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Promotion of Climate Resilience for Food Security in ASEAN

Rice, Maize and Cassava







Imprint

This publication is a joint undertaking by the ASEAN Technical Working Group on Agricultural Research and Development (ATWGARD) and the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH
through the ASEAN-German Programme on Response to Climate Change (GAP-CC).

In partnership with the Southeast Asian Regional Center for Graduate Study and Research in Agriculture (SEARCA).

Published by the
Deutsche Gesellschaft für
Internationale Zusammenarbeit (GIZ) GmbH

Registered offices
Bonn and Eschborn, Germany

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As at
April 2015

Printed by/design and layout
SEARCA
College, Los Baños
Laguna - 4031

Cover Photo Credits
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On behalf of the
German Federal Ministry for Economic Cooperation and Development (BMZ)
Alternatively: German Federal Foreign Office

Promotion of Climate Resilience for Food Security in ASEAN

Rice, Maize and Cassava

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

AMS	ASEAN Member States
APAN	Asia Pacific Adaptation Network
ASEAN	Association of Southeast Asian Nations
ASEAN-CRN	ASEAN Climate Resilience Network
ATWGARD	ASEAN Technical Working Group on Agricultural Research and Development
AWD	Alternate Wetting and Drying
CCA	Climate Change Adaptation
CCAFS	CGIAR Research Program on Climate Change, Agriculture and Food Security
CCROM	Center for Climate Risk and Opportunity Management in Southeast Asia and Pacific
CSA	Climate Smart Agriculture
GAP-CC	ASEAN-German Programme on Response to Climate Change
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH
IRRI	International Rice Research Institute
NGO	Non-goverment organization
R&D	Research and development
PIRCCA	The Policy Information and Response Platform on Climate Change and Rice in the ASEAN
SCOPSA	Sustainable Corn Production in Sloping Areas
SEARCA	Southeast Asian Regional Center for Graduate Study and Research in Agriculture
SSNM	Site-specific Nutrient Management
WIBI	Weather index-based insurance

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Foreword
Thai Department of Agriculture

Agriculture is a vital sector for the Association of Southeast Asian Nations (ASEAN) community and the ASEAN Member States (AMS) are established as important world suppliers of agricultural commodities. Food security is a priority to meet the needs of the AMS's expanding population as well as underpin the steadily growing role in the export of agricultural and forestry products to global markets.

Southeast Asia is highly vulnerable to climate change as a large proportion of the population and economic activity is concentrated along coastlines with high dependence on agriculture, natural resources and forestry for livelihoods. The AMS, though not the source of significant emission of greenhouse gases, have taken actions to address climate change through various environmental, economic and social activities over the years.

Almost all of the AMS have also started strengthening their adaptive capacity through mainstreaming climate change adaptation in their national development planning. The ASEAN Leaders expressed ASEAN's common position and aspirations towards a global solution to the challenge of climate change and their resolve to achieve an ASEAN Community that is resilient to climate change through national and regional actions.

The ASEAN governments now view climate change as a priority issue, especially in terms of its potential impacts on food security, and expressed the need for clear directions in addressing both issues.

While technical and policy measures to ensure food security in the context of climate change are numerous, interrelated, and complex, the successful implementation of programs and projects calls for simple and flexible solutions that carefully consider the capabilities of relevant stakeholders at the regional, national, and local levels. The findings of the national studies were therefore further synthesized to be an input for the drafting of the ASEAN Regional Guidelines for Scaling-up Climate Smart Agricultural Practices developed by the ASEAN Climate Resilience Network (ASEAN-CRN) for submission to the 2015 ASEAN SOM-AMAF for consideration and endorsement.

This national studies report would not be possible without the support from the ASEAN-German Programme on Response to Climate Change (GAP-CC). Therefore, on behalf of the all the AMS, we acknowledge with great appreciation this support from the Federal Government of Germany.

Dr. Suwit Chaikiattiyos
Deputy Director General

Foreword

Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

Southeast Asia is highly dependent on agriculture and its natural resources. At the same time, the region faces the continuing challenge of climate change impacts on agriculture value chains while ensuring food security for its ever growing population.

The Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, through the ASEAN-German Programme on Response to Climate Change (GAP-CC), funded by the German Federal Ministry for Economic Cooperation and Development (BMZ), assists the ASEAN and its Member States in addressing this challenge. GAP-CC supports ASEAN in advancing the formulation and implementation of regionally coordinated strategies and policies for food security and climate change. It aims to channel lessons and experiences from individual country action into the work of the regional organization and vice-versa.

This series of national studies is a milestone activity supported by GAP-CC. It provides an assessment of the adaptive capacities of 7 member states (with the special participation of Brunei and Malaysia) in the crop production system of rice, corn and cassava. Taken together, this exercise provides ASEAN with the reference point in determining climate smart agriculture practices existing in the region; the technical requirements for practical applications; the technical and institutional challenges; and areas for regional collaboration in order to promote their wider use.

These national studies, as well, form the basis of policy guidelines for ASEAN to promote climate resiliency within the region through the scaling up of priority good practices. One such example is the recently endorsed, **ASEAN Guidelines for Scaling-up Climate Smart Agricultural Practices**.

These national studies--a result of national consultations at a regional scale-- also paved the creation of a platform for regional exchange called the ASEAN Climate Resilience Network (ASEAN CRN). I believe the existence of this network is in itself an achievement due to the various strategies outlined by members, and the partnerships created in support of its goals.

GAP-CC stands to support the initiatives that came out of the conduct of these national studies until 2017.

We are very fortunate to find a genuine proposal and leader from the Thailand Department of Agriculture, which initially sought our support to promote resiliency of rice production system in the region. We also could not find a more energetic champion, as the ASEAN Technical Working Group on Agriculture Research and Development (ATWGARD), which co-supervised the national studies, and fostered the birth of the ASEAN CRN. Along the way, the partnerships from international research institutions, specifically from the Consultative Group for International Agricultural Research (CGIAR) proved invaluable. I would also like to thank the Southeast Asian Regional Center for Research and Graduate Study in Agriculture (SEARCA) for coordinating the whole regional exercise and opening its vast network to us.

While there are complex initiatives and technical details all existing in the region which we could not all possibly include in this compilation, we hope that the readers find this publication useful. We are very proud to be a part of this endeavor.

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Mr. Thomas Heindrichs
Head of Programme, GAP-CC

Foreword

Southeast Asian Regional Center for Graduate Study and Research in Agriculture (SEARCA)

As part of our commitment to promote inclusive and sustainable agricultural and rural development (ISARD) in Southeast Asia, SEARCA is pleased to present seven national studies on the *Promotion of Climate Resilience in Rice, Maize and Cassava*.

The national studies stem from the project, ASEAN Network on Promoting Climate Resilience of Rice and Other Crops, which was a joint undertaking of the ASEAN Technical Working Group on Agricultural Research and Development (ATWGARD), GIZ, and SEARCA. The project promoted a common understanding and facilitated exchange of experiences on climate change and agriculture focusing on rice, maize, and cassava in seven pilot AMS, namely Cambodia, Indonesia, Lao PDR, Myanmar, Philippines, Thailand, and Vietnam.

Each of the seven national studies presents a review of the climate change impacts and vulnerabilities of each country as well as the policies and successful practices in climate change adaptation at the AMS level. This study also features a value chain map of each country's priority crops as well as areas for regional collaboration to make Southeast Asia climate resilient. Our goal is to upscale the results and recommendations of this study to contribute to agricultural and rural development in the region.

Finally, we wish to thank and congratulate the authors of the national studies. Our sincere appreciation to ATWGARD, the Thai Department of Agriculture, and GIZ for the technical and financial support they contributed to this project. We hope to continue our partnership as we strive to address new and emerging issues and challenges confronting Southeast Asia's agriculture sector.

SEAMEO SEARCA

Dr. Gil C. Saguiguit, Jr.
Director

Background and Rationale

Southeast Asia is one of the regions in the world that are most vulnerable to climate change. Climate hazards, such as temperature increase, erratic rainfall patterns, and extreme climatic events, disrupt ecosystems, livelihoods, and various aspects of human systems. Climate change threatens agricultural production, consequently endangering food security, ecological stability, and sustainable development.

A food resiliency index[1] commissioned by the ASEAN-German Programme on Response to Climate Change (GAP-CC) identified rice, maize, and cassava as the staple crops most vulnerable to climate change in Southeast Asia. Climate hazards adversely affect the sustainable production of these major crops, resulting in a decrease in yield and areas suitable for cultivation. Coping strategies and adaptation measures are vital in making crop production systems more resilient to the negative effects of climate change.

Studies show that many Southeast Asian countries employ good practices in crop production systems. These good practices range from indigenous to field-tested crop management measures, to knowledge-based options. These location- and situation-specific practices can be modified to suit the local settings of other areas with similar conditions. These good practices, along with recently developed and tested climate change adaptation (CCA) measures, form the knowledge base from where cost-effective and -efficient strategies can be formulated to promote climate resilience of rice and other crops in Southeast Asia. As those practices and measures increase climate resilience with potential co-benefits like reducing greenhouse gas emissions, they constitute climate smart agriculture (CSA) practices.

Recognizing the importance of cooperation and knowledge exchange in confronting the emerging threats of climate change in Southeast Asia and the role that ASEAN could play to promote this, the government of Thailand submitted a proposal, Production System Approach for Sustainable Productivity and Enhanced Resilience to Climate Change, to the ASEAN Technical Working Group on Agricultural Research and Development (ATWGARD). The proposal called to organize a regional network to address issues of climate change in Southeast Asia and to ensure that ASEAN Member States (AMS) are in a better position to adapt their agricultural sector to climate change and optimize its mitigation potential. Based on the proposal and the initiative by Thailand, at the 8th Meeting of the ATWGARD in Singapore, 2013, the ASEAN Climate Resilience Network (ASEAN-CRN) was established. The ASEAN-CRN was established firstly to facilitate the review of the adaptive capacities of ASEAN Member States to sustain food security amidst climate change; and to support the process of scaling up climate smart agriculture practices amongst the AMS through regional cooperation. The ASEAN-CRN, is supported by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) through the GAP-CC that supports ASEAN in improving selected framework conditions for sustainable agriculture and forestry in AMS.

The first major activity of the ASEAN-CRN was to facilitate a coordinated regional study across AMS. While Cambodia, Indonesia, Laos, Philippines, Thailand and Vietnam received support from GAP-CC in conducting the research, Brunei and Malaysia were actively engaged in knowledge exchange activities and contributed their experiences from their own resources. The participation of Myanmar in the process was partially supported by the International Rice Research Institute (IRRI) through the The Policy Information and Response Platform on Climate Change and Rice in the ASEAN (PIRCCA) Project.

[1] CCROM (2014). Food Secutity in ASEAN and Climate Change: An Assessment of Vulnerabilities of Staple Food Crops in ASEAN Member States

Research Objectives

The research on Promoting Climate Resilience of Rice and other Crops lays an important basis for ASEAN's cooperation on and knowledge exchange through the ASEAN CRN. The research combines a vulnerability assessment of the value chains of two major food crops in the participating AMS with a stocktaking on existing good practices that could become subject of regional exchange and be promoted for scaling-up.

The research composed of national studies from the participating member states focused on climate change adaptation measures employed in crop production systems of rice, maize and cassava following the Value Chain Approach.

It has the following objectives:

(1) To identify good practices in the ASEAN region, which address climate change related vulnerabilities that could lead to food insecurity of the three critical food crops in the region: Rice, Maize and Cassava using a value chain mapping approach.

(2) To identify where vulnerabilities exist or are likely to exist, in the supply of the identified food crops, with a primary focus on production and related inputs and a secondary focus on post-production activities; specifically drawing out where regional collaboration could be most valuable.

(3) To identify the good practices in terms of its technical requirements for practical applications, institutional issues and implementation challenges focused on scaling up regionally.

(4) To use the learning from existing good practices to stimulate and spread meaningful action across the region.

The outputs of the research project are seven national studies of AMS on the promotion of climate resilience in rice, maize and/or cassava value chains. The findings in the national studies provided the main input for the development of the ASEAN Regional Guidelines on Scaling-up Climate Smart Agriculture Practices which have been discussed and approved in the 4th Special ATWGARD Meeting in May 2015, in Ho Chi Minh City, Vietnam. This ASEAN Regional Guideline, in turn, provides the ASEAN-CRN with priority activities for the overall objective of promoting climate smart agriculture and resiliency of the region.

Approach and Methodologies

The national studies were conducted in seven AMS, namely Cambodia, Lao PDR, Indonesia, Myanmar, Philippines, Thailand and Vietnam. The Southeast Asian Regional Center for Graduate Study and Research in Agriculture (SEARCA) has been commissioned by GAP-CC to coordinate the conduct of the national studies at a regional level and in the collaborating AMS.

The studies center on CSA practices employed in crop production systems of rice, maize, and cassava in the seven AMS. The selection of these three crops is based on a vulnerability assessment in staple food crops in AMS, which was conducted by the Center for Climate Risk and Opportunity Management in Southeast Asia and Pacific (CCROM) with technical inputs from Alexander Ballard Ltd. and financial support from GIZ through GAP-CC. Good practices in rice, maize, and cassava production are identified using a 6-Step Methodology for scoping adaptive capacity of value chains.

Step 1 -	Crop Selection & Value Chain Mapping: Selection of the area of focus and development of a Value Chain Map for the selected crops
Step 2 -	Review Climate Change Impacts: Review information sources on current and future Climate Change impacts in the respective country
Step 3 -	Identification of areas where action is needed through the location of points in the value chains, or in activities designed to develop the value chains, that are vulnerable to climate change impacts
Step 4 -	Identify areas for Good Practice Case Studies: Projects and other areas of effective climate adaptation activity relevant to the selected value chains are outlined
Step 5 -	Reporting Structure: A reporting structure is provided, allowing direct comparison and collective analysis to be made using data from multiple countries.
Step 6 -	Report Consultation and Endorsement: A national and project consultation process was encouraged and supported prior to official endorsement by the respective AMS government.

Research teams were equipped with an elaborate guidance document on how to use the methodology. Each good practice is documented in terms of its technical requirements for practical applications as well as institutional issues and implementation challenges.

The conduct of the national studies was lead by a National Team Leader and coordinated by a Regional Team supported under the auspices of the GAP-CC, with oversight supervision by SEARCA and the AMS' respective ATWGARD focal persons. National consultative meetings and field visits, as well as review of literature and focus group discussions, were conducted to assess climate change impacts on selected sectors, identify, prioritize, and fully document country-specific CSA practices, as well as factors for its scaling-up and replication. The planning, reporting, and monitoring of national studies were done in coordination with the ATWGARD in three special meetingsI during one year. CCROM provided technical expertise derived from the previous work on the vulnerability index of major crops within ASEAN, along with Climate Sense, a UK based consultancy, to shape the methodology of the research.

Table 1 gives an overview of the institutions which were involved in the process of regional exchange and developing the national studies.

Table 1. ASEAN-CRN's partner institutions.

National research institutions	
Cambodia	Cambodian Agricultural Research and Development Institute (CARDI), Royal University of Agriculture
Indonesia	Indonesian Centre for Food Crop Research and Development (ICFORD), Indonesian Agency for Agricultural Research and Development (IAARD), Bogor Agricultural University
Lao PDR	National Agriculture and Forestry Research Institute (NAFRI), Northern Agriculture and Forestry College
Myanmar	Department of Agricultural Planning, Department of Agriculture, Centre for South East Asian Studies
Philippines	Department of Agriculture-Bureau of Agricultural Research (DA-BAR), University of Philippines Los Baños (UPLB)
Thailand	Department of Agriculture (DOA), Field Crops Research Institute, Rice Department
Vietnam	Ministry of Agriculture and Rural Development (MARD), Institute of Policy and Strategy for Agriculture and Rural Development (IPSARD)
International research institutions	
International Rice Research Institute (IRRI) through the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS)	

The ASEAN-CRN links these policy makers, scientific institutions, universities, national research institutions in agriculture, and international organizations and was the coordinating hub for the research process.

The Kick-off Workshop of the ASEAN-CRN and the national studies was held in Pattaya, Thailand last 21-22 January 2014, in the 1st Special ATWGARD meeting. Workshop participants from the ATWGARD as well as partner institutions defined the objective and scope of the research process under existing ASEAN frameworks, validated and finalized the the expected objectives and outputs. They shared information on the current status in each member state, and finalized the research methodology which includes criteria on sector selection, scope of analyses, current/future climate impacts, and selection criteria for best practices. Each research team was invited to select two crops out of the three focus crops to take into account, rice and either maize or cassava. The list of selected crops for each participating AMS is presented in Table 2.

Table 2. Summary of priority crops selected by ASEAN member states.

Priority Crops	Participating Countries
Rice and Maize	Brunei, Lao PDR, Indonesia, Myanmar, Philippines, Thailand, Vietnam
Rice and Cassava	Cambodia, Malaysia

After a series of national consultative meetings conducted by the respective AMS, the CRN convened the 2nd Special ATWGARD Meeting on 17 June 2014 in Bangkok, Thailand presented the preliminary findings of the national studies of the participating AMS on climate resilience of rice, maize and cassava. The workshop aimed at sharing information as well as: identifying and exchanging CSA good practices among the AMS; identifying regional areas of collaboration; and providing technical input and exchange among the AMS.

CSA Practices

While taking a value chain approach to assess vulnerabilities to climate change in the selected food crops, the primary focus of the research lies in the production phase of those crops. Acknowledging the importance of post-harvest, storage and distribution, a secondary focus for assessing vulnerabilities and identifying good practices goes beyond primary production to cover those segments further downstream in the value chain.

Each national study was invited to prioritize and select a maximum number of five cases of good practices for the two selected crops combined. The CSA practices identified in the national studies and which are pilot-tested and promoted among AMS are summarized in Table 3.

Table 3. Summary of identified and prioritized good practices employed by collaborating ASEAN member states to enhance climate resilience of rice, maize, and cassava.[2]

Good Practices Identified in National Studies									
	BN	KH	ID	LA	MY	MM	PH	TH	VN
1. Rice									
- Alternate Wetting and Drying						x	x	x	x
- System of Rice Intensification				x		x			
- Integrated Crop Management				x		x			
- Crop Insurance			x					x	
- Cropping Calendar	x		x		x			x	x
- Crop Diversification				x		x			
- Optimal Row Spacing			x						x
- Rice Shrimp Farming									x
- Nutrient Management	x				x				
- Stress Tolerant Varieties	x	x	x	x	x	x	x		
- Short-duration Varieties						x			x
2. Maize									
- Improved Varieties			x			x	x	x	x
- Site Specific Nutrient Management						x	x		
- Cropping Pattern / Intercropping			x	x		x			x
- Cropping Calendar			x			x			
- Using Crop Residues			x			x			
- Diversification						x			
- Appropriate Row Spacing									x
- Post-Harvest Handling				x			x		
- GAP in Sloping Areas							x		x
- Seed Production and Seeding				x			x	x	
3. Cassava									
- Healthy Planting Material		x			x				
- GAP in Sloping Areas		x							

[2] Makara, O. (2014 October 6-8). Promotion of Climate Resilience of Rice and Other Crops. 2nd Mekong River Climate Change Forum. Siem Reap: Cambodia

The identified CSA practices include the use of varieties that are resistant to drought, salinity, pest and diseases, and other climate related stress. Further, prioritized CSA practices include improved crop management measures during crop growth and development; use of technological advances and science-based knowledge ; crop diversification, including changing crops or commodities (e.g., shrimp farming in the Mekong River Delta); and further innovations such as agri-insurance.

In recent years, national agricultural research centers tested and promoted alternate wetting and drying (AWD), a technique developed by the International Rice Research Institute (IRRI). Furthermore, contour farming in maize production in developing countries is being implemented under Sustainable Corn Production in Sloping Areas (SCOPSA). This strategy for soil and water conservation addresses accelerated soil erosion in upland areas. Moreover, climate risk management through weather index-based insurance (WIBI) products (e.g., rainfall-based drought insurance) has been found attractive and efficient, except for the high cost of insurance premium. These widely implemented good practices have been proven effective in enhancing climate resilience of crop production systems.

Some good practices are similar across AMS. These practices can be modified to suit the local settings of other areas with similar conditions. Institutional and human capacity measures relevant to the scaling up and replication of such practices were also identified.

First drafts of the national studies were presented during the Second Special Meeting of the ATWGARD in Bangkok, Thailand on 17 June 2014. Following the discussion of good practices identified in each national context, AMS representatives were invited to express interest in practices which they would prefer to be covered in knowledge exchange activities. The interest expressed by AMS is outlined in Table 4.

Table 4. AMS' preferred good practices for knowledge exchange per crop.

AMS	Identified Good Practices		
	Rice	Maize	Cassava
Brunei Darussalam	Cropping calendar AWD Stress-tolerant varieties	Maize (special type, for consumption)	
Cambodia	Stress-tolerant varieties Crop diversification/ model farming Best crop management practices		Healthy planting materials Contour inter-cropping
Indonesia	Dynamic cropping calendar New varieties Crop insurance (WIBI)	Dynamic cropping calendar New varieties Crop insurance (WIBI)	
Laos	Crop diversification Post-harvest technologies Thai smallholder seed production	Crop diversification Post-harvest technologies Marketing issues	
Malaysia	Cropping calendar Drought-tolerant varieties Water use efficiency		Planting materials GAP Post-harvest technologies

cont... Table 4.

AMS	Identified Good Practices		
	Rice	Maize	Cassava
Myanmar	Climate-resilient varieties AWD SSNM (Site-specific Nutrient Management Proper post-harvest technologies	SSNM SCOPSA Quality Protein Maize	
Philippines	Climate-ready varieties Crop diversification Cropping calendar Rice-shrimp farming	Stress-tolerant varieties SSNM SCOPSA	
Thailand	Cropping calendar Stress-tolerant varieties Remote Sensing-based Information and Insurance for Crops in Emerging Economies	Breeding and production of stress-tolerant varieties	
Vietnam	Rice shrimp farming Crop insurance AWD	Stress-tolerant and high-quality varieties Optimal row spacing and density SSNM	

Table 4 shows that some practices receive priority from a number of AMS and hence provide potential for comprehensive regional exchange and knowledge events in ASEAN while other practices are of particular interest to one or a few AMS and could be object of targeted country to country exchange or support activities. Stress tolerant rice varieties are of particular interest and where mentioned by seven AMS during the workshop. Furthermore improving the cropping calendar for rice is a topic of high interest for five AMS. AWD, stress tolerant rice varieties, diversification, sustainable soil and nutrient management and crop insurance are further topics with considerable interest by a number of AMS (three to four).

Institutional and Implementation Challenges

Despite the fact that many CSA practices and their benefits are well known and understood in the respective AMS government and research agencies, the sector-wide implementation of those practices is often lacking behind. This "Implementation Gap" is a considerable challenge in all of the AMS country studies. Understanding why implementation is lacking and what enabling framework conditions need to be in place to promote the scaling-up of CSA practices will be crucial for promoting sector wide impacts and to adequately respond to the challenge of climate change in food security.

To address this major concern, research teams were encouraged to assess the institutional and implementation challenges that have been faced by the respective good practices identified in their specific country context. Insights into these constraints and possible solutions to address them pose a topic of high interest for regional exchange, beyond the exchange of technical knowledge.

During the Second Special Meeting of the ATWGARD in Bangkok, Thailand on 17 June 2014 the participating AMS presented their initial findings on institutional and implementation challenges and commonalities were discussed.

The following major institutional and implementation challenges were highlighted during the meeting:

(1) Inadequate mechanisms for the transfer of CSA technology and knowledge through agricultural extension programs;

(2) Lack of opportunity for field demonstrations and piloting of CSA options in selected areas;

(3) Sharing and dissemination of CSA-related data and information as well as transfer of technology within and among AMS;

(4) Implementation of effective regional networking and collaboration for research and development (R&D) activities and projects;

(5) Availability of effective, efficient, accessible, and affordable climate risk management measures such as risk sharing or transfer through agri-insurance (e.g., use of WIBI products in Indonesia and the Philippines); and,

(6) Sustainability of financing mechanisms for CSA practices.

This assessment provides an important basis for dialogue and support through the ASEAN-CRN on how to overcome implementation challenges and how to develop effective systems for scaling-up CSA practices.

Recommendations

The ASEAN-CRN aims to ensure that AMS are in a better position to adapt their agricultural sector to climate change and optimize its mitigation potential by promoting the scaling-up of identified CSA practices through regional exchange and advocacy in ASEAN. This will include effective approaches to address the identified institutional and implementation challenges. The ASEAN Guidelines for Scaling-up Climate Smart Agricultural Practices constitute the major framework to guide ASEAN towards this objective. The Regional Guidelines have been developed based on the findings of the national studies and the learnings and agreements throughout the process of regional cooperation and exchange in the first year of operation of the ASEAN-CRN.

The ASEAN-CRN through its members and partners and the national teams from AMS recommend the following actions:

(1) Regional collaboration among participating AMS to facilitate the sharing of information on good practices and transfer of technology through existing networks and programs of regional institutions. The CRN can tap existing networks such as SEARCA; CGIAR Research Program on Climate Change, Agriculture, and Food Security (CCAFS); and Asia Pacific Adaptation Network (APAN) to fast-track the exchange of information, expertise, and experiences on CSA practices. These include downscaled climate scenarios, information on seasonal climate forecasts, knowledge management, and planting calendar, among others.

(2) Partnership and collaboration of agricultural R&D institutions with local groups, such as local government units, non-government organizations (NGOs), and people's organizations, is essential in facilitating capacity building and enhancing climate resilience of local communities and crop production systems.

(3) Facilitation of climate-proofing other crop production systems such as integrating CSA practices to farm production activities in livestock, aquaculture, and agroforestry.

(4) Implementation of multi-level capacity-building programs such as executive fora for planners, training of trainers, and training of key local stakeholders.

(5) Implementation of R&D on CSA practices with technical assistance from experts in Southeast Asia, along with provision of technical inputs on CSA options, procedures and protocols, and crop production inputs (e.g., improved and climate stress-tolerant varieties).

(6) Establishment of a monitoring and evaluation system for assessing climate resilience of local stakeholders, crop production systems, and ecosystems. This will involve specifying and measuring key indicators for monitoring resilience.

(7) Recognition of CSA as an investment that requires integrating CSA practices and business plans in agricultural farm production. Sustainability should be considered to ensure resilience to climate hazards. Joint-venture projects and related activities on CSA interventions, such as funding and links with existing programs, should be explored.

(8) Formulation of the ASEAN Protocols and Guidelines on Promotion of Climate Resilience that include policy briefs on good practices for CSA, prioritizing R&D activities (e.g., climate field schools), mobilizing and allocating funding, expert dispatch and technical assistance, and sustainable financing of CSA for climate resilience.

(9) Establishment of a Center for studying and analyzing national and regional climate scenarios, issuing seasonal climate forecasts, providing regular crop forecasts given seasonal climate outlook, and assisting in mainstreaming climate change policy formulation in AMS local and national levels (as suggested in the national reports). This could be linked to the ASEAN Regional Cooperation Mechanism for Improved ASEAN Cooperation in Food, Agriculture and Forestry, which is currently being proposed.

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Promotion of Climate Resilience in Rice and Cassava

Cambodia National Study

Imprint

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Deutsche Gesellschaft für
Internationale Zusammenarbeit (GIZ) GmbH

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As at
April 2015

Printed by/design and layout
SEARCA
College, Los Baños
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On behalf of the
German Federal Ministry for Economic Cooperation and Development (BMZ)
Alternatively: German Federal Foreign Office

Promotion of Climate Resilience in Rice and Cassava

Cambodia National Study

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

ABK	Aphivat Bandanh Kasekar
AMS	ASEAN Member States
AQIP	Agricultural Quality Improvement Project
ASEAN	Association of Southeast Asian Nations
CARDI	Cambodian Agricultural Research and Development Institute
CCA	Climate Change Adaptation
CelAgrid	Centre for Livestock and Agriculture Development
CIAT	International Center for Tropical Agriculture
DNT	Domnak Teuk Group Company
FAO	Food and Agriculture Organization
GDA	General Directorate of Agriculture
GDP	Gross Domestic Product
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH
IPCC	Intergovernmental Panel on Climate Change
IRRI	International Rice Research Institute
MOE	Ministry of Environment
NGO	Non-government Organization
NIS	National Institute of Statistics
PDA	Provincial Department of Agriculture
RUA	Royal University of Agriculture
UNDP	United Nations Development Programme
WB	World Bank
WFP	World Food Programme

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Foreword

The Cambodian Agricultural Research and Development Institute (CARDI) is proud to endorse this national study of climate adaptive practice to ensure resiliency of rice and cassava in Cambodia, and in the region. Climate change has brought about so many threats to our country's agricultural production, with rice and cassava as particularly vulnerable. These threats include numerous climate risks such as flood, drought, sea water intrusion, pests and diseases, extremely hot days, land degradation, nutrient depletion. However, despite the significant degree of risk and uncertainty that climate change has brought, there are practices that can be adapted with no regrets. Within the course of this study, five good adaptation practices have been identified. Among them, three are identified as practical intervention for rice value chain, namely: model farming, and use of submergence tolerant as well as drought tolerant varieties; while the two remaining are recommended for cassava value chain, namely: use of healthy planting materials and contour intercropping.

We believe that these practices need to be encouraged and replicated in similar areas, through regional collaboration of joint measures such as research and information exchange. This body of work is not only useful to our work in Cambodia, but as well to other relevant entities which work with farmers and climate change. We are happy to be able to contribute to this exercise through the ASEAN Technical Working Group on Agricultural Research and Development (ATWGARD) with the support of the ASEAN-German Programme on Response to Climate Change (GAPCC). We look forward to witnessing similar practices be promoted in a larger scale that will benefit the people of Cambodia.

Signed:

Dr. Ouk Makara
Director

Executive Summary

Cambodia is one of the countries in the Association of Southeast Asian Nations (ASEAN) that are most vulnerable to the impacts of climate change. The country's high vulnerability is connected to various socio-economic factors (e.g., high dependency on agriculture and natural resources, income inequality, poverty, and low education) and poor adaptive capacity (e.g., low public awareness, lack of early warning systems, poor access to irrigation water, and weak national research systems).

Agriculture is the core driver of economic development in Cambodia, where rice is the major crop and the main source of food, nutrition, and income, followed by cassava and maize. The country's climate is governed by a tropical monsoon with distinct wet and dry seasons. Rainfed lowland rice has the biggest share of wet season rice and plays a significant role in the national economy.

Cassava, on the other hand, is mainly produced in the rainfed uplands. These crops and their ecosystems are highly vulnerable to climate change. As such, they were selected for this study, which aims to promote climate resilience of crops for the sustainable development of the country.

In Cambodia, climate-related hazards have caused substantial damages. These hazards negatively affect people's livelihoods, particularly the rural population whose main income depends heavily on agriculture. Studies suggest a rising trend in all climatic factors such as temperature, rainfall, sea level, and wind storm. Increases in average temperature, rainfall intensity, and saltwater intrusion in coastal rice production areas will most likely influence the productivity of rice and cassava, and thus affect the farmers' livelihoods.

The Cambodian agricultural production system is characterized by smallholder farming. Cambodian farmers, who are generally economically resource poor, are among the people that are most vulnerable to climate change. Climatic threats to agricultural production, particularly the production of rice and cassava, include floods, droughts, pest and disease outbreaks, saltwater intrusion, extremely hot days, land degradation, and nutrient depletion, among others. To effectively respond to these threats, appropriate adaptation practices must be developed and implemented.

The following case studies on good practices in climate change adaptation (CCA) options for rice and cassava were prioritized: for rice, (1) model farming (integrated farming system), (2) use of submergence-tolerant varieties, and (3) use of drought-tolerant varieties; and for cassava, (1) use of healthy planting materials and (2) contour intercropping. The five suggested good practices are applicable to situations in Cambodia, but they can also be adopted by other countries in the region.

Climate change is a global phenomenon. Factors such as population growth, economy, and politics are specific to each country, but climate-related problems are similar across the ASEAN region. Good practices in CCA options that are effective in one country have the potential to be successful in other countries. Therefore, instead of working in isolation, ASEAN Member States (AMS) should collaborate to respond to climate change. Several platforms for regional collaboration, such as exchange of experts between countries, establishment of a regional ministry or council for climate change science, and/or creation of a regional research center on climate change, can help strengthen regional partnerships and enhance regional adaptive capacity.

I. INTRODUCTION

The Kingdom of Cambodia is located in the southwestern corner of Indochina in Southeast Asia between latitudes 10°N and 15°N and longitudes 102°E and 108°E. Cambodia, which covers an area of 181,035 square kilometres (km2), shares borders with Lao PDR and Thailand to the north, Thailand and the Gulf of Thailand to the west, and Vietnam to the east and south (Figure 1).

Geographically, Cambodia is characterized by a low-lying central plain dominated by the Great Lake (Tonle Sap). The plateau region is dominated by the Mekong valley in the east; Dangrek Mountain in the north; and Kravahn (Cardamom) Mountains and Damrei (Elephant) Mountains in the southwest, which separate the coastal region from the rest of the country.

Figure 1. Countries bordering Cambodia
Source: www.maps.com

The country's climate is governed by a tropical monsoon with distinct dry and wet seasons. The dry season is from November to April, while the wet season is from May to October. The annual rainfall, which ranges from 1,250 millimeters (mm) to 4,000 mm, is low in the central plain and increases towards the Gulf of Thailand. The mean temperature ranges from 21ºC to 35ºC, with April as the hottest month and December as the coolest month.

In Cambodia, a low-income country with an estimated gross domestic product (GDP) per capita of USD 1,007 in 2013, more than 20.5 percent of the population live below the national poverty line of USD 1 per day and 40 percent of the children are chronically malnourished (World Bank 2013, 2014).

Approximately 80 percent of the estimated total population of 14.7 million live in rural areas, where poverty incidence is found to be higher and people are more likely to be less educated and solely dependent on farming for their livelihoods (RGC 2010). Among all sectors of the national economy, which include services and industry, agriculture contributes about one third to the GDP, where half of this contribution comes from rice (MAFF 2013).

This report provides insights to rice and cassava production systems in Cambodia, assesses the climate change vulnerability of these two production systems using value chain analysis, and identifies good agricultural adaptation practices that can be nationally and regionally adopted.

II. VALUE CHAIN MAPPING

Cambodia relies heavily on agricultural production. Crops are the biggest contributor to the national GDP, accounting for 50-60 percent of the contribution from the agricultural sector. The country has a total land area of about 18.1 million hectares (ha). At present, about 3.9 million ha (21%) of the total land area is cropped. Rice occupies more than 3 million ha (76.4%) of the total cropped area, followed by cassava (10.5%) and maize (6%) (Table 1).

Table 1. Crop production (%) in agricultural land in Cambodia, 2010–2013

Rank	Crop	2010		2011		2012		2013	
		ha	%	ha	%	ha	%	ha	%
1	Rice	2,795,892	79.51	2,968,529	77.60	3,007,545	76.71	3,052,420	76.44
2	Maize	205,070	5.83	174,257	4.56	216,330	5.52	239,748	6.00
3	Cassava	190,525	5.42	391,714	10.24	361,854	9.23	421,375	10.55
4	Soybean	101,904	2.90	70,584	1.85	71,337	1.82	80,688	2.02
5	Mungbean	66,265	1.88	68,111	1.78	66,850	1.71	54,312	1.36
6	Vegetables	49,873	1.42	53,757	1.41	76,495	1.95	52,449	1.31
7	Others	106,690	3.03	98,354	2.57	120,017	3.06	92,456	2.32
Total production area		3,516,219	100.00	3,825,306	100.00	3,920,428	100.00	3,993,448	100.00

Source: Annual Reports, MAFF (2011–2014)
Note: Other crops include peanut, sugar cane, sweet potato, sesame, jute, and tobacco.

Rice production in the country dominates the crop sector in terms of planted area, food security, and employment. Rice provides up to 75 percent of the population's total calorie intake and employs more than 70 percent of the labor force, of which 52 percent are women (MOE and UNDP 2011).

Rice is cultivated in both wet and dry seasons, accounting for 83.5 percent and 16.5 percent of the rice cultivated area, respectively (MAFF 2013). Wet season rice depends heavily on rainfall between May and October, whereas dry season rice is cultivated under either full or supplementary irrigation or in receding floodwaters between November and April. Rainfed lowland rice, deepwater rice, and rainfed upland rice account for about 93 percent, 5 percent, and 2 percent of the total production area of wet season rice, respectively (Figure 2).

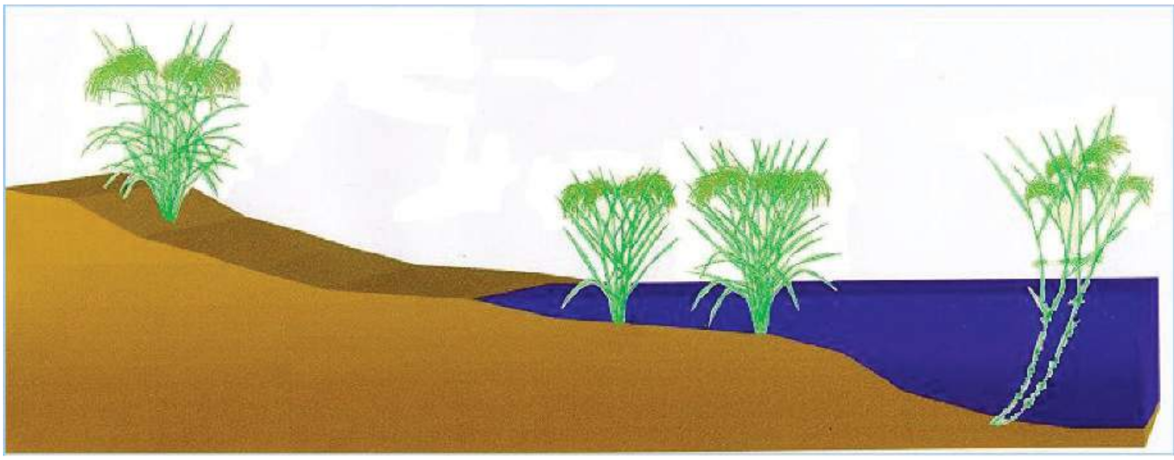

Figure 2. Rice agro-ecosystem in Cambodia, wet season
Source: Sarom (2013)

Rainfed lowland rice can be found in all provinces, but its production is concentrated in the central plain around the Great Lake (Tonle Sap) and in the lower streams of the Mekong River and Bassac River. It is also produced in the coastal areas to the west and southwest as well as in the highlands of the north and northeast of the country (Figure 3). The average annual rainfall in the central plain is from 1,200 mm to 2,000 mm.

