be planted in the northeastern region • RD6, the improved glutinous variety that was released in 1978, could give a higher yield (sown in 83% of the total glutinous area) (Ekasingh et al. 2004)
	Rainfed/ upland rice	• Ekasingh et al. 1999 mentioned that rainfed/upland rice has the following features: - Entirely dependent on rainfall and the mountainous area of the north and northeastern regions - Natural day length or photo-period affects rice growth - Photosensitive varieties (e.g., Kor Khor 15 and KDML 105) can be planted in the northeastern region - Small farms at an average size of less than 4 ha - Dual production system: 1) Subsistence rice farmers (60% of households) produce rainfed glutinous rice for home consumption and localized sales 2) With irrigation facilities producing non-glutinous varieties destined for urban and export markets
	Floating rice	• Grown in areas with floodwaters up to 2 meters deep (Ekasingh et al. 2007)
Production technologies	Land and seed preparation	• Land preparation and seed preparation are done simultaneously
	Plowing	• Using either traditional animal-powered wooden ploughs or two- or four-wheeled tractors
	Casting	• Immediately after plowing, rice seedlings that are prepared in a separate field are transferred to the plowed field. Hand casting by experienced farmers is preferred so that even rows will be produced. The rice sprouts will mature to young plants in a few days. Water is then drained into the field until its level reaches that of the lowest leaves on the rice plant. The water level must not exceed a height of 2–3 centimeters.
	Resting	• For the next 3–4 months, rice plants will be left to grow into paddy and turn light brown in color. In the meantime, the rice field remains flooded.
	Draining	• Once the rice paddy turns light brown, water is drained and the field is left to dry. After the drained field is completely dry and the plant turns hay in color, the paddy is harvested
	Harvesting	• Harvesting is done by sickle or machine

cont...Table 2.

Rice production cost and profit		• Ekasingh et al. (2004) cited that for major rice and second rice, approximately 85 percent of the total cost was variable costs. Labor cost accounted for approximately 67 percent of the total cost for major season rice, but only 43 percent for second season rice. Other important costs were on materials, including seed, fertilizer, and pesticide. These costs were higher for second season rice (about 38% of total cost) than major rice (about 18% of total cost) due to the higher cost in seed, fertilizer, pesticide, and fuel.
Rice processing		• Rice milling is the most common and important value addition process for rice. It could be a one- or two-step process, or a multi-stage process. In the one-step milling process, the husk and bran are removed in one pass and milled (i.e., white rice is produced directly). In the two-step process, the husk and bran are removed separately (i.e., brown rice is produced immediately). In the multi-stage process, rice undergoes several different processing steps (IRRI 2006). • Rice grading is usually performed at the mills, and it uses a minimum of broken kernels as a major grading standard (Ammar and Viroj 1990). • IRRI reported that most rice varieties are composed of roughly 20 percent rice hull, 11 percent bran layers, and 69 percent starchy endosperm, also referred to as the total milled rice. Total milled rice contains whole grains or head rice, and brokens. The by-products in rice milling are rice hull, rice germ, bran layers, and fine brokens (IRRI 2006). • Value-added rice-based products are used for domestic consumption and export. Products included in this category are non- glutinous flour, glutinous rice flour, rice noodles, rice cracker (crisp bread), and rice paper.
Rice marketing	Market Intermedi-aries	• A review of the literature reveals that there are two rice marketing channels: the paddy rice markets and milled rice markets. At the local market, intermediaries include the local buyers or assemblers, cooperatives, farmers groups, central markets, millers, wholesalers, and retailers. At the regional level, the major intermediaries are more of large-scale assembling market centers and large millers. At the country level, intermediaries include commission agents, wholesalers, and exporters. • The paddy collectors can be divided into two groups: (1) village collectors who do not have storage facilities, and (2) district and provincial collectors who have their own (larger) storage facilities. They are located close to the farmers in sub-provinces and facilitate the transaction by providing transport (e.g., a pick-up truck or a six-wheeled truck) to collect paddy from farmers (NESDB 2005). • Aree and Yaowares (2001) reported two types of farmers' organizations: farmers' groups and agricultural cooperatives. A farmers' group is composed of at least 30 farmers who form an operational unit, undertake the marketing activities, hiring or acquiring facilities, raising bargaining power by acting together, performing financial transactions, purchasing and operating transport vehicles and equipment, and providing storage. In addition, they sell directly their paddy rice to rice mills. • Furthermore, Aree and Yaowares (2001) reported that central paddy rice markets serve as a meeting place for assemblers and millers to interact, negotiate, and transact. Facilities provided can include labor, moisture gauges, drying yards, warehouses, and loans, depending on the size of the market centers. A large central market owner usually refrains from trading to avoid price interference, preferring to earn fees, rent, and interest from loans. The market owners are sometimes assemblers and/or millers. Central paddy rice markets are either set up by private entrepreneurs or by government agencies. Three market centers set up by the BAAC are located in three major rice production areas in the northern, northeastern, and central regions.

cont...Table 2.

Rice marketing	Market Intermediaries	The other 176 sub-district paddy rice centers belong to the Department of Agricultural Extension, Ministry of Agriculture and Cooperatives. • Pornsiri (2004) mentioned that in 2002, 71 central paddy rice markets (38, 14, and 18 in the northern, northeastern, and central regions, respectively) that were set up by the private sector received support from the Ministry of Commerce in their establishment and management. • Ekasingh et al. (2004) cited that rice grading is usually performed at the mills. A Rice Standard Regulation had been promulgated to enforce the grading system. Inspection is compulsory for exports. In keeping with rice standard regulations, rice must be graded and inspected before it can be exported. Inspection is carried out at mills or riverside warehouses before ship loading by the semi-official Rice Inspection Committee, Board of Trade. Millers also play important roles in price transmission. They are intermediaries who have good connections about rice prices, gathering information from brokers, exporters, and among themselves to calculate the purchase and sale prices for paddy rice. The price information from millers and other sources (e.g., brokers and exporters) also helps to set the prices for rice in the rice market. • Kasetsart University (1997) reported that wholesalers in the provinces far from Bangkok normally contact millers directly. The wholesaler's business size is measured by the monthly sales volume. Small wholesalers have a sale volume of less than 500 t/month, while medium wholesalers have a volume of 500–1,000 t/month. Large wholesalers have a sale volume in excess of 1,000 T/month. On the wholesale market, rice is traded in sacks and packages of 2 kg or 5 kg. • Ekasingh et al. (2004) mentioned that the broker's main function is to build marketing connections between rice exporters or wholesalers and millers. The broker searches for certain types or qualities of rice and quantities to meet the demand of exporters. Except for a few large ones, most millers sell rice to wholesalers and exporters through brokers. The brokerage fee is 2–3 percent of the sale value. • NESDB (2005) mentioned that many exporters in Thailand have their own mills. The exporter collects rice from commission agents or directly from mills. Exporters without milling plants depend on brokers to guarantee an adequate supply of specified rice. • The Ministry of Commerce issued the Rice Trading Act B.E. 2489, which requires every exporter to be registered. The majority of exports are handled by the private sector, with only around 5 percent of exports being carried out by the government (NESDB 2005).
	Marketing chains	• Ekasingh et al. (2004) reported two major marketing channels: subsistence and marketed production. Of the paddy available after deducting losses, animal feed use, and seed uses, about one fifth was retained by the farmers for their own consumption and four fifths was marketed commercially. The farmers directly milled their on-farm paddy consumption from village mills or small commercial mills. Given an estimated recovery rate of 65 percent for village mills, approximately 1.1 million t of milled rice was for on-farm rice consumption. On the other hand, about 6.8 million t of paddy rice was available for private and cooperative milling. Paddy sales were as follows: 15 percent to primary collectors, about 5 percent through the central markets, about 50 percent from farmers to millers, and about 30 percent from cooperative farmers to their mills. Using a recovery rate of 65 percent, about 6.8 million t of paddy rice amounted to 4.4 million t of milled rice.

cont...Table 2.

Rice Marketing	Marketing chains	• NESDB (2005) reported that there are different channels for domestic market and export market. The milled rice for the domestic channel is marketed to traders, direct sales to retailers, and wholesalers. There are various markets for by-products. Of the rice produced in the northeastern region, about one quarter goes into the regional market for retail sales (90%) and for further processing (10%). The remainder goes through traders and wholesalers to markets outside the region. Approximately 10 percent is shipped to southern retail markets, about one third is used for domestic consumption in Bangkok and surrounding areas, and one third is exported.
	Marketing cost and margins	• Rabobank (2003) reported that the costs and margins in the rice production and marketing chain usually vary due to a number of factors, including climate change, drought, flooding, quality of paddy, yield, national production, and competition in the export market. • NESDB (2005) reported that for the KDML 105 market, millers, retailers, and exporters obtained the largest value chain of marketing margin (defined as the percentage of the final selling price). When considering the total profit (calculated as the difference between total revenue and total costs) for the KDML 105 export market, millers received the largest share of total profit, while exporters and collectors accrued approximately the same share. However, the size of the benefits accruing to the millers, collectors, and exporters varies with changes in farmer shares. This is similar for KDML 105 sold in the domestic market. The only difference is that retailers in the domestic market have higher profit shares than collectors. • NESDB (2005) also reported about the marketing margins and total benefits in the glutinous rice value chain. Millers and retailers received the largest marketing margins. Farmers accrued the largest share of total profit, followed by millers and retailers. These results demonstrate that stakeholders further downstream tend to be better protected in their profit margins against changes in prices, whereas farmers absorb much of the price changes. The relatively stable returns to glutinous rice (compared to KDML 105 and non-glutinous rice) for farmers could explain the popularity of glutinous rice production in the northeastern region.
	Rice exports/ imports	• White rice and parboiled rice are two of Thailand's major exports in the world market. Thailand exports mostly to Asia, Africa, and the Middle East. Other important regions include Europe, the USA, and Oceania (Department of Internal Trade 2006). • The Rice Exporters Association of Thailand (2006) cited that rice for export consists of several types, and each type is divided into "whole" or "head" and "broken" rice. Both the "head" and "broken" labels are classified into different grades. The types of rice include white rice, glutinous rice, cargo rice, parboiled rice, and rice n.e.s. (not else-where specified). Market share for high quality rice-white non-glutinous rice was 100 percent, and 5 percent and 15 percent made up over 52 percent of the total rice export volume. • The OAE (2005) reported that the decline in the significance of the Asian market may be attributed to the increase in regional competition from other major rice-producing countries such as Vietnam and China. Meanwhile, the African market remains a very promising market outlet for Thailand, given its large population, high consumption, and restrictions on rice production. Exports to the USA are thriving well in the region, since rice production in the USA is increasing and prices are more competitive. KDML 105 comprised about 22 percent of the total export volume.

cont...Table 2.

Rice Marketing	Rice exports/ imports	• NESDB (2005) reported that glutinous rice amounted to only 4 percent of exports, providing only a small market for the 40 percent of farmers in the northeastern region that are planting KDML 105. • The OAE (2005) reported that besides rice, rice-based products also are exported. The leading rice-based product that accounts for 36 percent of total exports in terms of value is the rice cracker. Japan is the major importer of rice crackers, accounting for 40 percent of Thailand's rice cracker export value. This is attributed to the increasing Japanese snack market and Japanese consumption preferences. The other important importers are Australia, the USA, and the Netherlands (Rabobank 2003). • AFSIS (2014) reported that in the ASEAN region, Thailand exports to Brunei Darussalam (18,237 t), Cambodia (1,089 t), Indonesia (36,393 t), Lao PDR (3,442 t), Malaysia (115,855 t), Myanmar (281 t), the Philippines (55,671 t), Singapore (31,964 t) and Vietnam (933 t). Thailand also imports rice from Cambodia (90 t), Lao PDR (0.10 t), Malaysia (0.001 t), Myanmar (0.08 t), and Vietnam (192 t).

2.1.7 Price Support and Trade Policies

Yoovatana (2013) cited that rice exports are operated under sales arrangements, which comprise 90 percent of the export volumes. Inter-governmental arrangements comprise the remaining 10 percent. The government of Thailand has trade agreements with several countries under different terms such as loans, barter trade, and foreign trade. Various policies that apply to rice, in light of its importance in the national economy, include measures to stabilize market and supply, increase production efficiency, target the niche market, enhance competitiveness and value addition, and improve the trading system. Most of the production promotion policies, including general government services referred to in the previous section, apply to rice. In addition, policies to support the rice trade are also implemented. These include advance exports, loan provision, paddy pooling, monetary support provision for paddy traders and millers, purchase of milled rice, government to government rice export, and support for high-quality milled rice, among others.

According to Kajonwan (1999), the producers usually get a low price in rice harvesting and selling because of large supplies. Therefore, the government uses the Public Warehouse Organization (PWO), rice buffer stock, paddy mortgage program, and consumer subsidy program to intervene in the market. The PWO, which was established in 1955, aims to collect farm paddy right after the harvesting period. The Market Organization for Farmers (MOF), which was set up in 1974 as a center for farm commodity transactions, is mandated with price support programs from year to year in place of the PWO. In 1976, the MOF began undertaking the paddy price support program. In its purchase program, it paid local prices that could not exceed the prices set by the Farm Price Stabilization Committee, while a standard maximum price was determined. This price support program failed and gave way to the rice buffer stock program. The milled rice buffer stock was generated to raise paddy prices. Rice stocks were set up in the export market and in the central markets of the producing regions to assemble the rice buffer stock as determined. Some parts of the rice buffer stock were released to the market, which led to lower consumer price during the short market supply. The production supply price remained stable throughout the year.

The government of Thailand has been allowing the market to determine rice price since the early 1980s (Kajisa and Akiyama 2003). It offered the paddy price support program to the producers until 1983, during which it was transformed into the paddy mortgage program. In implementing the mortgage program, the Bank for Agriculture and Agricultural Cooperatives (BAAC) was asked to defer farm debt payments to develop the farmers' ability to store their paddy for sale at a later date and for a better price. As such, the producers who wanted to do so could haul their paddy to the PWO storage, where the paddy owners had to pay the charge in the course of mortgaging their harvests with BAAC. Another condition imposed was that the paddy mortgages must be redeemed on or before the deadline. Otherwise, the mortgage ownership will fall under BAAC, which will be eligible to trade it to pay for the outstanding debt.