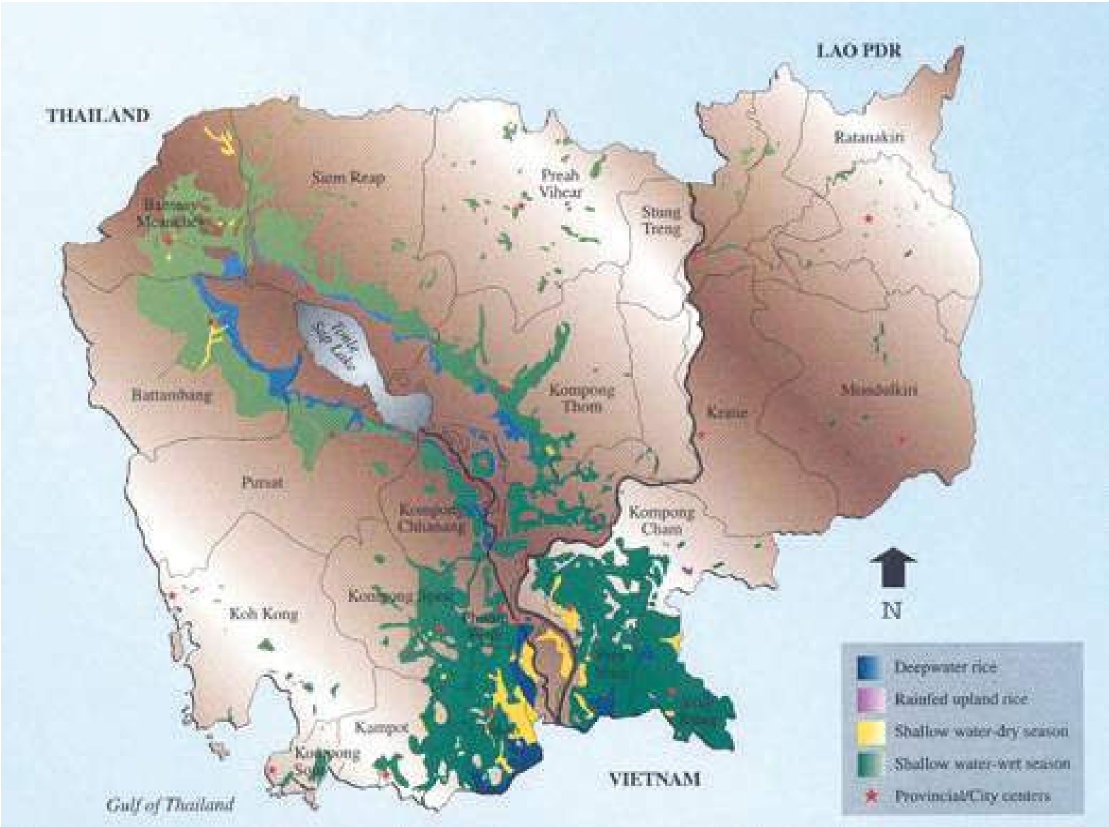

Figure 3. Major rice areas in Cambodia
Source: Nesbitt (1997)

Deepwater rice is also cultivated in the same areas as rainfed lowland rice, but it is concentrated along the edges of lakes where water is deeper than in higher fields. Rainfed upland rice is grown in small pockets, mainly in hilly regions in northern and northeastern Cambodia where the annual rainfall is higher than in the central plain.

The rice production environment in Cambodia is generally harsher than the fertile lowlands in other AMS. Soils are generally poor, often becoming waterlogged during the wet season, and commonly prone to floods and droughts, which can negatively affect production. Poor production consequently affects the national economy and the livelihoods of poor farmers. From its own side, wet season rice production produces a significant amount of greenhouse gases, mainly methane, which contribute to a certain degree of global warming.

Cassava is the next most important crop in Cambodia after rice. It is grown mainly by smallholder farmers for food to supplement the rice diet, animal feed, and extraction of starch from its roots. In recent years, there has been a major interest in the use of cassava as a raw material for ethanol production. Cassava production areas in Cambodia expanded exponentially from less than 20,000 ha in 2010 to more than 400,000 ha in 2013 (Table 1). Cassava is cultivated in almost all provinces in the country, but it is mainly produced in Kampong Cham, Battambang, Pailin, Kratie, and Kampong Thom. Cassava production areas range from 20,000 ha in Pailin to almost 70,000 ha in Kampong Cham (MAFF 2013).

Cassava is believed to cause serious soil degradation due to excessive uptake of nutrients, leading to soil nutrient depletion, or serious soil erosion when grown on slopes. On the contrary, however, research has shown that cassava extracts fewer nutrients from the soil than other food crops (Howeler 1991). Nevertheless, when the crop is grown continuously on the same land without inputs of manure or fertilizers, soil nutrients will eventually be depleted and productivity will decline, as is true for all crops.

In some areas the problem is alleviated by bush-fallow rotations, but where such rotations are not possible, farmers need to apply animal or green manure, or chemical fertilizers to maintain yields. Soils are mainly susceptible to erosion during the initial stage of the crop before the canopy closes; therefore, rain at the early growth stage can significantly affect soil quality (Putthacharoen et al. 1998).

Cassava processing produces large amounts of wastes, including solids and liquids, which are high in organic matter and cyanide. Solid wastes mainly derived from cassava chip processing, if properly managed, can be utilized in many ways. Liquid (water) waste, on the other hand, has the potential to pollute groundwater or lakes, rivers, or streams into which it flows. Cassava processing can also produce unpleasant odors and unattractive surroundings. Given these problems, cassava processing has always been regarded as a major environmental pollutant.

Both rice and cassava are very important to the daily diet of the Cambodian people and the national economy (Tables 2 and 3). However, these crops and their ecosystems are highly vulnerable to climate change. As such, they were selected for this study, which aims to promote climate resilience of crops for the sustainable development of the country. This report focuses on production activities, including the inputs to production (e.g., seed supplies). Rainfed lowland rice, which occupies more than 80 percent of the country's rice production, and rainfed upland cassava, the only production system available for the crop, were selected.

Table 2. Types and volume of rice production systems in Cambodia, 2013

Production system type	National production volume (t)	National production value (million USD)	Assessment of impact on national/regional consumption (1–3)	Indication/estimate of relative vulnerability to climate change (1–3)
Irrigated Lowland (Dry season)	2,118,710	423	1	2
Rainfed Lowland (Wet season)	7,271,251	1,818	3	3

Note: In the assessment of impact on national/regional consumption, the production system is estimated to represent the following values of domestic rice consumption for national food security: 1 – Low (less than 30%), 2 – Medium (30%–55%), and 3 – High (greater than 55%). In the relative vulnerability to climate change, the following descriptions apply: 1 – Low (any impact upon the production system is likely to be manageable), 2 – Medium (without intervention, the production system is likely to suffer problems in the future), and 3 – High (the production system is already experiencing significant problems with extreme weather events and these are very likely to become more severe in the future).

Table 3. Types and volume of cassava production systems in Cambodia, 2013

Production system type	National production volume (t)	National production value (million USD)	Assessment of impact on national/regional consumption (1–3)	Indication/estimate of relative vulnerability to climate change (1–3)
Rainfed upland (Wet season)	7,632,997	534	3	3
Rainfed upland (Dry season)	300,384	22	1	2

Note: In the assessment of impact on national/regional consumption, the production system is estimated to represent the following values of domestic rice consumption for national food security: 1 – Low (less than 30%), 2 – Medium (30%–55%), and 3 – High (greater than 55%). In the relative vulnerability to climate change, the following descriptions apply: 1 – Low (any impact upon the production system is likely to be manageable), 2 – Medium (without intervention, the production system is likely to suffer problems in the future), and 3 – High (the production system is already experiencing significant problems with extreme weather events and these are very likely to become more severe in the future).

A value chain, which has two sequential functions (i.e., seed or planting material supply and production), consists of a functional map combined with a map of actors depicting the following diagrammatically (Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, 2007):

(1) The sequence of related business activities (functions) from the provision of specific inputs for growing and harvesting a specific crop through primary production, distribution, marketing, trading, and retailing of the final product to consumers (the functional view of a value chain)

(2) The set of enterprises (operators), which are linked by a series of business transactions in which the product is passed on from primary producers (growers) to end consumers, performing these functions (i.e., producers, processors, traders, and distributors of a particular product)

Based on the value chain analysis, many rice seed producers and distributors were listed, while only a few cassava seed suppliers were identified. The rice value chain has a number of seed suppliers, which include the following:

■ **General Directorate of Agriculture (GDA)** – GDA, which is under the Ministry of Agriculture, Forestry, and Fisheries (MAFF), primarily provides technical support on crop production to farmers in the country. They also participate in rice production as seed regulatory and rice seed distributor.

■ **Cambodian Agricultural Research and Development Institute (CARDI)** – CARDI, a public semi-autonomous institution, is the prime agricultural research institute in the country. It primarily develops agricultural technologies for sustainable agricultural production and transfers newly developed technologies to farmers. CARDI is the main producer and supplier of rice seeds, mainly breeder and foundation seeds, of all varieties that it has released. In 2012, it produced 6,112 kilograms (kg) of foundation seeds; 11,910 kg of registered seeds; and 27,706 kg of graded seeds and supplied them to seed production companies (CARDI 2013).

■ **Private seed distributors**

a. **Agricultural Quality Improvement Project (AQIP) Seed Production Company** – AQIP, a public-private seed production company, works with its provincial or district branches to supply large quantities of rice seeds to its growing market. In 2014, the company supplied 3,600 tons (t) of rice seeds to farmers and some development agencies and projects (Sak Choeun, personal communication).

b. **Aphivat Bandanh Kasekar (ABK)/ HCLP Co. Ltd – ABK/HCLP,** an affiliate of a non-government organization, produces quality premium aromatic rice and guarantees accessibility to the market. It works entirely on aromatic rice varieties, particularly Phka Rumdoul.

c. **Domnak Teuk Group Co. Ltd (DNT)** – DNT, an operational hand of the Centre for Livestock and Agriculture Development (CelAgrid), provides market access support to farmers through their contract business on quality rice production. In 2012, DNT supplied about 23 t of commercial seeds to its farmers' cooperators (Khieu Borin, personal communication).

■ **Farmer seed associations** – Given the limited capacity of the formal seed sector, local seed production associations that vary in size and structure also produce and distribute seeds. Many farmer seed associations can be found in Siem Reap, Battambang, Kampong Cham, and Kampong Thom.

A general mapping of the stakeholders in the rice and cassava production chains is presented in Figures 4 and 5.

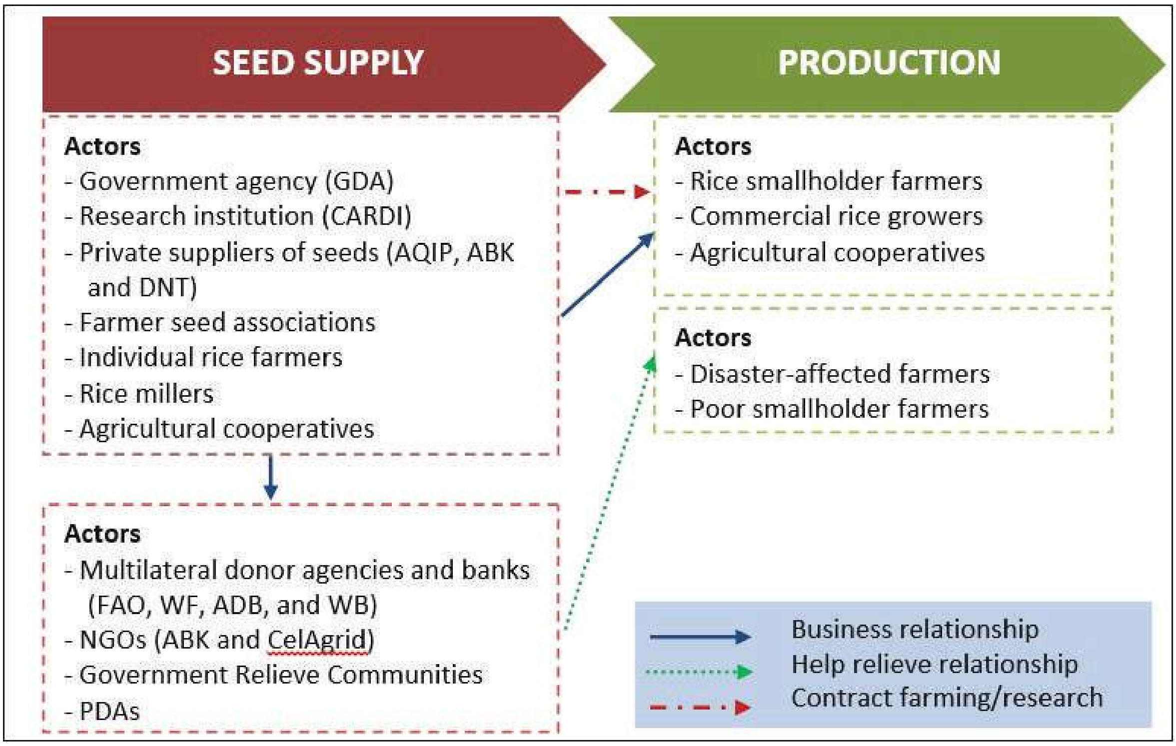

Figure 4. Rice value chain in Cambodia

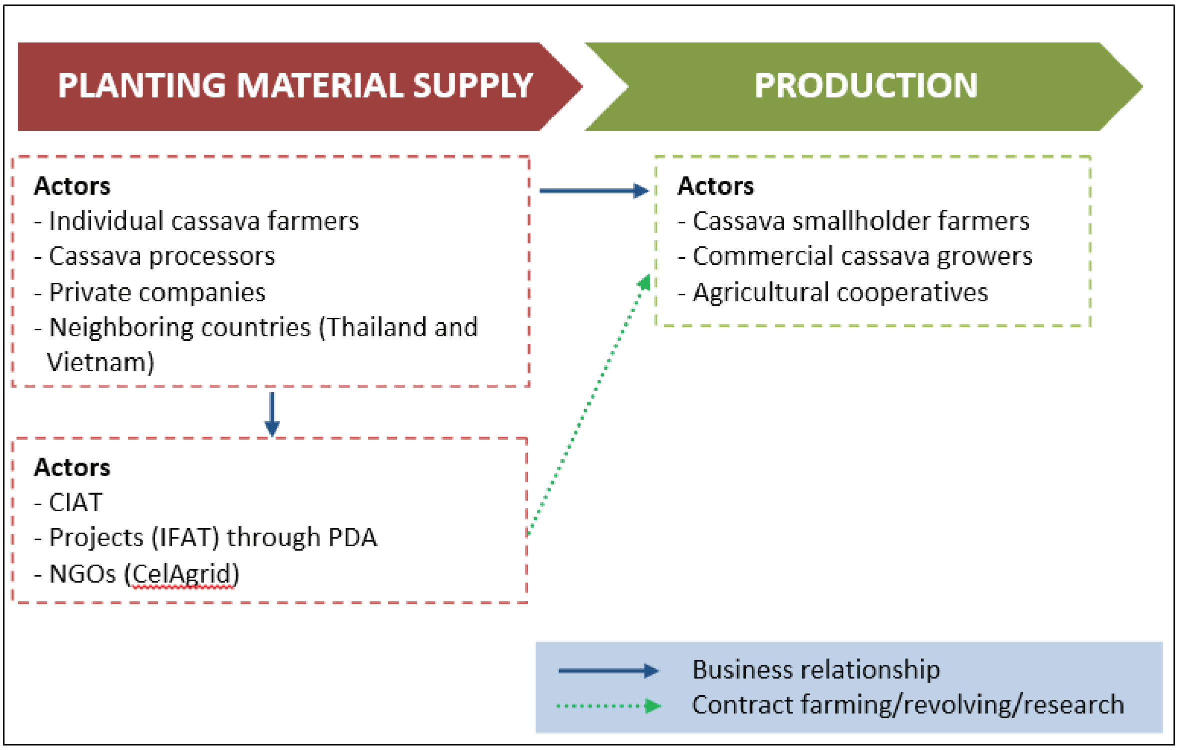

Figure 5. Cassava value chain in Cambodia

III. REVIEW OF CLIMATE CHANGE IMPACTS AND VULNERABILITIES

This study used the following terms as defined by the Intergovernmental Panel on Climate Change (IPCC) (IPCC 2007; Low 2007):

- **Vulnerability to climate change** – The degree to which a system is susceptible to, or unable to cope with, the adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptability.
- **Exposure** – The nature and degree to which a system is exposed to significant climatic variations.
- **Sensitivity** – The degree to which a system is affected, either adversely or beneficially, by climate-related stimuli.
- **Adaptive capacity** – The ability of a system to adjust to climate change, including climate variability and extremes; moderate the potential damage from it; take advantage of its opportunities; or cope with its consequences.

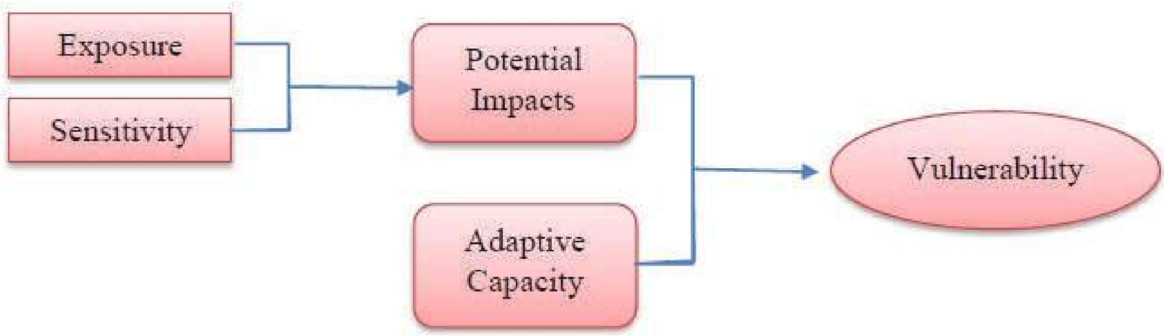

Figure 6. Climate change impacts and vulnerability

Based on a report by IPCC (2001), Cambodia is one of the AMS that are most vulnerable to the impacts of climate change. Its high vulnerability to climate change can be attributed to its socio-economic factors and adaptive capacity.

Cambodia is an agrarian country where agriculture accounts for about one third of the national GDP. Its economy is highly dependent on agriculture and natural resources. Approximately 80 percent of the population live in rural areas, where farming is the main source of income. Farm productivity in the country is low in terms of area and labor. In an unpublished survey conducted by Suvedi and Sarom (2012), rainfed lowland rice farmers occupied an average cultivated land of about 2.59 ha per household. This figure is relatively higher than the figure determined by the National Institute of Statistics (2011), who reported that 46 percent of the sample occupied less than 1 ha per household. Both findings still classify Cambodian farmers as smallholders.

Cambodia faces the sensitive issue of income inequality among its people as well as between cities and rural areas. In an assessment conducted by the Ministry ofEnvironment (MOE) and United Nations Development Programme (UNDP) (2011), the share of national wealth between the richest and the poorest 20 percent of the population displayed a clearly skewed distribution. It has also been reported that more than 30 percent of the Cambodian population live below the national poverty line of USD 1 per day. The poverty incidence is found to be higher in the rural areas, where people are more likely to be less educated and solely dependent on farming for their livelihoods (RGC 2010). Poor farming communities with limited resources for coping and adaptation are the most sensitive to climate change. According to Roberts and Parks (2007), as cited in MOE and UNDP (2011), "Countries with high levels of income inequality experience the effects of climate disasters more profoundly than more equal societies."

Climate hazards frequently experienced in Cambodia include floods, droughts, and wind storms. In coastal areas, underground water salinization and saltwater intrusion are the common problems. Floods and droughts are occurring more frequently and at a higher intensity throughout the country under changing climate conditions. The successive and combined occurrences of these hazards have resulted in considerable economic, human, and property losses as well as food insecurity.

Cambodia has already experienced changes in climate patterns in the form of unusually high temperature, higher rainfall with strong thunderstorms, occurrence of a number of typhoons, and frequency of other extreme weather events. Seasonal water shortages, drought spells, and floods have become more common and severe as saltwater intrusion. Such changes are expected to negatively affect natural ecosystems, agriculture, and food production, and magnify the problem of supplying food to a growing population. The impacts of such changes are likely to be severe in Cambodia where many communities derive their income from agriculture and natural resources.

From 1960 to 2005, the average temperature in Cambodia increased by 0.8ºC. Yearly within that period, hot days and nights increased by 12.6 percent and 17.2 percent, respectively, while cold days and nights decreased (McSweeney et al. 2008).

Similarly, the mean monthly rainfall increased by 15 mm over a 20-year period (1986–2006). The trends appear to be rising, but accurate information on climate change in Cambodia is very limited. Available information is often drawn from global or regional models, with varying degrees of relevance at the national level. Quantitative information is lacking and most of the data are presented in terms of broad potential trends in climatic conditions. Nevertheless, it is predicted that both temperature and rainfall in the country will increase, but the changes will vary according to geographic location.

UNDP Cambodia (2012) studied climate changes spanning 30–40 years through a vulnerability reduction assessment of 145 villages in 15 provinces and with more than 3,400 respondents. The assessment found that the length and frequency of droughts, frequency of high and increasing temperatures, and occurrence of widespread insect infestations have increased and continue to rise (Figure 7).

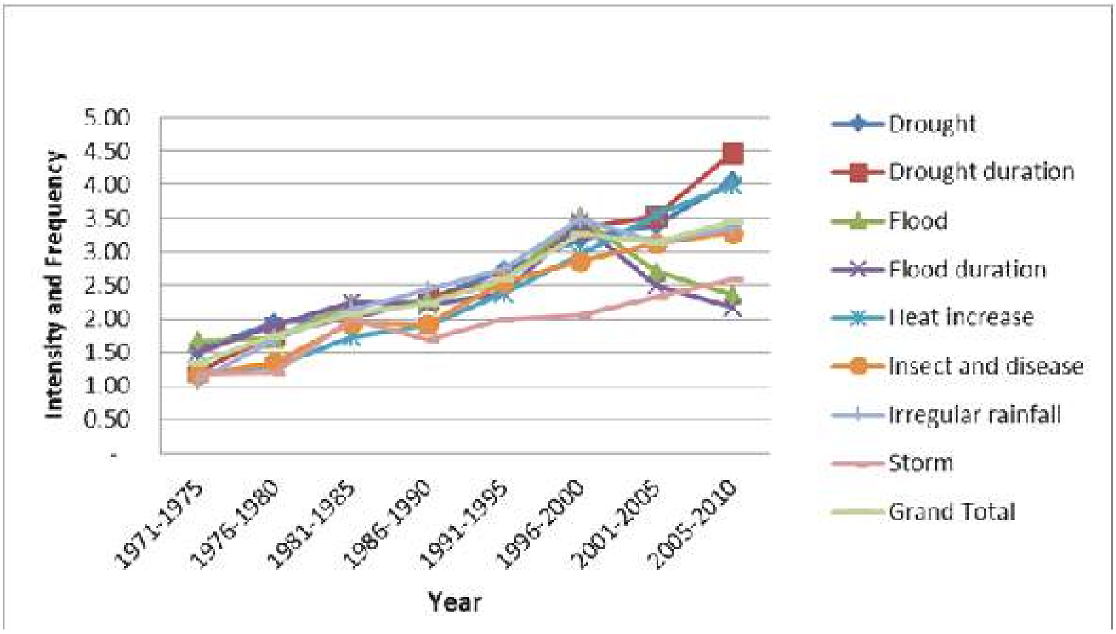

Figure 7. Climate change trends in Cambodia
Source: Adopted from UNDP (2012)

Floods have decreased in the last few years. However, unlike droughts, the effects of floods usually extend beyond agriculture. For instance, one of the worst floods in Cambodia in recent history occurred in 2000. It affected an estimated 3 million people and damaged infrastructure, excluding lost production and other secondary impact costs of more than USD 150 million (MOE and UNDP 2011). Such scenarios show that climate change and its impacts are a reality for Cambodians, especially farmers.

Farmers throughout the country have been noticing marked changes in the climate for the past 40 years (MOE and UNDP 2011). Data on the extent of crop damage from 1995 to 2013 from MAFF suggest a rising trend in the intensity of damages caused by floods, droughts, and insects, particularly from 2006 onwards (Table 4). In addition, results revealed that overall crop damage in rice production is primarily caused by floods (91.26%), followed by droughts (7.66%) and insects (1.08%).

Table 4. Rice crop areas damaged by droughts, floods, and insects, 1995–2013

Year	Damaged area (ha)			
	Droughts	Floods	Pests and diseases	Total
1995	9	147	0	156
1996	-	-	-	0
1997	98	39	0	137
1998	368	30	0	399
1999	9	50	0	60
2000	7	401	0	408
2001	66	197	0	262
2002	78	85	0	163
2003	57	4	0	61
2004	247	11	0	258
2005	7	21	0	27
2006	9,347	17,515	3,382	30,244
2007	5,653	31,008	1,092	37,753
2008	1,653	1,310	193	3,156
2009	66	143	59	268
2010	2,934	17,357	298	20,589
2011	53	267,184	0	267,237
2012	19,420	16,510	95	36,025
2013	178	127,634	548	128,360
Total damage	40,250	479,646	5,667	535,563
% of damage	7.66	91.26	1.08	100

Source: Annual Reports, MAFF (1996–2013)

Despite some variations, it is clear that the damages increased in 19 years. Floods and droughts were the two major persistent climate-related disasters in Cambodian farming during this period. Despite having variable intensities, both hazards negatively affected rice crops every year from 1995 to 2013. The magnitude of their impact increased markedly after 2006. The more catastrophic damages caused by floods were recorded in 2011, when about 267,000 ha or 11 percent of wet season rice production were eradicated. In the following year, droughts destroyed nearly 20,000 ha of rice cultivation (Table 5).

Table 5. Areas damaged by droughts, floods, and pest and diseases relative to the total planted area

Year	Total planted area (ha)	Droughts		Floods		Pests and diseases	
		ha	%	ha	%	ha	%
1995	1,869,991	9	0.0005	147	0.0079	0	0.0000
1996	1,936,900	-	0.0000	-	0.0000	-	0.0000
1997	1,827,328	98	0.0054	39	0.0021	0	0.0000
1998	1,873,093	368	0.0196	30	0.0016	0	0.0000
1999	1,915,592	9	0.0005	50	0.0026	0	0.0000
2000	2,058,648	7	0.0003	401	0.0195	0	0.0000
2001	1,926,004	66	0.0034	197	0.0102	0	0.0000
2002	1,821,225	78	0.0043	85	0.0047	0	0.0000
2003	2,030,735	57	0.0028	4	0.0002	0	0.0000
2004	2,048,360	247	0.0121	11	0.0005	0	0.0000
2005	2,116,098	7	0.0003	21	0.0010	0	0.0000
2006	2,212,015	9,347	0.4226	17,515	0.7918	3,382	0.1529
2007	2,241,114	5,653	0.2522	31,008	1.3836	1,092	0.0487
2008	2,255,104	1,653	0.0733	1,310	0.0581	193	0.0086
2009	2,334,228	66	0.0028	143	0.0061	59	0.0025
2010	2,391,016	2,934	0.1227	17,357	0.7259	298	0.0125
2011	2,496,569	53	0.0021	267,184	10.7020	0	0.0000
2012	2,512,038	19,420	0.7731	16,510	0.6572	95	0.0038
2013	2,567,723	178	0.0069	127,634	4.9707	548	0.0213

Source: Annual Reports, MAFF (1996–2013)

The adverse effects of climate change on cassava production are also rising. The damaged cassava production area increased from less than 4,000 ha in 2010 to more than 40,000 ha in 2013, while the damaged cassava planted area steadily increased from less than 2 percent in 2010 to more than 10 percent in 2013 (Table 6).

Table 6. Damages to cassava production in Cambodia, 2010–2013

Areas (ha)	2010	2011	2012	2013
Planted area (ha)	190,525	391,714	361,854	421,375
Harvested area (ha)	186,789	369,518	337,800	377,239
Damaged area (ha)	3,736	22,196	24,054	44,136
Relative to planted area (%)	1.96	5.67	6.65	10.47

Source: Annual Reports, MAFF (2011–2013)

The mean annual temperature throughout the country is expected to increase by 0.3ºC–0.8 ºC by 2030, 0.7ºC–2.7oC by 2060, and 1.4ºC–4.3 ºC by 2100 (MOE and UNDP/GEF 2001; MRC 2009). The mean annual rainfall throughout the country is also predicted to increase, especially during the wet season (Table 7).

Table 7. Historical and projected trends in selected climate variables in Cambodia

Variable	Specific climate risk/ opportunity	Historical trend	Projections	References
Mean temperature	Extremely high temperature Droughts Freshwater shortage Pest and disease outbreak	Increased	Increase of 0.3ºC–0.8ºC by 2030	MOE (2001) MRC (2009)
Minimum temperature	Lower rice yield	Increased	Increase	MOE and UNDP (2011) IRRI (2008)
Wet season rainfall	Droughts Floods Disease outbreak Land degradation Nutrient leaching	Increased	Increase of 3–35 percent by 2100	MOE (2002)
Dry season rainfall	Droughts Pest outbreak	Decreased	Decrease	MOWRAM (1997–2011)
Number of rainy days	Droughts High-intensity floods	Decreased	Decrease	MOWRAM (1997–2011)
Saltwater intrusion	Increased salinity in rice fields	Increased	More than 10 percent of the rice production area will be under sea water in 2005	MOE and UNDP/ GEF (2001)

Increasing rainfall and varying extremes are mainly projected in the central agricultural plain, which stretches from the southeast to the northwest. The increase in rainfall will be higher in the lowlands (4%–8%) than in the highlands and coastal areas (0%–4%) in 2025 (MOE and UNDP/GEF 2001).

Despite increases in rainfall, more dry spells with greater extremes between wet and dry seasons are projected. As with other AMS, floods and droughts are expected to increase in terms of frequency, severity, and duration. Seasonal water shortages and floods, as well as saltwater intrusion due to storm surges and sea level rise, are expected to worsen. If the sea level increases by 1 meter, about 10 percent of coastal rice production areas in the country will be inundated and 44 km2 of Koh Kong province will permanently be submerged (MOE and UNDP/GEF 2001). As a result of the changing climate, these changes will profoundly affect agricultural production in the country.

Cambodia's low capacity to adapt to climate change can be categorized in different areas. People in rural areas still make their own decisions, within their families and their own communities, about how they should respond to climate change. In most cases, they lack knowledge on climate change, which limits their preparedness and adaptive capacity. Discussions with farmers in different parts of the country revealed that farmers have their own methods of coping with the changing climate, such as praying for rain during drought conditions; collecting water from big streams, lakes, or rivers; or taking more baths when days are hotter, among others.

Early warning systems for floods exist, especially along the Mekong River, but early warning systems for droughts remain underdeveloped (MOE and UNDP 2011). As such, establishing and disseminating climate change information should also be prioritized. Cambodian farmers who rely heavily on seasonal changes in rainfall will greatly benefit from weather forecasting, which will enable them to make informed decisions on when to plant their crops or which crops or rice varieties to plant when anticipating a drought year or season.

The farmers' low capacity to adapt to climate change can also be attributed to their lack of access to irrigation systems. Aside from the limited coverage of irrigation systems over crop production areas, particularly rice, the efficiency of existing irrigation systems is also an issue. In a survey conducted in 2009, the respondents perceived that of the developed irrigation systems, only 6 percent functioned properly, 62 percent did not function, and 32 percent partially functioned (MOE and UNDP 2011).

With the increasing frequency, intensity, and duration of floods and droughts as well as saltwater intrusion into the land, the most effective adaptive response to these climate risks is to develop appropriate adaptive technologies that can sustain food supply to smallholder rural communities. However, the country's national research system is weak and incapable of effectively responding to the challenges of climate change. CARDI, the most prominent national agricultural research system and the only crop-based research institute in Cambodia, is critically under-resourced as evidenced by the number of rice varieties it has released. From 1990 to 2000, when CARDI was fully funded by an Australian aid program, it released 34 varieties at an average rate of 3.4 per year. From 2001 to 2013, when it no longer received funding from the aid program, it released only five varieties without new potential varieties in the pipeline (CARDI 2000–2012; MAFF 2014).

Climate change will seriously affect agricultural production in Cambodia. Despite having no specific model about the impacts of climate change on the country's agriculture, the potential scenarios and impacts were identified (Table 8) (Sarom 2013).

Table 8. Climate change scenarios and their impacts on agricultural production

Scenarios	Potential impacts on agricultural/rice production
Current	• Floods account for 91 percent of the damages to rice areas (MAFF 1995–2013). • Droughts account for 8 percent of the damages to rice areas (MAFF 1995–2013). • Pests and diseases account for 1 percent of the damages to rice cultivated areas (MAFF 1995 –2013) and more than 10 percent of the damages to total cassava planted areas (MAFF 2013).
Increases in the mean annual temperature	• A rise in temperature will suppress yield and lead to changes in crop water requirement. Hotter and dryer conditions may increase the amount of water required by plants. • The number of extremely hot days may increase in the coming years. If extremely hot days occur during flowering, the plant may experience floret sterility and consequently produce low yield with poor grain quality (in rice). • The incidence of pest and diseases may increase in rice and cassava production systems.
Changes in rainfall patterns (rainfall during the wet season will increase, with more variability in time and location, while the dry season will be longer and drier)	• The rice production system and its productivity may change. Wet season crops may increase and decrease in some areas. • The productivity of rainfed lowland rice and dry season rice may increase and decrease, respectively. • A decline in water surface during the dry season may lead to high use of groundwater. Over exploitation of this may lead to environmental problems, such as heavy metal and sand contamination and salinity. • As a result of more intense rainfall and long droughts, damages caused by pest and diseases may increase in incidence and severity and with different patterns. • Floods and droughts will be more intense and more frequent, with unpredictable

Table 8. cont....

Scenarios	Potential impacts on agricultural/rice production
	drought spells during the wet season and unexpected rainfall during the dry season. • The onset of the seasons will be less predictable.
Sea water rises and saltwater intrusion into freshwater streams and agricultural lands	• Cropping patterns will change. The current rice varieties used in present cultivation areas may no longer be suitable. • Natural ecosystems in the coastal zones may change as more salt-loving plant species dominate the areas. • Freshwater supply for farming activities may become inadequate.

Based on the assessments of climate change impacts on agricultural production in Cambodia, including the projected trends that will likely affect production, different climate-related hazard scenarios were drawn. Such hazards faced by rice and cassava production, their biophysical impacts, the CCA options to be undertaken, and the actors that should be involved in implementing the CCA options are listed in Tables 9 and 10.

Table 9. Climate-related hazards in the rice value chain

<table>
<tr><th>Climate related hazards</th><th>Biophysical impacts</th><th>Adaptation options</th><th>Relevant actors</th></tr>
<tr><td>Droughts</td><td>Low yield and poor grain quality due to weak/reduced growth, delayed flowering, and high sterility</td><td>• Use resistant varieties
• Develop rainwater and floodwater harvesting techniques</td><td rowspan="6">• Researchers (CARDI)
• Agricultural extension services and relevant technical departments (GDA)
• Academicians and students (RUA)
• PDA
• Provincial Department of Water Resources and Meteorology
• NGOs (CelAgrid and ABK)
• IRRI
• Farmers and farmer associations
• Farmer water associations</td></tr>
<tr><td>Floods</td><td>Low yield and poor grain quality due to weak/reduced growth, delayed flowering, and high sterility</td><td>• Use resistant varieties
• Establish alternate cropping systems</td></tr>
<tr><td>Pest and disease outbreaks</td><td>Low yield and poor grain quality due to weak/reduced growth</td><td>• Use resistant rice varieties</td></tr>
<tr><td>Heat/high Temperature</td><td>Low yield and poor grain quality due to high sterility</td><td>• Use resistant rice varieties
• Establish rice-sesbania intercropping systems</td></tr>
<tr><td>Freshwater scarcity</td><td>Low yield and poor grain quality due to wilting, stunting, and death of plants</td><td>• Develop rainwater and floodwater harvesting techniques
• Establish crop-based farming systems
• Develop varieties with high water use efficiency</td></tr>
<tr><td>Salinity</td><td>Low yield and poor grain quality due to stunting and high sterility</td><td>• Use resistant rice varieties
• Use saline-tolerant crops
• Apply integrated nutrient management
• Build barrage</td></tr>
</table>

Table 10. Climate-related hazards in the cassava value chain

Climate related hazards	Biophysical impact	Adaptation options	Relevant actors
Pest and disease outbreaks	Low yield and poor root quality due to weak growth and deformation	• Use healthy planting materials	• Researchers (CARDI) • Agricultural extension services and relevant technical departments (GDA) • Academicians and students (RUA) • PDA • NGOs (CelAgrid and ABK) • CIAT • Farmers and farmer associations
Heavy rainfall	Low yield and poor root quality due to slow growth of the cassava plant	• Apply contour intercropping • Develop cover systems • Raise bed planting	
Land degradation/ soil erosion	Low yield and poor root quality due to weak growth	• Apply contour intercropping • Develop mulching systems	
Lower fertility	Low yield and poor root quality due to stunting	• Apply integrated nutrient management • Establish integrated farming systems • Develop mulching systems	
Droughts	Low yield and poor root quality due to slow growth of the cassava plant	• Use tolerant varieties • Calendar planting • Manage planting materials	

The climate change impact assessment and vulnerability rating (Annex 1) for rice and cassava production are presented in Tables 11 and 12.

Table 11. Climate change impact assessment and vulnerability rating for rice production

System of interest	Climate change trend	Socio-economic impact	Exposure	Sensitivity	Ability to respond	Vulnerability rating (1–3)
Increase rice productivity	Increasing floods	High	High	High	Low	3
	Increasing droughts	High	High	High	Low	3
	More acute water shortages	High	High	High	Low	3
	Pests and diseases	Medium	Medium	Medium	Medium	2
	Salinity	Low	Low	Medium	Medium	1
Diversify farming systems	Increasing floods	High	High	High	Low	3
	Increasing droughts	High	High	High	Low	3
	Pests and diseases	Medium	Medium	Medium	Medium	2

Note: In the vulnerability rating, the following descriptions apply: 1 – Low (any impact upon the production system is likely to be manageable), 2 – Medium (without intervention, the production system is likely to suffer problems in the future), and 3 – High (the production system is already experiencing significant problems with extreme weather events and these are very likely to become more severe in the future).

Table 12. Climate change impact assessment and vulnerability rating for cassava production

System of interest	Climate change trend	Socio-economic impact	Exposure	Sensitivity	Ability to respond	Vulnerability rating (1–3)
Increase cassava productivity	Soil erosion	High	Medium	High	Low	3
	High temperature	Medium	Low	Medium	Low	3
	Pests and diseases	High	High	Medium	Low	3
	High rainfall	Medium	High	Medium	Medium	1
Develop contour intercropping systems	Soil erosion	High	Medium	High	Low	3
	High rainfall	High	High	High	Low	3
	Pests and diseases	Medium	Medium	Medium	Medium	2

Note: In the vulnerability rating, the following descriptions apply: 1 – Low (any impact upon the production system is likely to be manageable), 2 – Medium (without intervention, the production system is likely to suffer problems in the future), and 3 – High (the production system is already experiencing significant problems with extreme weather events and these are very likely to become more severe in the future).

IV. AREAS OF REGIONAL COLLABORATION

Factors such as population growth, economy, and politics are specific to each country, but climate-related problems are similar across the region. Assessments by researchers and perceptions of people in rural areas indicate that climate change is real (UNDP 2012). The region is already experiencing frequent floods, droughts, thunderstorms, and typhoons; increasing temperatures; higher inland salinity; and more extensive pest and disease outbreaks.

Concerns regarding the national and regional impacts of climate change have been raised after the following incidents: the devastating Typhoon Ketsana in Cambodia (2009) and Typhoon Haiyan in the Philippines (2013); severe floods in Cambodia, Thailand, and Vietnam (2011); and late onset of rain in Cambodia (2010). Considering that most ASEAN economies are agriculture-based and have a large population of farmers, climate change remains the main threat to food security in the region. Consequently, its adverse impacts can influence the lives of millions of farmers, particularly smallholders. Regional collaboration is necessary in identifying the best CCA and mitigation measures to help farmers cope with environmental changes.

For Cambodia, there are areas where regional collaboration is required. In both rice and cassava value chains, financial assistance for scaling up adaptation practices is essential. This could be in the form of a regional testing platform, which could be financed by multilateral donor institutions or ASEAN. Technical assistance through short- and long-term training courses, and/or placement of experienced regional experts to support the implementation of research programs, is highly welcome. Information sharing is another form of regional collaboration that may be mutually beneficial for all AMS.

In return, the Cambodian team is willing to provide technical or advisory support to other AMS. Rice production in Cambodia is frequently confronted with floods and droughts, making technical expertise in this field plentiful in the country. CARDI, which has been working extensively on developing stress-tolerant rice varieties, is also a wealthy source of expertise.

V. CASE STUDIES ON GOOD PRACTICES

Agricultural activities in Cambodia are mainly conducted by smallholder farmers on a small piece of owned land or on rented land (NIS 2011; Suvedi and Sarom 2012). These farmers, who are generally economically resource poor, are among the people that are most vulnerable to climate change. Climate change threatens agricultural production, particularly rice and cassava production, with numerous climate risks such as floods, droughts, pest and disease outbreaks, saltwater intrusion, extremely hot days, land degradation, and nutrient depletion, among others. However, despite the significant degree of risk and uncertainty brought about by climate change, there are practices that can be adapted using the "no regrets" approach. This section describes five good adaptation practices in Cambodia.

5.1 Rice

5.1.1 Model Farming (Integrated Farming System)

Description:

Model farming is a fully integrated farming system approach. A piece of land (from 0.5 ha to 1 ha) is divided into lowland and upland cropping areas. Rice is cultivated in the lowland area, while legumes and vegetables are cultivated in the upland area. A canal system, which is formed within and around the farm, has dual functions: irrigation and drainage. The canal system is linked to a pond, which serves as a rainwater harvester during the wet season and a water source for irrigation during the dry season. A tube well can be installed next to the pond in case more water is needed. The pond, from which fish can swim through the canal system to find food (insects) in the rice fields, is also used as a fish-breeding refuge. An animal shed can be built in one corner of the farm. Any type of animal (e.g., cattle, pig, and chicken) can be raised and their wastes can be used to fertilize farm soil. In another corner of the farm, a farm house with a small farm shed can be built.

Background and climate hazard addressed:

In Cambodia, water shortages commonly occur throughout the year. The results of one study revealed that 81 percent and 54 percent of the households interviewed suffered from shortages of water for agricultural and personal uses, respectively (MOE 2006). Given the effects of climate change and as predicted by some environmental models, freshwater supply is highly at risk. It is expected that there will be serious complications in many parts of the world, including Southeast Asia, particularly in large river basins that are likely to decrease (Low 2007). Therefore, along with population growth, increasing demand arising from higher standards of living, and farming activities, water shortages could adversely affect the country's development. As droughts become longer and more intense, the flow of major river systems and their tributaries is seriously affected (MOE and UNDP 2011).

Increasing temperatures, which is normally associated with high evaporation, also slows growth and fertilization. This can significantly reduce yields. Studies conducted at the International Rice Research Institute (IRRI) and in different AMS suggest that, on the average, rice yield can be expected to =decrease by 10 percent for every 1ºC increase in minimum temperature during the growing season (Peng et al. 2004; MOE and UNDP 2011). Lower rice productivity is highly likely. Therefore, with fewer cultivated areas and significant yield reduction due to low water availability, the food security of rural populations will certainly be affected. Migration to the city will consequently increase. Model farming is thus proposed as a climate change resilience model to aid in CCA and mitigation. It aims to successfully build the adaptive capacities of rural communities to climate change through promoting diversification within their own available agricultural land, improving their access to new agricultural and water management technologies, and enhancing their skills in linking production and market. Model farming seeks to contribute to the sustainable production of food crops under changing growing conditions.

Table 13. Criteria for the selection of model farming as a good practice

Criteria	Indicators/sub-criteria	Narrative descriptions
Effectiveness of adaptation	Adaptation function	The practice enhances resilience and augments economic opportunities for farmers.
	Robustness to uncertainty	The practice is effective under different climate scenarios and socio-economic scenarios.
	Flexibility	Subsequent adjustments can be made if all the conditions change or if the changes are different from those that were initially expected.
Side effects	No regrets	The practice contributes to more effective water management and is beneficial in terms of diversifying crops-based animal and fish production.
	Win-win	The practice contributes to closing the gap between water availability and demand.
	Positive spillover effects	The practice has a positive effect on community water management and local markets.
	Negative spillover effects	None
	Trade-offs	None
Efficiency/costs and benefits	Low regrets	The practice requires a relatively high investment that will be paid off shortly after it is established.
Framework conditions for decision making	Equity and legitimacy	The practice is more beneficial to women because they do not need to work very far from their house and have most of the things they need for their kitchen.
	Are decision-making procedures accepted by those affected? Are stakeholders involved in decision making?	The practice can be done only if the farmers wish to adopt it.
Feasibility of implementation	What are the barriers to implementing, scaling up, and replicating the practice at the regional level?	There are financial limitations.
Alternatives		There is no cheaper alternative.
Priority and urgency	The impacts of climate change have been felt	Water supply is a concern in farming communities, especially when the dry season is longer, because drought spells become more severe and temperatures are extremely high.

Value chain function:
This practice addresses the production segment within the rice value chain. However, by increasing rice and other crop productions, the system can also serve as a supplier of different agricultural products for household consumption and markets.

Beneficiary:
Farmers and farming communities will directly benefit from adopting this system. Diversified farm production will allow them to experience food security, while diversified food crops will help provide the appropriate nutritional value.

Expected change in the value chain as a result of implementing this practice:
The farmers' adaptive capacity will improve with their diversified incomes. This is possible because through increased farm productivity, improved certainty of water utilization, and enhanced knowledge on integrated farm production, farmers will certainly earn more than when they used traditional methods.

This practice has the following main barriers:

- This practice requires the strong involvement of farmers, which is not possible in most circumstances.
- This practice requires a high initial investment, which many farmers could not afford.
- The migration of young rural population to cities and other counties will lead to labor shortage within rural families.
- The funds for scaling up and extending the technology within the country are insufficient.

This practice has the following enablers:

- CARDI, the leading national agricultural research institute that developed this model, can assist the Provincial Department of Agriculture (PDA) to implement this practice at the local level.
- Crop diversification and water saving is listed in the government strategy.
- IRRI, which is active in the region, might be interested to support this initiative.

Regional support: This practice can be tested in other countries, but financial and technical support from multilateral donors and other AMS are important.

Stakeholders and their role:

- CARDI should improve and extend the practice to a wider range of farmers.
- The Royal University of Agriculture (RUA) should work closely with CARDI to train students and farmers.
- GDA should work with CARDI in disseminating the practice throughout the country.
- PDA should support local farmers who wish to adapt this practice at the village level.

Gender implications:
It applies to both genders. There will be many activities to be carried out indistinctively by both men and women, although women may have more work to do than men.

5.1.2 Use of Submergence-tolerant Varieties

Description:
The use of rice varieties that are tolerant to submergence in rice fields for a certain period is recommended. This is one of the cheapest options for farmers as well as one of the most effective adaptation measures against floods in the rainfed lowland areas of Cambodia.

Background:
Floods can seriously damage national rice production. Wet season rice, which occupies more than 83.5 percent of the total rice production area in Cambodia, is divided into three sub-ecosystems: rainfed lowland rice, deepwater rice, and upland rice. Rainfed lowland rice, which has a share of more than 90 percent of the total wet season rice production, encounters a number of climate-related disasters during its life cycle, including floods. Floods cause plants of susceptible varieties to either slow down their growth or wildly elongate. If this occurs regularly, flowering can be delayed and associated with high sterility, consequently leading to poor grain production and low yield. Data from

1995 to 2013 revealed that floods occurred yearly during the 19-year period. The intensity of the damages ranged from about 1 percent to about 11 percent. The more catastrophic damages caused by floods were recorded in 2011, when about 267,000 ha or about 11 percent of wet season rice production were eradicated.

Climate hazard addressed:
Floods and submergence are considered the main causes of low yield in the country's crop production, which is mainly rainfed. Damages caused by floods were as high as 11 percent of the total production. Developing varieties that are tolerant to this abiotic stress will improve rice productivity in the country.

Table 14. Criteria for the selection of the use of submergence-tolerant varieties as a good practice

Criteria	Indicators/sub-criteria	Narrative descriptions
Effectiveness of adaptation	Adaptation function	The practice enhances resilience and augments economic opportunities for farmers.
	Robustness to uncertainty	The practice is effective under different climate scenarios (e.g., flood-prone environments).
	Flexibility	Subsequent adjustments can be made if all the conditions change or if the changes are different from those that were initially expected.
Side effects	No regrets	The practice contributes to more effective crop management.
	Win-win	The practice improves the livelihoods of rainfed lowland rice farmers, who are generally resource poor.
	Positive spillover effects	The practice builds capacity in developing varieties that are resistant or tolerant to the effects of climate change.
	Negative spillover effects	None
	Trade-offs	None
Efficiency/costs and benefits	Low regrets	Extensive adaptation trials under local conditions are required before a variety is selected.
Framework conditions for decision making	Equity and legitimacy	It is a win-win situation for all.
	Are decision-making procedures accepted by those affected? Are stakeholders involved in decision making?	The practice can be done only if the farmers wish to adopt it.
Feasibility of implementation	What are the barriers to implementing, scaling up, and replicating the practice at the regional level?	There are financial limitations. A germplasm of flood-tolerant varieties is also needed.
Alternatives		There is no cheaper alternative.
Priority and urgency	The impacts of floods have been felt	Damages caused by floods are becoming more severe.

Value chain function:
This practice addresses the production segment of the rice value chain.

Beneficiary:
Farmers and farming communities will directly benefit from adopting this practice. The availability and use of submergence-tolerant rice varieties will augment rice production.

Expected change in the value chain as a result of implementing this practice:
The adoption submergence-tolerant rice varieties will greatly benefit rice farmers in rainfed lowland areas in Cambodia.

This practice has the following main barriers:

- A variety that is tolerant to a longer duration of floods (more than 15 days) has not yet been developed.
- There is no universal rice variety that can adapt to all situations because the rainfed lowland environment is very diverse.
- The national government has allocated only a small portion of the budget for research.

This practice has the following enablers:

- CARDI, as a national agricultural research institute has developed and released a number of varieties with different degrees of tolerance to submergence. Phka Rumduol, Phka Rumchek, and CAR 9, the three varieties that are widely known for their premium quality, are moderately tolerant to floods (CARDI 2009). They can be used as the basis for improving tolerance.
- This challenge is aligned with the rice policy of the government
- IRRI, which is active in the region, might be interested to support this initiative.

Regional support:
Technical support in developing a germplasm bank of submergence-tolerant rice varieties is needed from other AMS. Financial support from multilateral donors is also essential to achieve the desired outcome.

Stakeholders and their role:

- CARDI should develop rice varieties that are suitable for various flooding scenarios in the country.
- RUA should work closely with CARDI to train students and farmers.
- GDA should provide policy support to enhance the adoption of this practice.
- PDA should support local farmers who wish to adapt this practice at the village level.

Gender implications:
It applies to both genders. There is no gender discrimination as both genders will benefit if the activity is funded.

5.1.3 Use of Drought-tolerant Varieties

Description:
The use of rice varieties that are tolerant to droughts is recommended. This is one of the cheapest options for farmers and one of the most effectiveadaptation measures against droughts in the rainfed lowland areas of Cambodia.

Background:
Drought is the second most hazardous climate threat to rice production in Cambodia. It adversely affects plant development by reducing growth and biomass as well as delaying flowering. High sterility is very common and is strongly linked to yield reduction. Most of the time, affected rice crops produce grains of poor quality. Drought effects are highly variable. They can occur at different growth stages of the rice plant or have different duration and level of severity. The effects can be more hazardous if droughts occur after floods and/or at high temperature. On the average, damages caused by droughts are 8 percent of the total damages caused by climate-related factors. Droughts damaged about 20,000 ha of wet season rice area in 2012.

Climate hazard addressed:
Floods and droughts cause the greatest economic damages to rice production in the country, which is mainly rainfed. The extent

of damage can vary per year, but damages occur yearly. Developing varieties that are tolerant to this abiotic stress will improve rice productivity in the country.

Table 15. Criteria for the selection of the use of drought-tolerant varieties as a good practice

Criteria	Indicators/sub-criteria	Narrative descriptions
Effectiveness of adaptation	Adaptation function	The practice enhances resilience and augments economic opportunities for farmers.
	Robustness to uncertainty	The practice is effective under different climate scenarios (e.g., flood-prone environments).
	Flexibility	Subsequent adjustments can be made if all the conditions change or if the changes are different from those that were initially expected.
Side effects	No regrets	The practice contributes to more effective crop management.
	Win-win	The practice improves the livelihoods of rainfed lowland rice farmers, who are generally resource poor.
	Positive spillover effects	The practice builds capacity in developing varieties that are resistant or tolerant to the effects of climate change.
	Negative spillover effects	None
	Trade-offs	None
Efficiency/costs and benefits	Low regrets	Extensive adaptation trials under local conditions are required before a variety is selected.
Framework conditions for decision making	Equity and legitimacy	It is a win-win situation for all.
	Are decision-making procedures accepted by those affected? Are stakeholders involved in decision making?	The practice can be done only if the farmers wish to adopt it.
Feasibility of implementation	What are the barriers to implementing, scaling up, and replicating the practice at the regional level?	There are financial limitations. A germplasm of flood-tolerant varieties is also needed.
Alternatives		There is no cheaper alternative.
Priority and urgency	The impacts of floods have been felt	Damages caused by floods are becoming more severe.

Value chain function:
This practice addresses the production segment within the rice value chain.

Beneficiary:
Farmers and farming communities will directly benefit from adopting this practice. The availability and use of drought-tolerant rice varieties will augment rice production.

Expected change in the value chain as a result of implementing this practice:
The adoption drought-tolerant rice varieties will greatly benefit rice farmers in rainfed lowland areas in Cambodia.

This practice has the following main barriers:

- A variety that features high tolerance to droughts and the preferred eating quality has not yet been developed.
- There is no universal rice variety that can adapt to all situations because the rainfed lowland environment is very diverse.
- The national government has allocated only a small portion of the budget for research.

This practice has the following enablers:

- CARDI, as a national research institute has developed and released CAR 3 and CAR 4, two varieties with different degrees of tolerance to droughts (CARDI 2009). However, these varieties are only moderately resistant and lack the quality parameters required by famers and markets. Therefore, alternative varieties that can replace CAR 3 and CAR 4 are needed. This challenge is aligned with the general rice policy of the government, The Promotion of Paddy Production and Rice Export.

- IRRI, which is active in the region, particularly in the area of developing drought-tolerant varieties, might be interested to support this initiative

Regional support:
Technical support in developing a germplasm bank of drought-tolerant rice varieties is needed from other AMS. Financial support from multilateral donors is also essential to achieve the desired outcome

Stakeholders and their role:

- CARDI should develop rice varieties that are suitable for various drought scenarios in the country.
- RUA should work closely with CARDI to train students and farmers.
- GDA should provide policy support to enhance the adoption of this practice.
- PDA should support local farmers who wish to adapt this practice at the village level.

Gender implications:
It applies to both genders. There is no gender discrimination as both genders will benefit if the activity is funded.

5.2 Cassava

5.2.1 Use of Healthy Planting Materials

Description: The use of healthy planting materials is considered the most effective method in controlling pests and diseases, particularly mealy bug and cassava witches' broom, in cassava production. Clean planting material production through different techniques can be employed.

Background: Cassava production in Cambodia used to be farmstead crop production that was done mainly in the backyard of farmers' houses. Before cassava production became commercialized, there were no reports on any damages caused by pests and diseases. A rapid boom in cassava production in Cambodia and in the region brought new threats from pests and diseases from South America, where the crop originated. Pests and diseases spread as infected cassava planting materials were moved from one place to another without any protocol on sanitation. Several pests and diseases emerged and attacked cassava production, including the pink mealy bug and cassava witches' broom. Therefore, clean planting materials are vital in achieving successful cassava production. Though the extent of damages caused by the mealy bug and cassava witches' broom has not been quantitatively reported, they significantly threaten the country's cassava production.

Climate hazard addressed:
Pests and diseases, particularly the mealy bug and cassava witches' broom, can reduce cassava yield, starch yield, and the quality of both. The production of clean seeds is vital in achieving sustainable cassava production, especially for smallholder farmers.

Table 16. Criteria for the selection of the use of healthy planting materials as a good practice

Criteria	Indicators/sub-criteria	Narrative descriptions
Effectiveness of adaptation	Adaptation function	This practice reduces the risk of planting materials being affected by pests and diseases.
	Robustness to uncertainty	The practice is effective under different climate scenarios.
	Flexibility	Subsequent adjustments can be made if all the conditions change or if the changes are different from those that were initially expected.
Side effects	No regrets	The practice contributes to more effective crop management.
	Win-win	The practice encourages cassava planting material production.
	Positive spillover effects	The practice has a positive effect on national clean planting material production, which could consequently reduce oil and air pollution through cassava planting material transportation from Vietnam and Thailand. Another spillover effect is the development of new cassava varieties with higher starch content.
	Negative spillover effects	None
	Trade-offs	None
Efficiency/costs and benefits	Low regrets	The practice requires extensive analytical work in identifying the most effective methods to produce healthy planting materials.
Framework conditions for decision making	Equity and legitimacy	It is a win-win situation for all.
	Are decision-making procedures accepted by those affected? Are stakeholders involved in decision making?	The practice can be applied by cassava farmers who are also interested in cassava varieties with higher starch content.
Feasibility of implementation	What are the barriers to implementing, scaling up, and replicating the practice at the regional level?	There are financial limitations.
Alternatives		There is no cheaper alternative.
Priority and urgency	Damage caused by emerged pests and diseases in cassava production is reported in the recent year	The rising trend in damages to planting areas is alarming and hampers sustainable cassava production.

Value chain function:
This practice addresses the input supply section within the cassava value chain.

Beneficiary:
Smallholder cassava farmers will directly benefit from adopting this practice. Increased availability of and access to clean planting materials will allow farmers to increase their crop yield. Increased crop yield will lead to increased income.

Expected change in the value chain as a result of implementing this practice:
The use of clean planting materials will reduce production damages caused by pests and diseases, and consequently improve household income.

This practice has the following main barriers:

- An effective method for early detection of pathogens has not yet been developed.
- There is no single effective method for eradicating all pathogens.
- Funding for conducting research on this practice is also a concern.

This practice has the following enablers:

- The International Center for Tropical Agriculture (CIAT) is willing to assist in developing the tool for this practice.
- GDA, CARDI, and RUA, which are actively working in the area, can be effective and efficient instruments for this initiative.

Regional support:
Emerging pests and diseases in cassava production is a regional issue. As a problem that transcends national borders, it requires a regional solution that can only be achieved through regional collaboration.

Stakeholders and their role:

- CIAT should continue developing the most appropriate tool for clean planting material production.
- CARDI, RUA, and GDA should work closely with CIAT in developing the tool and extend it to all cassava farmers in the country.
- PDA should support local farmers who wish to adapt this practice at the village level.

Gender implications:
It applies to both genders. There is no gender discrimination as both genders will benefit if the activity is funded.

5.2.2 Contour Intercropping

Description:
Cassava is planted on established vegetative or cropping contours. A scrub leguminous plant Leucaena is planted in one hedge row at high density and follows a row of lemon grass on top of the slope. These complementary plant hedgerows provide ground to minimize soil erosion and nutrient leaching, especially during heavy rains. Leucaena is known as a nitrogen-fixing plant that can enrich mono-cropping or unfertilized cassava production. It is planted to protect the cassava planting area from erosion. In addition, its leaves are rich in protein that can be used for animal production, while lemon grass can be used for culinary purposes. The size of the contours varies depending on the sloping pattern—the steeper the slope, the closer the contour. Nevertheless, this practice may not be appropriate if the slope is steeper than 30 degrees. To prevent the cassava plantation area from being in direct contact with rain, a fast-growing crop such as pumpkin should be planted simultaneously with cassava.

Background and climate hazard addressed:
In Cambodia, cassava is mainly produced in the northern uplands. It is planted chiefly in sloping areas where the slopes range from gentle to very steep. As the plant generally has a slow initial growth, erosion and soil nutrient depletion can occur if production practices are in their favor. Damages caused by soil nutrient depletion and erosion threaten future cassava production in the country. As research on this crop is limited, there is no reliable quantitative evidence of the damages. Nevertheless, it is a serious problem, especially in the course of climate change, as the areas experience rainfall of high intensity.

Table 17. Criteria for the selection of contour intercropping as a good practice

Criteria	Indicators/sub-criteria	Narrative descriptions
Effectiveness of adaptation	Adaptation function	The practice reduces the risk of soil erosion. It also enhances resilience and augments economic opportunities for farmers.
	Robustness to uncertainty	The practice is effective under different climate scenarios in sloping areas.
	Flexibility	Subsequent adjustments can be made if all the conditions change or if the changes are different from those that were initially expected.
Side effects	No regrets	The practice contributes to more sustainable soil management.
	Win-win	The practice improves the livelihoods of rainfed upland farmers, whose main source of household income is cassava cultivation.
	Positive spillover effects	The practice builds capacity in developing varieties that are resistant or tolerant to the effects of climate change.
	Negative spillover effects	None
	Trade-offs	None
Efficiency/costs and benefits	Low regrets	The practice requires a relatively high investment during the first year of application. The costs will decrease in subsequent years.
Framework conditions for decision making	Equity and legitimacy	It is a win-win situation for all.
	Are decision-making procedures accepted by those affected? Do they involve stakeholders in decision making?	This practice can only be done if the farmers wish to adopt it.
Feasibility of implementation	What are the barriers to implementing, scaling up, and replicating the practice at the regional level?	There are financial limitations.
Alternatives		There is no cheaper alternative.
Priority and urgency	The impacts of soil erosion have been observed	Soil damages caused by surface flow of rainwater from upper to lower areas have been rising.

Value chain function:
This practice addresses the production segment within the cassava value chain.

Beneficiary:
The adoption of contour intercropping will reduce the damages caused by soil nutrient depletion and erosion. It will aid cassava farmers in achieving sustainable production.

Expected change in the value chain as a result of implementing this practice:
Contour intercropping will promote sustainable cassava production with minimal nutrient leaching and erosion.

This practice has the following main barriers:
- The farmers might not fullyparticipate in contour intercropping because of lack of technical knowledge, limited financial resources, and complexity of application.
- Funding to test the suitability and appropriateness of this practice in sloping cassava production is also a concern.

This practice has the following enablers:
- CIAT, which is very active in this area, might be interested to support this initiative.
- GDA, CARDI, and RUA, which are actively working in the area, can be effective and efficient instruments for this initiative.

Regional support:
This practice can be adopted as is or with modifications in most sloping agricultural areas in the region. Financial and technical support from multilateral donors and other AMS are important, especially in scaling up the practice at the national and regional levels.

Stakeholders and their role:
- CIAT should provide technical and financial assistance in developing and testing this practice at the production level.
- CARDI and RUA should work closely with CIAT to test this practice in various locations with different sloping conditions.
- GDA, through its extension department, should help disseminate this practice to cassava farming communities.
- PDA should support local farmers who wish to adapt this practice at the village level.

Gender implications:
It applies to both genders. There is no gender discrimination as both genders will benefit if the activity is funded.

VI. CONCLUSION

Climate change is a global issue. All AMS, especially Cambodia, are now experiencing its impacts in the form of highly unusual and devastating typhoons, floods, droughts, pest and disease outbreaks, and other climate-related extremes, among others. The substantial human and property losses caused by climate risks will significantly affect the livelihoods of millions of resource-poor farmers who are prone to various climate hazards. It is projected that a continued change in climate will have dire consequences on crop production. There is an urgent need to identify good practices in CCA to sustain the production of rice and cassava, the two crops that are most susceptible to climate change.

Given that the climate problems encountered by AMS are similar, good practices in CCA that are effective in one country can also be successful in other countries in the region. The following platforms for regional collaboration can be considered:

(1) Given that the level of economic development among AMS varies, an exchange of experts for a certain period or allocation of experts from more advanced to less developed AMS may help stimulate regional integration to effectively address regional issues such as climate change. Some AMS are highly developed and equipped with better human resources and infrastructure than others.

(2) The establishment of an ASEAN ministry or council for climate change science may advance efforts in dealing with the impacts and identifying adaptation and mitigation strategies for the benefit of the entire region.

(3) The establishment of a regional research center on climate change in one of the AMS may improve regional collaboration. The main role of this center is to coordinate all AMS to work toward solving specific regional issues that are economically important.

The five suggested good practices are applicable to situations in Cambodia, but they can be modified to suit local conditions in other AMS. For replication, a technical consortium between countries can be formed to assist in refining such practices to ensure adaptability, proper allocation of resources, value for money, and effective problem solving, among others.

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ANNEX 1

MATRIX FOR ESTIMATING VULNERABILITY RATING

Exposure	Sensitivity	Ability to respond	Vulnerability rating
High	High	High	High
High	High	Medium	Very high
High	High	Low	Very high
High	Medium	High	Medium
High	Medium	Medium	High
High	Medium	Low	Very high
High	Low	High	Low
High	Low	Medium	Medium
High	Low	Low	High
Medium	High	High	Medium
Medium	High	Medium	High
Medium	High	Low	Very high
Medium	Medium	High	Low
Medium	Medium	Medium	Medium
Medium	Medium	Low	High
Medium	Low	High	Very Low
Medium	Low	Medium	Low
Medium	Low	Low	Medium
Low	High	High	Low
Low	High	Medium	Medium
Low	High	Low	High
Low	Medium	High	Very Low
Low	Medium	Medium	Low
Low	Medium	Low	Medium
Low	Low	High	Very Low
Low	Low	Medium	Very Low
Low	Low	Low	Low

ANNEX 2
CAMBODIA NATIONAL TASK FORCE

National Focal Point: Dr. Ouk Makara

Project Committee:

Ms. Chan Phaloeun	Deputy Director General, GDA
Dr. Ouk Makara	Director, CARDI
Dr. Seng Vang	Deputy Director, CARDI
Ms. Sakhan Sophany	Deputy Director, CARDI
Mr. Som Bunna	Head, Agricultural Engineering, CARDI
Mr. Lor Bunna	Head, Agronomy and Farming Systems, CARDI
Dr. Pol Chanty	Head, Training Centre, CARDI
Mr. Men Pagn-Chak Roat	Research Assistant, Socio-Economics Division, CARDI
Dr. Preap Visarto	Director, Department of Plant Protection, GDA
Mr. Am Phirum	Deputy Director, Department of Agricultural Land Resource Management, GDA
Mr. Iv Phirun	Deputy Director, Department of Industrial Crops, GDA
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Mr. Kim Soben	Director, Climate Change Centre, RUA
Ms. Chhit Chan Lida	Lecturer, RUA
Mr. Sokphon Sopheak	Deputy Director, Prek Leap National Agricultural School
Mr. Chin Chharom	Director, CamConsult
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Published by
giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

In cooperation with

SEAMEO SEARCA

Promotion of Climate Resilience in Rice and Maize

Indonesia National Study

Imprint

This publication is a joint undertaking by the ASEAN Technical Working Group on Agricultural Research and Development (ATWGARD) and the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH through the ASEAN-German Programme on Response to Climate Change (GAP-CC).

In partnership with the Southeast Asian Regional Center for Graduate Study and Research in Agriculture (SEARCA).

Published by the
Deutsche Gesellschaft für
Internationale Zusammenarbeit (GIZ) GmbH

Registered offices
Bonn and Eschborn, Germany

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As at
April 2015

Printed by/design and layout
SEARCA
College, Los Baños
Laguna - 4031

Photo Credits
Indonesian Agency for Agricultural Research and Development. (IAARD)

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German Federal Ministry for Economic Cooperation and Development (BMZ)
Alternatively: German Federal Foreign Office

Promotion of Climate Resilience in Rice and Maize

Indonesia National Study

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

AMS	ASEAN Member States
ASEAN	Association of Southeast Asian Nations
ATWGARD	ASEAN Technical Working Group on Agricultural Research and Development
BULOG	Badan Urusan Logistik (Indonesia Logistics Bureau)
CCA	Climate Change Adaptation
DITLIN	Directorate of Crop Protection
ENSO	El Niño and Southern Oscillation
GAPCC	German-ASEAN Programme on Response to Climate Change: Agriculture, Forestry, and Related Sectors
KUD	Koperasi Unit Desa (A community- or village-owned business unit)
GAPOKTAN	Gabungan Kelompok Tani (A larger group of farmer group or the second level of farmer organizations)
ICCSR	Indonesia Climate Change Sectoral Maps
MoA	Ministry of Agriculture of Indonesia (Kementerian Pertanian)
POKTAN	Kelompok Tani (Farmer group)
RAN-API	National Action Plan for Climate Change Adaptation
RASKIN	Beras Miskin (Rice distribution program for low-income households in Indonesia)
SEARCA	Southeast Asian Regional Center for Graduate Study and Research in Agriculture

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Foreword

The Indonesian Agency for Agriculture Research and Development (IAARD) under the Ministry of Agriculture is very proud to be a part of this regional study through the ASEAN Technical Working Group on Agricultural Research and Development (ATWGARD) with the support of the GIZ through the German-ASEAN Programme on Response to Climate Change (GAPCC), which seeks to promote resiliency of rice and other crops. Indonesia has good examples of climate adaptive practices, and through this project, we are happy to be given the opportunity to share and learn from our neighbors at ASEAN.

Global climate change poses a challenge to crop production in Indonesia. A number of studies already revealed the impacts of climate change on crop production, which is reasonable as climate variability significantly contributes to crop productivity. These climate change hazards include increased frequency of flood and drought, erratic rainfall particularly on harvesting period, increased temperature, and increasing infestations of pests and diseases. Within the course of this study, five good adaptation practices have been identified. Among them, three are identified as practical intervention for rice value chain, namely: crop insurance, planting calendar, and innovations on cropping strategies; while the remaining two are recommended for maize value chain, namely: production of silase for animal feed, and relay planting of maize using hybrid cultivars.

We hope that the examples provided by the national study will lead towards greater implementation of adaptive practices within Indonesia, and our neighboring countries that will overall benefit the region. These adaptive practices ensure that our people achieve food security, despite the threats of climate change.

Dr. Agung Hendriadi, M. Eng
Executive Secretary
Indonesian Agency for Agricultural
Research and Development (IAARD)

Executive Summary

The impacts of climate change on agricultural production, particularly the potential direct impacts of climate variation on crop growth and development, have been studied intensively in the last two decades. Many studies, including Masutomi et al. (2009) and Mathauda et al. (2000), reported the potential impacts of future climate change on the increase/decrease in rice yield, ranging from +1.5 percent to −2.3 percent, in countries in the Association of Southeast Asian Nations (ASEAN).

To address the potential impacts of climate change, seven ASEAN Member States (AMS) conducted national studies under the project ASEAN Network on Promoting Climate Resilience of Rice and Other Crops. The project is supported by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH; funded by the German-ASEAN Programme on Response to Climate Change: Agriculture, Forestry, and Related Sectors (GAP-CC); and implemented by the Southeast Asian Regional Center for Graduate Study and Research in Agriculture (SEARCA). The primary aim of the project is to identify good practices in climate change adaptation (CCA) within the participating AMS.

As its contribution to the project, Indonesia explored the potential impacts of climate change on crop production and identified CCA options that have been applied or planned. The study, which focused on rice and maize production systems, employed value chain mapping, literature review, stakeholder discussions, and field visits. Documents on climate change impacts and adaptation measures published by the government of Indonesia were used as the main references. Agricultural data published by Kementerian Pertanian, the Ministry of Agriculture (MoA), were analyzed to support the study. CCA options that have been planned or implemented were explored through literature review and two national consultation meetings attended by experts on agriculture and other related fields. Sites in Indramayu, the main rice cultivation area in West Java, and Jember, the main rice and maize cultivation area in East Java, were visited to gather information on issues associated with post-harvest losses and actors involved in the rice and maize value chains.

The potential impacts of global climate change on Indonesia's climate are manifested in increasing air temperature and changing rainfall patterns. The available literature notes that air temperature has been increasing and will continue to rise. As for precipitation, it is difficult to draw a conclusion for rainfall trends as rainfall patterns vary over geographic locations. Rainfall variability is also changing, but the magnitude may increase or decrease depending on the area. Surveys conducted in Indramayu and Jember show that the respondents have also been experiencing warmer conditions and erratic rainfall. The rising sea level is projected to be even higher in the future, which may cause saltwater intrusion and loss of coastline in low-lying areas.

The potential effects of climate change on crop production in Indonesia are frequently identified based on the consequences of climate-related disasters such as floods and droughts. These two events frequently occur and can decrease crop production or cause crop failure. The Directorate of Crop Protection (DITLIN), MoA reported that the floods that occurred throughout Indonesia from 2009 to 2011 damaged the following crop areas: 222,481 hectares (ha) in 2009; 307,809.6 ha in 2010; and 169,464.3 ha in 2011. It also reported that the droughts that occurred from 2009 to 2011 damaged the following crop areas throughout Indonesia: 231,912 ha in 2009; 96,721.3 ha in 2010; and 250,836 ha in 2011. Based on the report, the areas totally damaged by floods (failure or puso) were 67,821 ha in 2009; 93,929.4 ha in 2010; and 29,383.1 ha in 2011; while the areas totally damaged by droughts (failure or puso) were 18,975 ha in 2009; 20,856 ha in 2010; and 53,127 ha in 2011.

Future climate change is generally expected to adversely affect rice and maize production due to the projected increase in the frequency of floods and droughts. The application of modeling tools showed that future climate change that alters the magnitude and pattern of climate variables (e.g., rainfall and temperature) may decrease rice and maize productivity. In addition to the impacts of climate change, potential losses during post-harvest activities from harvesting to milling dry grains or gabah kering giling remain a challenge for Indonesia. Losses are mainly due to unavailability of farming technology or improper use of farming technology that are accessible to farmers.

Understanding the above challenges, the government of Indonesia has been serious in identifying CCA and mitigation measures. Research activities on cultivars have been conducted to develop crop varieties that are tolerant to floods, droughts, salinity, and pests and diseases. The main challenge is farmers' low adoption of new crop varieties. Promoting interaction among actors within the value chain of each crop will likewise increase the acceptance of interventions. For instance, farmers highly consider the consumers' demand for a certain type of rice.

Crop insurance, web-based planting calendar, silase for animal feed, and climate-smart farming practices are the CCA options that can be scaled up nationally and regionally. The availability of human resources, specifically extension workers, is a critical element in promoting the adoption of these CCA options (e.g., introducing new technologies or practices to farmers). Farmers usually decide what farming practices they will employ, but collaboration between extension workers and farmer groups could influence the farming activities in a particular region or location. Therefore, it is advisable to consider the distribution of extension workers in Indonesia during the introduction or implementation of CCA options.

The capacity of both farmers and extension workers is another challenge in implementing CCA options. The government of Indonesia should consider the farmers' educational background and socio-economic conditions. For instance, the farmers' low education and poor economic conditions may hinder the successful implementation of crop insurance and the web-based planting calendar developed and maintained by MoA. The use of the web-based planting calendar requires familiarity with the system and knowledge of its functions. Extension workers should also have sufficient knowledge of the program so that they can guide farmers in using it. The local government should promote the cropping calendar and build stakeholder capacity through communicative and interactive methods such as counseling, training sessions, and workshops, among others.

The successful implementation of CCA strategies highly depends on strong collaboration between national and local governments and all actors in the rice and maize value chains. It is imperative to implement these strategies because global climate change also threatens national food security.

I. INTRODUCTION

Crop production is highly vulnerable to the impacts of climate change because climate variability influences crop growth and development (Hoogenboom 2000; Motha and Baier 2005; Tubiello, Soussana, and Howden 2007). Globally, future climate change is expected to decrease global crop production with or without the inclusion of carbon dioxide fertilization effects (Cline 2007). It should be noted that the impacts are disproportionately felt by each country around the globe. Countries located near the equator are estimated to experience the most adverse impacts of climate change, while those in the middle latitude may benefit from the positive effects (Cline 2007).

AMS, which are mostly located near the equator, have been addressing the potential consequences of climate change. A regional study conducted for AMS found that extreme climate hazards are increasing as a result of global warming and climate change in the last few decades (ADB 2009). This reflects the urgency of CCA and mitigation efforts in crop production.

To address the potential impacts of climate change, seven AMS conducted national studies under the project ASEAN Network on Promoting Climate Resilience of Rice and Other Crops. The project is supported by GIZ, funded by GAP-CC, and implemented by SEARCA. The primary aim of the project is to identify good practices in CCA within the participating AMS. Each AMS conducted a national study to explore the potential impacts of climate change on crop production and identify CCA options that have been applied or planned. The next steps are to scale up the selected CCA practices nationally and regionally. The CCA options, which were identified using value chain mapping, literature review, stakeholder discussions, and field visits, focused on the main crops (i.e., rice and maize or cassava) of each AMS.

The Indonesia team, which is composed of MoA as the country's focal point to the ASEAN Technical Working Group on Agricultural Research and Development (ATWGARD), and the Climate Center for Risk and Opportunity Management in Southeast Asia and Pacific of Bogor Agricultural University, conducted the national study. The Indonesia team studied the potential impacts of climate change on rice and maize based on existing literature and stakeholder consultations. CCA measures that have been planned or implemented were also explored through literature review and two national consultation meetings attended by experts on crop production and other related fields.

As recommended during the first national meeting in Bogor on 3 April 2014, rice and maize production centers were also visited. Sites in Indramayu, the main rice cultivation area in West Java, and Jember, the main rice and maize cultivation area in East Java, were visited. West Java and East Java considerably have the largest planted area for crop production in Indonesia (Figure 1). The total areas reported in 2011 were 1,151,322 ha for West Java and 1,143,780 ha for East Java, which accounted for about 8.35 percent and 8.29 percent of the national total area, respectively.