Initially, only a few farmers were interested in the program. Improvements and additional conditions, including allowing farmers to store their paddy rice in their own farms to reduce cost, reducing the interest charge on the mortgage loan, and raising the initial payment from 80 percent to 90 percent of the paddy price estimate, were imposed to encourage more farmers to participate in the scheme. More farmers joined the program after such changes were implemented. This policy intervention also influenced the prices that the farmers received through the higher market price of the fragrant paddy.

The packing credit, which began in 1975, is another form of rice export support to help expand export volume at low cost. It serves as a low-interest export subsidy for rice exporters. This program continues to be a good policy instrument for rice market expansion.

2.1.8 Research and Extension

In the past, rice research in Thailand focused on improving rice quality, particularly grain length and cooking quality. The objective of rice research changed during the mid-1960s after the International Rice Research Institute (IRRI) released IR8. Called the "miracle rice," IR8 captured the attention of rice growers in tropical Asia. It increased the rice output of many importing countries and reduced their import demand (Suthad 1996).

In 1966, the Rice Department (RD) produced RD1 or Kor Khor 1 by breeding IR8 with the local Thai variety Leuan Tawng. RD1 was the first non-photo-period-sensitive rice variety in Thailand to be used in irrigated areas. Its yield was 50 percent higher than traditional varieties (Suthad 1996). The subsequent varieties, such as Kor Khor 7, Kor Khor 15, and Kor Khor 23, were developed and became dominant in the irrigated areas in the country (DOA 2002). These high-yielding varieties (HYVs) increase rice quantity in the market, but most of their outputs are not consumed domestically. They are either used to make parboil rice for export or exported as lower-quality rice when prices are not attractive.

In the 1980s, the decline in the international rice price pressured the Thai export market, especially since Vietnam was emerging as a major rice exporter (Suthad 1996). There was a substantial drop in the international market price of lower-quality rice. In contrast, the price of higher-quality rice showed an upward trend. This had triggered the former Rice Research Institute of the Department of Agriculture (DOA), which is directly involved in rice research, to revive its research efforts on rice quality. The subsequent quality varieties, such as Kor Khor 6 and Kor Khor 15, which were bred from the local variety KDML 105, became the commercial rice varieties in Thailand, including the northeastern region. There were low adoption rates of HYVs in the northeastern region because HYVs require good water control, fertilizers, and chemicals. More importantly, HYVs did not taste as good as traditional varieties like KDML 105. Farmers in the northeastern region gradually transferred to some HYVs (e.g., Kor Khor 6, Kor Khor 8, Kor Khor 15, and KDML 105) because of the government extension and promotion program.

Established in 2006, RD is mandated to conduct research not only on increasing rice productivity through breeding and improving cultural practices, but also on promoting rice value addition by developing rice-based products.

2.1.9 Rice Strategic Plan

According to Luanmanee and Lertna (2013), the government of Thailand has a zoning policy for some economic crops such as rice. It plans to adjust rice production in irrigated areas to less than two crops a year by urging the farmers to adopt a rotation system in their paddy field. Implementing an inter-cropping system is more advantageous than intensive rice cultivation. It is a way to maintain ecosystem balance and disrupt the life cycle of insects and pathogens. Soil fertility will also improve if rice is grown in rotation with legumes. In addition, the government plans to run green agricultural production, which is less harmful to ecosystems, by reducing the burning of rice straw and other residue through prohibition, regulation, or promotion of compost production.

The Thai Rice Exporters Association (2014) reported measures that will be implemented by Prime Minister Prayut Chan-o-cha to help rice farmers. Such measures, including farmland development and advanced planning through inter-agency cooperation, will be carried out as part of long-term efforts to help protect farmers from the continuing low price of rice. The Interior Ministry will further examine farm zoning, which is still on the agenda. The key policies to address the issue include developing land in major river basins into farmland instead of factories or other industries. The focus will be on utilizing less farmland and water while increasing productivity.

OAE (2014) provided the rice strategic plan under three strategic thrusts: research and development (R&D), improving productivity and products development, and capacity-building for farmers (Table 3).

Table 3. Rice strategic plan, 2012–2017

Strategic Thrust	Strategies
Research and development (R&D)	• Conduct research driven by the stakeholders' needs • Accelerate R&D to improve rice productivity and value addition for rice, products, and farmers • Promote integrated multi-sectoral approach and commercial research • Research networking among related agencies and international research collaborations • Develop a new generation of rice farmers • Enhance research efficiency through new technologies and exchange of scientists • Establish a national rice R&D center to serve as the research center for rice and products • Establish an R&D foundation to support Thai rice R&D • Provide incentives to motivate rice researchers to produce quality research • Promote and support the dissemination and publication of innovative research
Improve productivity and products development	• Establish a production plan and rice zoning base on the suitability of the area, and establish the rice production system through stakeholder participation • Promote rice production following GAPs for rice, complete cycle rice production, organic and safe rice, non-genetically modified organisms (GMOs), and adoption of good management practices (GMPs) • Promote and support rice value addition, the Thai niche market, and networking among operators, consumers, and producers; and establish geographic indicators • Improve logistics management of rice and products • Promote the use of technologies in the production of rice and its products, and support the development of rice mechanization, including improving efficiency in the farmers' technology transfer and knowledge management • Develop the production and distribution systems of rice seeds, and set up a mechanism for the certification of rice seeds • Improve efficiency in quality inspection and certification for rice and products to meet international standards • Develop early warning systems for natural calamities, and enhance institutional capacity to control and eradicate the outbreak and infestation of pests and diseases • Expand and improve irrigation systems, agrarian reform, and rehabilitation of rice cultivated areas • Disseminate information and publicize efforts to improve awareness on the value of rice and its products
Capacity-building for farmers	• Establish networks and transfer of technologies for production and production management among government agencies and farmers, and between public agencies and farmers, and encourage the participation of farmer-leaders to serve as resource persons for the farmers • Develop a new generation of rice farmers to lead community change and promote farming to the next generations • Promote and support the establishment of a community rice center to serve as a center for rice production • Develop and build the competitiveness of farmers and farmer organizations • Establish the welfare of rice farmers through a foundation • Develop a system for farmer's registration and usability • Promote income guarantees and rice disaster insurance funds • Promote rice production for food security and livelihood development of farmers • Conserve and promote Thai rice culture and traditional knowledge • Improve mechanisms and promote services to farmers by developing one-stop farmers' service centers and rice community centers, and a modern management information system

Source: OAE (2014)

2.2 Maize

Economically, growing maize is as important as growing rice. Maize (Zea mays L.) is not a native crop; it was first domesticated in Central America at least 4,000 years ago. Growing maize in Thailand gained popularity in the 1960s when the country was developing rapidly. Given limited lowland areas for paddies, Thai farmers moved to the uplands and cleared the forests to grow cash crops like cassava and maize, which can thrive on relatively poor soils. Maize production continued steadily over the years, although available land in the uplands and highlands had become increasingly limited.

Portuguese traders introduced maize to Thailand more than 400 years ago (Falvey 2000). Planted in the uplands and highlands, it was only used for home consumption and household animal feed (Ekasingh et. al. 2004). Kasetsart University, the Rockefeller Foundation, and CIMMYT started long-term breeding programs in the early 1970s. In 1975, they successfully released an improved open pollinated variety (OPV) of maize called Suwan 1. Suwan 1, which was developed from 36 maize varieties from international germplasm collections, was resistant to downy mildew. It spread rapidly in the Thai uplands, particularly in the northeastern region, because it was easy to grow as well as tolerant to droughts and dry climate (Ekasingh, Phrek, and Kuson 1999).

Maize can be planted twice a year, during the early rainfall season or the late rainfall season (Luanmanee and Lertna 2013). The early rainfall season is at risk of droughts, but the farmers can plant two crops a year. Maize, sorghum, mungbean, sesame, and sunflower are optional choices for the second crop. As with rice and sugarcane cultivation, the farmers will most likely use a machine for harvesting. After harvesting the maize stalk, the farmland will be burned to accelerate land preparation for the second crop. This causes carbon dioxide emission as well as loss of moisture and soil nutrients.

2.2.1 Maize Production Area, Harvested Area, Production Value, and Yield per Rai

Data on the planted area, harvested area, production volume, and yield per rai for maize were presented in the Agricultural Statistics of Thailand 2013 (OAE 2013) (Table 4). The production area and volume for both crops were higher in 2013 than in 2009. In 2013, the country's total planted area for maize was 7.64 million rais, whereas the harvested area was 7.16 million rais. The production volume was 5.06 million t at the country's average yield of 707 kg/rai. The northern, northeastern, and central regions are the three major maize-producing areas in Thailand. Comparing maize production by region, the northern region had the highest planted area at 5.09 million rais. The planted area in the northeastern and central regions was 1.74 million rais and 0.71 million rais, respectively. The harvested area was 4.87 million rais in the northern region, 1.61 million rais in the northeastern region, and 0.68 million rais in the central region. The production volume was highest in the northern region at 3.34 million t. The northeastern region produced 1.25 million t, while the central region produced 0.47 million t. The average yield per rai was 691 kg/rai in the northern region, 761 kg/rai in the northeastern region, and 694 kg/rai in the central region.

Table 4. Maize production

Region	Planted area (million rais)		Harvested area (million rais)		Production volume (million t)		Yield per rai (kg/rai)	
	2009	2013	2009	2013	2009	2013	2009	2013
Country Total	7.09	7.64	6.91	7.16	4.62	5.06	668	707
North	4.43	5.09	4.33	4.87	2.98	3.34	689	691
Northeast	1.68	1.74	1.62	1.61	1.00	1.25	621	761
Central	0.99	0.71	0.96	0.68	0.63	0.47	657	694

Source: OAE (2013)
Note: 1 ha = 6.25 rais

According to AFSIS (2014), the increase in maize production in Thailand is due to the increase in yield while the planted area decreased. The country's ratio of maize production (5,061,133 t) to domestic utilization (4,716,029 t) is 107.32 percent, which is at the border line of self-sufficiency.

2.2.2 Damaged Area

In 2004, AFSIS reported that the total damaged area was 53,617 ha. This was caused by droughts (28,056 ha) and diseases (25,561 ha).

2.2.3 Maize Value Chain

Yoovatana (2013) reported that maize production remains at about 4 million t, with some ups and downs over time. Since 1990, the planted area has been declining at about 2 percent per year, while the average yield has been increasing at a similar rate. In Thailand, maize consumers include the livestock industry and other livestock-related industries. About 95 percent of the total local production is used by the livestock industry, and only 5 percent is used for cooking oil and as planting material. Maize-related marketing problems include low prices, which are being dictated by processing mills during the harvesting season; lack of storage facilities, which poses the risk of aflatoxin contamination; limited foreign market access, which is caused by the low quality of harvest; and high transportation cost.

The value chain matrix for the maize crop system is presented in Table 5.

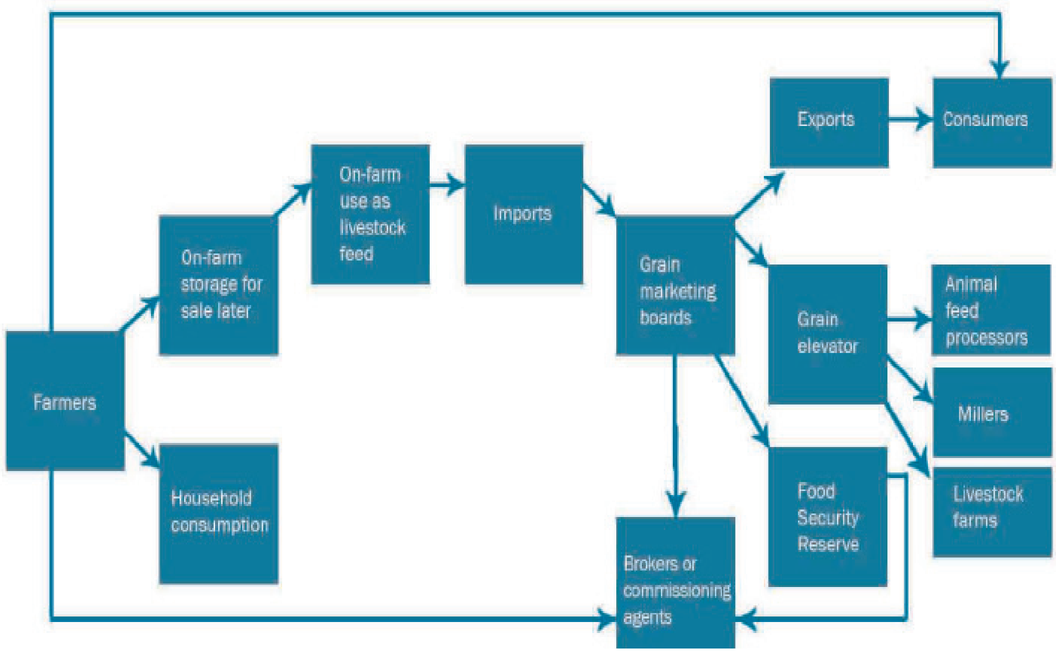

Figure 2. Maize value chain in Thailand.
Source: FAO (2014)