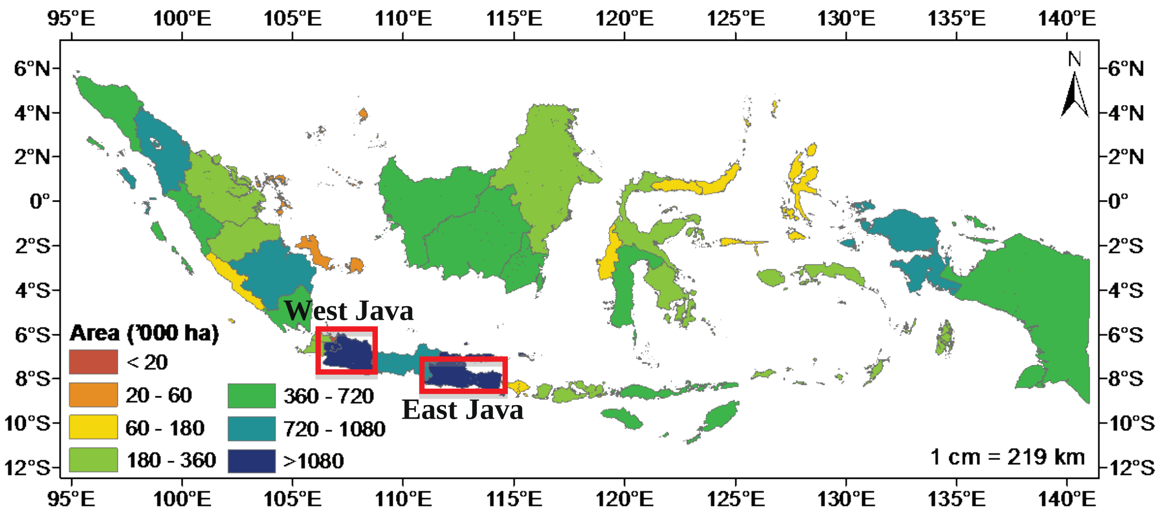

Figure 1. Total area of agricultural production by region in Indonesia

Note: West Java and East Java are indicated by the red rectangles. The area is the total area for inundated field (sawah) and dry land (ladang) reported in 2011.

Source: MoA 2014

The government of Indonesia has already documented studies on climate change, as well as its impacts and vulnerabilities, into national reports. These reports include the Indonesia Climate Change Sectoral Maps (ICCSR) (2010); the Indonesia Second National Communication under the United Nations Framework Convention on Climate Change (MoE 2010); and more recently, the National Action Plan for Climate Change Adaptation (RAN-API), which promotes the need for national adaptation to climate change (BAPPENAS 2013). The Ministry of Environment published Pedoman Umum Adaptasi Perubahan Iklim Sektor Pertanian (General Guidance of Climate Change Adaptation for Agriculture Sector) (BPPP 2011), which reviews the potential impacts of climate change on agriculture and the directions for adaptation actions to enhance and support national food security. The above documents served as the chief references for this report.

II. VALUE CHAIN MAPPING

2.1 Value Chain Selection

This study explored the potential impacts of climate change on rice and maize production because of the national production volume and value of the two crops (Table 1). The study focused on lowland rice and maize production, but it also investigated upland maize production in Jember to complete the analysis.

Table 1. Rice and maize production systems in Indonesia, 2012

Production system type	National production volume (t)	National production value (IDR 10,000 = USD 1)	Assessment of impact on national/regional consumption (1–3)	Indication/estimate of relative vulnerability to climate change (1–3)
Rice	69.056.126[a]	USD 3.298.811.139[b]	3	3
Maize	19.387.022[a]	USD 615.925.689[b]	2	3

Sources: [a]Central Bureau of Statistics of Indonesia website; [b]Trade Performance of Agriculture Commodities, Data Center website, and Agriculture Information System of MoA

Note: In the assessment of impact on national/regional consumption, the production system is estimated to represent the following values of domestic rice consumption for national food security: 1 – Low (less than 30%), 2 – Medium (30%–55%), and 3 – High (greater than 55%). In the relative vulnerability to climate change, the following descriptions apply: 1 – Low (any impact upon the production system is likely to be manageable), 2 – Medium (without intervention, the production system is likely to suffer problems in the future), and 3 – High (the production system is already experiencing significant problems with extreme weather events and these are very likely to become more severe in the future).

Rice is a staple food for the majority of the Indonesian people, and its availability is crucial to the country's development.

According to Simatupang and Rusastra (2004), rice is important to the Indonesian economy in the following ways: (1) the rice agribusiness system strengthens national food security; (2) rice farming activities are labor-intensive and major contributors to the national farming system; and (3) many rice farmers are still considered poor and thus sensitive to any production loss. Compared to other countries in Asia where rice is also the staple food, rice consumption in Indonesia is the highest. With an average consumption rate of about 102 kilograms per capita per year (kg/capita/year), Indonesia surpasses Malaysia (80 kg/capita/year), Thailand (70 kg/capita/year), Japan (50 kg/capita/year), and Korea (40 kg/capita/year) (Neraca 2013).

Given the high demand for rice commodities, paddy rice is grown in several areas in Indonesia. The majority of paddy-growing areas are in Western Indonesia, mostly in Java Island (Figure 2). The climate and soil types in this part of the country are more suitable for paddy growth and development than in the eastern part. Java Island, where West Java and East Java are located, contributes 36,526,000 tons (t) or about 52.9 percent of the national production.

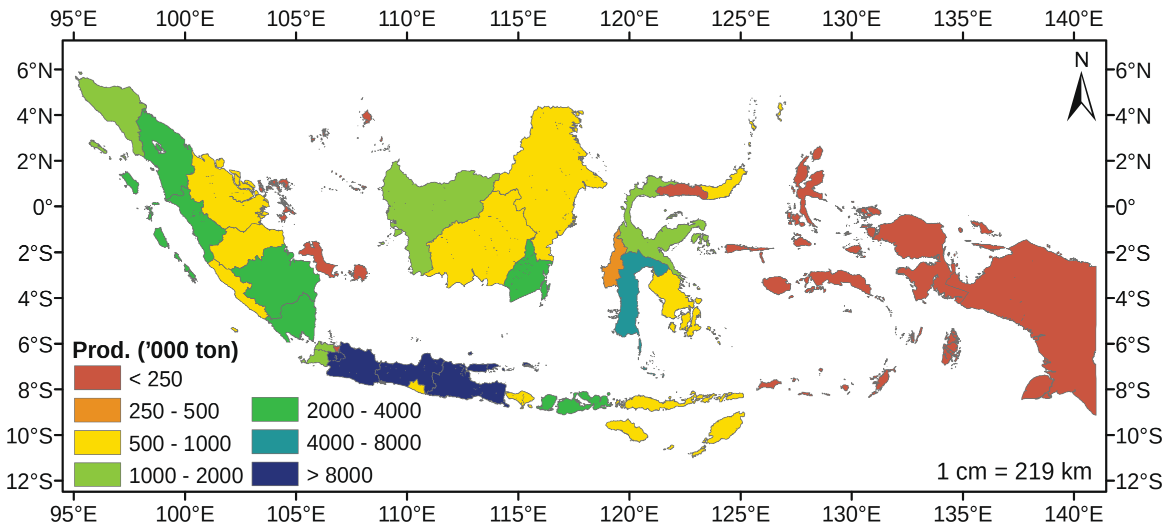

Figure 2. Distribution of paddy production in Indonesia, 2012
Note: The image was created based on data of total agricultural production by province.
Source: Central Bureau of Statistics of Indonesia 2014

Harvested paddy yield produced in the major growing areas are then distributed to consumers through a value chain system (Figure 3). The long and complex value chain may contribute to price disparity received by farmers and paid by consumers. The diagram displays the supply chains of paddy from farmers to consumers. Harvested paddy will pass through post-harvest activities such as drying and milling to produce rice. Rice is then stored and directly distributed to consumers through supermarkets. Rice can also pass through bazaar traders that will sell rice to retailers or small traditional markets where consumers can buy rice. Small millers that process paddy into rice send rice to Koperasi Unit Desa (KUD), a cooperative or community-owned business unit that sends rice to Badan Urusan Logistik (BULOG), the Indonesia Logistics Bureau. BULOG is a state-owned company that may sell rice at a lower price for low-income households.

The following are the general rice supply chains:

- Farmer --> Collective --> Bazaar Trader--> Retail Seller --> Consumer
- Farmer --> Collective --> Bazaar Trader --> Small Traditional Market --> Consumer
- Farmer --> Collective --> Supermarket --> Consumer
- Farmer --> Collective --> Coop --> BULOG --> Low-income Households

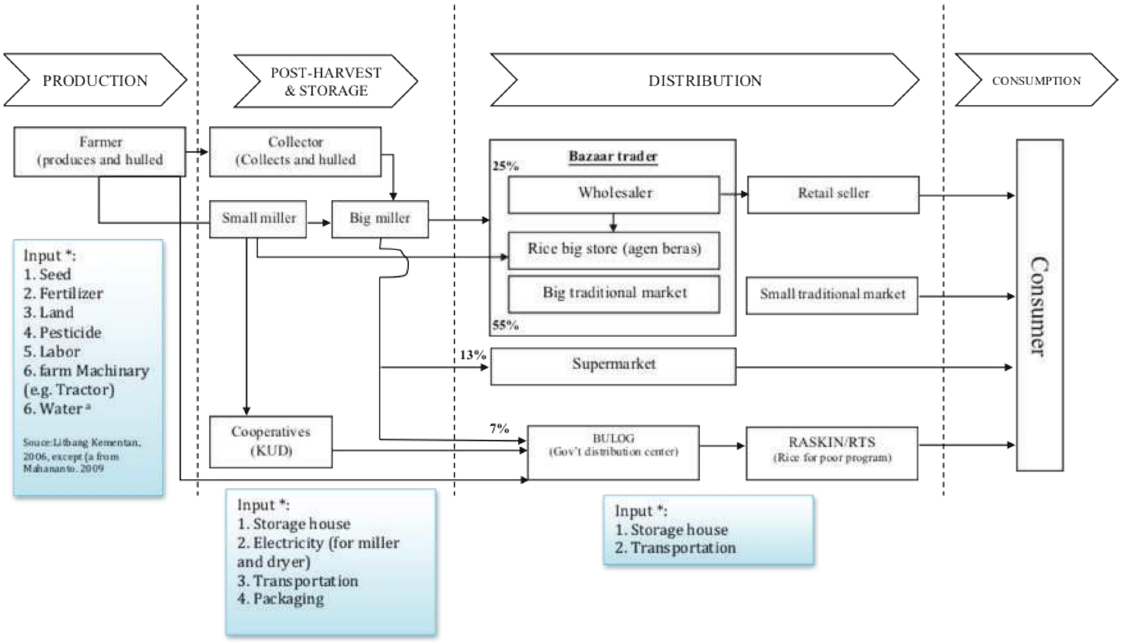

Figure 3. Rice value chain in Indonesia

As discussed during the second national meeting in Bogor on 22 May 2014, BULOG also buys paddy directly from farmer groups (BULOG 2014a). The BULOG representative who attended the second national meeting also mentioned that the company works with farmer groups in post-harvest processing of paddy to rice, allowing it to buy rice directly from farmer groups. BULOG also supplies rice to low-income households at a lower price through a rice distribution program called Beras Miskin (RASKIN) (BULOG, 2014b). These efforts show the government's commitment to help farmers and households access the staple food and maintain food security.

Farmers can buy production inputs such as seeds and fertilizers from agricultural shops.

The national government also supplies seeds and fertilizers to farmers. The seed supply from the government is usually in the form of seed subsidy or for testing a new variety (Figure 4). The government, through the Research and Development Agency of MoA, has produced several new rice varieties that aim to boost rice productivity. Unfortunately, as discussed during the second national meeting, the acceptance of new varieties is still low as farmers regularly choose rice varieties based on market or consumer demand. For example, since consumers already accept the Ciherang variety, it is recommended to name a new variety based on the consumers' preference or knowledge. It was also discussed that the specifications of the milling machinery suit the physical characteristics of the Ciherang variety.

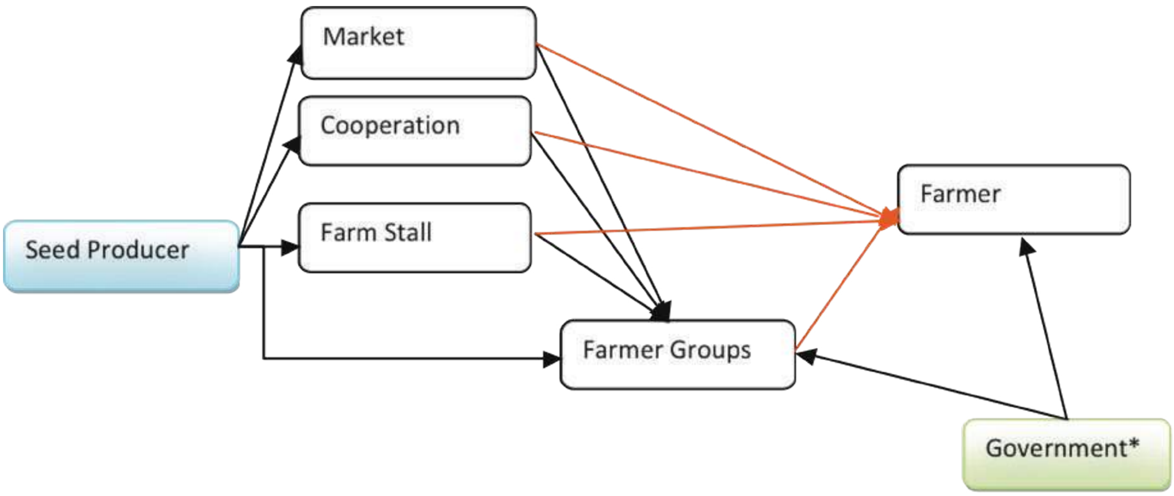

Figure 4. Distribution of rice seeds from producer to consumers

Maize is the second most important commodity in Indonesia. In some areas, people consider this crop as their staple food, such as Ampok Rice and Maize Rice in East Java, Pencok in Bali, Kemunak Rice in Jambi, and Binte Biluhuta in North Sulawesi (Krisnamuthi 2010). Approximately 55 percent of maize domestic production goes to the feed industry, where maize is used as raw material to produce livestock feed. As with paddy rice production, the major maize-growing areas are mostly in Java Island (Figure 5). East Java, which has the highest total maize production among the main maize-growing areas in Java Island, is considered the main maize producer. The total production for East Java reported in 2012 was about 6,295,000 t, which accounted for 32.5 percent of the national production. Some people in East Java also consume maize as their staple food, which can be one of the reasons why maize is mostly cultivated in the province.

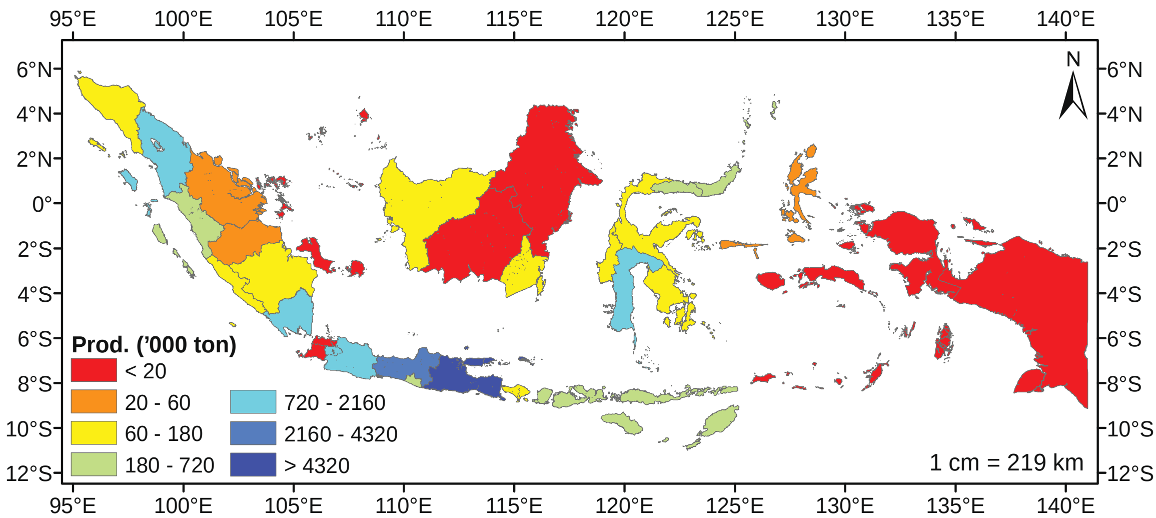

Figure 5. Distribution of maize production in Indonesia, 2012

Note: The image was created based on data of total agricultural production area by province.

Source: MoA 2014

Maize is not only produced for human consumption but also for producing livestock feed. These different demands result in two big schemes of maize supply chain from producers to consumers. In the first chain, harvested yield is delivered to dryers, collectors, wholesalers, retail sellers, and consumers. The second is similar to the first chain, but the collectors send maize yield to the corn-based industry for further post-processing then distribute the post-processed products to wholesalers, retail sellers, and consumers. The schemes are presented in Figure 6.

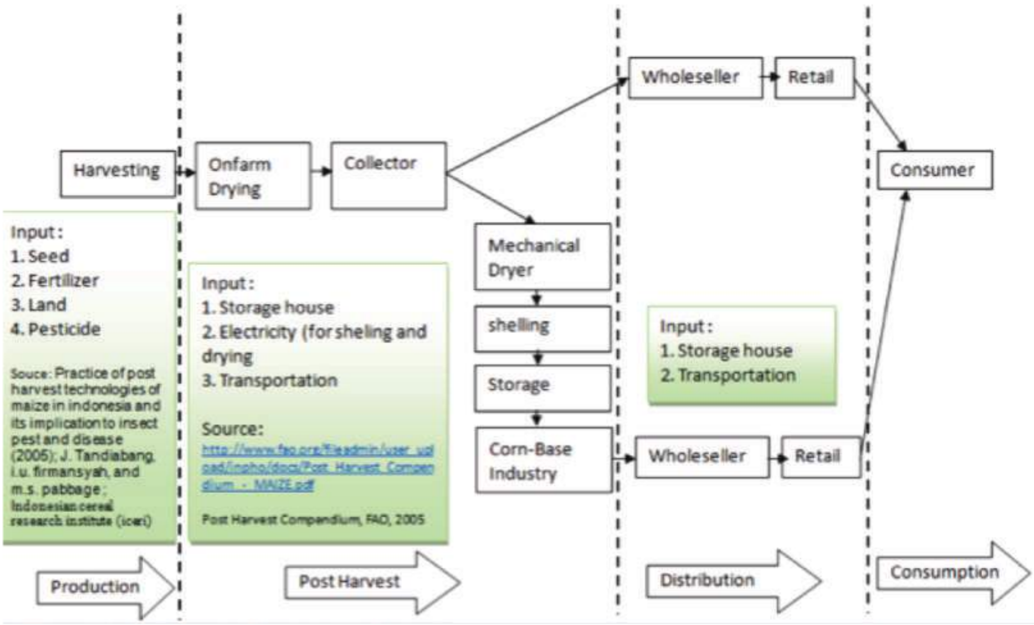

Figure 6. Maize value chain in Indonesia

The government's involvement in maize production is minimal compared to its involvement in rice production. Farmers usually purchase production inputs from agricultural shops, but many private companies also supply seeds. As discussed by a representative during the first and second national meetings, Dupont-Pioneer, a seed company that focuses on maize, already works closely with farmers and farmer groups through the company's extension workers to educate them on the new seeds that they sell. It also supplies post-processed maize to the feed industry. The feed industry has a high demand for silase, a corn-based product that is used to feed cattle. Silase, which is produced from the maize stalks, can reduce feeding costs because cows eat less silase (25 kg/day) than green grass (70 kg/day). Milk producers have also tapped Dupont-Pioneer as a silase supplier.

2.2 Role of Value Chain Players

The roles of players or actors in each stage of the rice and maize value chains are similar. The inputs required for production and post-harvest processes are also similar, but with some exceptions. For example, there is generally no government subsidy for maize seeds. Thus, the information of inputs required for each value chain and actor are also similar. For instance, seeds, fertilizers, and pesticides are produced by associated companies for the farming inputs and purchased by farmers. The inputs and actors in the rice supply chain are presented in Table 2.

Table 2. Inputs and actors in the rice supply chain

Input and actor	Description
Production	
Seeds	Farmers can obtain seeds for their planting activities from numerous sources. They can get it from GAPOKTAN, a group of farmer cooperations (Koperasi Tani) (Darwis 2012), to which MoA distributes seeds subsidized by the government; and seed markets. They could also use the seeds that they stored from their previous harvest. Regarding seed provision, MoA usually provides superior seed varieties to increase harvested yield or productivity, but such projects usually fail because of farmers' lack of knowledge and support. Also, some varieties may not grow well because they are not suitable for some land types (Firdaus, Baga, and Pratiwi 2008). Generally, seeds can be obtained through farmers, individual suppliers, associations (e.g., farmer associations that also distribute seeds), and cooperatives (KUD).
Fertilizers	There are two types of fertilizers: organic and inorganic. As with seeds, farmers can obtain fertilizers from several sources, such as GAPOKTAN, cooperatives, or fertilizer traders. In the market, there are also two types of fertilizers: subsidized or non-subsidized. Based on discussions during the experts' meeting, the issue of accessing subsidized fertilizers is usually related to limited stocks or farmers' lack of knowledge on how to obtain subsidized fertilizers. Farmers can also make their own organic fertilizers using crop residues or manure. Generally, fertilizers can be obtained through individual suppliers, associations (e.g., farmer associations that also distribute fertilizers), and cooperatives (KUD).
Pesticides	The use of pesticides increased during the agricultural intensification program announced by the government in the 1970s. Most farmers depended on it and assumed that pesticide application was the only way to control pests. During the experts' meeting, a representative of MoA mentioned that to reduce farmers' reliance on toxic chemical pesticides, the government issued several programs to inform the public about using the correct amount of pesticides. It also introduced the use of biopesticides. Generally, pesticides can be obtained through individual suppliers, associations (e.g., farmer associations that also distribute fertilizers), and KUD.
Land	The two common land problems are (1) high rate of land conversion, wherein rice-growing areas are turned into land for residential and industry purposes (Departemen Pertanian 2010); and (2) suitability of land for rice production, which depends on land types, morphology, and climate, among others (Departemen Pertanian 2010).
Water	Water, one of the most important inputs for rice production, can be obtained from rainfall or rainfed systems and irrigation systems.
Machinery	Machinery can be obtained from individual suppliers and farmer associations.
Labor	Labor for farming activities can be categorized into (1) family members and (2) farm workers. They are hired (1) throughout the growing season or (2) only during a certain stage, such as planting or harvesting. Farm workers are paid either monthly or by the end of the season
Post-harvest	
Collectors	Collectors are individuals who often gather harvested paddy directly from the field or farmland.
Rice dryers and millers	Farmers commonly send the harvested paddy to a milling center. The drying and milling centers can be privately owned, belong to a farmer group, or managed by KUD.
Cooperatives (KUD)	A cooperative is an economic institution at the village level that is originally a combination of an agricultural cooperative and a village cooperative (Government Regulation No. 60/1959).
Storage house owners	Rice and other grains are kept in a storage house before they are sent to the distributor. In Indonesia, rice and other grains are stored in open bags or granaries, exposing them to insect, rodent, and bird attacks. High equilibrium moisture content is greater than 14. Grain is not always protected from rain.

cont... Table 2. Inputs and actors in the rice supply chain

Input and actor	Description
Transportation (workers)	Workers need to have proper transportation to move rice from the storage house to the distributor.
Electricity	Electricity is required for milling and drying.
Packaging facilities	These facilities are necessary for packaging rice before distribution.
Distribution	
Bazaar traders	Bazaar traders, such as wholesalers, big rice stores, and large traditional markets, are traders who sell rice in large quantities.
Supermarkets	Supermarkets are larger versions of the traditional grocery store. They are self-service shops that offer a wide variety of food and household products.
BULOG	BULOG is a state-owned company engaged in food logistics. It covers business logistics or warehousing, surveying, pest eradication, plastic bag provision, transport business, food commodities trading, and retail businesses. In terms of RASKIN distribution, BULOG moves the rice into its storage house, transports it to the distribution point, and delivers it to the RASKIN working group or a village shop. A village shop is a regular shop that sells agricultural products such as rice. From the working group or village shop, RASKIN delivers the rice to poor households. BULOG has a number of dropping points for RASKIN distribution.
Retail sellers and small traditional markets	Retail sellers and small traditional markets are traders who sell rice in small quantities.
Consumption	
Consumers	Consumers are the people who purchase and eat rice.

2.3 Post-Harvest Losses

The post-harvest processes for rice and maize are almost similar as shown in Figures 3 and 6. The team wanted to elaborate on post-harvest losses, but adequate information on such was found for rice only. Therefore, this section discusses post-harvest losses in rice production (Table 3).

Table 3. Post-harvest losses in rice production in Indonesia

Production stage	Losses (%)		
	1986–1987	1995–1996	2007
Harvest	9.19[a]	9.52[a]	1.57
Separation	5.48[a]	4.78[a]	0.98[a]
Transportation	0.59	0.19	0.38
Drying	1.94[a]	2.13[a]	3.59[b]
Milling	3.51[b]	2.19[b]	3.07[b]
Storage	0.32	1.61	1.68
Total	21.03	20.51	11.27

Source: Translated from the book published by MoA (BBPMP 2011).
Note: [a]Percentage of GKP (gabah at dry harvest), [b]Percentage of dry milled gabah

According to Pak Koesnomo Tamkani, a former agriculture extension worker for about 30 years and also a former director of Dinas Pertanian Indramayu, the Agricultural Agency of Indramayu, post-harvest losses when processing harvested paddy to rice can be due to (1) natural causes or (2) behavioral causes. Natural causes occur because the water content of rice should be reduced before the product is sold to consumers. Reducing the water content is also necessary to maintain rice quality during storage. After harvesting, the farmers will dry unhulled paddy (gabah) under the sun. Gabah is gathered by separating produced paddy seeds from the paddy crop. The paddy crop is pounded into a base and gabah is collected using a plastic base (Figures 7 and 8).

Figure 7. Harvesting time in Indramayu
Source: IAARD 2015

Figure 8. Separating paddy seeds (gabah) from paddy crops in Indramayu
Source: IAARD 2015

Drying can reduce 24 percent to 27 percent of water content, depending on the frequency of rainfall during harvesting. The process requires complete sun exposure. Furthermore, the water content of gabah should be lower than 17 percent before it can be moved to storage. The next step is milling the gabah to produce rice. The produced rice is about 63 percent to 67 percent of harvested paddy, depending on the quality of rice produced. Rice of good quality is about 67 percent of the harvested paddy, while rice of poor quality is about 63 percent of the harvested paddy. Post-harvest losses due to behavior are mainly the result of the technology that the farmers used for post-harvest activities. For example, the use of a plastic bed as shown in Figure 8 can minimize losses as gabah will be collected in the plastic base. However, a rectangle separator may be added to the plastic bed to prevent the gabah from being scattered across the field. The use of a dryer can also minimize losses, but the machine is costly to farmers. The potential post-harvest losses in Indramayu are presented in Figure 9.

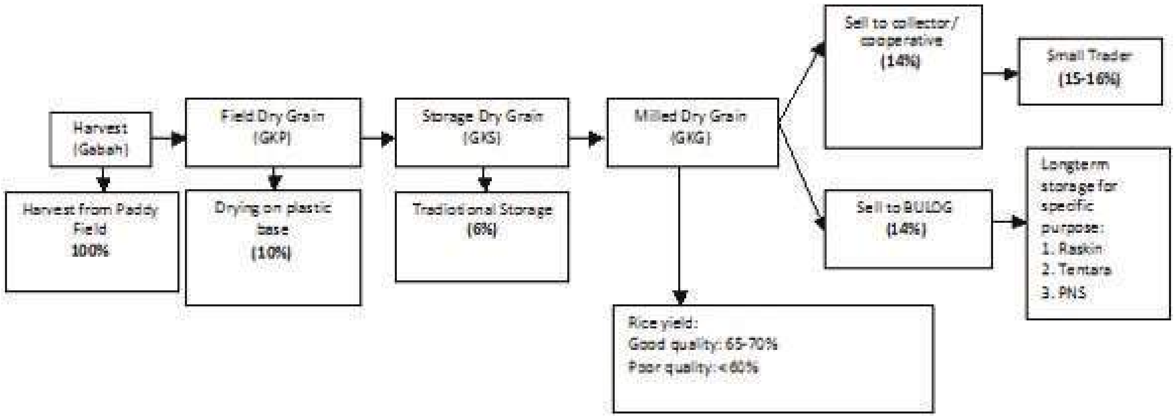

Figure 9. Potential losses during post-harvest in Indramayu

Note: The potential losses during the post-harvest processes from harvest to milled dry grain (gabah) are indicated by numbers in the brackets based on survey in Indramayu. After gabah, the numbers in the brackets indicated water content allowed by a buyer to buy rice.

Furthermore, as documented in the book Mekanisasi Pasca Panen Padi di Indonesia: Tinjauan dari Aspek Teknis dan Budaya (Mechanization of Post-Harvest Paddy in Indonesia: Technical and Cultural Aspects), post-harvest losses in the form of decreased yield or susut hasil can be categorized as absolute losses and relative losses (BBPMP 2011). In absolute losses, gabah losses are irrecoverable. In relative losses, losses can be recovered by using tools and technology (e.g., drying and milling machinery). All post-harvest losses from harvesting to storage are now lower than two decades ago. Losses can be reduced from over 20 percent to about 11 percent. As reported in the book, the farmers' behavior during harvesting and behavior during separating the seeds of paddy crop are the two components contributing to higher losses, which indicate the need for positive behavior change. The use of technology can also reduce losses, but the socio-cultural conditions of a region should be considered before a new technology is introduced. Such conditions vary per location.

For example, as discussed during the second national meeting, the farmers in East Java were more accepting of new technologies (e.g., dryer and thresher) than those in West Java. This can be attributed to differences in socio-cultural conditions as well as the costs associated with the use of machinery. Participants of the second national meeting proposed that the government of Indonesia should help the farmers access affordable machinery instead of subsidizing production inputs such as seeds and fertilizers. A representative of MoA responded that the government is already helping the farmers minimize post-harvest processes, particularly through technical guidance or bimbingan teknis given in training sessions or workshops. The government has been supplying machinery for production, depending on the farmers' requests. The farmers' needs vary depending on the location. Some devices, such as the thresher, can be produced by local machinery shops.

The application of technology to support rice production, including minimizing post-harvest losses, should be promoted. It will help farmers be more productive and thus improve their welfare.

III. REVIEW OF CLIMATE CHANGE IMPACTS AND VULNERABILITIES

The potential impacts of global climate change on Indonesia's climate as well as on the country's rice and maize production systems were reviewed based on available literature. Climatic trends and potential impacts were evaluated. Surveys were conducted during field visits to assess if the respondents were already experiencing the effects of climate change on rice and maize production. During the interview, questions were also asked to explore CCA practices that have been implemented. The team visited Indramayu and Jember.

The identified impacts of global climate change on Indonesia's climate were mostly based on temperature trends and changing rainfall patterns, which have caused devastating floods and droughts (MoE 2007). Floods in many parts of Indonesia are becoming more frequent, as evidenced by the 530 floods that affected the country in 2001–2004 (MoE 2007). In the last four decades, droughts have also become more frequent (Boer and Subbiah 2005). The increased frequency of floods and droughts may be a result of the increased frequency of climate extremes in Indonesia. Climate variability in the country is strongly influenced by the El Niño Southern Oscillation (ENSO), which is commonly known as El Niño and La Niña. Longer dry seasons that may cause droughts are often associated with the onset of El Niño, while high-intensity rainfall that may cause floods is often associated with La Niña. A study conducted by Timmermann et al. (1999) alarmed Indonesia, cautioning it to pay more attention to the potential impacts of future climate change on climate extremes, as the study reported that global warming may increase the frequency of ENSO events.

The impacts of global climate change on Indonesia's climate are already manifested in increasing air temperature and changing rainfall patterns, which are expected to continue. The available literature notes that air temperature has been increasing and will continue to rise. As for precipitation, it is difficult to draw a conclusion for rainfall trends as rainfall patterns vary over geographic locations. Rainfall variability is also changing, but the magnitude may increase or decrease depending on the area. Surveys conducted in Indramayu and Jember show that the respondents have also been experiencing warmer conditions and erratic rainfall. The rising sea level is projected to be even higher in the future, which may cause saltwater intrusion and loss of coastline in low-lying growing areas. The trends in climate variables in Indonesia are presented in Table 4.

Table 4. Historical and projected trends in climate variables in Indonesia

Variable	Specific climate risk/ opportunity	Historical trend	Projections	Confidence	References
Mean temperature	Increase in temperature	Increase	Increase of 0.5ºC–3.92ºC by 2100	High	Cruz et al. (2007) Hulme and Sheard (1999) UK Department of Energy and Climate Change (2011)
Minimum temperature	Increase in temperature	Increase	Increase of 0.04ºC–0.07ºC annually	Medium	Boer, Sutardi, and Hilman (2007)
Precipitation	Water stress Floods Droughts	Change	Annual rainfall increase of 5–10 percent in Kalimantan and 0–5 percent in Sumatra by 2100 Annual rainfall increase throughout Indonesia—except Southern Indonesia (including Java), which will experience a decrease of 15 percent—by 2100 Higher rainfall intensity and shorter rainfall duration in North Sumatra and Kalimantan Lower rainfall intensity and longer rainfall duration in the southern part of Java and Bali	High	Hulme and Sheard (1999) UK Department of Energy and Climate Change (2011) Naylor et al. (2007)
Sea level	Loss of coastline Saltwater intrusion	Increase of 0.8–1.6 mm/ year	Increase of 5 mm per year By 2050, the sea level will be 35–40 cm higher than the sea level in 2000	Medium	Cruz et al (2007) BAPPENAS (2013)

The Indonesian government, through Badan Perencanaan Pembangunan Nasional or the Ministry of National Development Planning, has already documented studies that assessed the potential impacts of climate change on Indonesia's climate. The report documented the current climatic trends and projections of air temperature, rainfall, sea level, and extreme climate events associated with ENSO (BAPPENAS 2013).

As discussed above, the impacts of climate change on rice and maize production are associated with the occurrence of floods and droughts that can decrease crop yield or cause crop failure (puso). The effects of floods and droughts caused by climate extremes were already documented in the report, Pedoman Umum Adaptasi Perubahan Iklim Sektor Pertanian (General Guidance of Climate Change Adaptation for Agriculture Sector) (BPPP 2011). The adverse impacts of floods can also exacerbate the potential yield loss of paddy rice, since floods may increase pest infestations as described by studies documented in the report (BPPP 2011) and the ICCSR (2010). Increasing temperature and increasing humidity can also increase disease infestations such as Bulai, which was also mentioned by the respondents in Jember. The potential adverse impacts of climate change on crop production pose a serious challenge, especially when agricultural land conversion threatens food security. Boer et al. (2009) reported that paddy rice production in Java may decrease by 5 million t in 2025 and 10 million t in 2050 as a consequence of both the impacts of global climate change and agricultural land conversion.

Increasing temperature is expected to decrease both rice and maize yields (Tables 5 and 6). A higher temperature will trigger a higher transpiration rate, which requires higher water consumption or respiration that destroys accumulated biomass. Changing rainfall patterns can also delay post-harvest activities. Erratic rainfall makes the start of the growing season unpredictable. Rainfall during harvesting can also affect the quantity and quality of crops that require an adequate amount of solar radiation. The book Mekanisasi Pasca Panen (Mechanization of Post-Harvest) (BBPMP 2011) and the field surveys revealed that yield losses may occur during drying, milling, storage, and distribution. Climate conditions strongly

influence drying activities. The potential impacts of sea level rise were measured by estimating the inundated areas that may decrease planted areas, which will eventually decrease crop production. In addition to the potential increase in salinity, sea level rise can decrease crop production.

Table 5. Climate change impact assessment and vulnerability rating for rice production in Indonesia

System of interest	Geographic location	Climate change trend/signal	Biophysical impact	Socio-economic impact	Exposure	Sensitivity	Ability to respond	Vulnerability rating	References
Rainfed rice	Lowland	Increasing frequency of floods and droughts	Decreasing or failed yields	Decreasing production and increasing risk of food insecurity	High	High	Low	Very High	BPPP (2011) Field visit to Indramayu, West Java
	National	Increasing intensity and frequency of storms, floods, and droughts	Decreasing yields	Decreasing production by 2050	High	High	Low	Very High	Syaukat (2011)
Rice	Java Island	Increasing temperature and excessive rainfall	Affecting yields by 2030	Risk of food insecurity	High	Medium	Medium	High	Widiyanti (2009)
	Lowland	Increasing temperature	Decreasing yields	Decreasing production	High	High	Medium	Very High	Mathauda et al. (2000)
	National	Increasing temperature	Yield change ranging from -20 percent to +10 percent	Yield change	High	High	Medium	Very High	Lobell, Schlenker, and Costa-Roberts (2011)
Rice variety	Lowland and upland	Increasing temperature	Shifts of agro-ecological zones Introduction of new varieties	Decreasing yields (lowland) Increasing yields (upland)	High	Medium	Medium	High	Boer, Sutardi, and Hilman (2007)
Growing season	National	Shorter wet season Longer dry season	Floods (for the crops in the first season/ wet season) Droughts (for the crops in the second season/dry season)	Shorter growing season and harvesting index	High	High	High	High	Naylor et al. (2007)

cont... Table 5. Climate change impact assessment and vulnerability rating for rice production in Indonesia

System of interest	Geographic location	Climate change trend/signal	Biophysical impact	Socio-economic impact	Exposure	Sensitivity	Ability to respond	Vulnerability rating	References
Delay of the onset of seasons	National	Shorter wet season Longer dry season	Flowering stage for the second planting of rice (April–June) may be exposed to droughts	Decreasing yields	Medium	Medium	Medium	Medium	Naylor et al. (2007)
Rice	National	Sea level rise	Decreasing planted areas	Decreasing production by 2050	Medium	High	Low	Very High	Handoko and Hardjomidjojo (2009)
	Lowland (Indramayu)	Increasing salinity	Decreasing yields	Decreasing production	Medium	High	Medium	High	Boer et al. (2009)
	Java	Higher rainfall and temperature (inter-annual climate variability)	Yield losses	Decreasing rice grain yields	High	Medium	Medium	High	Amien et al. (1999)

Table 6. Climate change impact assessment and vulnerability rating for maize production in Indonesia

System of interest	Geographic location	Climate change trend/signal	Biophysical impact	Socio-economic impact	Exposure	Sensitivity	Ability to respond	Vulnerability rating	References
Rainfed maize	National	Increasing intensity and frequency of storms, floods, and droughts	Decreasing yields	Decreasing production by 2050	High	High	Low	Very High	Syaukat (2011)
	National	Increasing temperature leads to increasing respiration	Decreasing yields	Decreasing production by 2050	High	High	High	High	Handoko and Hardjomidjojo (2009)
Maize	National	Sea level rise	Decreasing planted areas	Decreasing production by 2050	Medium	High	Low	Very High	Handoko and Hardjomidjojo (2009)
	Endemic in a district of West Kalimantan and East Java	Increasing temperature and humidity	Maize disease (Bulai)	Decreasing or failed yields	Medium	High	Medium	High	BPPP (2011) Field visit to Jember, East Java

The potential impacts of climate change described above are mostly based on the assessments of the potential impacts of changing climate variables (e.g., rainfall and temperature) on crop production using modeling approaches. The effects of recent climatic trends are already experienced in Indonesia. Climate-related disasters (e.g., floods and droughts) frequently occur and can decrease crop production or cause crop failure. DITLIN MoA reported that the floods that occurred in Indonesia from 2009 to 2011 damaged the following crop areas: 222,481 hectares (ha) in 2009; 307,809.6 ha in 2010; and 169,464.3 ha in 2011. Based on the report, the areas totally damaged by floods (failure or puso) were 67,821 ha in 2009; 93,929.4 ha in 2010; and 29,383.1 ha in 2011. The three flood events that occurred in 2010 were the largest in terms of affected area and crop failure. The spatial distribution of the total area affected by flood and crop failure in 2010 is presented in Figure 10.

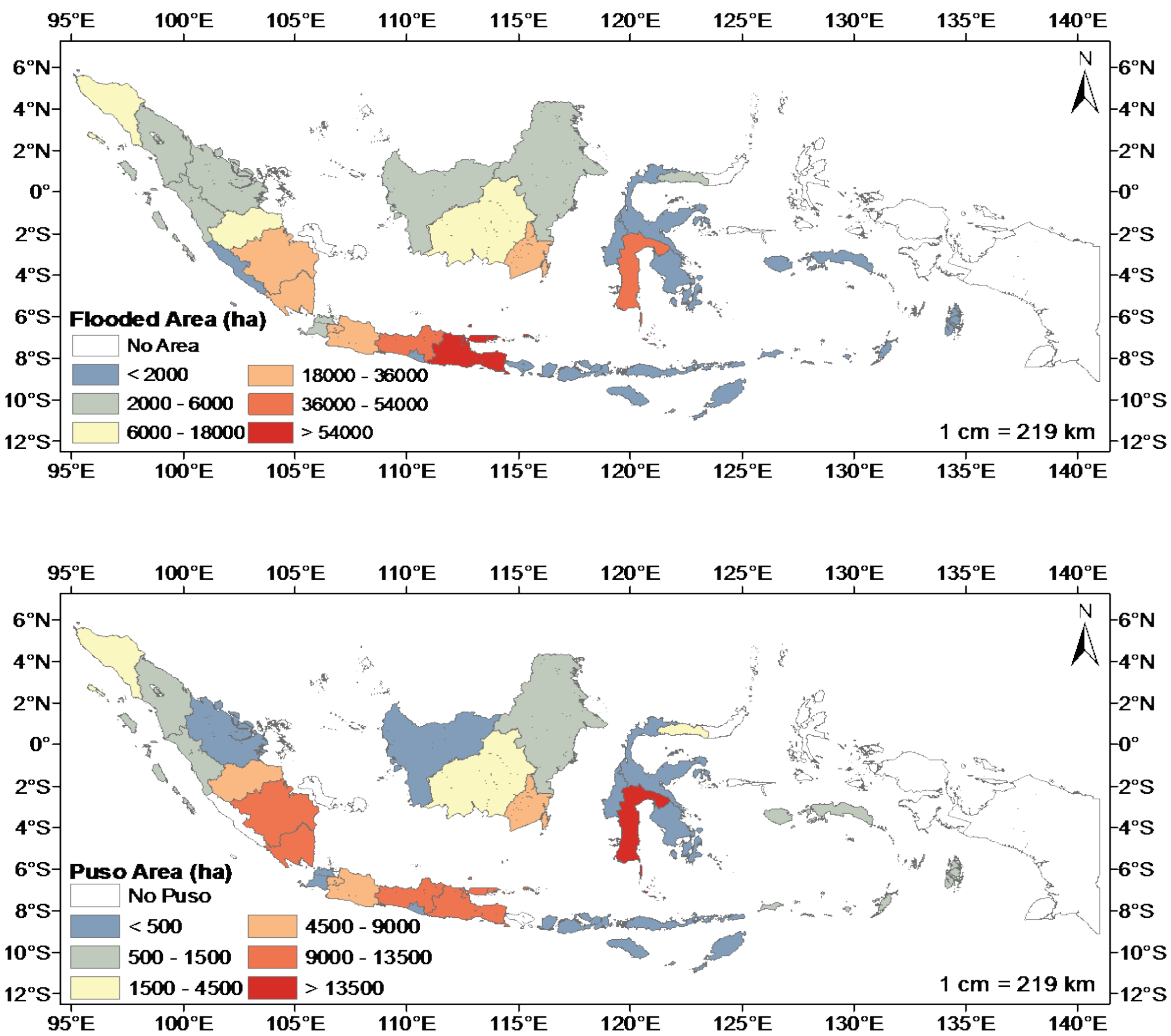

Figure 10. Total area of flood-affected paddy production (above) and resulting crop failure (below) in Indonesia, 2010

Note: Total crop failure is locally known as puso.

Source: MoA 2014

The flood event that occurred in 2010 affected more crop production areas in the western part of Indonesia than in the eastern part. The total area of crop production affected by flood was higher for Java Island, South Sumatra and Kalimantan, and West-South Sulawesi than for other areas such as Bali, Nusa Tenggara Barat, and Nusa Tenggara Timur. There is no information for Papua province because the data reported zero values.

West Java and East Java experienced higher losses in paddy rice production because of floods. East Java experienced more losses than West Java in 2010 and 2011. The total affected area for East Java in 2010 was about 60,000 ha. On the other hand, the total affected area for West Java in 2009 was about 40,000 ha (Figure 11). Flood frequently occurs in January and February as these are the peak months of the rainy season in both provinces (Figure 12).

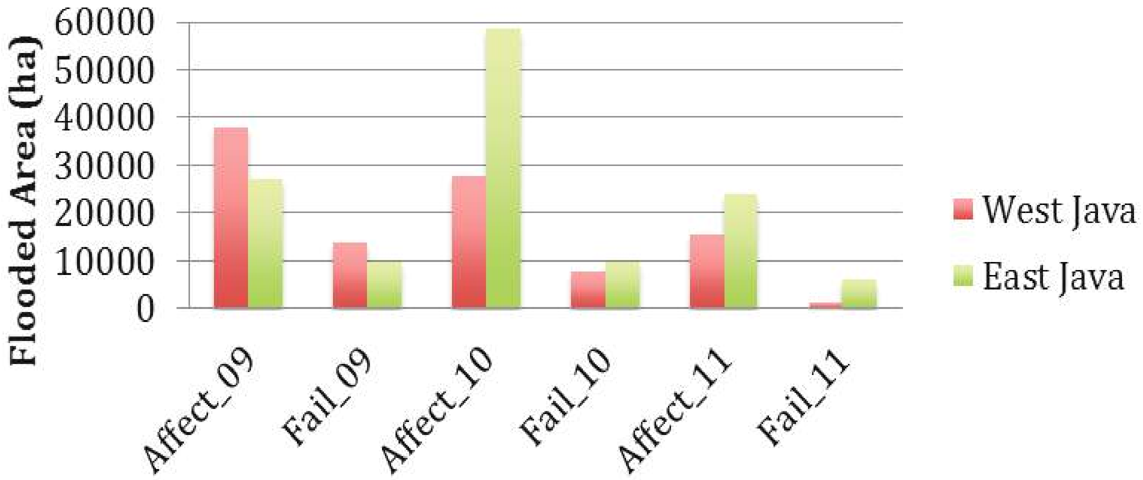

Figure 11. Annual total area of flood-affected paddy production (affect) and resulting crop failure (fail) in West Java and East Java, 2009–2011
Source: MoA 2014

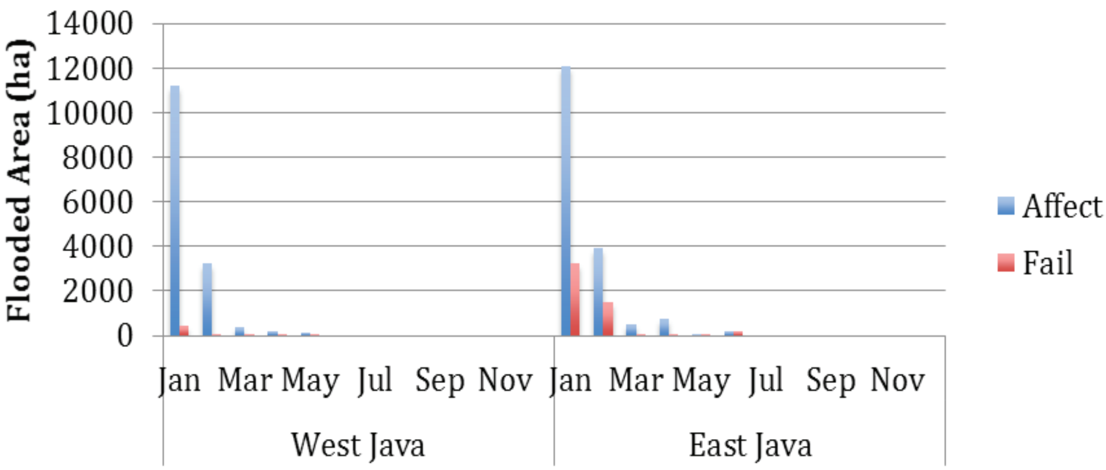

Figure 12. Monthly total area of flood-affected paddy production (affect) and resulting crop failure (fail) in West Java and East Java, 2012
Source: MoA 2014

DITLIN, MoA also reported that the droughts that occurred from 2009 to 2011 in Indonesia damaged the following crop areas: 231,912 ha in 2009; 96,721.3 ha in 2010; and 250,836 ha in 2011. Based on the report, the areas totally damaged by droughts (failure or puso) were 18,975 ha in 2009; 20,856 ha in 2010; and 53,127 ha in 2011. The spatial distribution of the total affected area in 2011 is presented in Figure 13. The distribution of the total drought-affected area is almost similar to the distribution of the total flood-affected area. This indicates that crop production regions, such as West Java and East Java, are considerably prone to floods and droughts.

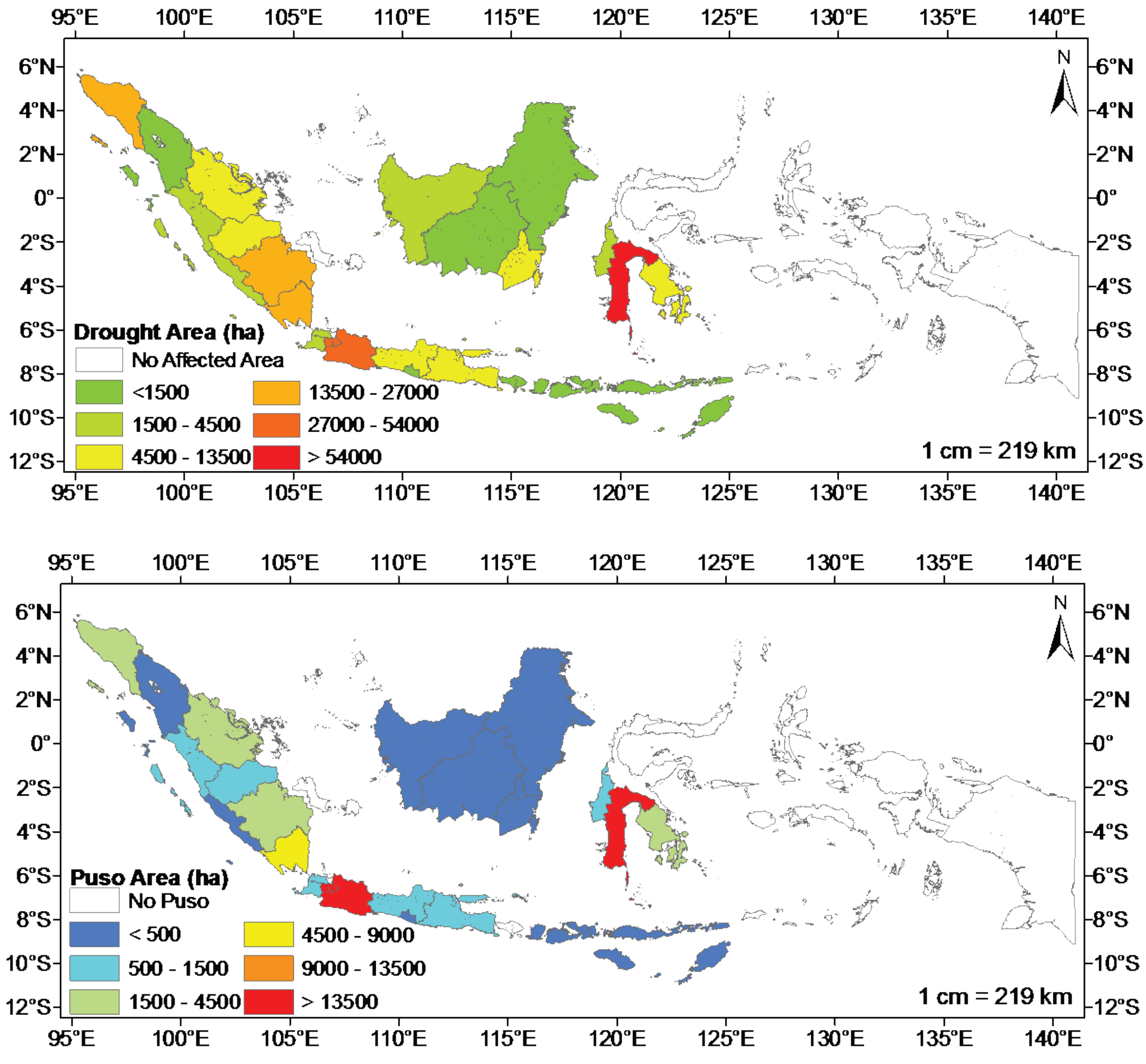

Figure 13. Total area of drought-affected paddy rice production (above) and resulting crop failure (below) in Indonesia, 2011

Note: Total crop failure is locally known as puso. Source: MoA 2014

West Java suffers more from droughts than East Java. The drought that occurred in 2011 affected over 50,000 ha of paddy fields in West Java and caused about 14,000 ha of crop failure (Figure 14). Nevertheless, since the two provinces have similar climate types (i.e., monsoonal), droughts frequently occur during the dry season spanning June to September, with the peak months being July and August (Figure 15).

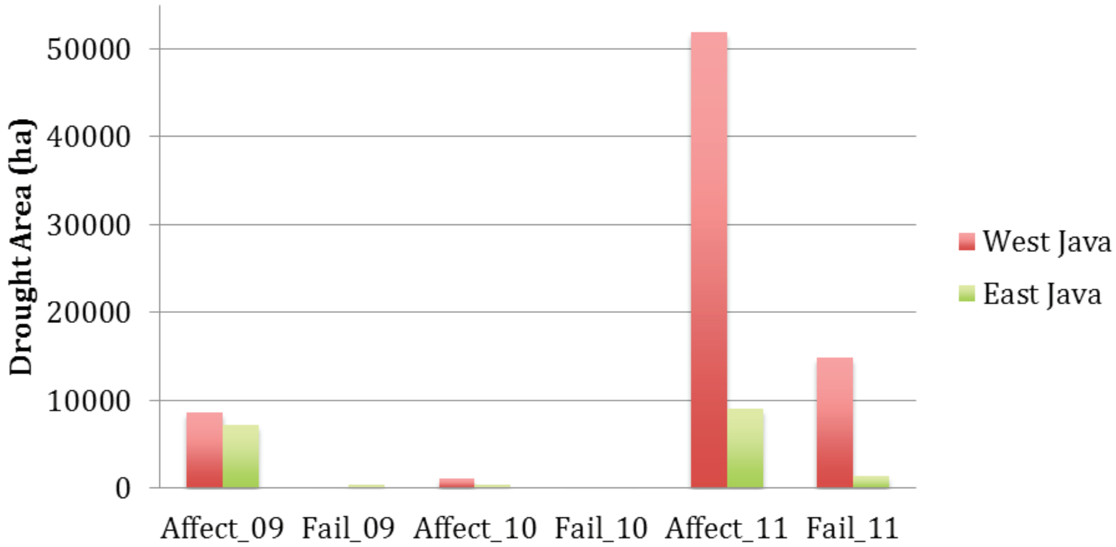

Figure 14. Annual total area of drought-affected paddy production (affect) and resulting crop failure (fail) for West Java and East Java, 2009–2011

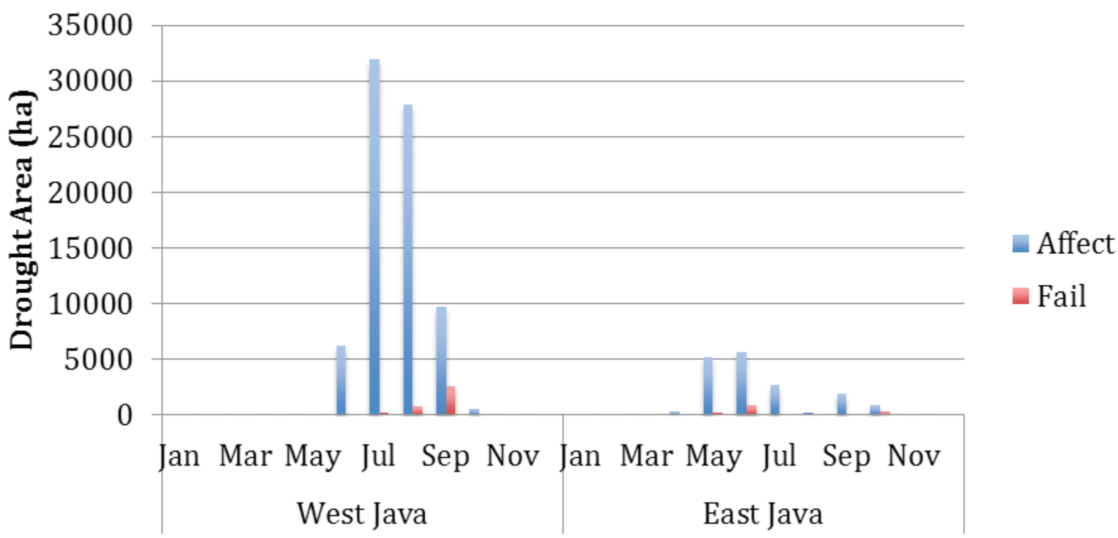

Figure 15. Monthly total area of drought-affected paddy production (affect) and resulting crop failure (fail) in West Java and East Java, 2012

To minimize crop losses caused by droughts, farmers regularly use water pumps to obtain water from soil or river to irrigate their paddy farms. Based on data from 2010 to 2012, the government already supplied 6,760 units of water pumps. Water pumps are primarily distributed to the main production regions, such as those located in Java Island, including West Java and East Java. Most of the water pumps are distributed to Sumatra Island, particularly South and North Sumatra, Nusa Tenggara Timur, and Southwest Sulawesi (Figure 16).

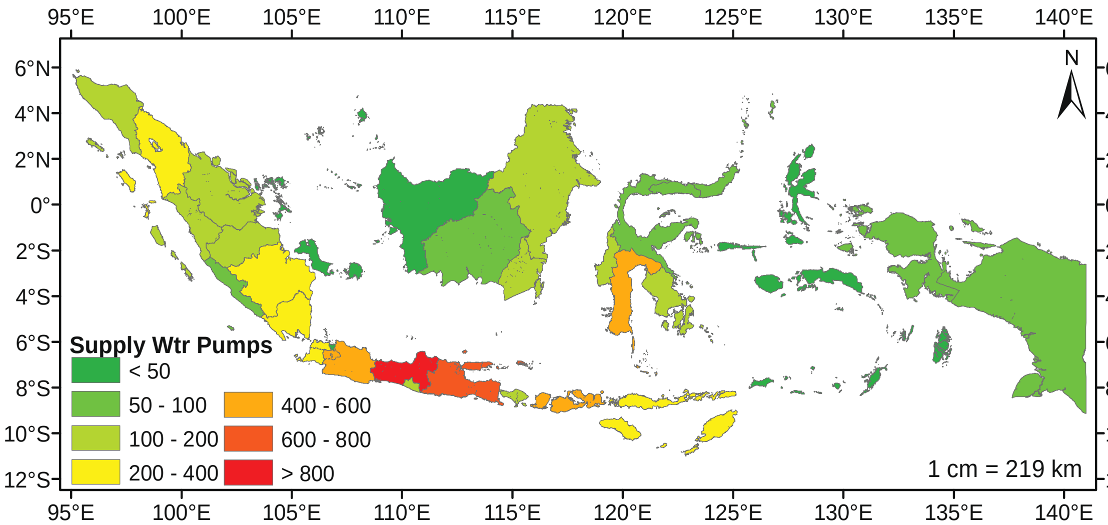

Figure 16. Distribution of total water pumps supplied by the government in Indonesia, 2010–2012
Source: MoA 2014

In the context of gender, the impacts of climate change are not disproportionately felt by men and women. This was found during the literature review, national consultation meetings, and field visits to Indramayu and Jember. Farming decisions are made by men as the head of the family, although the women (i.e., wife and daughter) can also contribute their ideas as they usually help in farming activities, particularly in post-harvest activities.

3.1 Farmer Groups and Stakeholder Consultations (Field Visits)

In Indonesia, farmers usually live in certain areas or regions with farmer groups called Kelompok Tani (POKTAN). Many farmer groups then form a larger group called Gabungan Kelompok Tani (GAPOKTAN). Agricultural programs from either the government or the private sector are usually communicated through the leader of a GAPOKTAN or POKTAN. Farmers usually decide what farming practices they will employ, but they often discuss plans and options with other farmers within their POKTAN. Given that the main production areas are located in Java Island, the majority of POKTAN are formed in Java, expanding from West Java to East Java (Figure 17). Based on data from 2011, there are now about 299,759 POKTAN throughout Indonesia. Approximately 25,802 (about 8.6%) POKTAN are in West Java, while about 30,128 (about 10.1%) POKTAN are in East Java.

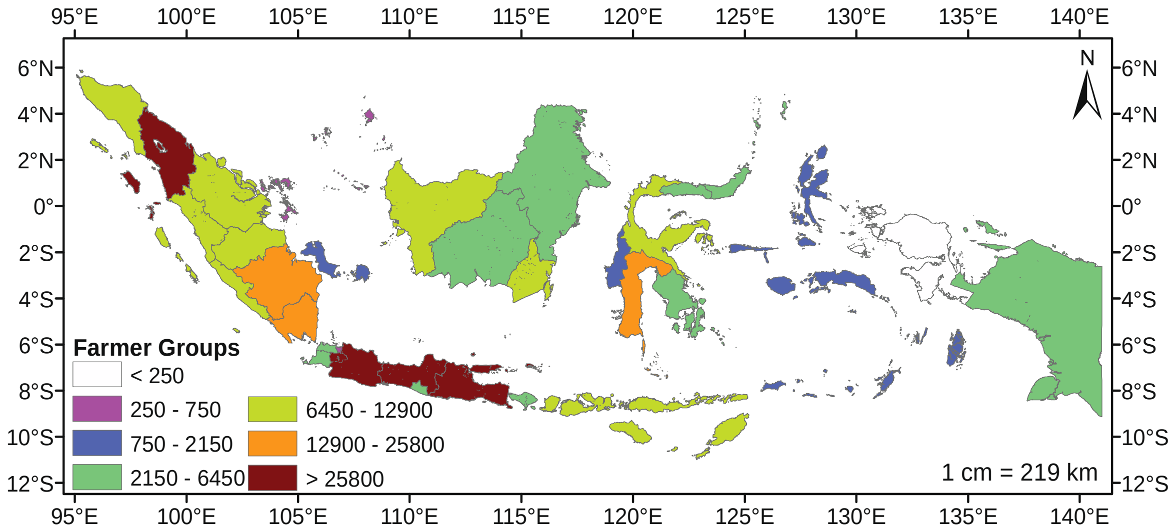

Figure 17. Distribution of farmer groups in Indonesia, 2011
Source: MoA 2014

Extension workers, who could be permanent government employees, hired labor, or private labor, are those who work closely with farmers. Extensions workers who are familiar with working with farmers are usually involved in introducing new technology through training sessions and workshops, including the climate field school, which teaches farmers how to use climate information to support farming practices. Based on data from 2012, there were 58,091 extension workers in Indonesia, distributed mostly in the main agricultural areas. There were approximately 5,002 extension workers in West Java and 7,348 extension workers in East Java.

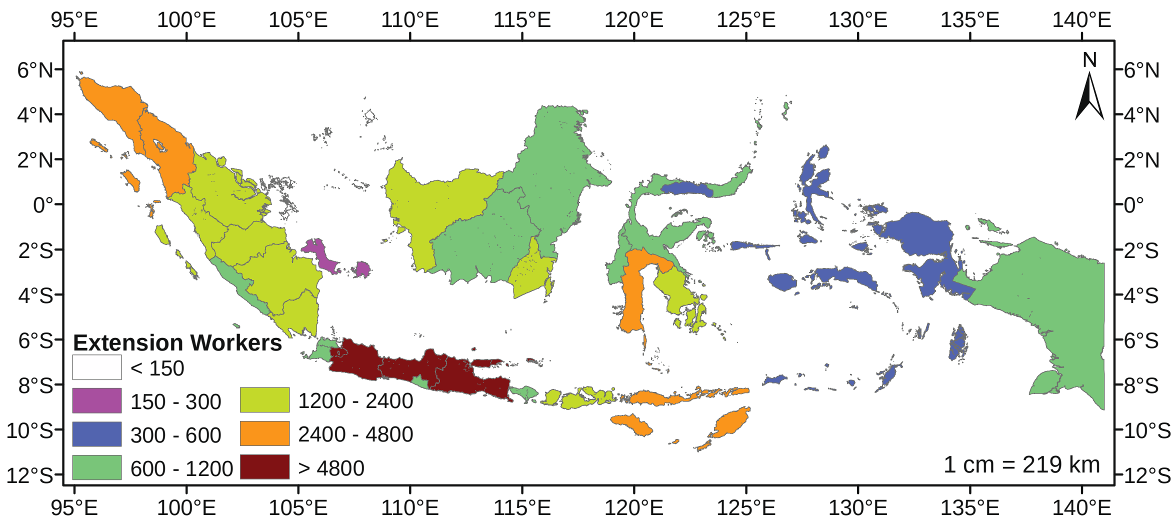

Figure 18. Distribution of extension workers in Indonesia, 2012
Source: MoA 2014

As an attempt to explore the role and connection among stakeholders of rice and maize value chains, sites in Indramayu (as a representative of West Java) and Jember (as a representative of East Java) were visited and surveyed. The surveys were conducted on 12 May 2014 in Indramayu and on 12–15 May 2014 in Jember. The study team decided to spend more time in Jember, since it is the main rice and maize cultivation area in East Java. In addition to the respondents from the local government, Dinas Pertanian, BULOG, and Trade Agency, the study team interviewed other stakeholders within the value chain (Table 7).

Table 7. Stakeholders interviewed during the field visit to Jember

Stakeholder	Location	Crop	Water source
Collectors	Upland	Maize	Irrigation
Farmer group leader	Upland	Paddy/Maize	Rainfed
Farmer group leader	Upland	Paddy/Maize	Rainfed
Farmer	Upland	Maize	Irrigation
Farmer group leader	Upland	Paddy/Maize	Irrigation
Seller	Upland	Paddy/Maize	Irrigation
Seller of agricultural inputs	Upland	-	-
Cooperatives	Upland	-	-
Seller	Upland	Maize	Irrigation
Farmer group leader	Upland	Maize	Rainfed/Wells
Farmer	Upland	Maize	Rainfed/Wells
Farmer	Upland	Maize	Rainfed/Wells
Storage owner	Lowland	-	-
Farmer	Lowland	Paddy/Maize	Irrigation/Wells
Collector	Lowland	Paddy/Maize	Irrigation/Wells
Farmer	Lowland	Paddy/Maize	Irrigation/Wells
Famer	Lowland	Paddy/Maize	Irrigation/Wells
Seller of agricultural inputs	Lowland	-	-
Farmer	Lowland	Paddy/Maize	Irrigation/Wells

The interviews explored issues related to production inputs, and the flow of harvested rice and maize from farmers to consumers within each value chain. There is minimal difference between rice and maize value chains in terms of production inputs and flow of harvested crops. As discussed during the first national meeting, the difference is reflected in the efforts of the national government to support the production of the two crops. The government of Indonesia prioritizes rice because it is a staple food for the majority in the country. The main findings from the interviews are summarized on Table 8.

Table 8. Impacts of climate change on rice production

Input and actor	Description
Seeds	There is no problem in obtaining seeds because farmers can purchase them in the market. Farmers have already used new cultivars that are resistant to pest and drought stress.
Soil fertility	Soil fertility has diminished because of chemical fertilizers. Organic fertilizers are now used to recover soil fertility.
Irrigation	Irrigation is used to supply water to support crop growth and development.
Pesticides	Higher rainfall at harvesting time can trigger pest and disease infestations. Pesticides are used to manage such infestations. Warming conditions may kill parasites and bacteria as well as improve grain quality.
Government	Irrigation is controlled by the local government agency. The national government provides subsidy for organic fertilizers, although the availability sometimes becomes an issue.
Storage	Storage is used to control price at harvesting time. Java is known as the rice production center in Indonesia. At the peak of harvesting, the supply increases and the price is low. Storing a portion of the supply will help stabilize supply and price. If a portion of the supply is not stored, the lack of supply will induce an increase in price. As distribution to provinces outside Java requires higher transportation costs, consumers in those provinces will face even higher prices.
Rice distribution	Rice is distributed through partnerships between farmers and millers (about 10%), selling to collectors in the field (about 40%), selling after drying (about 35%), and selling after milling (about 15%).

Table 9. Impacts of climate change on maize production

Input and actor	Description
Seeds	Farmers use seeds that are tolerant to droughts or pests and diseases. These seeds are varieties with shorter maturity.
Government	The government of Indonesia runs reforestation programs and promotes the use of maize cultivars with shorter maturity. It also provides subsidized seeds, but farmer groups (GAPOKTAN) may refuse as they do not want to take any risks that could affect their members.
Water resources	These are rainfall and wells used by farmer groups. The government supports the development of wells.
Miller	Farmers can rent mobile milling machinery.
Storage	Harvested maize that has been milled will be sold to storage or a feed factory.
Collector	A collector (penebas) can purchase maize directly from farmers or collect maize from the field themselves. The collector can also give loans to farmers in the form of seeds and fertilizers. Farmers pay the debt by selling harvested yield to the collector. The collector is also connected with the seller of agricultural inputs, storage owner, and factory of feeds for chickens or cows.

Table 10. Role of each actor in rice and maize production

Actor	Description
GAPOKTAN leader	The GAPOKTAN leader is responsible for gathering farmers for information dissemination, counseling, and training, among others. The leader may serve as a facilitator for government programs directed to farmers and provide load or credit to farmers in some regions. The credit system has the following steps: (1) the farmers will provide a list of required production inputs, (2) the leader will collect the list from the farmers, (3) the leader will purchase the requested production inputs and distribute them to the farmers, and (4) the farmers will pay the debt to the leader after harvesting (at a price that is 7%–10% higher than what they owe).
Cooperatives (KUD)	A cooperative can be an alternative financial institution (saving and lending) for farmers. It can provide production inputs for farming activities and serve as a collector. Farmers can sell their farming products to KUD.
Collectors	Collectors gather harvested yield. They can also be the owner of machinery for farming and post-harvest activities.
Farmers	Farmers are people who cultivate land for crop production. Crop production is usually dominated by men. Women help their husbands in farming activities or do the farming themselves if they are widowed. Women can influence decisions in farming activities such as seed selection.
Small agricultural shops (kios)	Agricultural shops supply production inputs and tools for farming activities. They also supply fertilizers, including those subsidized by the government.
Maize storage owners	Storage owners obtain maize from collectors or buy from other provinces when quality and price are considerably better and cheaper.
Government (agricultural agency)	The government helps farmers boost their crop production through counseling, which is done by extension workers, and supply/control irrigation. It may subsidize seeds and fertilizers. The national government often works with agricultural agencies to introduce new varieties that were produced by the Research and Development Agency, MoA.

IV. AREAS WHERE REGIONAL COLLABORATION CAN STRENGTHEN APPROACHES

The availability of human resources, specifically extension workers, is a critical element in promoting the adoption of CCA options. Extension workers and farmers have a long history of working together. Extension workers are present whenever a new technology or practice from the government or the private sector will be introduced to farmers. Farmers usually decide what farming practices they will employ, but collaboration between extension workers and farmer groups could influence the farming activities in a particular region or location. The majority of extension workers are currently located in the major crop cultivation areas (e.g., Java Island), where many farmers who need their guidance are located (Figure 19).

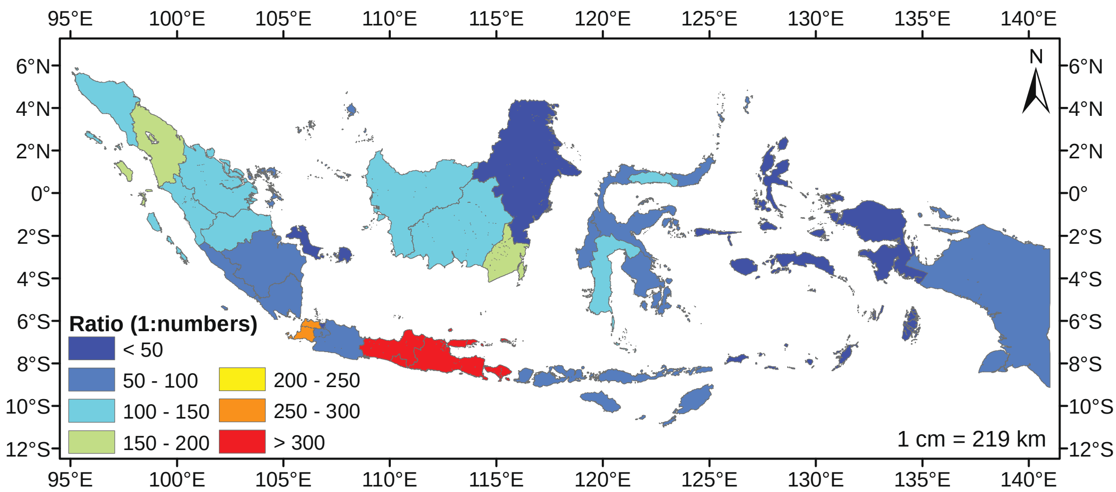

Figure 19. Distribution of ratio of extension workers to members of farmer groups in Indonesia
Note: *T*he image was created using data on extension workers and members of farmer groups at the provincial level. It was assumed that there was a minimal change in the number of farmers between 2011 and 2012 considering data availability. "Members of farmer groups" refers to farmers from all farmer groups in a province.
Source: MoA 2014

The ratio of extension workers to farmers shows that a single extension worker counsels tens to hundreds of farmers. The study did not intend to measure the sufficiency of available extension workers, but Figure 19 can provide a configuration on how to disseminate new information on agricultural techniques or practices to farmers in Indonesia. Given the critical role of extension workers in disseminating agricultural information to farmers, it is advisable to consider the distribution of extension workers in Indonesia during the introduction or implementation of CCA options.

The challenges for agricultural development in relation to CCA and mitigation measures were discussed during the second national meeting. The meeting highlighted thefollowing issues that should be considered:

(1) The farmers' adoption of new crop varieties is still low. The farmers prefer varieties with high market and consumer demand, such as the Ciherang rice variety that is slim and long.

(2) MoA already made efforts to develop new varieties and disseminate the results to farmers. The Agency of Assessment Technology (Balai Pengkajian Teknologi Pertanian), MoA is responsible for the adoption

of innovations (e.g., introducing new varieties to farmers).

(3) The local government should be engaged in agricultural activities or programs, and increase farmers' knowledge through counseling, training sessions, and workshops, among others.

(4) The supply system for seeds should promote local development of a production region.

(5) Information on the availability of agricultural machinery should be included in the planting calendar to construct a web-based system named Agrowebinfo.

(6) Farmers' land ownership and workers should be considered to ensure the successful implementation of CCA programs.

(7) The local government should promote and support the web-based planting calendar developed and maintained by MoA. Extension workers play a crucial role in disseminating farming activities recommended by the online system.

(8) Gender perspectives may not be a formal issue, but it may need to be addressed depending on the socio-cultural conditions of a specific region.

The team also identified institutional challenges and requirements in implementing good practices. The following challenges should be considered:

(1) The capacity of both farmers and extension workers is a challenge in implementing CCA options. The government of Indonesia should consider the farmers' socio-economic conditions and educational background. For instance, the farmers' low education and poor economic conditions may hinder the successful implementation of crop insurance and the web-based planting calendar developed and maintained by MoA. The use of both programs requires familiarity with the system and knowledge of its functions. Financial institutions dedicated to agriculture are still lacking. There are approximately 29,013 farmer groups in 451 districts or cities of 33 provinces. These groups can create a network and link with financial institutions to optimize farmers' financial access. Crop insurance is also new to farmers and the local government, and purchasing the premium remains a challenge for farmers. Avenues for training and socialization are needed to increase the capacity of both farmers and local government officers (extension workers).

(2) The government has already made efforts to support farmers' agricultural activities. Extension workers of agricultural agencies guide farmers about farming practices, but farmers who are members of farmer groups usually have their own farming preferences. Traditional farming practices are still followed because the machinery needed to mechanize post-harvest activities (e.g., dryer) is either insufficient or too expensive for farmers.

(3) The farmers' adoption of new farming technologies and practices is low. For instance, new rice varieties have been developed and released in the market, but only a few of them are popular among consumers. The farmers only adopt those that are popular because wholesalers and collectors prefer varieties with high market and consumer demand. Trading and production systems are highly influenced by market and consumer preferences. CCA can also be seen as a new paradigm in Indonesia compared to mitigation. Information, education, communication, and capacity-building activities are needed to increase understanding and adoption of CCA strategies at the local level.

V. CASE STUDIES ON GOOD PRACTICES

Farmers in Indonesia are already familiar with the consequences of climate-related hazards. For instance, farmers in Indramayu will plant again, if possible, after their lands are affected by floods. In drought conditions, farmers will seek various water sources to irrigate their farms. Water pumps are frequently employed to obtain water from soil or river. The government also provides assistance by giving farmers access to water pumps. The two practices can be seen as CCA options implemented by farmers to address the challenges posed by climate extremes. These practices show that farmers are familiar with the concept of CCA.

CCA aims to minimize the risks and maximize the benefits of the changing climate. CCA options for crop production aim to adjust current cropping practices and implement innovations (e.g., new crop varieties and farming technology). Through MoA, the government of Indonesia has already made efforts to improve crop productivity (KEMENTAN 2011). Potential CCA options, specifically for crop production, were described in documents published by the government (BPPP 2011; ICCSR 2010). The general approaches for CCA include improving crop seeds by developing new cultivars; increasing water supply, including its availability and accessibility; and improving post-harvest processes to minimize loss. The answers of respondents from Indramayu and Jember were also considered in identifying CCA options for rice and maize (Table 11). A number of CCA options that can be scaled up nationally and regionally in ASEAN were selected for further consideration (Table 12).