Table 5. Maize value chain matrix

Production system		• There are two cropping seasons for maize: (1) early rainy season during March–May, and (2) end of the rainy season to the start of the dry season during October–December. • The center of maize production in Thailand has been the northern and central regions. Maize areas and production in the northeastern region have been about one fourth of the total maize areas and production in the country. • All maize cropping systems are mostly rainfed. The amount of rain in these growing areas is about 966–1298 mm/year depending on year and location. • Ekasingh, Phrek, and Kuson (2003) reported that the farmers in the northeastern region enjoy relatively larger farms than the farmers in other regions. The maize farmers in Dan Sai, Loei, who farm in relatively high sloping areas, had an average of 6–8 ha of maize per household. They owned 63–100 percent of the land and rented the rest. The farmers in more moderate sloping areas (in Loei and Nakhon Ratchasima) had an average of 6 ha. They owned 50–100 percent of the land. The large farmers in Pak Chong, Nakhon Ratchasima had an average of 26 ha of maize per farm. They owned 24 percent of the land and rented 76 percent. The large farmers were highly mechanized.
Production technology		• Most maize fields are in the uplands. The farmers start planting maize early in the rainy season in April, as soon as the first rainfall, or in May or June. Planting maize is largely the women's task. In, February and March, much labor is invested in burning, tilling, or ploughing the fields. The burning of dry weeds and the remaining leaves and stalks of a previous harvest is one of the major sources of carbon dioxide emission. Growing corn the traditional way may not be the answer to countering the problem of the earth's GHGs. • Farmers spray herbicides to kill weeds that compete for nutrients. Regular weeding of the fields is also required. Traditionally, this is the most labor- intensive part of the maize cycle. Harvest time is in September and October. The maize are simply broken off from the stalks and collected in bags. The small farmers may carry a large part of their harvest to their homes, where the cobs are hung under the roof or in barns, to allow the kernels to dry. • Starting 1975–1980, private companies were increasingly investing in research on maize. By 1988, private hybrid maize varieties were released and sold in the market. The most popular hybrid maize varieties during the 1990s were the CP-DK 888 varieties, which were first released in 1991. Since then, hybrid maize varieties, with their high yield, have been popular among farmers (Ekasingh, Phrek, and Kuson 1999). The farmers were switching to hybrid maize varieties, mostly produced and sold by private companies. By 1997, only 4.7 percent of all maize areas were under public-sector hybrids and OPV (OAE 1997).
	Seeds	• Ekasingh, Phrek, and Kuson (2003) reported that maize farmers are now commercialized, although their modes of production are quite varied if they are large or small farmers. The so-called green revolution technologies, as products of research, were welcomed by farmers who were willing to invest in fertilizers and high-yielding technologies.

cont...Table 5. Maize value chain matrix

Production technology	Seeds	• The farmers have switched from OPV maize to hybrid maize in the last 15 years. By 2000, the farmers were reporting that the hybrid varieties gave higher yields, big pods, small cobs, and large grain, and were tolerant to diseases and drought. Good grain color for better marketability was also reported. The C919, C717, and C949 hybrids from the Pioneer Hi-Bred company were the popular varieties in Pakchong, Nakhon Ratchasima. C919, which was reported to be early maturing, was suitable for double cropping of maize popular in the areas. C717 was reported to be cheaper in its seed prices relative to other hybrids. In Loei, CP-DK 888 hybrid variety was popular. This variety was adopted because it gave good weight grain. Similar reasons were given in Pakchong areas. For the farmers in Loei, maize-only or maize-rice beans were dominant cropping systems. All over the country, there were more than 10 popular hybrid varieties from different companies. Each hybrid variety had different advantages and disadvantages. Most were yellow, flint hybrid varieties used mostly for animal feeds. OPV are hardly found these days even in remote areas. Some farmers in the northern and central regions were found to plant F2 hybrid with a cheaper seed price, but this was not evident among farmers in the northeastern region.
	Land preparation	• In large and medium farms, big tractors were used for land preparation and seeding. Two rounds of tillage were common. For small farmers, the slash-and-burn technique for land preparation was used. Planting was done manually.
	Fertilizer application	• Farmers adopted the use of hybrid seeds, and recognized that the use of fertilizers is necessary to ensure good yield. More commercialized farmers used 300–375 kg/ha of 16-20-0 and 46-0-0 fertilizers. The application was done twice: (1) when planting was done, and (2) when the crop was 60 days old. Medium farmers used 175–225 kg/ha of 16-20-0, and also applied it twice. Small farmers used 125–150 kg/ha of the 16-20-0 fertilizers in a single application within 20 days of planting.
	Harvesting	• The average yield of field corn is 4.20 t/ha. The average yield is 4.39 t/ha in the northeastern region, and 4.14 t/ha in the northern and central regions. • Harvesting was done by hired labor for large and medium farms, and by exchange labor for small farmers (Ekasingh, Phrek, and Kuson 2003). • Maize yield (at 14% moisture content) was recorded at an average of 4.46 t/ha for farmers in Pak Chong, Nakhon Ratchasima; 3.1–3.8 t/ha for farmers in Muang Loei District, Loei; and only 2.1–2.2 t/ha for Dan Sai, Loei in 1999. For large farmers, yield in the late season rain was higher at 5.1 t/ha. The national average for the same year was 3.66 t/ha (Ekasingh, Phrek, and Kuson 2003).
	Processing	• The kernels may be removed by means of simple graters and are sun-dried in front of the huts. • In contrast to rice, little or nothing of the corn harvest is consumed locally. Most small farmers will sell at least 90 percent of their harvest to dealers, while about 10 percent is stored at home. Part of this will be reserved for the next year's planting, while a considerable portion is fed to the pigs and chickens. Some may be fermented and distilled to make lao khao phot, the local corn liquor. The latter is especially important to a number of hill tribes, among them the Lisu. In fact, the Lisu dedicates one of their major festivities, the "new corn festival," to the harvest of corn. It is unthinkable without the local liquor flowing lavishly.

cont...Table 5. Maize value chain matrix

Production technology	Processing	• In general, however, farmers will transport most of their harvest to a dealer, using their carts powered by tractor engines. The dealers may run a small- or medium-sized agro-industry. Their plant sites usually include silos for the storage of agricultural produce. Here, the kernels are removed mechanically from the core of the cob, and the farmers are paid according to the net weight and the quality of their loads. Such industries are established all over the northern region, while the leftovers of the initial step of processing (i.e., the husks and cores) are often burned at these widely dispersed sites. • Alternatively, farmers from one or more villages may collectively rent a machine for removing the kernels from the cobs. In this case, it is transported to a suitable location, often alongside a main road, and the farmers will bring their harvested corn cobs in bags to this site. Their bags are emptied into the top of the machine, while the steady flow of kernels streaming from the base is collected in bags. At the end of the day, huge piles of dried husks and cores are left smoldering along the roadside. • Commercial farmers sell their maize immediately after harvest, while upland farmers keep their maize dry in the field for two months before selling because of high moisture, low prices, and difficult (high slope) terrain in the rainy season. At selling time, maize will be threshed by a motored thresher. Only maize grain is sold by weighting it before bagging. This reduces the time of storage and the chance of alfatoxin contamination. • After the farmers sell maize, the grain will be transported and sold to the nearby mills or companies where maize will be dried and kept in a silo. Final buyers of maize grain are animal feed mills that operate in the main provinces of each region. Animal feed meal will then be processed at the feed mill factory according to requirements of the livestock companies. Different formulas are required for each animal. The largest consumers of maize are broilers, followed by pigs and layers. Poultry exports from Thailand had been on the rise since 1992. In 2000, exports of frozen chicken peaked at 240,000 t/year. In later years, the bird flu epidemic has dampened poultry exports and the demand for maize has somewhat slowed down.
Marketing		• There were reports of hundreds of feed manufacturers and feed mills in the country, but the feed industry is effectively dominated by 5–6 extremely large firms. CP is the largest firm, being a vertically coordinated business covering seed, feed, and livestock lines of production. Price competition among these large firms does not appear to be very strong (Ekasingh and Kuson 2004). Nakhon Ratchasima (Korat) is a major center for both maize and feed mills. Road transport to and from this province to Bangkok is very convenient by the Mitraphap highways. In other provinces in the northeastern region, output prices are higher while input prices are lower. Loei, on the other hand, is far from the center of maize activities. Transportation poses major problems, making the production cost higher for maize farmers. This translates to lower profits. Nevertheless, maize is still more competitive compared to other crops. • Farm-level maize marketing is from individual farmers selling to individual assemblers, who would sell it to feed factories or exporters. As for maize seeds, fertilizers, and other inputs, they are supplied by companies through competitive marketing chains. Processing of maize as animal feed is done by feed companies who would either sell it to their vertical integrated livestock companies or other livestock companies. About 5–6 large vertically integrated livestock companies operate in Thailand, with CP being one of the largest.

cont...Table 5. Maize value chain matrix

Marketing		• Marketing is done throughout the year every five months from August to December. There is a growing demand for the field corn grains. In 2013, the demand totaled 6.40 million t, which is an increase of 12.9 percent from the 2011 total of 5.67 million t. The domestic production is not sufficient to meet the demand, and there is a shortage of about 1.39 million t. As such, Thailand imported from the neighboring countries such as Lao PDR and Cambodia. The average price of the field corn grain at moisture content not exceeding 14.5 percent is THB 8.05/kg with a deviation of THB 0.86/kg.
Distribution export/import		• Thailand's sweet corn exports accounted for 7 percent of the world market share and contributed substantial foreign exchange earnings to the kingdom. • A larger part (more than two-thirds) of the annual harvest is absorbed domestically by the livestock feed industries. The rapid expansion of the livestock industry triggered an increase in local demand for corn, thus curtailing corn export availability. • Corn flour is widely used in Thai cuisine. Corn oil, which is extracted from the germ of the corn kernels, is a popular form of cooking oil. Cooked corn kernels mixed in dough may be boiled in oil to make tasty snacks. At markets, corn on the cob is boiled and sold for about THB 10 per large cob. The cooked kernels are also a favorite ingredient in a popular market vendor's snack consisting, besides corn, of a choice of jellies, cubes of dried bread, pieces of melon, cooked red beans, and other ingredients, which are served in sweet coconut milk and crushed ice. Baby corn, on the other hand, is an ingredient in a number of popular dishes, such as kaeng liang, a curry resembling a vegetable soup; and phat khao phot het fang kung, fried baby corn with straw mushrooms and shrimps. Despite these, corn is not prominent in Thai cuisine. • Maize has been increasingly absorbed by the domestic market with a growing livestock industry. The trend in domestic use, exports, and imports in previous decades (1980–2000) in Thailand shows that the exports of frozen chicken increased from 44,000 t in 1985 to 240,000 t in 2000. Apart from the poultry industry (e.g., broilers and layers), other livestock industries (e.g., pork, dairy, and beef cattle) also expanded in previous decades. Increasingly, rice, maize, soybean, cassava, groundnut, oil palm, and fishmeal are being used as feed in the domestic market for domestic and export supply of livestock products (Saroj 2004). In 1983, domestic animal feed production was registered at 1.6 million t but increased more than four folds to 7 million t in 1998. • The demand for maize in the domestic industry is increasing, but the actual supply is not keeping up as the areas of maize have decreased continuously due to competition in other cash crops (e.g., cassava and sugar cane) (OAE 1995, 1997). At the same time, research on feed ingredients has introduced more feed substitutes (e.g., cassava and soybean meal) in place of maize, which is more expensive and continually in short supply (CAER 2000). The actual exports and imports of maize are variable from year to year, but they were low during 1992–2000 due to fluctuations in livestock demand. However, starting 2001, maize exports have expanded, especially in the wake of the avian flu epidemic in 2004–2005 when many countries refused Thai chicken exports. In 2004-2005, fresh and frozen chicken exports from Thailand were reduced drastically, although exports of chicken were done in the form of proceed meat and were expanding at a rate of 30 percent annually.

cont...Table 5. Maize value chain matrix

Distribution export/import		• The major player in both the maize and livestock industries is the Thai-owned multi-national company CP, which is the biggest vertically coordinated agribusiness company in the country. It owns the most popular maize hybrid (CP-DK888) and is the biggest buyer of maize for its feed mills. It is also a major producer and exporter of poultry products. CP is divided into many subsidiary firms, each connected to the CP Group. While there are many other feed mills operated and a couple of major companies apart from the CP mills, CP feed mills play major roles in maize price setting. Nevertheless, the fact that exporting and importing maize are always a possibility, domestic prices of maize cannot be independent from its world prices. • AFSIS (2014) reported that in the ASEAN region, Thailand exports maize to Indonesia (2,600 t), Lao PDR (5 t), Malaysia (1,100 t), Myanmar (30 t), the Philippines (223,475 t) and Vietnam (19,950 t). Thailand also imports from Lao PDR (4 t).

2.2.4 Production Cost and Profit

Ekasingh, Phrek, and Kuson (2003) found that in 1999, the cost for farmers was THB 2.62/kg in Pak Chong, Nakhon Ratchasima and THB 3.1–3.6/kg for Dan Khun Tood district in the same province and in Loei province. The production cost for farmers in Dan Sai district, Loei was estimated to be as high as THB 4.5/kg in the same year. Cash cost was about 75 percent of the total cost for large and medium farms, and it was 50 percent for small farmers with high use of family and exchange labor.

Maize grain price ranged from THB 0.2/kg to THB 4.58/kg in 1999. Large farmers were getting an estimated margin of THB 1.1/kg for maize in Pak Chong, Nakhon Ratchasima; THB 0.2–0.8/kg in Dan Khun Tood, Nakhon Ratchasima and Muang Loei, Loei; and THB 0.1/kg in Dan Sai, Loei. Accounting only for cash cost, all farmers received THB 1.7–2.0/kg of margin in that year. The farmers' profit per hectare was THB 6,010 in Pak Chong; THB 1,933–3,030 in Dan Khun Tood and Muang Loei; and THB 932 in Dan Sai. The profit per household was THB 152,000 for large commercial farmers in Pak Chong who farmed an average of 26 ha with good yield; THB 19,000 for Dan Khun Tood and Muang Loei; and THB 9,000 for farmers in Dan Sai who farmed an average of 6–8 ha with lower yield. This reflects the differentiation among various sizes of households in the same region.