Table 11. Identified adaptation options for rice and maize production in Indonesia

Crop	Hazards related to climate change		Good practices to address these hazards	
	Hazard	Description	Good practice	Description
Rice	Increasing frequency of floods and droughts	Higher rainfall intensity and shorter rainy season can cause floods and droughts in crop-growing regions (e.g., Indramayu in West Java). Floods may also increase the occurrence of pest infestations.	Crop insurance	Early planting is chosen as a technique to minimize potential losses caused by floods. The idea is to have a relatively mature paddy when flood occurs. For droughts, farmers choose rice varieties with shorter maturity and use water pumps to irrigate paddy fields. Crop insurance based on indemnity loss and climate index was introduced to protect farmers from yield loss. Crop insurance based on indemnity loss is designed to provide a claim of yield loss due to floods, droughts, and pest infestations. Crop insurance based on climate index allows farmers to claim for a guarantee when a specific climate index (e.g., a range of rainfall amounts over a specific period) is not reached over the period.

cont.. Table 11. Identified adaptation options for rice and maize production in Indonesia

Crop	Hazards related to climate change		Good practices to address these hazards	
	Hazard	Description	Good practice	Description
	Erratic rainfall patterns	The onset of the rainy season is changing over the years. As such, farmers could not use their prior experience or local knowledge to determine the beginning of the rainy season to prepare for planting.	Planting calendar	Climate field schools were introduced about a decade ago to teach farmers how to use climate information for their farming activities. Recently, a web-based planting calendar was developed and introduced to provide guidance on planting season, farming practices, and management at the sub-district level.
	Rainfall patterns during harvesting	Rainfall that occurred at harvesting time poses problems in post-harvest activities.	Adequate amount of solar radiation	An adequate amount of solar radiation is needed to dry paddy yields during harvesting. If it rains, farmers will compile paddy yields on their farm and wait until the rain stops. At the farm level, a simple technique for drying paddy is also practiced using solar radiation as the source of energy. Farmers utilize plastics as a pedestal to minimize the yield loss caused by drying. The mechanization of post-harvesting activities (e.g., use of dryers) is recommended.
	Increasing temperature as well as changing rainfall patterns and intensity	Increasing temperature leads to increasing evapotranspiration that demands more water for crop growth and development. Changing rainfall patterns may reduce water availability for paddy fields.	Innovations on cropping strategies	Innovations on cropping strategies include the application of new "superior" paddy varieties that are tolerant to environmental exposures (e.g., floods, droughts, and salinity), use of balanced fertilizers or organic fertilizers for specific locations, and improvement of row spacing (Jajar Legowo). The application of balanced fertilizers is proposed to improve land fertility. Jajar Legowo is employed to optimize fertilizers applied to soil and increase solar radiation acceptance.
Maize	Increasing temperature	It is estimated that increasing temperature, along with insufficient water supply, can decrease maize yields.	Application of new "superior" cultivars	New "superior" drought-tolerant cultivars include Bima, Lamuru, Sukmaraga, and Anoman. Dupont-Pioneer, a private company, has already worked with farmers to introduce and increase the use of hybrid varieties.
	Changing rainfall and temperature patterns	Current climatic changes challenge innovations on planting practices of maize to increase maize production and optimize the use of production units.	Relay cropping strategy	Relay planting is proposed to increase the frequency of maize planting in main maize-growing areas in Indonesia. One of the advantages of relay cropping is lower moisture depletion. The additional maize production will supply base materials to produce silase for animal feed (cows).
	Increasing occurrence of disease infestations (e.g., Bulai) due to increasing temperature and humidity that may cause yield loss	High rainfall during the early vegetative stage can negatively affect maize growth and development.	Innovations on pest- and disease-tolerant varieties	The invention of flood-tolerant varieties is also offered to help farmers cope with higher rainfall during the vegetative stage. The new varieties are developed through breeding technologies.

cont.. Table 11. Identified adaptation options for rice and maize production in Indonesia

Crop	Hazards related to climate change		Good practices to address these hazards	
	Hazard	Description	Good practice	Description
	Erratic rainfall and temperature patterns	Climatic changes push farmers to select a crop that is suitable for the climatic conditions experienced by their region to minimize the potential risks. Post-harvest activities are also challenging due to insufficient facilities and location of maize-growing regions.	Crop selection and planting calendar	Crop selection and planting calendar should be used to decide what crops are suitable for a specific growing season. Maize is usually planted to replace rice in the second dry season. In dry areas, maize may be planted twice. Beyond climatic conditions, some of the main problems of maize production in Indonesia are the lack of infrastructure and facilities in maize-growing regions located in remote areas. If farmers do not have a dryer for post-harvest processing, maize quality will deteriorate before the crops reach the storage facility or market. Storage facilities can only maintain maize quality for a maximum of about one month.

Table 12. Proposed adaptation options for rice and maize production

Crop	Key good practice	Description
Rice	Crop insurance	The introduction of crop insurance based on indemnity loss has been tested through field trials in some districts in Indonesia. Crop insurance is declared as a way to protect farmers from yield loss in Law No. 19 issued in 2013 on "Protection and Empowerment of Farmers" ("Perlindungan dan Pemberdayaan Petani"). Crop insurance aims to protect farmers from losses caused by crop failure resulting from natural hazards, pest and disease infestations, impacts of climate change, and other risks ruled by ministerial decree. For the trial of crop insurance, a subsidy of about 80 percent is given to purchase premium issued by JASINDO, a state-owned crop insurance company. Research on crop insurance based on climate index is in progress in Indramayu. The majority of research activities aim to teach farmers and train local government officers about the climate index insurance.
	Web-based planting calendar	MoA operates a web-based planting calendar. The system will provide a nationwide map to guide farming practices at the sub-district level based on seasonal climate prediction for each growing season. There are three growing seasons in Indonesia starting with the rainy season. The information available online includes planting dates, areas prone to floods and droughts, pest and disease infestations, and seed and fertilizer recommendations. The web-based system is updated thrice a year, and the online information can be accessed through the website and short message service on smartphone.
Maize	Silase production for animal feed (cows)	Silase is produced using maize stalks as base material. Based on a discussion with a representative of Dupont-Pioneer, a private company, cows eat less silase (25 kg/day) than green grass (70 kg/day), which minimizes feeding costs. Silase production can also be seen as a way to optimize the use of additional maize production resulting from successful farming innovations or adaptation practices. Silase production can also create new business opportunities that will endorse the development of private-public partnership to benefit farmers. Milk producers such as Nestle visited and partnered with Dupont-Pioneer to supply silase for them.
	Maize farming practices	In Indonesia, maize is regularly planted after rice. Climatic changes could alter cropping patterns. Relay planting is introduced to increase the frequency of maize planting from once a year to four times a year. To support maize adaptation to environmental exposures, new cultivars that are tolerant to droughts and have shorter maturity were created. Bima, Lamuru, Sukmaraga, and Anoman are examples of drought-tolerant varieties. Hybrid cultivars have already been introduced to farmers. Farmers are also encouraged to use the planting calendar to select their cropping pattern following climate prediction.

VI. CONCLUSION

Global climate change already poses numerous challenges to crop production in Indonesia. A number of studies have already revealed the impacts of climate change on crop production, especially since climate variability significantly affects crop productivity. Most of the studies in the country evaluated the impacts of climate change on crop yield using modeling approaches. There is no information on the impacts on phenological stages identified through literature review or site visit. Nevertheless, the government of Indonesia has been serious in identifying measures that will help the country adapt to and mitigate the potential negative consequences of climate change on crop production. Research activities on cultivars have been conducted to develop crop varieties that are tolerant to floods, droughts, salinity, and pests and diseases. The main challenge is the farmers' low adoption of new crop varieties.

Crop insurance, web-based planting calendar, silase for animal feed, and climate-smart farming practices are the CCA options that can be scaled up nationally and regionally. These CCA options have already been tried or implemented in Indonesia, but the benefits of each should still be explored. It is imperative to implement these strategies because global climate change also threatens national food security. Agricultural land conversion and price stabilization are the other two biggest challenges that threaten domestic crop production in Indonesia, but a detailed discussion of these two issues are beyond the scope of this study. Further research can be directed towards the formulation of agricultural policies that are designed to specifically address the multiple interactions between and among agricultural issues.

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Acknowledgments

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Published by
Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH
In cooperation with

german cooperation
DEUTSCHE ZUSAMMENARBEIT

NAFRI National Agriculture and Forestry Research Institute

SEAMEO SEARCA

Promotion of Climate Resilience in Rice and Maize

Lao PDR National Study

Imprint

This publication is a joint undertaking by the ASEAN Technical Working Group on Agricultural Research and Development (ATWGARD) and the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH
through the ASEAN-German Programme on Response to Climate Change (GAP-CC).

In partnership with the Southeast Asian Regional Center for Graduate Study and Research in Agriculture (SEARCA).

Published by the
Deutsche Gesellschaft für
Internationale Zusammenarbeit (GIZ) GmbH

Registered offices
Bonn and Eschborn, Germany

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As at
April 2015

Printed by/design and layout
SEARCA
College, Los Baños
Laguna - 4031

Photo Credits
Souphaphone Rattanarasy (SEARCA Photo Contest)

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Promotion of Climate Resilience in Rice and Maize

Lao PDR National Study

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

ADS	Agriculture Development Strategy
AMP	Agricultural Master Plan
AMS	ASEAN Member States
ATWGARD	ASEAN Technical Working Group on Agricultural Research and Development
ASEAN	Association of Southeast Asian Nations
AWD	Alternate Wetting and Drying
CCA	Climate Change Adaptation
DAFO	Department of Agriculture and Forestry Office
DMC	Direct Seeding Mulch-based Cropping
DOA	Department of Agriculture
FGD	Focus Group Discussion
GAPCC	German-ASEAN Programme on Response to Climate Change: Agriculture, Forestry, and Related Sectors
GIZ	Gesellschaft für Internationale Zusammenarbeit
HRD	Human Resources Development
IRAS	Improving the Resilience of the Agriculture Sector to Climate Change Impacts
KII	Key Informant Interview
MAF	Ministry of Agriculture and Forestry
NAFRI	National Agriculture and Forestry Research Institute
PAFO	Provincial Agriculture and Forestry Office
SEARCA	Southeast Asian Regional Center for Graduate Study and Research in Agriculture
SRI	System of Rice Intensification

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Foreword

The National Agriculture and Forestry Institute (NAFRI) under the Ministry of Agriculture and Forestry is very happy to endorse this national study on promoting resiliency of rice and other crops. We are grateful to be given the opportunity through the ASEAN Technical Working Group on Agriculture and Research Development (ATWGARD) with generous support of GIZ to be able to participate and review good practices within the agriculture value chains that are currently being implemented in Lao People's Democratic Republic (PDR) to deal with the risks posed by climate change.

Climate change is a major driver of the economy and livelihoods of the Lao people, especially the marginalized rural poor for whom agriculture is extremely critical. The potential for agricultural production is set by many biophysical factors that include climate. Lao PDR faces the following climate hazards: drought, flood, erratic and more intense rainfall. The good practices identified in Laos for rice are: Rice Biodiversity, System of Rice Intensification (SRI), and improved varieties resistant to drought and submergence. For maize, the good practices identified are: Direct Mulching Crop (DMC) and maize integrated with legumes.

We hope that this good practices will be scaled up and replicated in other areas in order to minimize the threats of a changing climate to food security. We are looking forward to sharing these with our ASEAN neighbors, as well as learning and implementing the knowledge gained on adaptive practices from each national studies through regional collaboration of joint measures such as research and information exchange for the benefit of the people of Lao PDR and the region.

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Acknowledgement

This document is an output of the research project ASEAN Network on Promoting Climate Resilience of Rice and Others Crops. The project was financed by the Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH through the Association of Southeast Asian Nations (ASEAN) Technical Working Group on Agricultural Research and Development (ATWGARD); supported by the German-ASEAN Programme on Response to Climate Change: Agriculture, Forestry, and Related Sectors (GAPCC); and implemented by the Southeast Asian Regional Center for Graduate Study and Research in Agriculture (SEARCA). The views expressed herein are not necessarily those of GIZ, ATWGARD, GAPCC, and SEARCA. The accuracy of the content is the authors' sole responsibility.

Executive Summary

Farming is the backbone of the Lao people because agriculture is their main livelihood. Through daily agricultural practices, farmers observe changes in natural events, such as rainfall pattern, lightning, star clusters, and pest and disease outbreaks, which they strive to cope with to ensure food on the table for their family. Farmer communities in Lao PDR, mostly in the labor force, barter seeds and varieties among themselves. This is a good practice shared in their communities.

Seven ASEAN Member States (AMS) participated in the project ASEAN Network on Promoting Climate Resilience of Rice and Other Crops to determine good agricultural practices for rice, maize, and cassava. This report presents the results of the study conducted in Lao PDR. The following case studies on good practices in climate change adaptation (CCA) options for rice and maize were prioritized: for rice, (1) System of Rice Intensification (SRI), (2) rice biodiversity conservation, and (3) improving drought- and submergence-tolerant varieties in lowland areas; and for maize, (1) direct seeding mulch-based cropping (DMC) systems and (2) maize integrated with legumes.

Farmers' knowledge and skills in enhancing and creating diversity is important in local crop development. Farmers choose varieties (i.e., early, medium, and late varieties) based on different concerns (e.g., family labor distribution, climate risk, and traditional pest and disease management). They grow a number of rice varieties in the same field, but each variety is confined to a small plot. In general, three to five rice varieties of different maturities are grown. The rationale in growing several varieties is to reduce vulnerability to climate risks (e.g., erratic rainfall), meet religious requirements, match eating behavior, ensure the fair distribution of labor demand, and meet grain quality and specific consumption requirements for ethnic minorities (Appa Rao 2006).

The Lao PDR Agricultural Master Plan (AMP) 2011–2015 covers eight programs: (1) food production; (2) commodity production and farmer organizations; (3) sustainable production patterns, land allocation, and rural development; (4) forestry development; (5) irrigated agriculture; (6) other agriculture and forestry infrastructure; (7) agriculture and forestry research and extension; and (8) human resources development (HRD) (MAF 2010).

The government of Lao PDR prioritizes food production. As per the AMP 2011–2015, the smallholder farmers will have "food security based on increased productivity of rice and diversified farming systems that are resilient to climate change and related extreme weather events and induced disasters" (MAF 2010).

The Ministry of Agriculture and Forestry (MAF), Department of Agriculture (DOA), and National Agriculture and Forestry Research Institute (NAFRI) are mandated to implement and promote best agricultural practices. In the past, however, there were some limitations on best agricultural practices implemented by the government of Lao PDR and research institutions that focus more on research, where there is a need to translate research to action and implementation.

I. INTRODUCTION

Agriculture is the chief activity of most Lao people and the main driver of Lao PDR's economy. In the northern part of the mountainous country, slash-and-burn agriculture is a common practice (DOA 2012a). The potential for agricultural production is set by many biophysical factors such as climate, soil quality, topography, latitude, and altitude. Climate, particularly the amount and distribution of rainfall, largely influences the degree of potential production achieved each year (Lefroy 2010).

In 2012, Lao PDR had a total population of 6.5 million, of which 80 percent lived in rural areas and 81 percent depended on agriculture for livelihood. Rice, the staple food in the country, accounted for more than 80 percent of agricultural land and from 73 percent to 84 percent of the total agricultural output (DOA 2012a).

The impacts of climate change on rainfed agriculture are a particular concern because farm livelihoods that are based on rainfed crop cultivation are highly vulnerable to climate stresses (Chinvanno et al. 2006). Rainfed agriculture is the dominant economic activity of the region, engaging a high proportion of the population, especially in the eight northern provinces of Lao PDR (DOA 2012a). The harsh effects of climate change can significantly affect the economy of the country and the livelihoods of its people, especially the marginalized rural poor for whom agriculture is extremely critical.

II. VALUE CHAIN MAPPING

2.1 Rice

Agricultural practices in Lao PDR are classified into three ecosystems: (1) irrigated lowland, with a total land area of 711,134 hectares (ha); (2) rainfed lowland, with a total land area of 108,037 ha; and (3) rainfed upland, with a total land area of 119,840 ha (DOA 2012b).

Rice, currently the most important crop in Lao PDR, accounts for more than 80 percent of the cropped land area in the country. In 2013, approximately 88 percent of the area planted to rice and 83 percent of rice production came from wet season cropping activities.

In 2012, wet season lowland rice cultivation accounted for 85 percent of the lowland rice cultivated area and 82 percent of rice production. The rainfed upland environment accounted for a further 21 percent of the area and 12 percent of production. Dry season irrigated rice was grown to about 108,037 ha from 2011 to 2012 (DOA 2012a). Lao PDR is the largest producer and consumer of glutinous rice in the region. In 2005, rice accounted for about 67 percent of the people's calorie intake in the country (Schiller 2004).

The country's total planted, damaged, and harvested area; production volume; and average yield for rice in the wet and dry seasons are presented in Table 1.

Table 1. Rice area, production, and yield per region, wet and dry seasons, 2012

Region	Planted area (ha)	Damaged area (ha)	Harvested area (ha)	Production (t)	Yield (t/ha)
North	202,351	207	202,144	659,744	3.26
Central	494,234	2,918	491,316	1,890,322	3.85
South	242,426	2,119	240,307	939,144	3.91
Total	**939,011**	**5,244**	**933,767**	**3,489,210**	**3.74**

Source: DOA (2012)

In the dry season of 2012, the total planted, damaged, and harvested area for irrigated lowland rice was 108,037 ha; about 70 ha; and 107,967 ha, respectively. The production volume was 509,920 tons (t) with an average yield of 4.72 t/ha (Table 2)..

Table 2. Irrigated rice area, production, and yield per region, dry season, 2012

Region	Planted area (ha)	Damaged area (ha)	Harvested area (ha)	Production (t)	Yield (t/ha)
North	9,933	1	9,932	41,460	4.17
Central	73,453	69	73,384	343,745	4.68
South	24,651	-	24,651	124,715	5.06
Total	**108,037**	**70**	**107,967**	**509,920**	**4.72**

Source: DOA (2012)

The total planted, damaged, and harvested area for rainfed lowland rice was 711,134 ha; 5,106 ha; and 706,028 ha, respectively. The production volume was 2,763,150 t with an average yield of 3.91 a/ha (Table 3).

Table 3. Rainfed lowland rice area, production, and yield per region, wet season, 2012

Region	Planted area (ha)	Damaged area (ha)	Harvested area (ha)	Production (t)	Yield (t/ha)
North	104,560	138	104,422	458,740	4.39
Central	399,720	2,849	396,871	1,508,375	3.80
South	206,854	2,119	204,735	796,035	3.89
Total	**711,134**	**5,106**	**706,028**	**2,763,150**	**3.91**

Source: DOA (2012)

Farmers in irrigated lowland rice areas mostly use improved and short varieties. The maturity age of these varieties ranges from 135 days to 140 days. On the other hand, farmers in rainfed lowland areas tend to use a mixture of traditional and improved varieties, including the drought-tolerant khao dor nam pa. khao phair, khao deang dou, and khao mak kheu, which are also drought-tolerant varieties, are used in rainfed upland areas.

Farmers in irrigated lowland rice areas mostly use improved and short varieties. The maturity age of these varieties ranges from 135 days to 140 days. On the other hand, farmers in rainfed lowland areas tend to use a mixture of traditional and improved varieties, including the drought-tolerant khao dor nam pa. khao phair, khao deang dou, and khao mak kheu, which are also drought-tolerant varieties, are used in rainfed upland areas.

In the wet season of 2012, the total planted, damaged, and harvested area for rainfed upland rice was 119,840 ha; 68 ha; and 119,772 ha, respectively. The production volume was 216,140 t with an average yield of 1.80 t/ha (DOA 2012a) (Table 4).

Table 4. Rainfed upland rice area, production, and yield per region, wet season, 2012

Region	Planted area (ha)	Damaged area (ha)	Harvested area (ha)	Production (t)	Yield (t/ha)
North	87,858	68	87,790	159,544	1.82
Central	21,061	-	21,061	38,202	1.81
South	10,921	-	10,921	18,394	1.68
Total	**119,840**	**68**	**119,772**	**216,140**	**1.80**

Source: DOA (2012)

The government of Lao PDR has a policy to increase forest cover from 53 percent in 2010 to 65 percent in 2015 and to 70 percent in 2020 (MAF 2010). This is expected to affect rice production.

Farmers in the northern part of Lao PDR engage in upland agriculture and largely depend on rainfall. They practice permanent upland rice-based cropping systems. Many farmers take the risk of low production by planting during long drought periods. The outbreak of grub-devastated upland rice after the long drought period increases rapidly

during the initial part of the wet season.
The planted, damaged, and harvested area for permanent upland rice is 62,422 ha; 68 ha; and 62,345 ha, respectively. The production volume was 103,565 t with an average yield of 1.66 t/ha (Table 5).

Table 5. Permanent upland rice area, production, and yield per region, 2012

Region	Planted area (ha)	Damaged area (ha)	Harvested area (ha)	Production (t)	Yield (t/ha)
North	38,641	68	38,573	61,540	1.60
Central	17,434	-	17,434	32,306	1.85
South	6,347	-	6,347	9,719	1.53
Total	**62,422**	**68**	**62,345**	**103,565**	**1.66**

Source: DOA (2012)

2.2 Maize

A large percentage of maize production in Lao PDR occurs in Xayaboury (29.2%), Oudomxay (18.8%), and Borkeo (10.2%) (MAF 2007). The harvested areas in these provinces account for 53.4 percent and 58.2 percent of the country's total maize harvest and yield production, respectively (DOA 2012a; MAF 2007). In the wet season of 2012, the total planted area for maize was 196,815 ha. The production volume of 1,125,485 t represented 85 percent of the total country production (Table 6). Farmers in the northern part of Lao PDR use hybrid maize varieties such as LVN10 from Vietnam, and CP 888 and CP 999 Pioneer from Thailand.

Table 6. Maize national area, production, and yield, wet season, 2012

Particulars	Year	Planted area (ha)	Harvested area (ha)	Production (t)	Yield (t/ha)
Whole country	2012	221,885	196,815	1,318,865	5,100
Maize	2012	176,940	176,940	926,830	5,240
Sweet Corn		19,875	19,875	198,655	10,00
Total	**2012**	**196,815**		**1,125,485**	

Source: DOA (2012)

In 2012, the International Development Research Centre studied maize production costs and seed rates in five northern provinces of Lao PDR. In these provinces, it was found that an average farmer used 17–20 kilograms (kg)/ha of maize plantation. The planting distance used (e.g., 35 x 70 cm, 50 x70 cm, and 50 x 80 cm) varied from province to province. Maize seeds cost an average of USD 64/ha (Peñalba and Dulce 2013).

According to farmer respondents in Oudomxay, Bokeo, and Luang Namtha, which are more than 1,000 meters above sea level (masl), they start planting maize during the last week of May before the rain starts. They believe that the first rainfall is valuable because they can plant on time. They can harvest four months after transplanting.

During the focus group discussions (FGDs) and key informant interviews (KIIs), the farmer respondents said that if they plant from early May to June, they can harvest a higher yield than if they plant from July to August. However, farmers in Luang Prabang and Xayaboury, which are located less than 1,000 masl, plant maize in the middle of May before the rains start. In the dry season of 2012, the total planted area for maize was 25, 070 ha. The production volume of 193,380 t represented 15 percent of the total country production (Table 7).

Table 7. Maize national area, production, and yield, dry season, 2012

Particulars	Planted area (ha)	Harvested area (ha)	Production (t)	Yield (t/ha)
Whole country	25,070	25,070	193,380	6.59
Maize	16,955	16,955	111,675	6.59
Total			**111,675**	
Sweet Corn	8,115	8,115	81,705	10.07
Total			**81,705**	

Source: DOA (2012)

According to the farmers, maize planted from November to December produce higher yield than maize planted from January to February. Fog starts to decrease during the latter. In Luang Prabang and Xayaboury, farmers start planting maize during the dry season from the last week of December when fog falls during the night and early morning.

Next to rice, maize is considered a major agricultural commodity in Lao PDR. In 2012, the maize area increased to 188,690 ha.

According to the farmers, maize planted from November to December produce higher yield than maize planted from January to February. Fog starts to decrease during the latter. In Luang Prabang and Xayaboury, farmers start planting maize during the dry season from the last week of December when fog falls during the night and early morning.

Next to rice, maize is considered a major agricultural commodity in Lao PDR. In 2012, the maize area increased to 188,690 ha from 165,465 ha in 2009, and the production volume also increased to 1,043,740 t from 818,230 t in 2009 (DOA 2012b). In that same year, maize exports increased to 1,400,000 metric t from 124,000 metric t in 2002.

The total planted area for maize during the wet season was 159,975 ha. The production volume was 815,115 t with an average yield of 5.1 tons/ha (DOA 2012a). For sweet corn, the total planted area was 11,760 ha. The production volume was 116,950 tons with an average yield of 9.9 tons/ha. The total planted area for maize during the dry season was only 16,955 ha due to lack of water. The production volume was 111,675 t with an average yield of 6.5 tons /ha (DOA 2012b).

The government of Lao PDR aims to make the country self-sufficient in rice. It also aims to produce rice surplus for export to neighboring countries. Organic rice is preferred by the foreign clientele. In 2007, maize became a major agricultural export commodity that represented 19.8 percent of the total export of agricultural products. About 99 percent of maize products in Lao PDR were exported to neighboring countries (MAF 2010). In 2006–2007, maize exports to Thailand, China, and Vietnam comprised 83 percent, 11 percent, and 5 percent of total maize products from Lao PDR respectively (MAF 2010). However, the exportation of maize from Lao PDR is still vulnerable to bargaining power and market risks (Southavilay 2009).

As shown in the AMP 2011–2015, the government of Lao PDR also aims to expand rice production area and yield (Figure 1).

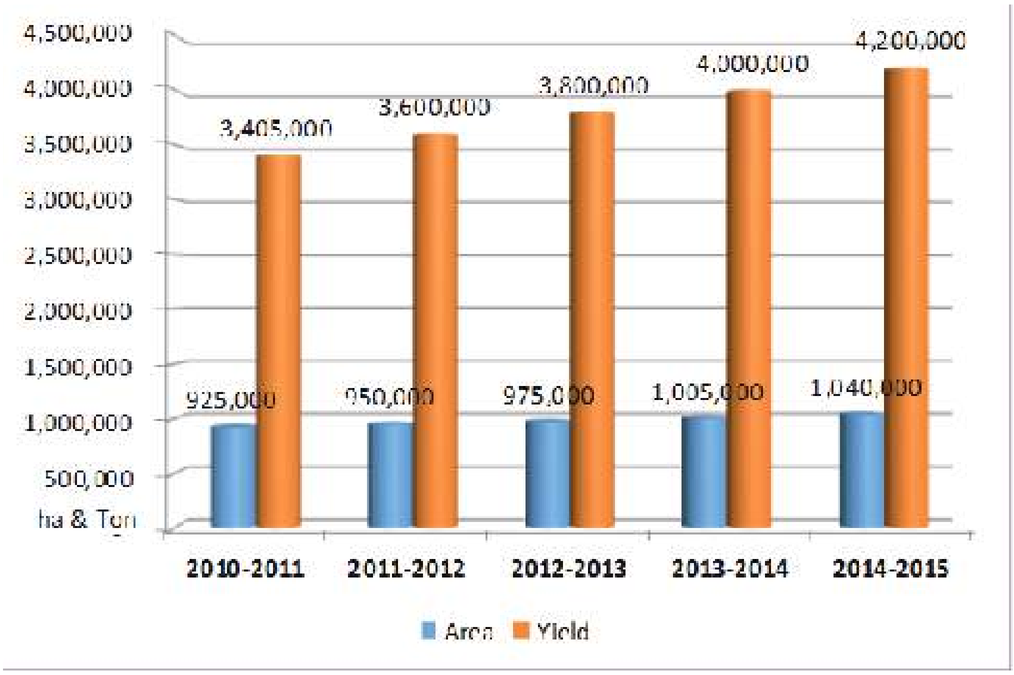

Figure 1. National rice production goals, 2011–2015
Source: MAF (2010)

However, upon comparing the current production system with the planned production system, it can be seen that the goals have not yet been achieved. This can be attributed to damages caused by floods and droughts throughout the country in 2011 (Figure 2).

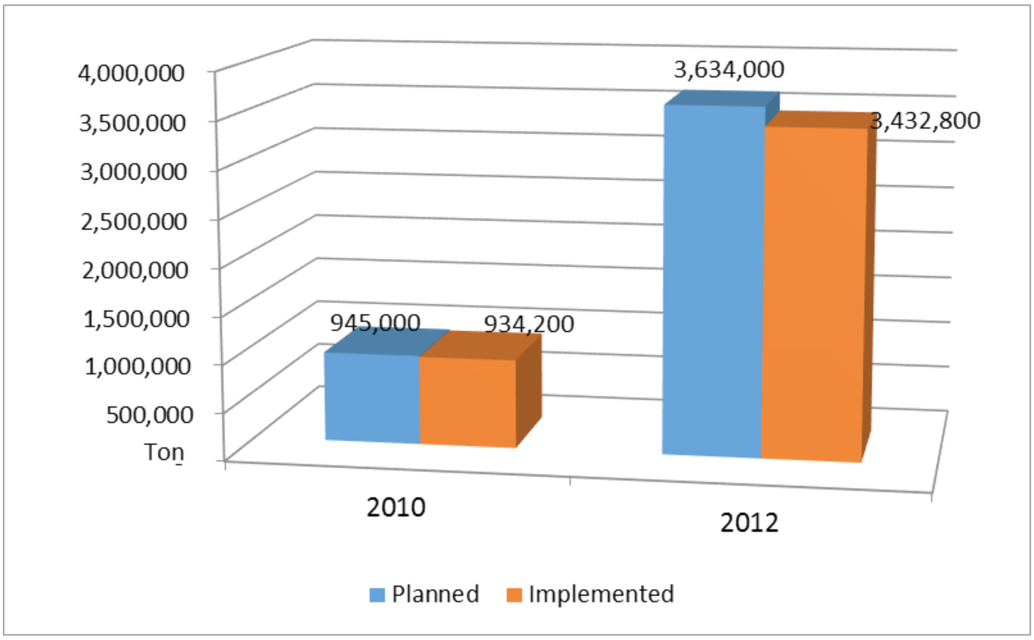

Figure 2. National rice production plans, 2010–2012
Source: MAF (2010)

III. REVIEW OF CLIMATE CHANGE IMPACTS AND VULNERABILITIES

Climate risks are not new to farmers in the lower Mekong region. These include mid-season dry spells that can damage young plants, and late-season floods just before harvest that can cause severe crop loss. Farmers have developed and used various measures to cope with such risks. Rice farmers' experiences in managing climate risks, and their perspectives on the potential for applying the same measures to adapt to climate change, were determined through interviews and FGDs conducted in selected farming villages in Lao PDR (Chinvanno et al. 2006). It was found that farmers use short, medium, and late varieties to cope with climate viability as well as with insects and pests' outbreak.

The inevitability of climate change is a major policy concern due to its expected impacts on food security and the livelihoods of small-scale farmers who largely depend on agriculture. It threatens the production systems, availability, and accessibility of food. The impacts of climate change on agriculture are expected to be multifaceted because farming systems across countries and agro-ecological zones are heterogeneous. Lao PDR and other AMS are among the countries whose exposure to climate risks seriously threatens food security and livelihood, particularly of small-scale farmers, due to the interaction of social, economic, environmental, and political factors that could affect food supply and demand (Soukkhy, et al. 2012).

Typhoon Haima (Nok Ten) in 2011 greatly affected 14 districts; 360 villages; 18,142 families; and 108,856 people, of which 32,000 were female. The most affected districts were Champhone, Xayaboury, Song Khone, and Art Saphangthong, where a total of 38,967 ha of paddy fields were destroyed.

3.1 History of Climate Change in Lao PDR

The National Strategy on Integrated Flood Management of the Department of Meteorology and Hydrology (2012) classified Vientiane, Bolikhamxay, Khammuane, Savannakhet, Saravane, Sekong, Attpeu, and Champasack as flood-prone provinces because they experience periodic flooding (Figure 3). It classified the northern provinces of Xayaboury, Xiengkhuang, Luang Prabang, Oudomxay, Luangnamtha, and Bokeo as flash flood-prone areas (Figure 4).

Figure 3. Flood-prone areas in Lao PDR
Source: MoNRE (2010)

Figure 4. Flash flood-prone areas in Lao PDR
Source: MoNRE (2010)

Based on record data of the Mekong River water level at the Vientiane gauging station from 1895 to 2011, the highest water levels were observed during the following years (MoNRE 2010):

- 1924 – Flooding caused the water level to rise to 12.6 m.

- 1966 – Flooding caused the water level to rise to 12.71 m. (dikes were constructed along the Mekong riverbanks in case of an emergency)

- 1971 – Flooding caused the water level to rise to 12.6 m and the dykes to collapse.

- 1978 – Agricultural production and public properties in Champasack were damaged by flooding. The maximum water level of the Mekong River at Pakse was 14.7 m on 17 August 1978 with a corresponding maximum peak flood discharge of 58,000 cubic meters per second.

- 2008 – Flooding caused the water level to rise to 13.67 m, which is the maximum. It was considered the most extreme rise in water level and the highest observed in 112 years.

- 2009 – In September 2009, the southern provinces of Saravane, Sekong, and Attapeu were inundated by the Sedone and Sekong rivers because of Typhoon Ketsana.

- 2011 – Eleven provinces were affected by Typhoons Haima and Nockten.

In 2011, insect pests destroyed a paddy field area of more than 32,608 ha, inflicting a yield loss of 100,000 t. The long mid-season drought spell made it conducive for grubs to destroy the root system of upland rice, a common scenario during such period (PAFO 2012).

Indications of climate change include increasing temperature; changes in precipitation; increase in the frequency, duration, and intensity of dry spells and droughts; changes in the timing, duration, intensity, and geographic location of rain; increase in the frequency and intensity of storms and floods; and greater seasonal weather variability and changes in the start and end of wet seasons.

In the summer monsoon season of 2013, a series of five major storms caused flooding in 12 of 17 provinces (52 of 145 districts) across Lao PDR. The natural disaster affected 395,000 people. Flooding is not unusual at this time of the year, but the individual floods were caused by different weather systems, which occurred in different locations at different points in time (i.e., starting in July and ending in October), and hit the affected areas with varying levels of severity. In the southern region of the country, the flood water levels were high for up to six days, inundating the rice crops that were almost ready to be harvested. Many fields in the country appeared lush green, but the rice crops were completely damaged because of prolonged submergence in water. Severe damage was mainly observed in agricultural land with rice, the Lao staple food and the single most affected crop (WFP 2013).

A total of 221 villages reported that their agricultural land was affected to some extent, while a countrywide a total of 50,247 ha of agricultural land for rice cultivation was lost during the 2013 harvest. The national production shortfall caused by flooding was assessed to be approximately 6.9 percent of the total area under production in the affected districts. The risk to national food security is rather low, but poor farming households who lost all of their crop and livestock are at risk of becoming food insecure in due course (WFP 2013).

3.2 Socio-economic Profile (Paddy Area and Production)

Between 2010 and 2012, the area harvested with paddy increased by an annual average rate of 6.4 percent in Savannakhet (162,767 ha in 2010 and 173,200 ha in 2012) and 10.6 percent in Luang Prabang (33,030 ha in 2010 and 36,532 ha in 2012) (Figures 5 and 6).

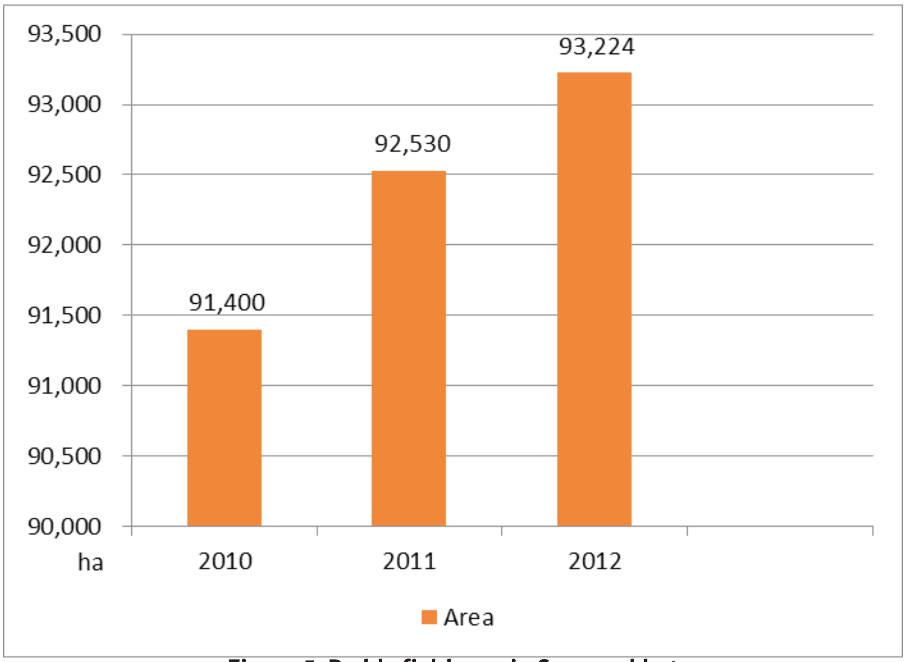

Figure 5. Paddy field area in Savannakhet
Source: Keo Oudone (2011)

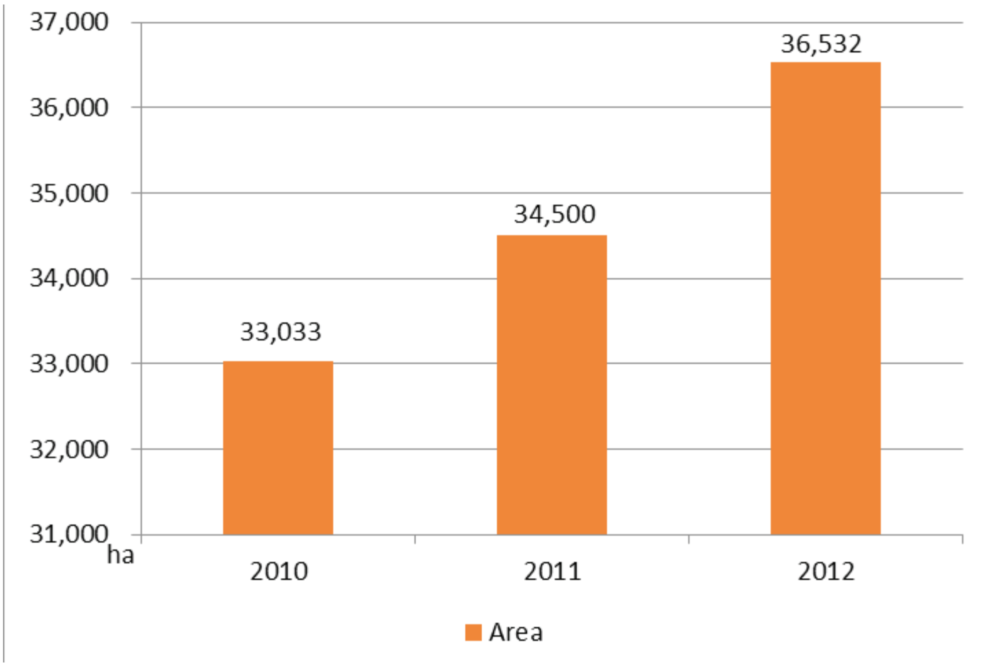

Figure 6. Paddy field area in Luang Prabang
Source: Sivilaysack (2012)

Typhoon Helen damaged 32.12 ha of paddy fields and 43.66 ha of upland rice in the districts of Phone Xay, Nam-bak, and Xieng-nueung in Luang Prabang (PAFO 2012). The total damage cost was about LAK 6,929,359,000 (USD 866,000) (PAFO 2012).

Farmers in Luang Prabang engage in upland agriculture and largely depend on rainfall. They practice permanent upland rice-based cropping systems. Many farmers take the risk of low production by planting during long drought periods. The outbreak of grub devastated upland rice after the long drought period increases rapidly during the initial part of the wet season. Upland yield is very low, ranging from 900 kg/ha to 1,200 kg/ha.

Farmers tend to increase the plantation areas to also increase yield. This forces farmers to resort to slash-and-burn agriculture, which destroys the forest.

In the northern provinces of Lao PDR, Xayaboury ranks first in maize production. The area planted to maize was 60,690 ha and production was 319,695 t in 2013 (Table 8).

Table 8. Maize area, production, and yield in the northern provinces, 2013

Province	Crop	Planted area (ha)	Damaged area (ha)	Harvested area (ha)	Production (t)	Yield (t/ha)
Phongsali	Yellow corn	3,735	-	3,735	17,655	4.73
	Sweet corn	680	-	680	6,890	10.13
	Total				**24,545**	
Luangnamtha	Yellow corn	3,450	-	3,450	12,110	3.51
	Sweet corn	810	-	810	7,840	9.68
	Total				**19,950**	
Bokeo	Yellow corn	13,555	-	13,555	91,710	6.77
	Sweet corn	-	-	-	-	-
	Total				**91,710**	
Luang Prabang	Yellow corn	7,360	-	7,360	34,960	4.75
	Sweet corn	1,490	-	1,490	16,005	10.74
	Total				**50,965**	
Huaphan	Yellow corn	18,565	-	18,565	103,060	5.55
	Sweet corn	75	-	75	745	9.93
	Total				**103,805**	
Xaiyaboury	Yellow corn	60,690	-	60,690	319,695	5.27
	Sweet corn	350	-	350	3,630	10.37
	Total				**323,325**	
Xiangkhoang	Yellow corn	25,535	-	25,535	134,455	5.27
	Sweet corn	510	-	510	4,545	8.91
	Total				**139,000**	
Total	**Yellow corn**				**852,645**	
	Sweet corn				**39,655**	

Maize cultivation is booming in the northern provinces of Lao PDR. The export of maize increased rapidly from 1996 to 2012. From 78,000 t in 1996 to 1,108,000 t in 2008, maize production increased to 14,000,000 t in 2012 (FAOSTAT 2012; MAF 2007) (Table 9).

Table 9. Maize production, 1995–2012

Market year	Production (t)	Growth Rate (%)
1995	50,000	NA
1996	78,000	56.00
1997	78,000	0.00
1998	110,000	41.03
1999	96,000	-12.73
2000	117,000	21.88
2001	112,000	-4.27
2002	124,000	10.71
2003	143,000	15.32
2004	204,000	42.66
2005	373,000	82.84
2006	450,000	20.64
2007	688,000	52.89
2008	1,108,000	61.05
2009	1,134,000	2.35
2010	1,080,000	-4.76
2011	1,250,000	15.74
2012	1,400,000	12.00

Source: FAOSTAT (2012)

The price of maize increased from only LAK 400–500/kg in 2000 to LAK 1,500–2,000/kg (Peñalba and Dulce 2013).

Big maize production areas are located in the following northern provinces, where the environment is favorable for maize production in both seasons: Xayaboury (yellow corn – 60,690 ha; sweet corn – 350 ha), Oudomxay (yellow corn – 32,975 ha; sweet corn – 1,295 ha), Luangnamtha (yellow corn – 3,450 ha; sweet corn – 810 ha), Luang Prabang (yellow corn – 7,360 ha; sweet corn – 1,490 ha), and Bokeo (yellow corn and sweet corn – 13,555 ha).

The average yield per hectare varies per province: 4.970 kg/ha in Oudomxay; 3.770 kg/ha in Luang Prabang; 5.050 kg/ha in Xayaboury; 5.370 kg/ha in Bokeo; and 3.690 kg/ha Luangnamtha.

A large percentage of maize production in Lao PDR occurs in Xayaboury (29.2%), Oudomxay (18.8%), and Borkeo (10.2%) (MAF 2007). The harvested areas in these provinces account for 53.4 percent and 58.2 percent of the country's total maize harvest and yield production, respectively (MAF 2010) (Table 10).

Table 10. Maize area, production, and yield per province, 2010

Province	Planted area (ha)	Harvested area (ha)	Production (t)	Yield (t/ha)
Xayaboury	63,025	63,025	317,650	5.05
Oudomxay	27,755	27,755	137,945	4.97
Luangnamtha	5,995	5,995	21,605	3.69
LuangPrabang	9,800	9,800	33,300	3.77
Bokeo	20,065	20,065	107,820	5.37
Vientiane	16,780	16,780	90,470	5.84
Savannakhet	4,025	4,025	9,250	3.49
Phongsaly	4,415	4,415	19,765	5.02
Huaphan	20,410	20,410	105,570	5.17
Xiangkhoang	20,400	20,400	81,675	4.00
Borikhamxai	3,300	3,300	16,385	5.72
Khammouan	1,245	1,245	6,090	3.97
Saravan	5,005	5,005	21,280	5.28
Sekong	905	905	3,470	5.36
Champasack	7,200	7,200	37,050	5.65
Attapu	170	170	680	4.67
Vientiane	1,810	1,810	9,235	5.01
Whole Country	**212,305**	**212,305**	**1,019,240**	**4.801**

Source: DOA (2012)

For the cropping calendar, farmers grow rice in the wet season from May to October and in the dry season from December to April. Other crops (e.g., vegetables) are grown from November to March (Table 11).

Table 11. Cropping calendar and months when water and food supply is critical

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Cropping calendar												
Wet season rice					x	x	x	x	x	x		
Dry season rice	x	x	x	x								x
Vegetables	x	x	x								x	x
Other crops												
Scarce water supply	x	x	x	x								
Excess water supply								x	x			
Food supply critical								x	x	x		

Source: Soukkhy et al. (2012)

Scarce water supply occurs from January to April, excess water supply occurs from August to September, and critical food supply occurs from August to October. After harvesting rice, farmers grow vegetables, such as yam, long bean, peanut, lettuce, cabbages, chili, eggplant, cucumber, and cow pea, during the dry season when they use less water.

IV. AREAS FOR REGIONAL COLLABORATION

4.1 Good Practices and Regional Collaboration

4.1.1 Regional Networking and Collaboration for Action Research and Development

There are many opportunities for regional networking and collaboration for action research and development (R&D) through the following channels: Asia Pacific Adaptation Network on climate change; CGIAR Research Program on Climate Change, Agriculture, and Food Security; SEARCA networks; International Rice Research Institute Rainfed Lowland Rice Consortium; and Lao Agriculture Development Strategy (ADS) 2011–2020. The ADS provides the framework, vision, and long-term development goals of the government of Lao PDR. The first priority is to improve livelihoods through agriculture and livestock activities, as well as food security (MAF 2010). Lao PDR will have more opportunities for regional cooperation with and among AMS.

4.1.2 Institutional Collaboration for Community-based Conservation of Rice and Maize Biodiversity

Institutional collaboration for community-based rice and maize biodiversity conservation will further strengthen cooperation among AMS. The government of Lao PDR will support the promotion of indigenous varieties of glutinous rice (e.g., khao kai noy) for climate change resilience, increase in productivity, and diversification of farming practices (mixed farming and agroforestry) to increase access to food for improved nutrition and greater food security (MAF 2010).

4.1.3 Lao PDR Climate Change Adaptation Research Center for Human Resources Development

The Lao PDR Climate Change Adaptation Research Center for HRD should be supported. As shown in the AMP 2011–2015, the government of Lao PDR prioritizes HRD activities under Program 8 (MAF 2010).

4.1.4 Capacity-building Activities on Climate Change Adaptation, Mitigation, and Resilience

The government of Lao PDR wants to learn how its neighboring countries adapt to and mitigate the effects of climate change, especially in similar scenarios.

4.2 Institutional Challenges

4.2.1 Human Resources Development for Climate Change

HRD on climate change in Lao PDR is inadequate. Most of the research and activities conducted through foreign aid focus on crop modeling. There is a need to strengthen HRD in climate projection and climate scenarios.

4.2.2 Climate Change Prevention

Preventive methods for climate change are not in place. Lao people, particularly farmers, are not equipped with early warning systems and devices. This is very critical since the country is frequently affected by typhoons and flash floods.

4.2.3 Unpredictable Weather Events

Unpredictable weather events make adaptation difficult. As such, the government of Lao PDR, through NAFRI, will establish a CCA Center in Vientiane, and recruit and assign knowledgeable technical staff on CCA who can work more actively. However, this will be a lengthy process because the working system in Lao PDR focuses more on administrative work than technical tasks.

4.2.4 Human Resources Development for National Disaster Management

Natural disaster management in Lao PDR is weak due to lack of human resources. There are no buildings or evacuation camps during disaster periods. Farmers' houses are located near the river bank so that it will be easier for them to plant and harvest, fetch water, bathe, fish, and garden. However, their proximity to water bodies makes them highly prone to flash floods. A flash flood that devastated the Nai Hua Phia Village in Houn, Oudomxay in 2013 left 13 people dead, and the farmers had to travel 7–30 km just to reach the nearest hospital (Sivilaysack 2012).

4.2.5 Climate-proofing Irrigation Systems

Climate change has made operating irrigation systems more uncertain. Therefore, climate-proofing irrigation systems through proper assessment is extremely important. The first step is to develop a guideline and framework for climate-proofing, followed by pilot implementation activities with AMS, especially the Philippines and Vietnam because they have experience in climate-proofing irrigation systems.

4.2.6 Focal Point Person for Lao PDR

There should be one designated focal point person for Lao PDR who understands and can relate to the objectives of the project. The focal point person should be capable in mediating with the government of Lao PDR on matters related to the project.

4.3 Good Practices for Replication

The following good practices from other AMS can be replicated in Lao PDR:

(1) NAFRI has the mandate to establish the Climate Change Agricultural Adaptation (CCAA) Center for Lao PDR. As such, it will provide all information on climate prediction to the farmers. NAFRI may want to learn and replicate this practice from Indonesia.

(2) Lao PDR should promote the sharing and transfer of CCAA information and technology nationally and among AMS.

(3) CCAA R&D collaboration and partnership with scientists from the Philippines who have experience in climate scenarios and Site-specific Nutrient Management for maize. Lao PDR needs to develop HRD in these fields.

V. CASE STUDIES ON GOOD PRACTICES

5.1 Rice

5.1.1 System of Rice Intensification

According to its production guidelines, one of the main potential benefits of SRI is the reported impact of wetting and drying cycles on root development during the first 50 days after transplanting. Improved root development allows the rice plant to exploit (to a greater degree relative to conventional production practices) the soil environment in which it is growing (Schiller 2004).

Uniform water application in the early stages of crop growth can only be achieved with even paddy fields. Many paddy fields in both the rainfed and irrigated lowland rice environments in Lao PDR do not have the required uniformity to provide the required level of water control.

In both on-farm and on-station conditions where high yields were achieved from SRI, the inputs of organic fertilizer, particularly farm yard manure, were high. Such levels would be difficult, if not impossible, to achieve with wider adoption of the production practices being followed in the country.

SRI production practices adopted in the irrigated environment under Lao conditions will only be appropriate for small areas of production per household. It is suggested that an average family could only manage an area of about 1 rai (<0.2 ha) (Schiller 2004).

The institutional challenges of SRI are listed in Table 12.

Table 12. Institutional challenges of SRI as a good practice

Factor	Challenge
Water control (wetseason)	Water control with alternate wetting and drying (AWD) cycles to promote root development was very difficult to achieve under wet-season conditions. Furthermore, many paddy fields were not leveled enough to allow appropriate water management, particularly in the early growth period when seedlings were still very short.
Water control (dry season)	Although not faced with the problem of flooding associated with wet-season rains, dry-season water management (i.e., irrigation and drainage) was very difficult to achieve under irrigated conditions. Furthermore, even with improved reticulation and drainage systems, on a "scheme" basis it would be very difficult to synchronize the plantings of all farmers within an area (to use SRI) and thereby try to synchronize water delivery and drainage, according the desired wetting and drying cycles recommended for SRI.
Use of young seedlings (15 days old)	Wet-season rains that occur immediately after planting sometimes result in the submersion and death of young seedlings.
Weed management	AWD cycles resulted in significantly greater weed problems associated with conventional planting and watering systems. Weed problems were further aggravated when side spacing was used. With closer spacing, the rice canopy quickly provided the ground coverage required to suppress weed ingress. With wider spacing combined with AWD in the first 50 days after transplanting, the weed ingress was significantly greater. Furthermore, weed problems with high levels of organic fertilizer input under SRI was significantly greater than with inorganic fertilizer inputs. However, it is also acknowledged that nutrient inputs from any source increase the problems associated with weed ingress, relative to the unfertilized situation.
Land preparation	The magnitude of weed control required over soil moisture in the early stages of crop growth makes SRI impractical for wet-season cropping under Lao PDR conditions. Early wet-season rains can result in the submergence and death of seedlings transplanted at a young age, while drainage (drying) of lowland rice areas is generally impractical in most lowland areas. In an environment where periodic drought can be a regular occurrence in the rainfed lowland environment, release of water from rice fields in the early stages of crop growth (as prescribed in SRI) can potentially make the crop more prone to drought.

Table 12. cont...

Factor	Challenge
Water management	In the dry-season irrigated environment, SRI is restricted by poor water management (both delivery and drainage). Uniform water application in the early stages of crop growth can only be achieved with even paddy fields.
Pest management	In the dry-season irrigated environment, young seedlings are susceptible to the golden apple snail, grasshopper, and other pests.
Drainage system	Drainage during the young seedling stage causes weeding problems.

Source: Schiller (2004)

5.1.2 Rice Biodiversity Conservation

In the traditional system, farmers grow a number of rice varieties in the same field, but each variety is confined to a small plot. On the average, three to five rice varieties of different maturities are grown. In 1995, up to seven and as many as 18 varieties were recorded in a single village in the southern and northern regions of Lao PDR, respectively (Appa Rao 2006). The rationale in growing several varieties is to reduce vulnerability to climate risks (e.g., erratic rainfall), meet religious requirements, match eating behavior, ensure the fair distribution of labor demand, and meet grain quality and specific consumption requirements for ethnic minorities (Appa Rao 2006).

Farmers in the northern part of the country are not new to climate risks. These include mid-season dry spells that can damage young plants, and late-season floods just before harvest that can cause severe crop loss. They plant drought-tolerant varities such as khao dor nam pa, khao nok kok peuk, khao phair, khao khao, and khao chao dor. They also plant early-maturing varieties that can solve the food shortage during September–October.

Table 13. Recommendations for rice and maize biodiversity conservation

Recommendations	Remarks
Build awareness on rice and maize biodiversity conservation	The decrease in the number of rice and maize cultivars as well as traditional varieties indicates the farmers' and other concerned organizations' low awareness on rice biodiversity value and conservation. Therefore, building the farmers' and other stakeholders' awareness on rice and maize biodiversity conservation is vital in addressing the loss of biodiversity in these crops. The first step could be information exchange between and among local agricultural officers and representatives from local agro-support and service providers. A review of the farmers' strategies in selecting varieties, taking into consideration long adaptation cultivars, can also be conducted.
Improve seed systems and policy	Seeds sourced from farmers had the greatest contribution to variety richness and area abundance of rice and maize varieties, especially the traditional ones. Strengthening seed systems includes improving farmers' seed infrastructure (e.g., seed stores or banks, seed and variety selection practices, and activities to promote seed exchanges). This can be done by training farmers and organizing farmer-based activities for participatory seed and variety selection. The results of research on improved seed systems indicated that there were a number of farmers who wanted to reuse some of the lost varieties, but there were no more seeds available from the seed system. To increase the farmers' seed access and variety choices for this use, seeds of traditional varieties should be included in the formal seed system. This can be carried out at policy level through analyzing seed policy and its implication at the local level. Re-distribution of traditional or good adapted varieties could be done to meet the farmers' rice variety preferences.
Establish community initiatives on rice and maize biodiversity conservation	It is the farmers' choice to undertake on-farm rice and maize biodiversity conservation. However, the provision of agro-support services and the relations within farmer networks influence their decision. Therefore, participatory activities are necessary to provide farmers with more opportunities and empower them to integrate conservation objectives into their livelihood activities. Effective participatory activities include participatory evaluation of rice cultivars, seed and variety selections, information and seed exchanges among farmers and communities, and decision-making on land use.
Strengthen institutional collaboration towards community-based rice and maize biodiversity conservation	To attain farmer-based rice and maize biodiversity conservation, complementary inter- and intra-level institutional collaboration should be undertaken.

The institutional challenges of rice biodiversity conservation are listed in Table 14.

Table 14. Institutional challenges of rice and maize biodiversity conservation as a good practice

Factor	Challenge
New Economic Mechanism (NEM)	In 1986, the government of Lao PDR applied NEM, which was implemented to boost the economy through wide-ranging reforms in the economic environment (Siene 2000). New cash crops and high-yielding rice and maize varieties were introduced. This process effected changes in the socio-economic conditions of farmers and farming communities. As a result, these changes affected the resource base (e.g., crop diversity in general, and rice and maize diversity in particular).
Depletion of traditional rice and maize varieties	In recent years, the extinction or depletion of traditional rice and maize varieties and their distinct species population have accelerated at an alarming rate. The principal cause of genetic erosion has been the widespread adoption of high-yielding varieties (Borromeo 2002).
Maize hybrids	Farmers use hybrid maize varieties such as LVN10 from Vietnam, and CP 888 and Pacific 999S, Pioneer from Thailand. Market-oriented farmers have to buy hybrid maize seeds every year and discard traditional varieties that are dependent on exotic seeds.

5.1.3 Improving Drought- and Submergence-tolerant Varieties in Lowland Areas

With policy support from the government of Lao PDR, MAF and DOA have been working closely with NAFRI in the project Improving the Resilience of the Agriculture Sector to Climate Change Impacts (IRAS) to address farmers' problems with climate change, especially with floods and droughts. The IRAS project also involves the Provincial Agriculture and Forestry Offices (PAFOs) and District Agriculture and Forestry Offices (DAFOs).

In the wet season of 2009, five submergence-tolerant rice varieties (i.e., Swarna-Sub1, SambaMahsuri-Sub1, BR11-Sub1, TDK1-Sub1, and IR64-Sub1) were tested and demonstrated in nine target villages of the Nam Theun-Hinboon Hydropower Company 2. Based on the participatory varietal selection conducted during the maturity stage, majority of the farmers preferred TDK1-Sub1 (glutinous) and IR64-Sub1 (non-glutinous, early maturity). In the dry season of 2010, the farmers chose these two varieties and distributed them to five districts in Savannakhet (Phetmanyseng 2014).

Twenty farmers were given TDK1-Sub1 (138 kg) and IR64-Sub1 (285 kg) seeds for distribution to 11 villages. Farmers who were involved in the activity were trained in participatory approaches and management techniques. The plot size for planting submergence-tolerant varieties varied and depended on the farmers' capacity in each site. The total area for growing submergence-tolerant varieties in the 11 villages was about 2.6 ha. Seeds were sown from 27 November to 16 December 2009, while transplanting was done from 18 December 2009 to 1 January 2010.

The submergence-tolerant varieties TDK 1-1 and IR 64-1 were planted in Xayaboury, Khammoun, and Savannakhet, where the Xebang Fai River causes unpredictable natural flooding annually. Flood duration, which varies from year to year, can range from three days to one month (Keo Oudone 2011). A total of 6,805 kg of submergence-tolerant rice variety seeds was achieved, of which 2,078 kg were TDK1-Sub1 seeds and 4,727 kg were IR64-Sub1 seeds. The largest production of TDK1-

Sub1 was in Nongbok (750 kg), Xebangfai (550 kg), Xaybloury (432 kg), and Mahaxai (346 kg). The largest production of IR 64-Sub1 seeds was in Mahaxai (2,131 kg), Xayaboury (2,196 kg), Xebangfai (200 kg), Nongbok (200 kg). Training on rice seed production techniques was conducted in four sites in four districts. Thirty-seven trainees from 11 villages in four districts participated.

In the wet season of 2010, 3,445 kg of seeds were disseminated to 171 households in 42 villages in five districts. Of this amount, 1,680 kg (49%) were TDK1-Sub1 seeds and 1,765 kg (51%) were IR 64-sub 1 seeds.

Flood- and drought-resistant varieties should be distributed to farmers at a price that they can afford.

5.2 Maize

5.2.1 Direct Seeding Mulch-based Cropping (DMC) Systems

DMC systems were introduced to farmer organizations in the four southern districts of Xayaboury. This supports DAFO in improving food security and livelihoods of rural communities, where the capacity of local agriculture trader associations is also being strengthened (Chanthasone 2013).

To promote the adoption and dissemination of DMC systems, various rural development actors in all stages of the process (e.g., input providers, farmers, extension workers, researchers, decision-makers like PAFO and DAFO, and the private sector) should be integrated because they play important roles in DMC activities. In addition, their awareness on decreasing soil fertility and related socio-economic issues should be heightened.

In DMC systems, DAFO technician-staff are responsible for one geographic area with 2–3 farmer groups composed of 50–120 households. During the first two years, the use of new technology (e.g., drum seeder, dry direct seeding, and direct seeding techniques) requires strong support and assistance from extension workers who are responsible for planning, coordinating, and training. Training for extension agents from DAFO agronomy and livestock departments focus on agro-ecology concepts and techniques (PASS-PRONAE). It is also important to raise the awareness of farmer groups and organizations. In the past, before farmer groups were established, farmers had no marketing power to negotiate with traders since they have varying price and quality of seeds. After farmer groups were created, input providers such as credit systems began setting up with traders. To ensure the proper application of DMC systems, extension activities and demonstrations (e.g., training sessions on direct seeding techniques, recourse to inputs, and on-farm demonstrations with farmer groups) should be conducted.

Table 15. Institutional challenges of DMC as a good practice

Factor	Challenge
Steep slope	DMC systems are not appropriate for steep slopes, where the decomposing biomass can easily run off. “There was a gradual increase in DMC yields from the first to fourth years due to slow biomass decomposition. In the fifth year, the benefits of DMC as a good practice were evident in the soil.”
Ease of use	DMC systems are difficult to practice because farmers burn the biomass for easy management, and cattle can enter the field after harvesting to eat plant residues.
Pest management	Plant residues are favorable to pests and insects, especially rodents, termites, and ants.
Overgrazing	The farmers cannot allow cattle to enter the field after harvesting the crop because of overgrazing.

Source: Chanthasone (2013)

5.2.2 Maize Integrated with Legumes

Farmers in Xayaboury, Oudomxay, and Luang Prabang practice integrating maize with legumes such as red bean, mungbean, and soybean.

The Napok Agriculture Research Center develops the following high-yielding legumes for distribution to the farmers: (1) Napok Agriculture Research 1 (100 days), (2) Napok Agriculture Research 2 (110 days), (3) Chiang Mai 60 (90 days), (4) DM12 (Vietnam) (90 days), and (5) KKU 35 (110 days). Most farmers plant soybean after harvesting.

Farmers plant legumes between rows of maize. Most farmers in Xayaboury integrate maize with legumes in two productions per year to control the weeds. The canopy of maize and legumes provide shade that can inhibit weed growth. Increased soil fertility reduces risks linked to variations in climate and maize price. The benefits from maize integrated with legumes are higher than mono maize planting by about 23 percent (MAF 2010).

VI. CONCLUSION

Lao PDR is classified into three zones: the northern region, which has many hills and steep slopes; the central region, which has many flatlands and is the rice basket of the country; and the southern region, which has many flatlands and sloping areas.

NAFRI served as the key implementing agency of this national study, which prioritized the following case studies on good practices in CCA options for rice and maize: for rice, (1) SRI, (2) rice biodiversity conservation, and (3) improving drought- and submergence-tolerant varieties in lowland areas; and for maize, (1) DMC and (2) maize integrated with legumes. These good practices in Lao PDR seem to be very location- and site-specific. The national study was conducted only in Xayaboury, Oudomxay, and Luang Prabang because of budget limitations and time constraints.

With policy support from the government of Lao PDR in conducting and strengthening good practices in the country, especially through DOA, NAFRI, MAF, PAFO, DAFO, and farmer organizations, the procedures and outcomes of the national case study were satisfactory. Two national consultative meetings were held at NAFRI to discuss the identified good practices in Lao PDR, where several scientists and researchers participated and contributed ideas to further the country's resilience to climate change.

Rice biodiversity conservation is commonly practiced in the eight northern provinces, where the topography is hilly and sloping. The northern region suits the country's three agricultural production systems: irrigated lowland, rainfed lowland, and rainfed upland. It also features more rice varieties because it is also home to diverse ethnic minorities, where poor farmers are found (Appa Rao 2006).

The rationale in growing several varieties is to reduce vulnerability to climate risks (e.g., erratic rainfall), meet religious requirements, match eating behavior, ensure the fair distribution of labor demand, and meet grain quality and specific consumption requirements for ethnic minorities (Appa Rao 2006). Among ethnic minority groups, the Hmong prefers non-sticky rice, the Lao Theung prefers sticky rice, and the Lao Loum prefers both. As reflected in the AMP, government policy also supports farmers in growing diversified crops and varieties to ensure food security and cope with unpredictable climate variability (MAF 2010).

Farmers in Xayaboury, the basket of maize production in the country, practice DMC. The number of farmers adopting DMC and direct seeding on plant cover quadrupled in the southern districts of Xayaboury. DMC and direct seeding on plant cover have been replicated in Luang Prabang and Oudomxay.

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Published by

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

In cooperation with

Promotion of Climate Resilience in Rice and Maize

Myanmar National Study

Imprint

This publication is a joint undertaking by the ASEAN Technical Working Group on Agricultural Research and Development (ATWGARD) and the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH through the ASEAN-German Programme on Response to Climate Change (GAP-CC).

In partnership with the Southeast Asian Regional Center for Graduate Study and Research in Agriculture (SEARCA).

Published by the
Deutsche Gesellschaft für
Internationale Zusammenarbeit (GIZ) GmbH

Registered offices
Bonn and Eschborn, Germany

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As at
April 2015

Printed by/design and layout
SEARCA
College, Los Baños
Laguna - 4031

Photo Credits
Kyaw Kyaw Winn (SEARCA Photo Contest)

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On behalf of the
German Federal Ministry for Economic Cooperation and Development (BMZ)
Alternatively: German Federal Foreign Office

Promotion of Climate Resilience in Rice and Maize

Myanmar National Study

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

AED	Agricultural Extension Division
AMS	ASEAN Member States
AVSI	Association of Volunteers in International Service
CCA	Climate Change Adaptation
CP	Charoen Pokphand
CURE	Consortium for Unfavorable Rice Environments
DAR	Department of Agricultural Research
DAP	Department of Agricultural Planning
DMH	Department of Meteorology and Hydrology
DOA	Department of Agriculture
FAO	Food and Agriculture Organization of the United Nations
GAP	Good Agricultural Practice
GRET	Groupe de Recherches et d' Echanges Technologiques
HYV	High-yielding Variety
INGO	International Non-Government Organization
INM	Integrated Nutrient Management
IPM	Integrated Pest Management
IRRI	International Rice Research Institute
JICA	Japan International Cooperation Agency
LIFT	Livelihood and Food Security Trust Fund
MADB	Myanmar Agricultural Development Bank
MMK	Myanmar Kyat
MOAI	Ministry of Agriculture and Irrigation
NGO	Non-Government Organization
OPEC	Organization of the Petroleum Exporting Countries
PVS	Participatory Varietal Selection
QPM	Quality Protein Maize
RSC	Rice Specialization Company
SLRD	Settlement and Land Record Department
SRI	System of Rice Intensification
SSNM	Site Specific Nutrient Management
YAU	Yezin Agricultural University
WRUD	Water Resource Utilization Department

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Foreword

The Department of Agricultural Planning under the Ministry of Agriculture and Irrigation is pleased to endorse this national study of climate adaptive practice to ensure resiliency of rice and maize in Myanmar, and in the region. We are happy to be able to contribute to this exercise through the ASEAN Technical Working Group on Agricultural Research and Development (ATWGARD) with the support of GIZ through the German-ASEAN Programme on Response to Climate Change (GAPCC).

Myanmar is already experiencing a range of observed climate changes, such as declining precipitation, increasing water scarcity, rising temperatures and growing frequency of extreme weather events. These changes pose a serious threat to the agro-ecosystems and natural resources that underpin the agriculture sector. Moreover, the ongoing and forecasted climate change is a great challenge that will compound existing development problems, affecting food security. Five good practices have been identified within the course of this study. Among them three are identified for rice value chain, namely: Good Agricultural Practices (GAP), traditional farmers' adaptation practices (change of crop/crop varieties/ cropping patterns, time of sowing and crop management practices depending on monsoon rain), and use of climate resilient varieties; while two categories (lowland & upland areas) of good practices of maize production are the recommended for maize value chain, namely: maize residues for cattle feed and compost and hybrid maize production (lowland areas); and maize cultivation before monsoon rains and use of Site Specific Nutrient Management (upland areas).

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Acknowledgment

We are fortunate to participate alongside other countries in the Association of Southeast Asian Nations (ASEAN) in the project ASEAN Network on Promoting Climate Resilience of Rice and Other Crops. We would like to express our deepest gratitude to the German-ASEAN Programme on Response to Climate Change and ASEAN Technical Working Group on Research and Development for giving Myanmar the opportunity to collaborate with other ASEAN Member States (AMS) on issues concerning climate change.

We would like to extend our gratitude and sincerest appreciation to the Ministry of Agriculture and Irrigation for assistance in preparing this report, especially staff of the Department of Agriculture (DOA), Department of Agricultural Research (DAR), and Yezin Agricultural University (YAU); and the extension workers of DOA and farmers in central Myanmar for their participation in the field surveys documented as national case studies. We are grateful for the support received from the International Rice Research Institute (IRRI) and the CGIAR Research Program on Climate Change, Agriculture, and Food Security (CCAFS), to organize a meeting of DOA, DAR, and YAU to peer-review this report, as part of their project, Policy Information and Response Platform on Climate Change and Rice in ASEAN and its Member Countries (PIRCCA).

We acknowledge the key roles played by individuals, including: Dr. Felino P. Lansigan, University of the Philippines, Los Baños; Dr. Tin Htut, Director General of the Department of Agricultural Planning (DAP); Dr. Myo Kywe, Rector of the Yezin Agricultural University (YAU); Dr. Rizaldi Boer, Executive Director of the Centre for Climate Risk and Opportunity Management in Southeast Asia Pacific (CCROM); Dr. Valerien Pede, Economist at IRRI; and Michael Sheinkman, CCAFS Collaborative Research Scientist at IRRI.

Executive Summary

Rice, a staple food in Myanmar, can be grown across the country throughout the year. It is grown mainly during the monsoon season as a single crop. In 1992, summer rice was introduced to regions across the country where irrigation facilities were available. In general, the sowing time of monsoon rice and summer rice are from May to October and November to March, respectively. This varies from region to region depending on geographic and climatic conditions.

Rice agro-ecosystems in Myanmar can be classified as favorable lowland areas (68%) or unfavorable rainfed areas (32%). There are considerable flood- and drought-prone areas in the country that are vulnerable to the yearly occurrence of extreme weather events. In the first case study, good agricultural practices (GAP) or best crop management practices in rice production that are encouraged by the Ministry of Agriculture and Irrigation (MOAI) are emphasized. To boost rice yield, MOAI laid down 14 guidelines for GAP in 2011 (DOA-MOAI 2013). Similar to the System of Rice Intensification (SRI), the guidelines for GAP include (1) using young seedlings, (2) planting a small number of seedlings per hill, (3) intermittent irrigation, and (4) Integrated Pest Management (IPM) and Integrated Nutrient Management (INM), among others. Evidence showed that these practices not only favor higher yield but also help plants adapt to climate extremes, since they are stronger and have a shorter lifespan than those grown using conventional practices. Intermittent irrigation and INM also mitigate greenhouse gas emissions from flooded rice paddy fields.

Drought is a hidden risk in rice production, particularly for farmers in the central dry zone. The farmers' traditional adaptation technologies, which are presented in the second case study, include (1) changing crop or crop varieties, (2) altering cropping patterns, and (3) adjusting sowing time and crop management practices depending on the monsoon rains (Swe 2011). The production of climate-resilient varieties, which is part of the rice crop improvement program of DAR, is explained in the third case study. For several decades now, the Rice Section of DAR under MOAI has been producing high-yielding varieties (HYVs) that are tolerant to unfavorable rice ecosystems. In collaboration with IRRI and other international organizations, DAR has released significantly improved rice varieties to farmers.

Maize is the second most important cereal used for local animal feed and export. It is grown during the monsoon and post-monsoon seasons under rainfed conditions. Maize area and production have increased rapidly over the last few decades due to area expansion and high yield per acre. Most of the yield growth is attributed to the adoption of hybrid maize varieties, which has expanded rapidly in recent years in response to the high demand for animal feed export to China and Thailand. Maize production in the lowlands/flatlands is discussed in the fourth case study. The survey results of study villages in Tatkone Township in Mandalay Region showed that there have been frequent and persistent droughts over the last few decades, causing delays in sowing and changes in cropping patterns in the region. Moreover, maize farmers have often made small profits due to higher input prices and wages as well as stagnation of output prices; however, as a good practice, they have tried to improve soil fertility through proper maize residue management and compost making.

Maize production in the uplands/hilly region observed in Naungcho Township in Northern Shan State is the subject of the fifth case study. Maize is the main crop of the study village where farmers often encounter late monsoon arrival and intense drought during the growth period. These climate problems cause poor kernel growth and yield. The farmers' readiness in sowing seeds during the monsoon season and their modification of fertilizer application methods are examples of good practices in climate change adaptation (CCA).

Approximately 70 percent of Myanmar's population live in rural areas and depend highly on agriculture and the country's natural resources. Nowadays, natural resource degradation is rampant mainly because of mismanagement, population pressure, and poverty, among others. Moreover, the ongoing and forecasted climate changes are great challenges that will compound existing development problems and affect food security. Myanmar has already experienced a range of observed climate changes, such as declining precipitation, increasing water scarcity, rising temperatures, and growing frequency of extreme weather events. These changes pose a serious threat to agro-ecosystems and natural resources that underpin agriculture.

As an agriculture-based country, Myanmar needs to adopt a path of climate resilience, low carbon, and sustainable development in agriculture. The areas for regional collaboration should take into account regional realities as well as the potential of changing cropping practices and patterns as CCA strategies. Agricultural sample surveys should include all zones of rice- and maize-producing regions to fully assess the effects of climate change. The production of varieties that are resilient to unfavorable agro-ecosystems should be scaled up to promote regionally beneficial agricultural initiatives among AMS.

I. INTRODUCTION

Based on the provisional results of the 2014 national population and household census, Myanmar's current population is 51.41 million, of which 70 percent live in rural areas and engage primarily in agriculture (DOP-MIP 2014). The main crops grown in the country are cereals (i.e., rice, maize, and wheat), pulses, and oilseed crops (i.e., sesame, peanut, and sunflower). Rice covers approximately 50 percent of the total sown area.

Rice has been cultivated in Myanmar since prehistoric times. Before World War II, Myanmar became the largest rice exporter in the world. The country's rice area reached 5 million hectares (ha), while exports amounted to 3 million tons (t). Rice area and production declined during the post-war era and has since failed to reach the levels achieved during the pre-war period. To improve the country's rice industry, The International Rice Research Institute (IRRI) launched a high-yielding variety (HYV) pilot project to support the distribution of technology and inputs, from 1977 to 1978. MOAI launched a special high-yielding paddy program in Shwebo (Central Myanmar) and Teikkyi (Lower Myanmar) Townships to support the distribution of technology and inputs, such as seeds, chemical fertilizers, and irrigation, as well as the close supervision of agricultural extension staff. This program introduced rice HYVs such as IR5 and IR8. The yields doubled with the application of improved techniques, such as the use of chemical fertilizers and pesticides, as well as proper water management (DAP-MOAI 2013b). The summer rice program, which was introduced in 1992, used short-duration HYVs and increased rice yield. The government of Myanmar strongly supported summer rice production, which was intensified yearly. Rice has been designated as a national crop and a priority crop for area expansion and yield increase. New irrigation dams, weirs, and reservoirs were established; existing irrigation facilities were improved; and groundwater was explored to further rice production.

Maize, the second most important cereal after rice, is also a foreign currency earner for Myanmar. Cultivated exclusively under rainfed conditions, maize occupies 364,983 ha (87% of the total sown area) during the monsoon season and 53,496 ha (13% of the total sown area) during the winter season. Cultivated areas of hybrid and local varieties are 84 percent and 16 percent of total sown areas, respectively (DOA-MOAI 2013). To date, there is no information regarding severe pest and disease infestation as well as serious weather-related yield loss in maize production.

As market demand for maize continues to rise, sown area and yield per acre have increased rapidly in the last decade due to the combined use of hybrid maize varieties and chemical fertilizers; however, rice and maize production in Myanmar are considered low compared to the production of the same crops in neighboring countries. Rice and maize production face several agronomic and input constraints that are compounded by present and future changes in climate.

In the rice value chain, the main actors are farmers, traders, collectors, millers, and exporters. The first step in the rice value chain is the development of new varieties that are high yielding and tolerant to unfavorable climate. DAR, through DOA, is primarily responsible for the production and distribution of rice seeds. The dealers sell other inputs such as chemical fertilizers and pesticides. For increased production, the farmers need inputs such as seeds and agro-chemicals. Financial support mostly comes from the millers and the money lenders.

The researchers from DAR who are involved in breeding local varieties are also important actors in the rice value chain. In breeding local varieties or hybridizing existing varieties, lines or varieties from other countries are introduced to existing varieties within the country. Before a new variety is released, DAR researchers spend several years testing its adaptability to specific localities and conduct yield trials at DAR satellite farms. Several private companies also undertake purified rice seed production. Climate strongly influences sowing time, transplanting time and methods, and crop management practices, including the time and rate of fertilizer application as well as weeding.

After harvest, many farmers set aside a portion of their crops for household consumption and store their seeds for planting in the next season. The rest of the output is sold to brokers or traders. Some farmers keep their products and wait for a higher price, since farm gate prices are generally lower in the harvesting season. Only a few farmers sell their paddy after milling when they think that it is more profitable. The millers often buy paddy to sell rice to larger cities. Since the rural financing system in Myanmar is not yet fully developed, resource-poor or smallholder farmers usually receive money from private money lenders. Some sell their products in advance and at a lower price. Some private companies and Rice Specialization Companies (RSCs) have introduced the contract farming system, wherein they provide the inputs (e.g., seeds and fertilizers) and buy the paddy at harvest price (Shwe 2011).

The Myanmar Agricultural Development Bank (MADB) provides seasonal loans to rice farmers, with the loanable amount increasing yearly. In 2012, farmers received MMK 100,000 (about USD 1,000) per acre of rice (DAP-MOAI 2013b). This amount was insufficient because it was less than half of the investment in one acre of paddy cultivation. Many farmers could not withstand a reduction in yield even for a season. Therefore, a sustainable credit system and a climate insurance system should be explored. RSCs and other private companies are establishing large, high-grade rice mills to produce better quality rice. RSCs have been playing a pivotal role in several segments of the rice supply chain through contract farming (Shwe 2011).

In the maize value chain, the main actors are farmers, traders, collectors, and commercial poultry farms. DAR and the Tatkone Agricultural Research Farm have been producing Yezin hybrid seeds for several years. They sell seeds to the farmers by collaborating with DOA. Thailand's Charoen Pokphand (CP) Company has been active in hybrid maize marketing in Myanmar since 1999. It sells seeds on a consignment basis in addition to offering other incentives. CP 888, CP's outstanding maize hybrid, occupies the substantial areas of the total maize area in Myanmar. The traders, who are the sub-suppliers of CP seeds, also collect and buy the farmers' products. They also sell the grains to Mandalay traders, who export to Muse, a city bordering China, and occasionally to CP Company in Yangon. The brokers or collectors gather maize from the village farmers and sell the grains to the traders in town. They also sell directly to Mandalay traders, who export the products to China. Commercial poultry farms occasionally buy maize directly from the farmers, but they usually course their purchases through the traders.