The farmers borrowed heavily for maize production. The average cash cost per hectare was about THB 7,600–8,000. With an average of 7–8 ha/household, the cash requirement was about THB 60,000/household. It was estimated that farmers borrowed about 70 percent of their credit needs from BAAC, cooperatives, merchants, and relatives for all farm types. These loans were refinanced annually (Ekasingh, Phrek, and Kuson 2003).

The ratio of maize income to total household income for farmers was as high as 80 percent if farmers specialized in maize production. For diversified farmers, the ratio was lower at 65 percent of total income. Most of the maize was for sale, with less than 5 percent of the output kept for seed or home use for all farm types.

2.2.5 Priority Constraints

Ekasingh et al. (2004) identified the priority constraints in four maize ecosystems: (1) irrigated environment; (2) rainfed upland favorable environment; (3) rainfed upland marginal environment; and (4) highland environment in the major maize-producing areas in the upper north, lower north, upper northeast, lower northeast, and central plain (Table 6).

Table 6. Priority constraints determined during the workshop, August 2001

<table>
<tr><th></th><th>Irrigated environment</th><th>Rainfed upland favorable environment</th><th>Rainfed upland marginal environment</th><th>Highland environment</th></tr>
<tr><td>Upper North</td><td rowspan="2">1. Incorrect land preparation
2. Inappropriate water management
3. Low seed quality
4. Seedling damaged by insects
5. Stems eaten by rats
6. Postharvest fungi (aflatoxin)
7. Lodging (strong wind)
8. Thrips</td><td>1. Lodging
2. Stem rot
3. Rust
4. Droughts
5. Downy mildew
6. Waterlogging
7. Low seed quality
8. Soil Infertility
9. Termite ants</td><td>1. Soil infertility
2. Inappropriate land preparation
3. Droughts
4. Low seed quality
5. Ear rot
6. Downy mildew</td><td></td></tr>
<tr><td>Lower North</td><td>1. Droughts
2. Flooding in some areas
3. Degradation of soil fertility
4. Rust
5. Stem borers</td><td>1. Droughts
2. Soil infertility
3. Rust</td><td>1. Leaching
2. Inappropriate land preparation
3. Droughts
4. Rust</td></tr>
<tr><td>Upper Northeast</td><td></td><td>1. Downy mildew
2. Droughts
3. Low seed quality
4. Rust
5. Stem borer
6. Fungi (aflatoxin)
7. Too much rain</td><td></td><td>1. Soil infertility
2. Ear rot
3. Low seed quality
4. Droughts
5. Downy mildew
6. Rats
7. Beetles</td></tr>
<tr><td>Lower Northeast</td><td></td><td>1. Droughts
2. Rust
3. Inappropriate land preparation
4. Unsuitable fertilizer application
5. Lack of land conservation and rehabilitation
6. Unsuitable seed rate
7. Too dense plant intervals
8. Aflatoxin</td><td>1. Droughts
2. Lack of land conservation and rehabilitation
3. Unsuitable fertilizer application
4. Inappropriate land preparation
5. Inappropriate maize variety choice</td><td></td></tr>
<tr><td>Central Plains</td><td></td><td></td><td>1. Droughts
2. Soil degradation
3. Unsuitable fertilizer application
4. Inappropriate land preparation
5. Too dense plant intervals
6. Inappropriate variety choice
7. Seedlings damaged by insects
8. Aflatoxin
9. Waterlogging</td><td></td></tr>
</table>

2.2.6 Price Support and Trade Policies

Thailand continues to impose product-specific surcharges (Yoovatana 2013). Currently, they are levied at 73 percent or THB 2.75/kg, whichever is higher. Maize imports, which are also subject to tariff quota, are often duty-free even under out-of-quota amount. In recent years, maize has been subjected to the pledging program.

As with all major crops, the government of Thailand attempted to stabilize maize prices through its minimum price support program. Following the rice price support program, the maize minimum price support program was introduced through government and state enterprise agencies such as the Marketing Board and BAAC. Under such program, a "mortgage" price was announced at the beginning of the main season and the farmers were asked to mortgage their crop to the implementing agency at the announced price. They had four months to redeem their mortgage and retrieve their maize, after which the output would be sold to the market and the proceeds paid back to the agencies in the name of the relevant farmers. Most of the farmers who participated in this program found it more convenient to not redeem their output because the difference in prices was not very high in the four months. However, it was found that the coverage of this program was limited, and only 10–12 percent of the national maize output was handled this way (Ekasingh and Kuson 2004). It had influenced maize prices minimally. Affluent and well-connected farmers had more access to this program than small farmers in remote areas.

Poramacon (2013) cited the income guarantee scheme as a recent agricultural policy related to maize. Maize is a major input in the poultry-raising industry. The farmers sell their products to field merchants or agricultural cooperatives, who then sell to local merchants. The local merchants sell to silo companies, exporters, or animal farms. Silo companies sell maize to exporters or their feed mills. Feed mills sell their products to exporters, distributors, and their farms. Most silo companies, feed mills, poultry farms, and distributors belong to the same owners.

2.2.7 Research and Extension

A survey conducted by Ekasingh, Phrek, and Kuson in 1999 revealed that some of the hybrids being sold in 1997 were released as far back as 1988 (e.g., the three-way cross Hercules 31 sold by Novartis Seeds). In 1990, Pacific Seeds released its double cross hybrid, PAC11, which was still used in 1998. In 1991, when Charoen Seeds of the Charoen Phokphand (CP) Group released the famous single cross CP-DK888, the three-way cross Uniseeds 38 and the double cross CP-DK818 were also released in the same year. In 1991–1993, hybrids were released at the rate of about three new hybrids per year by different companies. In 1994–1996, the rate of releases accelerated to about five new varieties a year. In 1997, there was a record release of seven private-sector new hybrid varieties, five of which were single crosses.

The public sector, including international research organizations like CIMMYT, has provided good support in research, research personnel, and facilitation roles for the private sector over four decades of maize development in Thailand. For example, the varietal testing and evaluation program, supported by CIMMYT, DOA, and public universities in Thailand, provided a mechanism for comparing and contrasting materials produced by the private and public sectors. The Tropical Asian Maize Network, established with the support of CIMMYT and the Food and Agriculture Organization (FAO), stimulated progress in hybrid maize research and a potential yield of 7–8 t/ha (Ekasingh, Phrek, and Kuson 1999; Vasal 1998; Yosaporn, Pichet, and Chokechai 1998). The maize area planted to hybrid varieties comprised 85 percent of all maize-cultivated areas in the country in 1996–1997, and the average yield was 3.42 t/ha against 2.33 t/ha for improved OPV and 1.98 t/ha for traditional varieties (Ekasingh, Phrek, and Kuson 1999). The use of hybrid maize varieties expanded to almost all maize areas in all regions by 2003 (Ekasingh et al. 2004).

2.2.8 Trade-related Price Policies

The Feedstuff Users Promotion Association (2006) reported that the government of Thailand regulates maize prices through its export and import policies. It imposed export quota on maize until 1981, when the export restrictions were lifted after the farmers' complaints became evident. This led to a surge in exports, which peaked to 3.5 million t of exports at a maximum free on board (FOB) price of THB 3.68/kg in 1985. In 1986–1987, the FOB price of maize was as low as THB 2.5/kg because of depressed world prices. Such events were coupled with a growing feed demand and the occurrence of competing crops like sugar cane and cassava.

On the import side, Ekasingh and Kuson (2004) mentioned that significant quantities of maize were imported for the first time in 1991 following a reduction in import tariff from 6 percent to 0.6 percent. Some 0.25 million t of maize were imported in 1991. In 1995, imports climbed to 0.39 million t. In 1997, the government removed all import duties on maize imports and was liberalized briefly in 1997–1998. When Thailand joined the World Trade Organization in 1995, it reinstalled a "reduced" tariff structure with a minimum access quota subject to a 20 percent import tariff and 76–80 percent import tariff for quantity beyond the quota. Such structure of tariff reversed the liberalization trend introduced during the no-tariff period of 1997–1998.

2.2.9 Maize Strategic Plan

OAE (2014) provided the maize strategic plan under five strategic thrusts: reaching targets, enhancing productivity and reducing production cost, value addition and marketing, R&D, and promoting climate change resilience of maize (Table 7).

Table 7. Maize strategic plan, 2012–2017

Strategic thrusts	Strategies
Thrust 1: Reaching targets	• Maintain the cultivation area of 7 million rais until 2017 • Increase the yield per rai at 14.5 percent moisture content from 653 kg/rai in 2012 to 825 kg/rai in 2017 • Increase the volume of production from 4.48 million t in 2012 to 5.80 million t in 2017 • Change the usual harvesting practice for rainy season planting (July–October) from 60 percent to 30 percent and during the cold season (November–February) from 35 percent to 60 percent, and lowland planting (March–April) from 5 percent to 10 percent in 2017
Thrust 2: Enhancing productivity and reducing production cost	• Production zoning • Registration of field corn farmers • Mass produce good quality seeds and non-GMOs for distribution to farmers to meet their needs and the needs of farmers' institutions, including seed exportation • Enhance production efficiency and transfer of technologies for GAP and sustainable use of water resources in the local community • Improve water reservoirs, production, and extension systems • Establish an insurance system for natural calamities • Establish a network of farmers' institutions • Establish community information networking to monitor the production, marketing, and early warning systems for calamities
Thrust 3: Value addition and marketing	• Expand the industries for corn flour, corn oil, and bioplastics, and establish trade networks • Value addition for farm residue from corn production • Promote the formation of farmers' groups and networks among the maize producers and consumers, including the development of farmers' institutions to buy the produce at a remunerative price • Promote the trade of field corn through the AFET system • Promote Thailand as the ASEAN trading center for field corn and products
Thrust 4: Research and development (R&D)	• Promote R&D of technologies suitable to the environmental conditions of each production area to enhance productivity and efficiency in the use of inputs to generate quality produce and products • Promote R&D of drought-, pest-, and disease-tolerant maize varieties with high oil content for value addition • Promote biotechnology as a tool for breeding varieties to increase yield and solve the problem of aflatoxin in corn grains • Promote R&D of technologies to improve maize productivity in marginal lands • Promote R&D of products from farm residue for maize production for value addition • Support public and private partnership • Improve the R&D system and regulations to expedite maize-breeding programs • Support the establishment of an organization that will directly supervise maize production
Thrust 5: Promoting climate change resilience of maize	• Enhance farmers' awareness and knowledge on the possible impact of environmental factors on maize production • Enhance farmers' understanding of modifying traditional practices to make them more suitable to the current climatic conditions (e.g., using a crop calendar to schedule planting, such that it coincides with the flowering or fruiting stage, under the most conducive environmental conditions) Breeding for maize varietal improvement with high water-use efficiency, fast growth, early maturing, deep and fibrous rooting, resistance to droughts (e.g., Nakhon Sawan 3 developed by DOA), and nutrient-use efficiency • Improve soil and water management and conservation practices suitable to the local conditions • Expand water reservoirs and irrigation infrastructure • Promote the formation of farmers' groups (e.g., seed producers for the mass production of Nakhon Sawan within the community, and provide community platforms where the farmers could exchange and view information, to reduce production cost, transportation cost, and loans as well as improve the bargaining capacities of maize producers

Source: OAE (2014)

III. REVIEW OF CLIMATE CHANGE IMPACTS AND VULNERABILITIES

3.1 Review of Related Studies

Koontanakulwong (2010), as cited by Luanmanee and Lertna (2013), reported that climate intensity in Thailand has changed. However, it is difficult to determine whether such change transpired early or was delayed. The country's overall maximum temperature had increased by 0.02ºC each year during the past 40 years from 1971 to 2007. The annual rainfall decreased at about 0.51 mm/year, with different rainfall distribution. This affected crop production significantly. It was estimated that the hotspots for reduced maize production was estimated to be about 0.225 million ha during 2000–2009.

The IPPC Special Report on Emission Scenarios (SRES) (2000) included scenarios grouped into four families of scenarios, namely, A1, A2, B1, and B2, with a total of 40 scenarios developed under these four families. The different scenarios produce large differences in the patterns of GHG-emissions during the 21st century.

The A1 scenario family describes a future world of very rapid economic growth, global population that peaks around the middle of the efficient technologies. This scenario assumes a substantial reduction in regional differences in per capita income, based on increased cultural and social interaction between and within nations. The A2 scenario group describes a very heterogenous world that maintains regional differences in population growth and economic development, and thus large regional differences are maintained in per capita income and in technological change. The B1 scenario follows a similar line to the A1 scenario in population growth, but with a rapid change in economic structures toward more service and information oriented economies and the introduction of clean and resource-efficient technologies. The emphasis is on global solutions to economic, social and environmental sustainability including improved equity. The B2 scenario group describes a world in which the emphasis is on local solutions to economic, social, and environmental sustainability. Global population increases at a rate lower than the A2 scenario, with intermediate levels of economic development, and slower and more diverse technological change than in the B1 and A1 scenarios.

The dataset and methodology of New et al. (2000) were used in the study to reconstruct the climate in Thailand from 1901 to 2005. This reconstructed climate was then analyzed for spatial and temporal changes in a range of climate parameters. The Climatic Research Unit (CRU) of the University of East Anglia produced the CRU TS2.1 Climate Dataset. It was reformatted by Antonio Trabucco of the International Water Management Institute for the Consultative Group on International Agricultural Research – Consortium for Spatial Information into ArcInfo Grid format, to provide easy access (http://csi.cgiar.org/cru/) and use for geospatial analysis using common geographic information system (GIS) software. The creator of this dataset and CRU retain full ownership rights (Mitchell and Jones 2005).

The following climate variables available through the CRU dataset were used in the study: (1) daily mean, minimum, and maximum temperatures; (2) precipitation; (3) wet day frequency; (4) diurnal temperature range; (5) frost day frequency; (6) vapor pressure; and (7) cloud cover (OAE, CIAT, and GIZ 2012). The annual mean, minimum, and maximum temperatures, as well as the annual and monthly rainfall in May, June, October, and November, were analyzed. These months were selected because they are the critical and more variable months for rainfall, falling at the beginning and at the end of the wet season. The annual temporal variation in climate parameters is large, especially for variables such as rainfall. For this reason, analysis, and more particularly the depiction of such time series data, must first be smoothed to make the trends more easily observable (Figures 3 and 4).

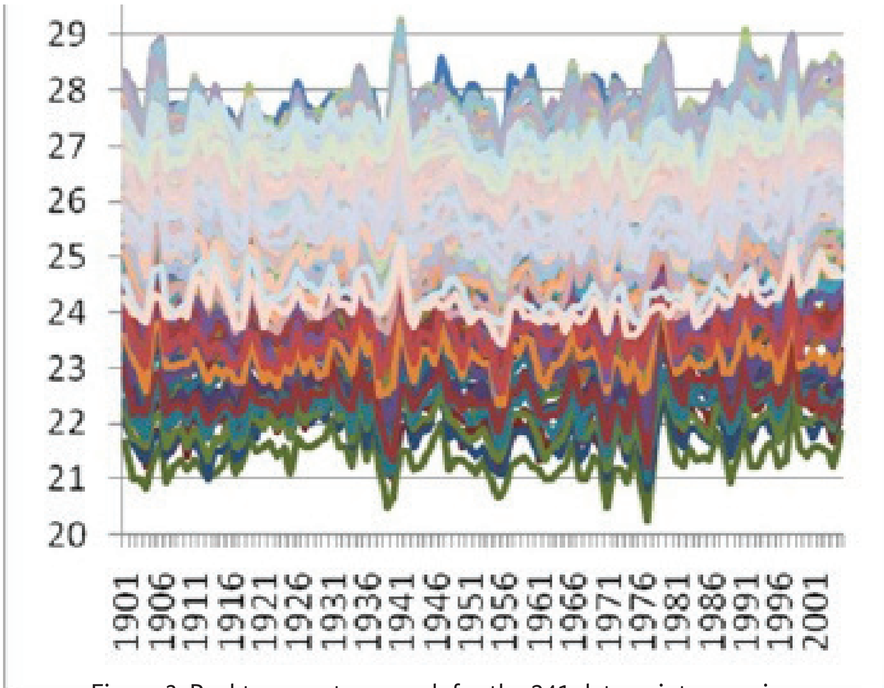

Figure 3. Real temperature graph for the 241 data points covering Thailand's territory.
Source: *OAE, CIAT, and GIZ (2012)*

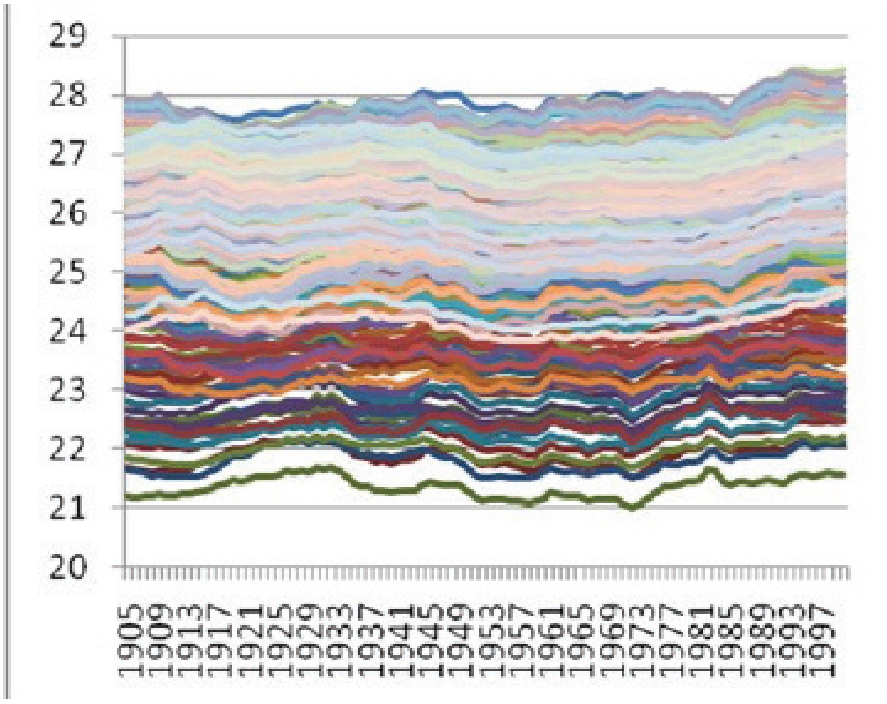

Figure 4. Smoothed temperature graph for the 241 data points covering Thailand's territory.
Source: *OAE, CIAT, and GIZ (2012)*

The most common technique is moving average smoothing, in which the non-systematic variations are cancelled by replacing each data point of the series by an average of the point and a number of surrounding points preceding and following it (Box and Jenkins 1976; Velleman and Hoaglin 1981). In the study, the CRU data for 1901–2005 were smoothed using a 10-year moving average to depict data and trends in graphs. For the statistical analysis, however, the unsmoothed data were used because using the smoothed data would have reduced the effective period of analysis to 1905–2000, which could have affected, albeit slightly, the analysis of trends.

The analysis of long-term climatic conditions in Thailand shows that climate is highly variable, particularly the amount and distribution of rainfall that includes huge year-to-year and within-year variations. This variability introduces great risk and uncertainty into agricultural systems, which is a major concern for marginalized smallholder farmers. The analysis of the climate in Thailand from 1901 to 2005, using a reconstruction of the climate based on the CRU dataset, highlighted this variability. However, it also showed some significant trends in climate variations. During the 20th century, minimum, mean, and maximum temperatures increased throughout the country, particularly since 1985. The minimum temperature increased by 0.1ºC–1.0ºC, while the mean and maximum temperatures increased by 0.0ºC–0.8ºC. There were also some slight increasing trends in mean, annual, and monthly rainfall, but these trends remained within the range of year-to-year variations of these variables characterized by irregular patterns (OAE, CIAT, and GIZ 2012).

3.2 Temperature

OAE, CIAT, and GIZ (2012) predicted that temperatures may increase in average by 0.4ºC every 10 years from now to 2050. By 2050, the minimum and mean temperatures will have increased by up to 2ºC compared to the 2010 value, and the maximum temperature will have increased by up to 1.8ºC. In particular, mean temperatures will reach values higher than 29ºC for all areas in the Chao Phraya River basin.

The evolution over time of temperature in the four regions of Thailand is presented in Figures 5, 6, and 7. The solid line represents the average value for the region, while the broken lines represent minimum and maximum values. The northern region has the largest temperature range from 21ºC to 28ºC. The temperature in the other three regions ranges from 24ºC to 28ºC. All regions showed a slight increase in temperatures after 1985, more visibly in the northeastern, central, and southern regions. In addition, in the northern and central regions, the maximum regional temperatures exceeded 28ºC for this period—values that were never reached in the 20th century.

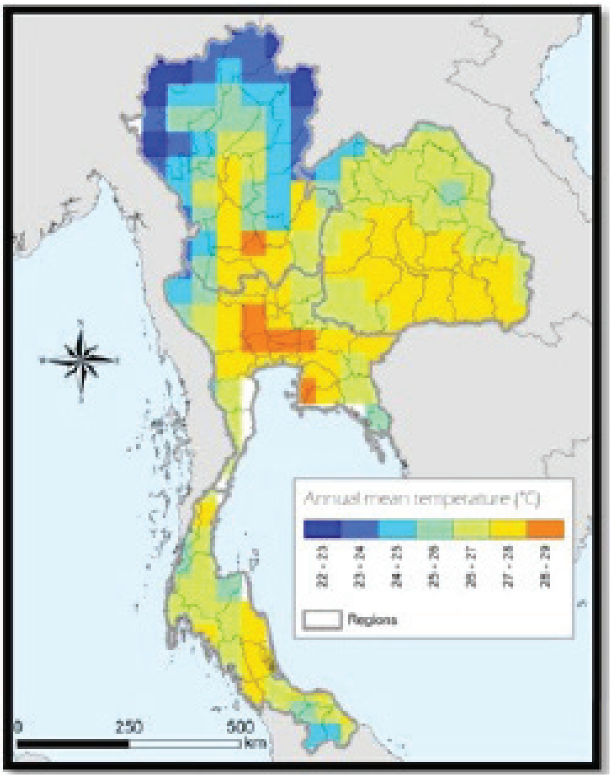

Figure 5. Average annual mean temperature, 1985–2005.
Source: OAE, CIAT, and GIZ (2012)

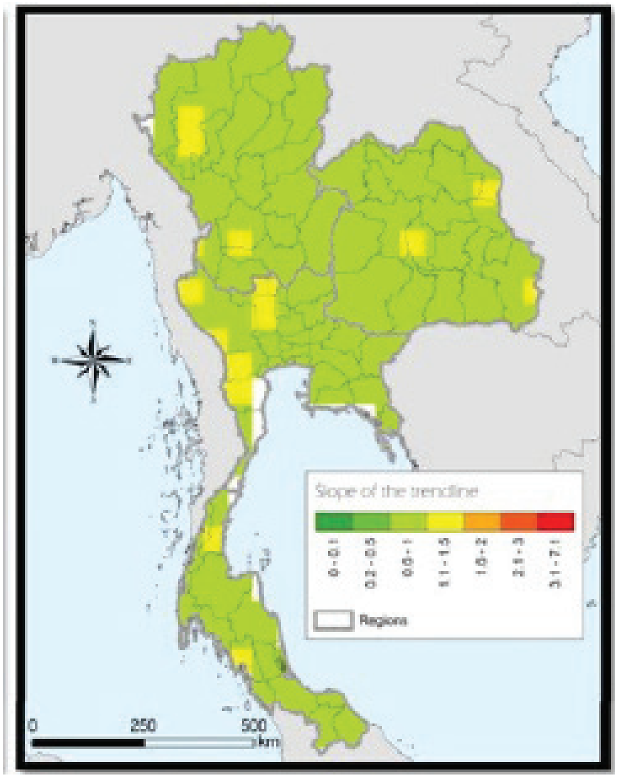

Figure 6. Change in annual mean temperature, 1901–2005.
Source: OAE, CIAT, and GIZ (2012)

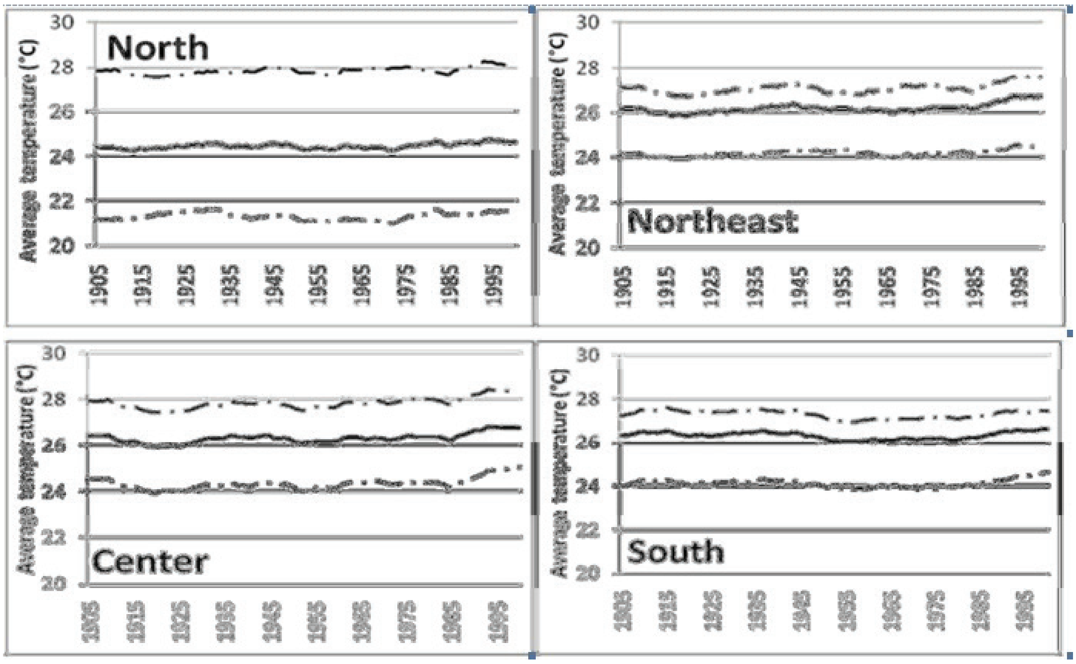

Figure 7. Smoothed annual mean temperature for the four regions of Thailand, 1905–2000.
Note: The solid line represents the average value for the region. The broken lines represent the minimum and maximum values.
Source: OAE, CIAT, and GIZ (2012)

3.3 Rainfall

OAE, CIAT, and GIZ (2012) also analyzed the rainfall pattern. The principle characteristic of annual and monthly precipitation evolution throughout the 20th century is the high year-to-year variability. During the 20th century, there were some slight increasing trends in mean annual and monthly rainfall, but none of these changes were significant compared to the large inter-annual variations.

The authors further predicted that the rainfall pattern to 2050 from the mean of seven global climate models (GCMs) and with the A1B scenario suggests that changes in rainfall will be different according to the area. The analysis revealed that the annual rainfall may decrease up to 250 mm in the central part of Thailand and increase up to 600 mm in the northern and southern regions. Monthly precipitations at the beginning and at the end of the rainy season may remain stable in most areas of the country. However, there will be a decrease of up to 120 mm in May in the eastern part of the country and in October in the central region, as well as an increase of up to 200 mm in November in the southern region. These changes in rainfall patterns are of the same order of magnitude as the variation between years, which means that the main aspect of rainfall that farmers should be aware of is the variability. The predictions for rainfall suggest that climate change will have varying effects on different areas.

Lefroy et al. (2010) reported that there is good evidence that the changes observed in mean values are driven partly by changes in extreme values. In particular, where increases in temperature have been observed, the trend has been for fewer cold nights and more hot nights—and to a lesser extent, fewer cold days and more hot days—rather than a general increase in mean values. For rainfall, even where there has been limited change in total precipitation, the incidence of heavy and very heavy rainfall appears to have increased.

While the incidence of tropical storms and hurricanes is highly variable, influenced by such factors as the El Niño Southern Oscillation, there is evidence that the number and intensity of storm events increased significantly in the last few decades of the 20th century. This trend is likely to continue and increase in frequency and intensity.

In addition to monthly and yearly mean values of temperature and rainfall, extreme events (e.g., extreme heat and cold, floods, and droughts) should also be considered. There is very limited capacity for prediction of extreme events in the GCMs largely because, by their very nature, they involve and require far greater temporal and spatial resolution than the annual or monthly means.

In summary, the climate has become hotter and this trend will likely continue. The variations in rainfall are within the order of the normal year-to-year variations, so the climate change-induced variations in rainfall patterns are unlikely to be observed easily, at least for some time. The danger of this may be complacency. Other studies showed that the incidence of extreme events (e.g., hotter nights and days, and heavy storms) is likely to increase. As a consequence, measures to increase farming system resilience to extreme events must be considered to limit the negative effects of such events (OAE, CIAT, and GIZ 2012).

3.4 Current and Future Crop Sustainability

CIAT, with support from Bioversity International and the International Potato Centre, developed a simple mechanistic model based on the FAO Ecocrop database of crop ecological requirements (ecocrop.fao.org/ecocrop/). Ecocrop is mechanistic in terms of the climatic niches to which a species is suited or less-well suited. The model, which uses the same name as the FAO database, Ecocrop, uses temperature and precipitation thresholds to evaluate the suitability of a certain place for a particular crop species. The model was developed to run from within the DIVA-GIS software (Hijmans et al. 2005). The model was developed to predict the suitability of various crops under different climatic conditions, and thus at different locations. The model is used to assess suitability rather than productivity or yield. In situations where there is abundant information on yields under different conditions and locations, it is possible that the suitability assessment can be interpreted in terms more closely related to yield.

The FAO Ecocrop database (ecocrop.fao.org/ecocrop/srv/en/home) was used to establish parameters to run Ecocrop. The Ministry of Agriculture and Cooperatives of Thailand provided parameters for maize and the two varieties of rice.

3.5 Current Suitability of Crops and Comparison with Current Cropping Patterns

The climate suitability for rice and maize, along with the actual distribution of growing areas and most productive provinces, is presented in Table 8. Current production areas for maize well overlay with climate-suitable areas.

Table 8. Parameters used to run Ecocrop

Crop	Gmin (days)	Gmax (days)	Tkill (ºC)	Tmin (ºC)	Topmin (ºC)	Topmax (ºC)	Tmax (ºC)	Rmin (mm)	Ropmin (mm)	Ropmax (mm)	Rmax (mm)
Rice											
KDML 105	120	150	0	8	25	35	42.5	600	800	1,200	1,500
Other varieties	110	120	0	15	25	33	42.5	600	800	1,200	1,500
Maize	100	120	9	10	25	35	40.0	400	500	800	1,300

Source: OAE, CIAT, and GIZ (2012)

Climate suitability based on the Ecocrop model for maize is presented in Figures 8, 9, and 10. Most of the suitable areas are located in the central continental part of the country where precipitations are low. Surrounding zones are less suitable because of high precipitations. Therefore, considering temperature and precipitation suitability separately, precipitation is a limiting factor for maize in most parts of Thailand. The productive and non-productive provinces, as well as provinces with the highest harvested areas and yields from 2007 to 2009, are presented in Figure 8. For maize, the main productive areas overlay with the central suitable area, while non-productive areas remain in the southern region and encircle less suitable provinces.

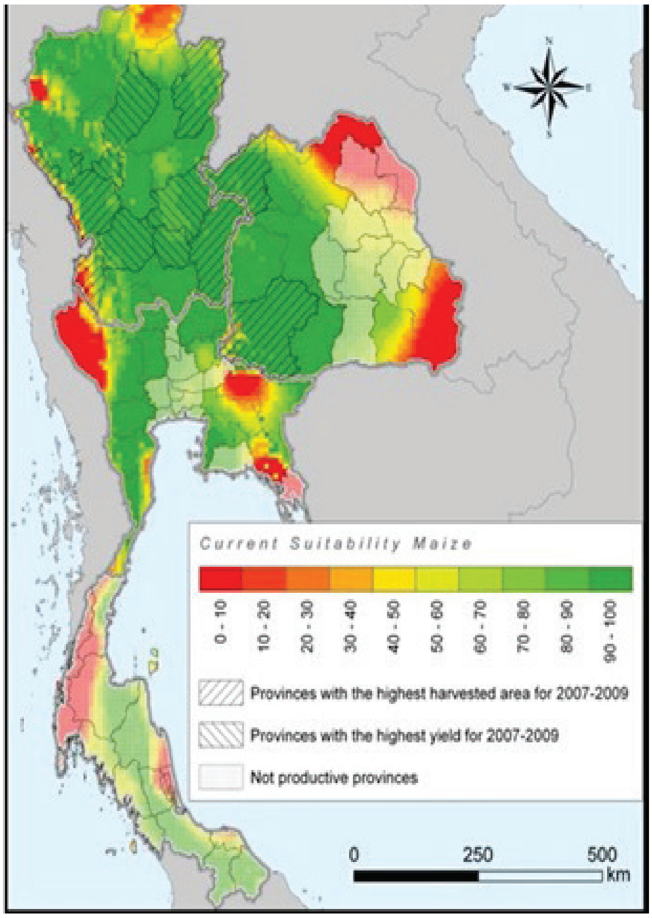

Figure 8. Suitability of maize in the current environment, Ecocrop assessment.
Source: OAE, CIAT, and GIZ (2012)

Rice (KDML 105 and other varieties) has bad suitability all over the country. The two different varieties of rice have very similar suitability distribution driven by low values and low range of water requirement (Table 8, Rmin, Rmax, and Rmax-Rmin), which leads to a reduced area fulfilling these requirements. Temperature suitability is high all over the country. Both varieties are grown in almost all areas of the country, but the main productive provinces are different according to variety (Figures 9 and 10).

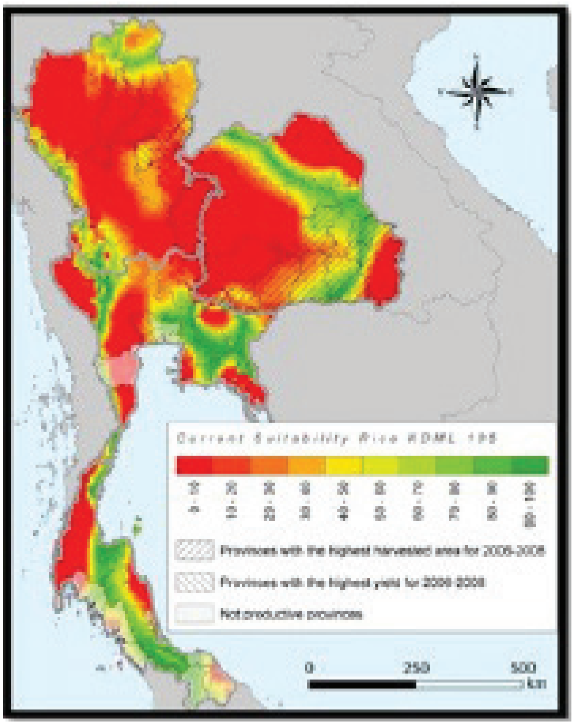

Figure 9. Suitability of rice in the current environment, Ecocrop assessment.
Source: OAE, CIAT, and GIZ (2012)

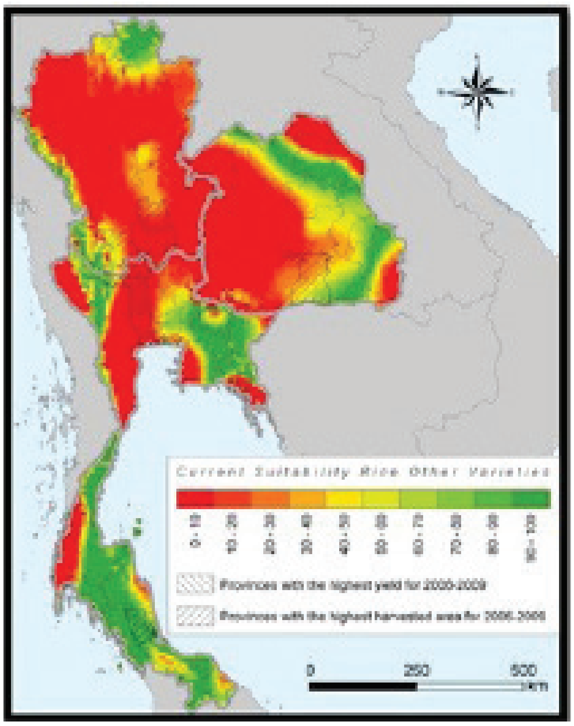

Figure 10. Suitability of other varieties in the current environment, Ecocrop assessment.
Source: OAE, CIAT, and GIZ (2012)

The authors explained that despite low climate suitability, the extent of production across the country is related to water management. Ecocrop suitability is based on "natural conditions" without any water management. However, good water management practices can highly improve natural potential as long as temperature suitability is fine.

According to Kabaki et al. (2003), several sources confirm that low precipitation is the principal limiting factor in improving rice yield in Thailand, while good water management practices are considered the best way to improve yield. Data on rice-growing practices show that 20 percent of rice production in the country is made under irrigation (OAE 2014). Even in rainfed conditions, basic water management to conserve water in paddies can help in circumventing the effects of droughts and low precipitation. Even if Thailand is not the most suitable area for rice culture because of limited precipitation, appropriate water management practices will allow it to obtain reasonable yield.

Isvilanonda and Praneetwatakul (2009) reported that the impact of climate change will reduce rice yield in the central plains to about 0.41 t/ha or about 6.85 percent of the current yield. A reduction in yield will probably be manifested in the rise in production cost per unit output. Frequent droughts or floods will result in uncertainty of production supply, creating food price variability.

The current suitability of maize and two varieties of rice was analyzed using the

Ecocrop bioclimatic suitability model (OAE, CIAT, and GIZ 2012). The results showed that climate suitability is driven mainly by the crop's water requirements in relation to precipitation values across the country. Maize and rice can be classified into two groups according to their current suitability:

(1) Maize: Crops with low water requirements are suitable for the central continental part of the country, in the northern and northeastern regions, which is the driest zone of Thailand

(2) Rice (KDML105 and other varieties): Crops with a restricted window of water requirement have variable suitability across the country; highly suitable areas are located in zones where annual precipitation is included in requirement range

The suitability was compared with the current distribution of the crops and main productive areas to assess the extent to which climate suitability drives such distribution. The results showed that maize current distributions seem to be driven mainly by climate suitability as productive areas match suitable areas, and main productive areas are located in highly suitable zones. Two varieties of rice present low climate suitability in most of the country, but they are grown in many parts, especially where water requirement is the limiting factor. In rice, good water management practices (e.g., irrigation or water recollection in paddies) in growing areas can largely limit the negative effects of low precipitation and allow culture in areas that the Ecocrop algorithm identifies as not suitable.

For rice (KDML 105 and other varieties) and maize, the high differences between GCM results did not establish clear patterns of changes in crop suitability. However, it appears that areas with the highest uncertainties correspond to zones where climate suitability is currently moderated. Without any clear tendency in terms of direction and size of the change, adaptation measures in these areas have to be oriented towards reducing vulnerability to changes of the current agriculture systems. As the suitability of these crops is driven mainly by precipitation, adaptation measures should especially involve reducing vulnerability to rainfall variability.

The bioclimatic suitability of rice (KDML 105 and other varieties) and maize was assessed against the current and predicted 2050 climate using the Ecocrop model. Ecocrop is based on temperature and rainfall limits for the crop to grow. An important result in terms of adaptation strategies is that climate suitability is driven mainly by precipitation. The results of the current suitability analysis for each crop are summarized in Table 9.

Table 9. Principal results for current climate suitability by crop

Crop	Principal limiting factor	High suitability zones	Correspondence with current production area	Other potential factors explaining distribution
Rice				
KDML 105	Rainfall	Strip around the center	-	Water management
Other varieties	Rainfall	Strip around the center	-	Water management
Maize	Rainfall	Central dry area	+	-

The central dry area refers to the central continental part of the country where annual rainfall is low. The strip around the center refers to areas with intermediate rainfall between the dry central zone and the wet surrounding areas.

The results also showed that the current production areas for maize overlay well with suitable areas. On the contrary, production areas for rice do not overlay with suitable areas. It is important to consider that Ecocrop only captured suitability according to precipitation and temperature, ignoring specific soil requirements, problems of pests and diseases, and socio-economic factors. The authors then suggested a hypothesis about non-climate factors, such as water management, economic attractiveness compared to other crops, and geographic characteristics, which can explain current production areas for these crops (OAE, CIAT, and GIZ 2012).

The authors reported that clear trends in terms of suitability were not established because of uncertainties and differences between the different GCM predictions for rice and maize (Table 10). The current crop suitability is driven mainly by precipitation. As such, most adaptation measures should focus on uncertain areas and on increasing the resistance of production systems to inconsistent rainfall.

Table 10. Uncertainty and evolution of suitability to 2050

Crop	Uncertainty	Suitability change
Rice		
KDML 105	High	High and low suitability stable
Other varieties	High	High and low suitability stable
Maize	Moderated	High and low suitability stable

IV. AREAS WHERE REGIONAL COLLABORATION CAN STRENGTHEN APPROACHES

In an effort to promote climate resilience of major food crops to ensure food security in the ASEAN region, Thailand proposes potential regional collaborations that could be developed from five research thrusts: (1) research network programs on climate change assessments, mitigation, and adaptation; (2) technology transfer; (3) HRD programs; (4) institutional support; and (5) ASEAN regional cooperation on climate resilience and food security (Table 11).

Table 11. Regional collaboration matrix

Research thrusts	Programs
Thrust 1: Research network programs on climate change assessment, mitigation, and adaptation	• Integrated farming systems, diversification, climate-smart agriculture, conservation agriculture (best practices) • Germplasm exchange for climate resilience • Breeding programs • Climate modeling • Protocol for vulnerability assessment • Econometric models for assessing climate vulnerabilities and resilience • Conservation and management of plant genetic resources • Food reserves forecasting in the ASEAN region • Production system approach to enhance climate resilience • Create integrative bio-economic models • Zoning
Thrust 2: Technology transfer	• Share knowledge and experience on climate-resilient agricultural and forestry-based technologies • Upscale technology to enhance resilience • Early warning systems for climatic disturbances, pest, and disease outbreak
Thrust 3: HRD programs	• Need-based exposure visits for scientists and farmers • Capacity-building relevant to stakeholders at the community level
Thrust 4: Institutional support	• Set up forecasting, early warning systems, and agro-advisory • Policy support for climate-resilient agriculture and forestry • Improve physical infrastructure (e.g., water reservoirs, water spillways, and irrigation systems)
Thrust 5: ASEAN regional cooperation on climate resilience and food security	• Mobilize existing ASEAN regional policies and initiatives related to AFCC as the platform for cooperation and collaboration with all related subsidiary bodies and ASEAN Technical Working Groups • Launch research programs focusing on techniques/methods of farming systems through research networks between AMS • Transfer of technology and scientist exchange program to address issues on climate-resilient agriculture and forestry • Adopt a regional climate protocol to enable environment for a green growth and low carbon production in the ASEAN region • Adopt a regional disaster response/relief protocol in ASEAN region • Adopt a regional climate risk management protocol

V. CASE STUDIES ON GOOD PRACTICES

5.1 Rice

5.1.1 Rice Crop Calendar

Rice-rice continuous cultivation is a major rice cropping system in irrigated areas, especially in the central plains of Thailand. Farmers prefer a rice cropping system of two crops a year. The aim of this rice cropping system research is to compare the economic returns between a two-crop rice cropping system and a three-crop rice cropping system. Experiments were conducted in farmers' fields at the Lumlookka district and the field of the Pathumthani Rice Research Center in Pathum Thani province in 2012–2013.

There were three experiments wherein the (1) same rice variety was planted throughout the year, (2) the rice variety was changed every season, (3) and the rice variety was changed every season with early maturity rice variety in the cropping system. Each experiment consisted of two treatments (Figure 11).

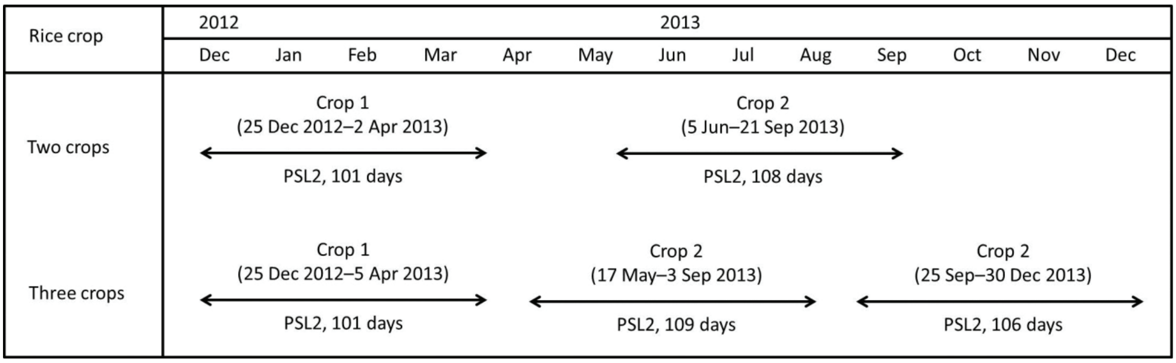

Figure 11. Growing the same rice varieties twice and thrice a year in Lamlookka.

The three-crop rice cropping system showed a higher total yield of 103–326 kg/rai/year and a higher total income of THB 721–2,282/rai/year. However, it offered a lower total profit of THB 1,838–3,388/rai/year than the two-crop rice cropping system (same rice variety and different rice varieties) throughout the year. In addition, the two-crop rice cropping system produced a higher total yield than the three-crop rice cropping system using early maturity rice varieties, which resulted in lower total income and profit.

Moreover, a two-crop rice cropping system will allow more time for fallowing the soil and breaking down the life cycle of insect pests. Therefore, even if a two-crop rice cropping system produces lower total yield, it offers a higher total profit than the three-crop rice cropping system in all cropping patterns (i.e., same rice variety, different rice varieties, and different rice varieties with early maturity).

5.1.2 Alternate Wetting and Drying (AWD) Technique for Mitigating Greenhouse Gases (GHGs) from Irrigated Rice Production in Deepwater Rice Areas

Rice production is an anthropogenic activity that produces GHGs, which are partially emitted into the atmosphere causing the "greenhouse effect." Mr. Chitnucha Buddhaboon, Ms. Benjamas Rossopa, Ms. Kingkaw Kunket, and Mr. Amnart Chit Thaisong conducted a study on the application of the AWD technique for mitigating GHGs from irrigated rice production in deepwater rice areas in the dry season of 2013–2014 at Prachin Buri Rice

Research Center. The objective of the study was to reduce 30 percent of methane (CH_4) emissions from irrigated rice production in deepwater rice areas by applying the AWD technique.

The experimental design was randomized complete block with three replications. Three treatments of (1) continuous flooding (CF) with a depth of 10 centimeters (cm); (2) AWD with a depth of 5–15 cm (AWD1); and (3) AWD with a depth of 10–15 cm (AWD2) were randomized completely in each replication. On 27 December 2013, pre-germinated seeds of the RD41 rice variety were broadcasted at a seed rate of 125 kg/ha. Two chemical fertilizer applications were broadcasted during the growing period at tillering stage and panicle initiation stage at total application rates of 75 kg–38.5 kg–38.4 kg N-P2O5-K2O/ha. Three sets of gas samples from three chambers were taken from each plot weekly throughout the season. CH44 concentration in collected gas samples were analyzed with gas chromatography. It was found that AWD1 and AWD2 treatments can reduce CH_4 emissions by 38 percent and 30 percent, respectively, compared with the CF treatment. There was no significant difference among the average yields of 5,292 kg/ha; 5,088 kg/ha; and 5,340 kg/ha from the CF, AWD1, and AWD2 treatments, respectively. Moreover, the AWD technique can reduce water supply for irrigated rice production in deepwater rice areas by 16 percent, as well as for AWD1 and AWD2 treatments by 7 percent, without affecting rice yield. Therefore, the AWD technique can be an alternative technology for mitigating CH_4 emissions and saving water in irrigated rice production systems in deepwater rice areas.

5.1.3 Remote Sensing-based Information and Insurance for Crops in Emerging Economies (RIICE)

There is a general agreement that rice production must increase substantially by 2050 to meet demand, and do so on less land and with greater pressure on water esources. Monitoring systems that provide spatial and temporal information on the rice crop would support policy decisions related to food security, resource management, national accounting, and climate resilience plans. This implies that key stakeholders must have assured access to reliable, accurate, and timely information on the rice crop, including rice area, cropping calendars or patterns, production estimates, seasonal forecasts, and water utilization and efficiency. This would form the basis of accurate baseline information on the rice crop, characterization of rice ecosystems, climate risk assessments, and food security scenarios.

The predicted increase in frequency and intensity of climate-related events such as floods and droughts will expose most parts of the rice value chain to higher risks and costs, particularly increasing the government's post-disaster recovery funds paid to the farmers. Switching the government's focus to pre-disaster insurance instead of post-disaster recovery funds could reduce the financial burden. As stated in the RIICE website (http://www.riice.org/about-riice/#sthash.V6BfHukx.dpuf), "The risks involved in agricultural lending by banks to rice smallholders can be reduced through insurance that protects the farmers' loans against defaulting due to yield losses and thus trigger more investments in agricultural production." In 2014, the government of Thailand prepared a budget for paying insurance premiums and providing compensation for possible damages to the rice crop. This scheme could provide direct benefits to the farmers by providing insurance for crops cultivated in the following season. The rice insurance also covers cases where production was lower than expected or where crops were damaged by flood, drought, or other natural hazards (The Nation, 2014). Accelerating the yield loss estimation process and the payout timeline of such financial interventions requires reliable, accurate, and timely information on the rice crop including yield histories, seasonal yield estimates, and area and production losses due to climate-related calamities.

RIICE is a public-private partnership that aims to reduce the vulnerability of rice smallholder farmers in low-income countries. Since 2012, the RIICE consortium has been collaborating with three main partners in Thailand: RD, the Geo-Informatics and Space Technology Development Agency (GISTDA), and BAAC. It has worked in close consultation with Department of Agricultural Extension and OAE.

RIICE provides information on the rice crop using an integrated suite of technologies, including remote sensing, efficient ground observation networks, crop growth simulation models, and web-based GIS (WebGis). The RIICE conceptual framework and technologies are illustrated in Figure 12. RIICE has successfully piloted these technologies in two sites in Thailand that represent the major rice ecosystems in the country: Suphan Buri, which represents irrigated, and intensive rice production systems; and Nakhon Ratchasima, which represents rainfed systems. RIICE has developed guidelines for the acquisition of remote sensing images, automated rice mapping processing chains (i.e., MAPscape-RICE), field monitoring protocols, yield estimation techniques (i.e., ORYZA2000), training materials, and WebGIS delivery platforms that function effectively for both ecosystems. These technologies are all currently available. They have been refined to work with rice ecosystems in Thailand and transferred to RD and GISTDA to develop national capacity for rice crop monitoring.

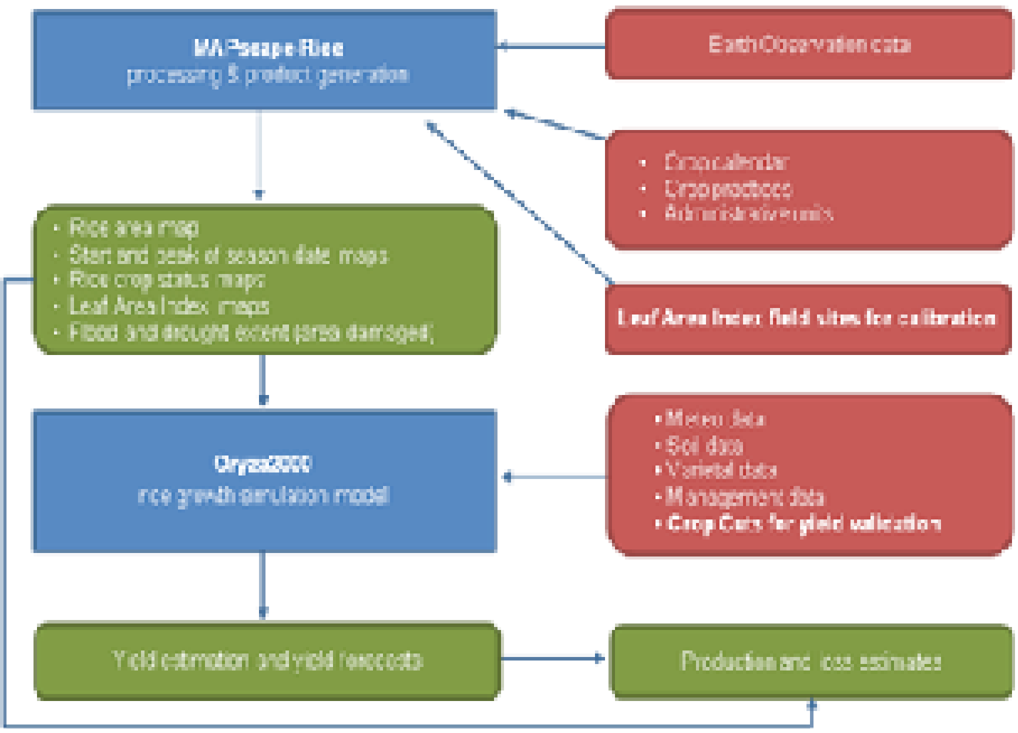

Figure 12. RIICE Conceptual Framework and Technologies.

In 2013, RIICE mapped and monitored over 550,000 ha of rice in Suphan Buri from May to September. The images used were taken every 16 days with a validated map classification of 87 percent at field level and an estimated yield of 4.9 t/ha as compared to data from agricultural statistics of 5.3 t/ha. In Nakhon Ratchasima, where a traditional crop with longer duration is cultivated, some 90,000 ha of rice was monitored every 16 days with a map classification of 86 percent and an estimated yield of 2.3 t/ha as compared to data from agricultural statistics of 2.6 t/ha. The estimated area, planting date, and yield for rice in Nakhon Ratchasima is illustrated in Figure 13.

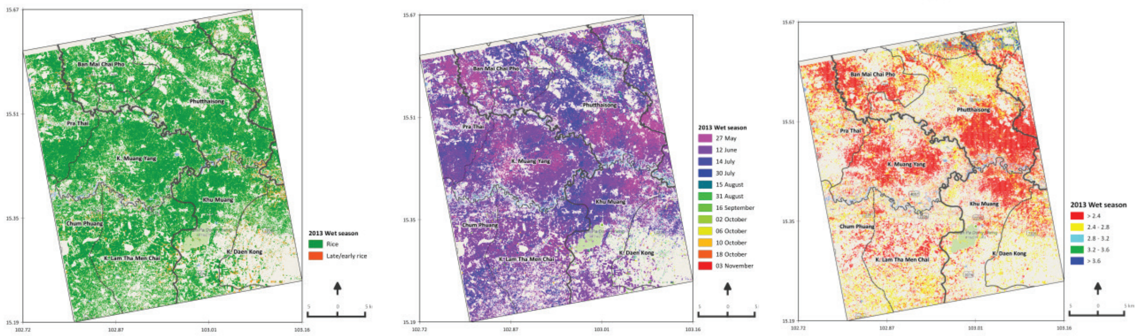

Figure 13. Area, Planting Date, and Yield for Rice in
Source: Nakorn Ratchasima (2013

In October 2013, floods resulted in rice area loss in some parts of Nakhon Ratchasima. This information was made available to RIICE partners through the Thailand WebGIS portal within a few days of receiving remote sensing imagery. The flood-affected areas in Nakhon Ratchasima are shown in Figure 14. Timely detection of the flood-affected areas and duration of submergence would not have been possible without the rice monitoring system.

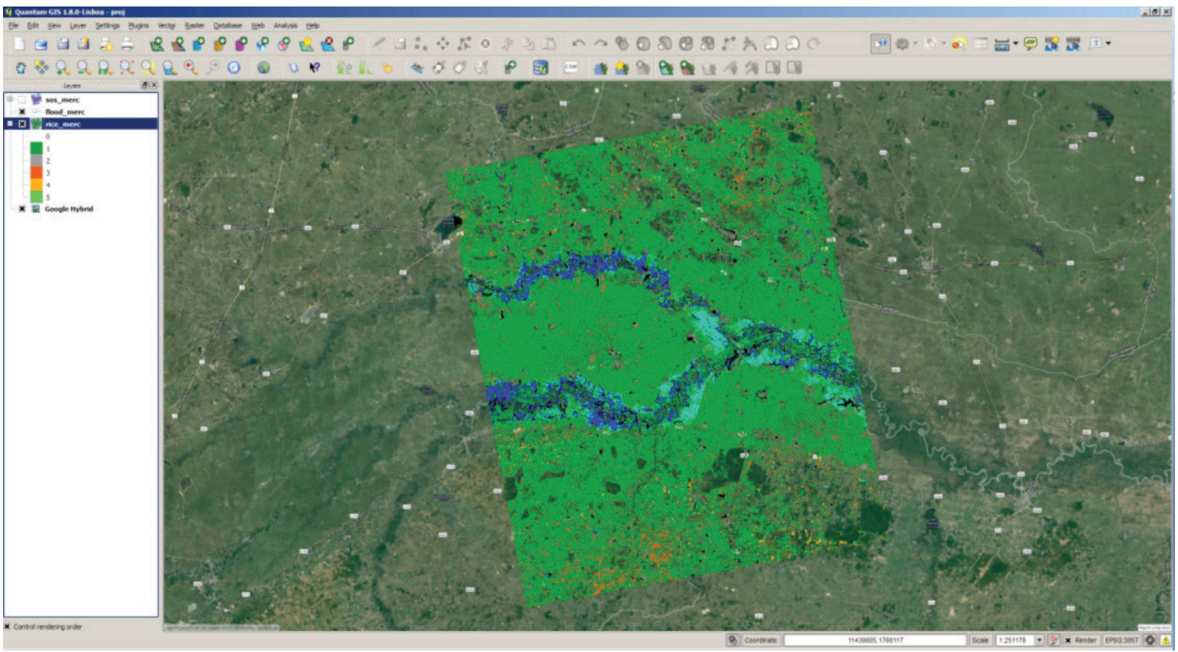

Figure 14. [Flood Affected Rice Area.
Source: Nakorn Ratchasima (2013)

The following are the key outcomes of RIICE:

(1) The pilot site results demonstrate that RIICE technologies in the hands of partners in Thailand can deliver accurate and relevant food security information on the rice crop in the major rice ecosystems of the country. Further technical assistance from RIICE to partners in Thailand in the form of free SAR (radar) imagery from Sentinel-1 could scale up this technology nationally.

(2) National workshops and consultations in Thailand in November 2014 confirmed that there is strong partner and government support to implement RIICE technologies on a larger scale across the country to support both research and policy-making related to rice crop security in a changing climate.

(3) Application of the technology for crop insurance will be assessed further through dry-testing area-based yield index insurance products, which rely on payout triggers from yield time series and timely in-season yield estimates from RIICE.

5.2 Maize

5.2.1 Strengthening Seed Production through Maize Seed Village in Thailand

Senior Agricultural Research Specialist Dr. Chutima Koshawatana of the Field and Renewable Energy Crops Research Institute is the project leader of the ongoing Maize Seed Village. The project, which began in 2012 and is expected to be completed in 2015, aims to (1) extend the seed production of hybrid maize varieties at the village and community levels by the farmers themselves; (2) transfer the research results related to breeding and hybrid seed production techniques, particularly the Nakhon Sawan 3 Hybrid, to the farmers; (3) reduce the farmers' production cost in terms of high seed prices; and (4) build the farmers' capacity to be self-reliant in hybrid seed production.

The project has eight stages: (1) organization of workshops and forums; (2) conduct of the production of pure hybrid lines (parent lines Tak Fa 1 x Tak Fa (3) by the Nakhon Sawan Field Crops Research Center; (3) conduct of varietal field trials; (4) model farmers' establishment of their pilot demonstration field; (5) selection of successful farmers; (6) establishment of seed production plots; (7) evaluation of farmers' satisfaction; and (8) reporting or monitoring.

The project was piloted by five farmers in the provinces of Nakhon Sawan, Phetchabun, Sukothai, and Tak. A total of 33.5 rais were used to serve as the model seed production plots for the neighboring villages to learn the technology. The demonstration plots were also established in the three research centers of DOA: Chiang Mai Agricultural Research and Development Center, Phetchabun Agricultural Research and Development Center, and Sukothai Agricultural Research and Development Center.

During the first year of the project (October 2012–November 2013), 140 farmers collaborated to produce seeds of Nakhon Sawan 3 in an area of 358.50 rais. A total of 80.69 t of seeds were produced. During the second year of the project (November 2013–January 2014), the seed production area totaled 155 rais. Data collection is in progress.

The farmers have proven to be capable in producing their own hybrid seeds through the technology introduced by DOA. The farmers in Maesod District in Tak are now scaling up the technology to put up their own village enterprise.

5.2.2 Maize Breeding for Drought Tolerance in Thailand

Teerasak Manupeerapan, Yodsaporn Chantachume, Pichet Grudloyma, Sompong Thong-chuay, and Somrak Noradechanon of the Nakhon Sawan Field Crops Research Center conducted maize breeding for drought tolerance in Thailand. Drought stress damages an estimated 3–22 percent of the country's planted maize area every year, resulting in yield losses estimated to be from 129,000 t to 858,000 t and worth USD 10–80 million. The maize breeding program for drought tolerance was established in Thailand in 1982. The maize population KK-DR was developed from six source materials and has been improved for drought tolerance using an S1 recurrent selection scheme. After three cycles of population improvement, three synthetic varieties were developed. These synthetics, together with seven other OPV and six hybrid varieties, were evaluated in 1991 and 1992 to compare yield potential and other agronomic characters under artificial water stress and non-stress conditions in the summer season. The experiments were also conducted in both years under rainfed conditions in the rainy season to compare seasonal effects. In general, hybrids out-yielded the OPV under drought conditions, and by an even greater margin under well-atered conditions. The results demonstra-ted, however, that not all hybrids performed better than the OPV under drought conditions. One of the synthetic varieties showed higher yield potential and more drought tolerance than some hybrids. Under plentiful water conditions, maize grown in the summer season showed higher yield potential than maize grown in the rainy season.

VI. CONCLUSION

6.1 Value Chain Analysis

By analyzing the rice value chain, Thailand has formulated a strategic plan for rice with three major strategic thrusts: R&D, improved productivity and products development, and capacity-building for farmers. Rice R&D is directed towards the improvement of rice productivity, value addition, promotion of integrated multi-sectoral approach and commercial research, networking, and dissemination of innovative research. Improvement of productivity and products development are directed towards rice zoning; adoption of GAPs; complete cycle rice production; organic and safe rice; non-GMOs; adoption of GMPs; geographic indicators for rice, rice brands, and products; rice mechanization; and development of rice seed distribution systems, early warning systems for natural calamities, and irrigation systems. Capacity-building initiatives are directed towards rice farmers' foundation service, income guarantee, and rice disaster insurance fund; rice conservation; one-stop farmers' service center; rice community center; and modern information management system.

For maize, the targets include (1) maintaining a cultivation area of 7 million rais until 2017; (2) increasing the yield from 653 kg/rai in 2012 to 825 kg/rai in 2017 at 14.5 percent moisture content; (3) increasing the volume of production from 4.48 million t in 2012 to 5.80 million t in 2017; (4) and changing the usual harvesting practice for rainy season planting (July–October) from 60 percent to 30 percent, for cold season planting (November–February) from 35 percent to 60 percent, and for lowland planting (March–April) from 5 percent to 10 percent in 2017.

For maize, the strategic thrusts are to (1) enhance productivity and reduce production cost through zoning, registering maize farmers, and mass-producing good quality seeds and non-GMOs for distribution to farmers; (2) enhance production efficiency and transfer of technologies for GAPs and sustainable use of water resources in the local community; (3) improve water reservoirs, production, and extension systems; (4) establish an insurance system for natural calamities; (5) establish a network of farmer institutions; and (6) establish community information networking to monitor the production, marketing, and early warning system for calamities.

For value addition and marketing, some of the initiatives include expanding the industries for corn flour, corn oil, and bioplastics; value addition; forming farmer groups and networks; creating linkages among maize producers and consumers; promoting maize trade through the Agricultural Futures Exchange in Thailand (AFET) system; and promoting Thailand as the ASEAN trading center for field corn and products.

The problem of aflatoxins in grains can be solved through R&D on technologies suitable to the environmental conditions of each production area. In addition, the efficient use of production inputs, development of maize varieties that are tolerant to drought and resistant to pests and diseases, value addition, and use of biotechnology as a tool for breeding varieties can contribute to curbing the problem.

Climate resilience of maize can be promoted by enhancing farmers' awareness and knowledge on the possible impact of environmental factors on maize production, and increasing understanding on modifying their traditional practices to be more suitable to current climatic conditions. This includes (1) using a crop calendar to schedule planting, such that it coincides with the flowering or fruiting stage, under the most conducive environmental conditions; (2) breeding for maize varietal improvement with high water-use efficiency, fast growth, early maturing, deep and fibrous rooting, resistance to drought (e.g., Nakhon Sawan 3 developed by DOA), and nutrient-use efficiency; (3) improving soil and water management and conservation practices suitable to the local conditions; (4) expanding water reservoirs and irrigation infrastructure; and (5) promoting the formation of farmer groups (e.g., seed producers) within the community.

6.2 Review of Climate Change Impacts and Vulnerabilities

CIAT conducted an analysis on long-term climatic conditions in Thailand as part of the project, Sustainable Palm Oil Production for Bioenergy in Thailand, which was commissioned by the German Federal Ministry of Environment, Nature Protection, and Nuclear Safety and implemented by GIZ in close cooperation with OAE of Thailand.

The results showed that climate is highly variable, particularly the amount and distribution of rainfall that includes huge year-to-year and within-year variations. This variability introduces great risk and uncertainty into agricultural systems, which is a major concern for marginalized smallholder farmers. The analysis of the climate in Thailand from 1901 to 2005, using a reconstruction of the climate based on the CRU dataset, highlighted this variability. However, it also showed some significant trends in climate variations. During the 20th century, minimum, mean, and maximum temperatures increased throughout the country, particularly since 1985. The minimum temperature increased by 0.1ºC–1.0ºC, while the mean and maximum temperatures increased by 0.0ºC–0.8ºC. There were also some slight increasing trends in mean, annual, and monthly rainfall, but these trends remained within the range of year-to-year variations of these variables characterized by irregular patterns (OAE, CIAT, and GIZ 2012).

OAE, CIAT, and GIZ (2012) predicted that on the average, temperatures may increase by 0.4ºC every 10 years from now to 2050. By 2050, the minimum and mean temperatures will have increased by up to 2ºC compared to the 2010 value, and the maximum temperature will have increased by up to 1.8ºC. In particular, mean temperatures will reach values higher than 29ºC for all areas in the Chao Phraya River basin.

The predictions for rainfall suggest that the effects of climate change will vary per area. The analysis revealed that the annual rainfall may decrease up to 250 mm in the central part of Thailand and increase up to 600 mm in the northern and southern regions. Monthly precipitations at the beginning and at the end of the rainy season may remain stable in most areas of the country. However, there may be a decrease of up to 120 mm in May in the eastern part and in October in the central region, as well as an increase of up to 200 mm in November in the southern region. These changes in rainfall patterns are of the same order of magnitude as the variation between years, which means that the main aspect of rainfall that farmers should be aware of is the variability. The predictions for rainfall suggest that climate change will have varying effects on different areas.

The bioclimatic suitability of rice and maize was assessed against the current and predicted 2050 climate using the Ecocrop model. Ecocrop is based on temperature and rainfall limits for the crop to grow. An important result in terms of adaptation strategies is that for the crops studied, the current climate suitability is driven mainly by precipitation. The current suitability was assessed and compared to the current distribution of the crops. For rice (KDML 105 and other varieties), rainfall is the principal limiting factor, where high suitability is in the strip around the center or areas of intermediate rainfall between the dry central zone and wet surrounding areas. However, the current production areas do not overlay with suitable areas, and the other potential factor explaining distribution is water management. For maize, rainfall is also the principal limiting factor, where high suitability is in the central dry area or the central continental part of the country where annual rainfall is low, and the current production areas well overlay with suitable areas.

6.3. Areas for Regional Collaboration and Strategic Approaches

Potential regional collaborations could be developed from five research thrusts: (1) research network programs on climate change assessment, mitigation, and adaptation; (2) technology transfer; (3) HRD programs; (4) institutional support; and (5) ASEAN regional cooperation on climate resilience and food security.

6.4 National Case Studies on Good Practices

The following good practices in promoting climate resilience were identified: for rice, (1) crop calendar, (2) AWD technique, and (3) RIICE technology using a combination of SAR remote sensing and crop modeling for government policy intervention and crop insurance programs; and for maize, (1) establishing maize seed villages in major maize-producing areas and (2) breeding drought-tolerant varieties.

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