II. VALUE CHAIN MAPPING

The rice and maize production value chains are shown in Figures 1 and 2, respectively.

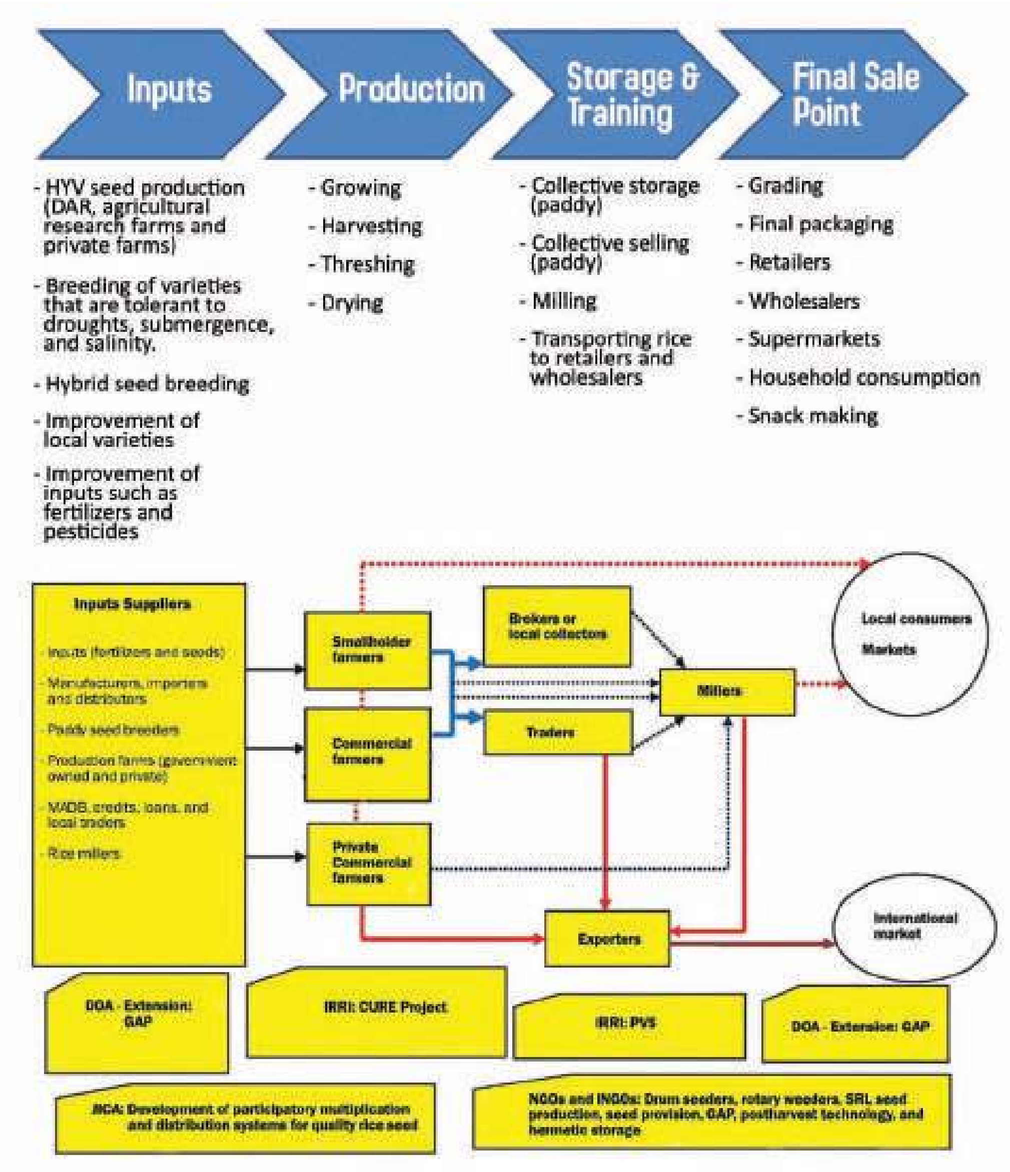

Figure 1. Rice production value chain (functions and operations along the value chain)

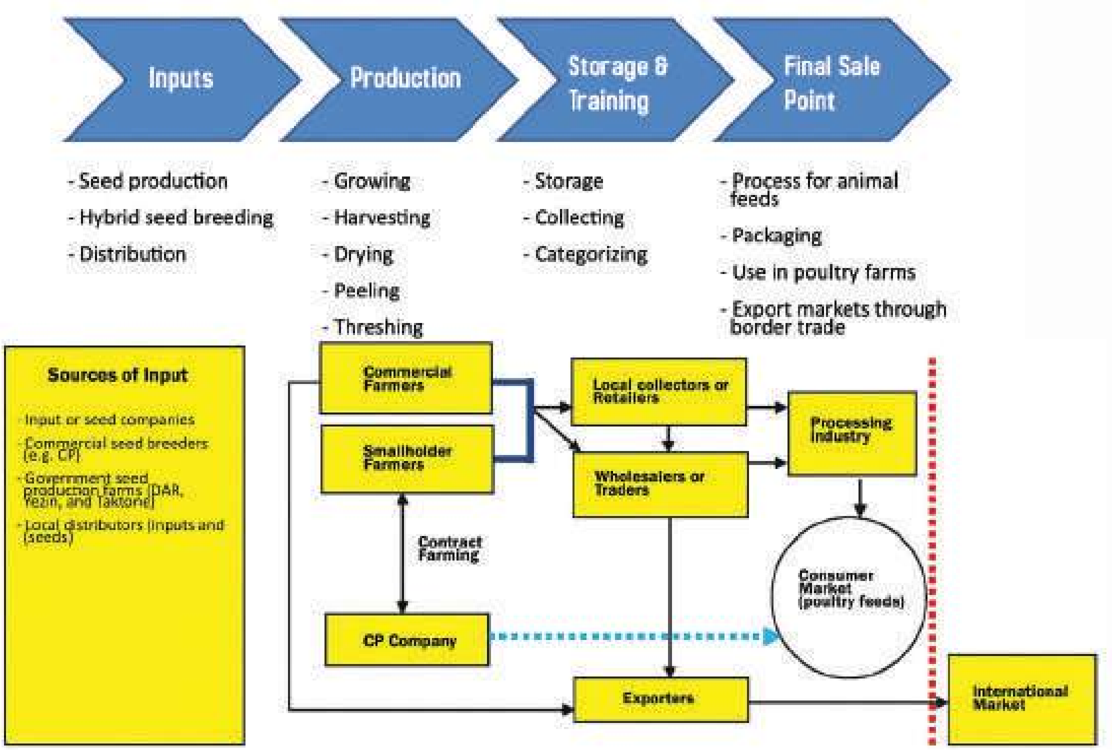

Figure 2. Maize production value chain (functions and operations along the value chain)

The production of both crops depends on seed source, inputs, and crop management practices. Climate is also one of the most decisive factors of a good harvest. The irrigation facilities are only available for the cultivation of monsoon rice and summer rice, covering less than 20 percent of the total sown acreage. Maize is grown exclusively under rainfed conditions in all states and regions in the country.

The rice and maize production systems in Myanmar are presented in Table 1.

Table 1. Rice and maize production systems, 2012–2013

Production system type	National production volume (t)	National production value (USD)	Assessment of impact on national/ regional consumption (1–3)	Indication/ estimate of relative vulnerability to climate change (1–3)
Rice				
Irrigated Lowland (Irrigated monsoon rice + summer rice)	8,197,523	1,639,504,600[a]	1	1
Rainfed Lowland (Total rainfed – rainfed upland [Yar] + Taungyar)	16,191,644	3,238,328,800[a]	3	3
Upland Production (Upland [Yar] + Taungyar)	3,329,698	665,939,600[a]	1	3
Total	27,718,865	5,543,773,000		

cont...Table 1. Rice and maize production systems, 2012–2013

Production system type	National production volume (t)	National production value (USD)	Assessment of impact on national/ regional consumption (1–3)	Indication/ estimate of relative vulnerability to climate change (1–3)
Maize				
Monsoon Production	1,324,333	433,056,859[b]	3	2
Post-monsoon production	201,340	65,838,200[b]	1	2
Total	1,525,673	498,895,059		

Source: Annual Report, AED, DOA (2012–2013)
Note: Upland (Yar in Myanmar language) is assumed as drought-prone/sandy soil condition (Thesan-konekyaw land). Total rainfed area also includes the Taung-yar system (traditional shifting cultivation system) on hilly lands. The assumption for overall rice production is USD 200/t. The assumption for overall maize production is USD 327t. Paddy export was 26,392 t worth USD 7.291 M (USD 276.3/t), and maize export was 556,989 t worth USD 182.196 M (DTP-MOC 2013)

In 2012–2013, the total paddy production was 27,718,865 t, where production in irrigated lowland, rainfed lowland, and upland was 30 percent, 58 percent, and 12 percent, respectively. On the other hand, the total maize production was 1,525,673 t, where production during the monsoon and post-monsoon seasons was 87 percent and 13 percent, respectively (DOA-MOAI 2013).

III. REVIEW OF LITERATURE ON CLIMATE CHANGE IMPACTS AND VULNERABILITIES

The Department of Meteorology and Hydrology (DMH), under the Ministry of Transport and Communication, noted the long-term changes of extreme weather events during the monsoon season in Myanmar (i.e., Myanmar Monsoon Climatology). Based on records, shorter monsoons (40 days less) started occurring after 1978 and the country lost about 30 percent of monsoon rains almost every year since. Before the 1980s, El Niño and La Niña episodes occurred every five to seven years. They occurred more frequently after the 1980s, and in recent years they occurred almost every one or two years (Htay 2011; NECC 2012). The specific climate risks are shortage of rainwater in rivers and shortened cultivation periods that are inadequate for some paddy varieties. Moreover, extreme weather events, such as floods, droughts, and heat waves, now occur more frequently, leading to the scarcity of agricultural water that is critical for areas in the central dry zone.

DMH predicted that low river flows in Ayeyarwady and Chindwin, two major rivers in Myanmar, are more likely to occur due to the accelerating disappearance of the Himalayan glaciers. These glaciers are a prime source of water during the dry season. The temperature is predicted to increase by 0.4ºC to 0.7ºC across Myanmar, with the Ayeyarwady Delta region to experience the greatest increase by 2020. Highly variable changes in rainfall will augment the frequency of floods and droughts throughout the country. Rainfall is predicted to increase by 228 millimeters (mm) in the northern hilly region and decrease by 58 mm in Rakhine, Yangon, Delta, and the southern coastal region of Taninthayi. Seasonal precipitation will decrease in the northern and central regions of the country, exacerbating drought events by 2020 (NECC 2012).

The International Food Policy Research Institute (2009) reported the additional percent change in production in 2050 due to climate change relative to 2050, with no climate change based on the calculation of the Commonwealth Scientific and Industrial Research Organization (% change). It noted that the rice yield reduction in world production was calculated to be from 11.9 percent to 13.5 percent. Moreover, simulations for major rice-growing regions in Asia found that there is a 7 percent decrease in yield for every 1ºC rise in temperature above the current mean temperature at existing atmospheric carbon dioxide concentration (IWMI 2007). It was also reported that yield reduction in rice has been correlated with increased nighttime temperatures. Grain yield declined by 10 percent for each 1°C increase in growing-season minimum temperature during the dry season in irrigated tropical rice (Peng et al. 2004).

Temperature increases in sub-tropical and temperate climate areas may have a positive or negative effect on rice crops, depending on the location. For example, an increase in temperature will improve rice establishment in Mediterranean areas, where cool weather usually causes poor crop establishment (Ferrero and Nguyen 2004; Nguyen 2004). On the other hand, an increase in temperature will reduce the benefits of low night temperature on grain production in northern Japan (16°–21°C) (Matsushima and Tsunoda 1958).

The climate change impact assessment and vulnerability rating for rice and maize production are described in Tables 2 and 3, respectively. For the socio-economic and biophysical impacts of climate change, factors such as potential impacts to food security, frequency of occurrence, and extent of expected damage are taken into account. Vulnerability is rated based on how the system of actors and assets is currently sensitive to climate variability and other factors.

Table 2. Climate change impact assessment and vulnerability rating for rice production

System of interest	Climate change trend/ signal	Biophysical impact	Socio-economic impact	Vulnerability rating (1–5)
Production phase	Late arrival of monsoon rains	Late sowing date, Changes in sowing practices from transplanting to broadcasting	Lower rice yield	5 – Short growth duration that leads to poor yield.
	Increased temperature during flowering	Rice sterility	Lower rice yield	3 – It occurs more in summer rice than in monsoon rice. Sowing time is crucial for this action.
	Prolonged droughts	Poor crop growth	Lower rice yield (50%–70% drop in transplanted rice areas in Magway Region (WFP 2009)	5 – Short-duration varieties can escape the serious impact of droughts, while medium-duration varieties are more vulnerable.
	High rainfall intensity	Rice sterility Logging	Lower rice yield	2 – Plant population is lower during the vegetative stage.
Flood Prevention measures	Floods and long inundation period	Poor crop growth Logging	Lower rice yield	5 – Flood prevention measures (e.g., dykes and embankments) are urgently needed.
	Humidity increases Warm and cloudy days	Pest and disease occurrence	Lower rice yield	3 – There is an outbreak of stem borers and brown plant hoppers.
Rainwater harvest in dams and tanks/village ponds	Erratic and low rainfall	Lack of irrigation for production	Lower rice yield	5 – Poor irrigation infrastructure should be renovated.
Irrigation	Infrequent rainfall is common	Increased pressure on groundwater that causes higher salinity in dry zones	Lower rice yield	4 – Poor irrigation infrastructure should be renovated.
	Sea level rise	More saltwater intrusion in coastal zone	Lower rice yield	3 – Seawater prevention measures (e.g., dykes and embankments) are needed.
Harvesting	Unseasonal rains	Low rice quality Poor germination	Postharvest losses Lower market price	3 – Dryers are unavailable in most areas
Crop storage	Humidity increases	Lower germination More pest and disease occurrence in storage	Postharvest losses	2 – Improved storage facilities are unavailable.

Source: Personal surveys and experts' judgment

Table 3. Climate change impact assessment and vulnerability rating for maize production

System of interest	Climate change trend/signal	Biophysical impact	Socio-economic impact	Vulnerability rating (1–5)
Production phase	Late arrival of monsoon rains	Late sowing date	Lower maize yield	5 – Short growth duration that leads to poor yield.
	Prolonged droughts Erratic and low rainfall	While droughts negatively affect all stages of maize growth and production, the reproductive stage, particularly between tassel emergence and early grain-filling, is the most sensitive to drought stress. Drought stress during this period results in a significant reduction in grain yield, associated with a reduction in kernel size.	Lower maize yield	5 - Constraint in fertilizer application by farmers
	Increased temperature during flowering	Maize sterility	Lower maize yield	3 – Seed formation is reduced.
	High rainfall intensity	Maize sterility	Lower maize yield	3 – Seed formation is reduced.
	Humidity increases Warm and cloudy days	Pest and disease occurrence	Lower maize yield	2 – Low productivity; Lower yield due to infestation;
Harvesting	Unseasonal rains	Low maize quality	Postharvest losses Lower market price	3 – Dryers are unavailable in most areas
Crop storage	Humidity Increases	Higher pest and disease occurrence Low maize quality	Postharvest losses Lower market price	2 – Improved storage facilities are unavailable.

Source: Personal surveys and experts' judgment

Among the systems of interest in rice production, "late arrival of monsoon rains" was rated the highest (level 5, highly vulnerable). Delayed monsoon rains cause short growth duration, which leads to poor yields. In addition, the trend of "prolonged droughts in the production phase" was rated as level 5. In current production systems, the more common medium-duration varieties give higher yield than the short-duration varieties, but only the latter can avoid the impacts of prolonged droughts. Therefore, long and intense droughts will significantly disrupt current production systems. Rainwater harvest in dams, tanks, and village ponds will be less because of erratic and low rainfall. As such, the water supply will be insufficient for irrigation or production, leading to lower rice yields. This scenario is considered "highly vulnerable," especially in dry zones across the country. "Flood and long inundation period" will also disrupt lowland rice production unless proper flood-prevention measures are put in place. Infrastructure development for disaster prevention is urgently needed.

In terms of climate change impacts on value chain functions, (1) an increase in the frequency of delayed monsoon rains will significantly influence sowing and/

or transplanting time; (2) an increase in the frequency of droughts and rising temperatures will seriously affect crop management (e.g., irrigation, fertilizer application, and weeding) for rice and maize; (3) a decrease in the duration of the monsoon season, as farmers have been experiencing very often, will lead to poor yields; (4) an increase in the frequency of seasonal inundation will significantly reduce production and harvest; (5) an increase in the number of warm and cloudy days or the onset of consecutive rainy days will promote the proliferation of pests (e.g., stem borer and brown plant hopper in rice, and Asian corn borer in maize) and diseases.

Similar findings were observed in the vulnerability rating for maize production. Maize cultivation during the monsoon and post-monsoon seasons is done almost entirely under rainfed conditions. Rice production is prioritized in the use of irrigation facilities. As such, dams and irrigation canals are not available to maize farmers. Maize seed production (except for fresh corn) is done exclusively under rainfed conditions because tube wells and underground water pumps are not feasible economically. Farmers rely fully on the monsoon rains for their harvest. Therefore, Myanmar is considered "highly vulnerable" to bad weather, delayed monsoon rains, prolonged droughts, and erratic and low rainfall.

3.1 Climate Change Impacts and Gender

The distribution of females and males in Myanmar's population of over 50 million is 51.8 percent and 48.2 percent, respectively (DOP-MIP 2014). The main livelihoods, such as crop cultivation, small- and medium-scale enterprises, and small-scale livestock breeding and/or fishery, are all related to agriculture. The risks associated with the impacts of climate change are different between women and men, with women being more vulnerable to such impacts, especially in the rural areas. When Cyclone Nargis devastated Ayeyarwady Delta in 2008, records showed that more women died than men (TCG 2008).

Yield reduction, the ultimate impact of climate change, has been rampant during the past decade. As it triggers food insecurity, women have to sacrifice for other family members by skipping meals or taking less food. The daily wages for women and men are different in all regions, with women receiving lower wages than men (e.g., MMK 2,000/day for women and MMK 3,000/day for men). Work opportunities (e.g., weeding, harvesting, threshing, and winnowing of paddy) are reduced because of poor crop establishment and poor yields. As labor supply exceeds labor demand, employment opportunities become more limited for women than men.

Prolonged droughts and erratic rainfall have made available water from nearby forests inadequate for drinking, household use, and cattle feed. Fetching water, collecting fuel wood, and feeding cattle are considered women's responsibilities, along with other household chores. The lack of water increases the time it takes for women to complete all tasks. Climate change and forest degradation also make it more tedious for women to gather non-timber forest products.

3.2 Agricultural Development Policies Related to Rice Production

Agriculture plays a vital role in the country's economy. In 2011–2012, it contributed 26 percent of Gross Domestic Product (GDP), 16.4 percent of total export earnings, and employed 61.2 percent of the labor force (CSO-MNPED 2012; DAP-MOAI 2013a). The total crop sown area covered 16.72 million ha in 2011–2012. According to the National Planning targets, the total paddy area was 8.1 million ha under monsoon paddy and 1.3 million ha under summer paddy, with an average yield of 3.9 t/ha, in 2011–2012. From 12.68 million t of utilization, 0.46 million t of surplus rice, and 108 percent of sufficiency in 1987–1988, rice production increased to 19.95 million t of utilization, 6.34 million t of surplus rice, and 168 percent of sufficiency, respectively, in 2009–2010. Concerning rice production, MOAI's Fifth Five-Year Short-Term Plan (2011–2012 to 2015–2016) aims to reach over 166 percent of rice food security, with an average yield of 4.28 t/ha or 82.9 baskets per acre (ac) and 33 million t of paddy production, and extend the irrigated area to 2.3 million ha (DAP 2013 b).

MOAI is responsible for the overall development of the crop sub-sector, including extension, research and development (R&D), irrigation, agricultural mechanization, formulation of agricultural plans and policies, higher education in agriculture, agricultural micro-credit and loans, agricultural land reclamation, land development and land reform, biodiversity, land surveying and mapping, and coordination with key concerned agencies. It aims to (1) increase crop production and productivity, (2) fulfill the needs of local consumption, (3) export more surpluses of agricultural products, and (4) assist rural development (DOA-MOAI 2012).

MOAI selected the following major crops to increase production and meet the targeted yields: paddy, sugarcane, long staple cotton, maize, groundnut, sesame, sunflower, black gram, green gram, and pigeon pea. For example, the targeted yields for paddy and maize are 5.16 t/ha and 4.93 t/ha, respectively (DAP-MOAI 2013a). To meet these targets, MOAI encourages the use of improved varieties, appropriate cropping patterns, and fertilizers and pesticides. The current strategy for crop production growth is to focus on the rigid implementation of crop production and productivity targets.

The following departments are part of MOAI's institutional structure[1]: DAP, DOA, Irrigation Department, Agricultural Mechanization Department, Settlement and Land Records Department (SLRD), Water Resources Utilization Department (WRUD), MADB, DAR, YAU, and Department of Industrial Crops Development. The following are brief stakeholder analyses for MOAI departments and non-government institutions that are key actors in the rice and maize value chains:

■ **DAP** – The main function of DAP is to coordinate with various departments inside and outside MOAI. Its major thrusts are assisting policy makers in adopting agricultural policies, formulating various agricultural plans, establishing linkages with national governments and international organizations, strengthening inter-agency cooperation and coordination, promoting agricultural trade and business management, reporting and compiling agricultural statistics, conducting surveys, providing recommendations to further develop agriculture, and developing human resources in agriculture.

■ **DOA** – The main functions of DOA, the largest institution under MOAI, is to transfer appropriate technologies to farmers, develop pest control and land utilization, cooperate and coordinate with DAR for technology dissemination, and distribute quality seeds to farmers. The eight sections under DOA are Extension Division, Planning Division, Seed Division, Land Use Division, Plant Protection Division, Horticulture and Biotech Division, Administration Division, and Finance Division.

■ **AED** – The Extension Division is the largest division under DOA. Under AED, the Plant Protection and Horticultural

[1]MOAI. http://www.moai.gov.mm

Divisions as well as the Plant Biotechnology Laboratory are being operated. Aside from overseeing industrial crops and plantation crops, AED leads in disseminating technology for rice and other major crops to farmers. Its main functions include providing improved agriculture technologies, extending cropping area, planning cropping patterns, identifying agricultural practices suitable for various agro-ecosystems, educating farmers using demonstration plots, producing and distributing quality seeds, and organizing capacity-development programs for DOA staff.

■ **DAR** – DAR is situated in Zeyar Thiri To nship, Nay Pyi Taw. It aims to develop high-yielding crop varieties, generate profitable cropping systems and cultural practices in various agro-ecosystems, and provide farmers with improved varieties and technologies through the Extension Departments. The six sections under DAR are Rice and Other Cereal Crop Division; Oil Seed Crops and Food Legumes Division; Industrial Crops and Horticulture Division; Soil/Water Utilization and Agricultural Engineering Division; Agronomy, Agricultural Economics and Statistics Division; Biotechnology, Plant Genetic Resources and Plant Protection Division.

■ **YAU**[2] – is situated in Zeyar Thiri Township, Nay Pyi Taw, which is about 254 miles from Yangon City. Its mission is to provide agricultural education and develop human resources to increase agricultural production through green growth, provide career as well as business options and produce well-equipped and professionally qualified agriculturists, and contribute to national agricultural research and extension constantly. Its estate is approximately 360 ac, including the campus farm which covers about 102 ac. YAU produces more than 200 graduates from bachelor and graduate programs annually. To date, it has already produced more than 9,000 Bachelor's degree holders, over 300 Master's degree holders, and 20 PhD degree holders. The students choose from nine major crop specializations during their final academic year. These specializations are offered in seven different states and regions in Myanmar. For example, students who intend to specialize in rice and maize as well as other cereal crops will study in Hmawbi, Yangon Region and Aungban, Southern Shan State, respectively. These specializations focus on agricultural education and new systems development; land and crop productivity management; soil and water management; crop eco-physiology and breeding; and promotion of technology transfer and farming systems of related crops. Crop specialization prepares graduates to be experts in sustainable agricultural development and management, especially in their chosen crops.

■ **MADB** – The main tasks of MADB are lending seasonal (short, medium, and long term) loans to farmers, collecting repayments of bank loans, and encouraging farmers to open deposit and saving accounts at MADB. From 2010 to 2011, MADB provided a total of about MMK 197,764.19 in farmer loans. The per-acre loan was increased from MMK 50,000 (about USD 50) to MMK 10,000 (about USD 100) in 2012. Farmers received credit from MADB, with a monthly interest rate of 2 percent, but only to cover less than 50 percent of the total production cost (DAP-MOAI 2013b).

■ **Farmer associations** – At the village level, 10-member farmer groups are organized in each village for dissemination of improved technologies. Each group has 10 farmers from neighboring fields and one leader. The leader serves as the facilitator, who is responsible for conveying the new agro-techniques or varieties during sowing, crop management, and harvesting. The ultimate aim of the farmer group is to create the farmer-led extension service system for agricultural technology distribution.

■ **RSCs** – RSCs and private companies, which are establishing large, high-grade rice mills capable of processing high-quality and exportable rice, are vital in several segments of the rice supply chain. There were 55 registered RSCs at the end of 2011, of which 42 contract-farmed 454,397 ac in monsoon crop (2.7% of total monsoon crop) and 20 contract-farmed

[2]YAU. (http://www.yaummr.org)

228,969 ac in the summer crop (7.4% of total summer crop). Through contract farming, they have provided good and certified seeds, fertilizers, and mechanization services to modern retailers like supermarkets and minimarkets with branded packaged rice. They have also started offering contract mechanization services for land preparation in many areas, mechanized threshing, and to a lesser extent, combined harvesting. For instance, RCSs in Ayeyararwady, Yangon, and Bago West Regions have started farming systems with forward sales contracts as well as provision of adequate loans and inputs to farmers. They plan to plant high-yielding and quality rice of the certified varieties in chosen localities with a strong back-up from seed production. RCSs aim to produce high-quality rice for export and the higher-income domestic market segment (ARDC 2012; Shwe, 2011).

■ **Local associations related to rice production** – The associations related to rice production include the Myanmar Rice Industry Association, Myanmar Paddy Producers Association, Myanmar Rice Millers Association, Myanmar Rice and Paddy Traders Association, and RSCs. They cooperate with farmers by providing the latter with inputs and credit to produce quality rice and enhance competitiveness in international markets.

■ **International cooperation on rice production** – Several internationally funded agricultural grant projects related to climate variability adaptation are currently being implemented. These projects, undertaken in cooperation with MOAI, include funds and technologies as well as capacity building for improved rice production. A number of international cooperation projects on rice production are described in Table 4.

Table 4. International projects on rice production

Name of the project	Location	Amount in USD (million)	Funding source	Duration	Implementing agency
Support to special rice production project	Thazi Yamethin Meiktila Pyawbwe Kalaw	1.55	FAO	June 2009–Nov 2013	DOA
Development of water-saving agriculture technology in the central dry zone	Bagan Nyaung-oo Magway Region	5.00	JICA	2011–2016	DOA
Project on improving machinery for polder and embankment rehabilitation in Ayeyarwady Delta	Latputta Pharpon Kyaiklat Bogalay Dedaye	4.51	JICA	2012–2016	Irrigation Department
Project on improving GAP on rice, vegetables, and fruits	SAI Pyinmana	1.30	Korea Rural Community and Agriculture Corporation	2011–2013	DOA
Project on setting up a rice bio-park	Nay Pyi Taw	0.23	Government of India	2012–2015	YAU
Support to hybrid rice development		0.23	FAO	2013–2014	DOA

Table 4. cont..

Project	Resource	Amount in USD (million)
Unilateral assistance and cooperation		
Quality rice seed	JICA, Japan	4.8 M
Flood control	JICA, Japan	14.51 M
International NGOs		
Seeds, inputs, and extension	International Volunteers Service Association	1.8 M
Irrigation and inputs in eight townships in Mandalay Region, Ayeyarwady Region, Shan State, and Rakhine State	Consortium Dutch NGOs (Netherlands)	3.3

Source: DAP-MOAI 2013b.

IV. AREAS FOR REGIONAL COLLABORATION

Many areas in regional collaboration are needed for sustainable production and improving farmers' income in Myanmar, especially in rice and maize production.

4.1 Institutional Capacity Building

DOA extension service personnel are primarily responsible for transferring technology to farmers through agricultural extension on crop cultivation practices, appropriate cropping patterns, provision and proper utilization of agricultural inputs, and systematic plant protection practices. Large-scale demonstration plots and block-wise crop production zones are often launched at the entrance and/or exist in each township. The field days are occasionally organized to disseminate the appropriate agro-techniques, use of new crop varieties, and organic and bio-fertilizers applications, among others. New varieties (e.g., high yielding, short duration, and flood- or drought-tolerant) are tested at suitable DAR satellite farms where farmers are invited occasionally to see the yield trials of demonstration plots. The knowledge and skills of staff from DOA, DAR, and the private sector need to be promoted through capacity-building programs.

4.2 Seed Production and Distribution Systems

Seed development activities are being carried out by DAR and the Seed Division (SD) under DOA according to the proper seed flow procedure. DAR produces the Nucleus Seed and the Breeder Seed (BS), and SD multiplies BS to produce the Foundation Seed (FS) and the Registered Seed (RS) at 34 Seed Farms to maintain the genetic purity of the variety. SD produces the Certified Seed (CS) through AED together with farmer cooperators (contract farmers). Finally, agricultural extension staff from each township distributes CS to farmers (Shwe 2011). Farmer-to-farmer distribution is also practiced.

Seed farmers under MOAI produced 0.17 million baskets and 0.11 million baskets of quality and high-yielding paddy (i.e., CS) in 2011–2012 and 2012–2013, respectively. Seed Model Villages, contract farmers, and private companies throughout the country produced 3.9 million baskets and 4.6 million baskets of CS in 2011–2012 and 2012–2013, respectively (DOA-MOAI 2013a).

As famers generally cannot maintain the purity of rice varieties by themselves, quality seeds should be substituted every three years for rejuvenating purposes. Myanmar's seeds sector is at a much earlier stage of development compared to other Asian countries. The challenges include the absence of a seed policy and the research system's inability to ensure an adequate flow of improved crop varieties, among others. Currently, CS is estimated to reach somewhere between 5 percent and 10 percent of the total rice area (FAO 2004). The production of purified/certified seeds should include public-private partnership, and crop variety programs and good practices in seed production should be shared and developed through regional cooperation. These will aid in making Myanmar's existing programs and activities more effective in scaling up the production of quality seeds that are tolerant to unfavorable climate conditions.

4.3 Water Resource Management

Water resource management, one of the main factors in maintaining increased crop production, is poorly managed in Myanmar agriculture. The development of water-saving agricultural technology in the central dry zone, and the improvement of polder and embankment rehabilitation in flood-prone areas in lower Myanmar (e.g., Ayeyarwady and Bago Regions), should be considered. Preventive measures for flood- and drought-prone areas are highly important for sustainable production in affected areas. There are several existing methods of irrigation available to farmers in drought-prone and water-deficit areas, such as extraction of underground water, shallow and deep tube wells irrigation, and water pumping from rivers. The short- and long-term advantages and disadvantages of these systems should also be assessed. Land degradation, salinity problems, and reduction in underground water sources are current and future challenges in water resource management, which will undermine sustainable production.

4.4 Production Technology Improvement

In Myanmar, current production technologies, such as use of inputs, sowing practices, and crop management practices, need to be updated to achieve sustainable production. Compared to neighboring countries, major crop productivity in Myanmar is very low. This can be overcome and solved through collaboration with other AMS. Examples of good practices and lessons learned from neighboring countries will accelerate the transformation of conventional practices into CCA. SRI, climate-smart agriculture, and sustainable development of crop land management need to be promoted.

4.5 Good Marketing System

Myanmar should make strenuous efforts to make its products (e.g., rice and seed maize) competitive in international markets. It is commonly noted that the country's milling, processing, and overall supply chain infrastructure is relatively poor. Myanmar Agricultural Product Trading Enterprise estimated that in 1994, there were 2,189 registered mills, with an estimated milling capacity of 50,000 t per day. The average milling recovery ranged from 45 percent to 65 percent, depending on mill type and paddy quality. Approximately 80 percent of the rice mills were small-scale with old technology. There were also very few rice processing plants (FAO 2004). It resulted in a high percentage of mill losses and poor rice quality, which is priced low in international markets. With regional collaboration, infrastructure development as well as the marketing networks can be improved to increase profits from agricultural products.

V. CASE STUDIES ON GOOD PRACTICES

5.1 Rice

5.1.1 Application of Good Agricultural Practices in Rice Production

Rice has been cultivated in Myanmar since prehistoric times. Before World War II, Myanmar became the largest rice exporter in the world. Rice area and production declined during the post-war era and has since failed to reach the levels achieved during the pre-war period. Rice production is increasing mainly due to area expansion rather than yield increase per unit area. As an important crop for home consumption and export, Myanmar designated rice as a national crop with a target yield of 5.2 t/ha (DAP-MOAI 2013a). In the phase of climate change, the country has been experiencing the negative impacts of floods, droughts, and high temperature, among others. The rice sown area, harvested area, and yields decline almost every year.

MOAI introduced the application of GAP as a policy in 2008–2009. To meet the target yield and production, suitable areas were selected from various states and regions. These areas were assigned to apply GAP in rice cultivation yearly, and the sown areas were extended year after year. In 2010–2011, GAP was applied to about 3 percent of the total sown areas of monsoon rice. In 2014–2015, 41.69 percent (2,134,389 ha) of the total sown area of monsoon rice (5,120,220 ha) were cultivated using GAP (Table 5). The application of GAP is more feasible in areas where irrigation and drainage are operated easily. DOA extension workers are currently striving to promote the farmers' adoption of GAP in monsoon rice and summer rice production (DOA-MOAI 2014).

The implementation of GAP is successfully in progress through the collaboration of DAR, YAU, AED of DOA, and model farmers. In 2011, MOAI set 14 guidelines for GAP in rice cultivation (New Light of Myanmar 2011). Among the guidelines, farmers mainly focus on the alternate wetting and drying technique for water management. They choose lands that are more suitable for proper water management of irrigation and drainage. The guidelines for GAP are also in line with SRI, which includes the following characteristics, among others:

- age of seedlings: young seedlings are transplanted at 8–12 days
- number of seedlings: 1–2 seedlings per hill are transplanted to a shallow depth of 1–2 centimeters (cm)
- spacing of plants: hills have a wider spacing of 20–30 cm
- water management: non-flooded aerobic soil conditions with intermittent irrigation
- weed and pest control: manual weeders can remove weeds and aerate the topsoil simultaneously; IPM practices are encouraged
- soil fertilization: organic matter is preferred to the extent feasible, but may be complemented with synthetic fertilizers

Table 5. GAP application in monsoon rice cultivation, 2014–2015

Region/State	Total monsoon rice sown area (ha)	Sown area with applied GAP (ha)	GAP area (%)
Nay Pyi Taw Council Area	32,321	12,615	39.03
Kachin	162,956	39,095	23.99
Kayah	32,551	11,279	34.65
Kayin	182,971	53,839	29.43
Chin	36,817	240	0.65
Sagaing	322,044	72,484	22.51
Tanintharyi	85,280	13,827	16.27
Bago	1,014,696	687,307	67.74
Magway	161,651	60,414	37.37
Mandalay	58,028	5,739	9.89
Mon State	269,866	38,233	14.17
Rakhine State	388,385	86,326	22.23
Yangon	461,839	158,326	34.26
Shan	492,619	153,904	31.24
Ayeyarwady	1,418,195	740,804	52.24
Union Total	5,120,220	2,134,389	41.69

Source: Annual Report, AED, DOA (2014–2015)

Among the GAP guidelines, farmers mainly focus on the Alternate Wetting and Drying (AWD) technique for water management, choosing lands that are more suitable for proper water management of irrigation and drainage. The traditional practice of growing rice in continuously flooded fields consumes a disproportional amount of water compared to other crops. Appropriate use of AWD offers considerable savings in water use during the rice-growing season without reducing crop yield (Lampayan et al., 2015).

Alternate Wetting and Drying also offers mitigation co-benefits through its capacity for reducing greenhouse gas (GHG) emissions, specifically methane, relative to traditional lowland rice cultivation. The combination of continuously flooded soils and the organic-rich rice paddy environment provides the ideal conditions for anaerobic bacteria to decompose organic matter, thereby producing methane as a byproduct. Proper implementation of AWD requires farmers to drain rice fields to the extent that soils become oxygenated, while still maintaining sufficient soil moisture to support optimum plant growth. The partial draining, however, is enough to inhibit the methane-producing bacteria and thus reduce methane emissions by 30-70% (Richards and Sander, 2014).

The application of GAP offers benefits that have significant climate adaptation potential, if applied on a large-scale, including: reduced demand for water and reduced methane gas emissions through Alternate Wetting and Drying; and increased yields, and reduced use of nitrogen fertilizers through SRI

In addition, rice plants that are grown using GAP have stronger stems and root systems that are more resistant to flooding and storm damage, compared to those grown using conventional practices. Their deeper root systems also make them more resistant to drought. Water for agriculture is becoming increasingly scarce, and climate change-induced higher temperatures will further augment crop water requirement. This will lead to more severe water shortages in the future. The application of GAP is more relevant to irrigated lands, where the irrigation and drainage systems are operated easily.

Apart from the efforts of MOAI, several non-government organizations (NGOs) and international NGOs (INGOs) are endeavoring to promote SRI in their project sites. A case study was done in Bogale and Mawgyun Townships, Ayeyarwady Region on the SRI initiative of Groupe de Recherches et d' Echanges Technologiques (GRET), a French INGO that engages in research and technology exchange. The Ayeyarwady Delta is known as the rice bowl of Myanmar because it is the largest area of rice production in the country. It is also famous for producing high-quality fragrant rice for domestic consumption and export.

In May 2008, Cyclone Nargis devastated the Ayeyarwady Delta. More than 2.4 million people were affected, wherein 138,000 died; over 33,500 were seriously injured; and approximately 800,000 were displaced. Myanmar's agriculture was severely damaged as the floods submerged more than 783,000 ha of rice fields. Over 85 percent of seeds were lost and 50 percent of draft animals died. Most of the people living in the Delta region are farmers, fishermen, or laborers (Shifflette 2011). More than five years after Nargis, the village economy remains depressed in spite of support from government agencies, local NGOs, INGOs, and donors. The livelihood security of rural households, especially in agriculture, is still unstable.

In 2011, monsoon rice was assessed in 70 village tracts with 620 households in Bogale and Mawgyun Townships. Most of the farmers sowed by broadcasting, and prepared the land using machines and hand tractors because draft animals declined after Nargis. Only about 8 percent of the sample farmers in the five villages prepared the land using their own buffalos (BATWG-GRET 2012).

The farmers in the project area gradually adopted the SRI techniques that GRET introduced, especially using young seedlings, applying fertilizer, and weeding. Most farmers adopted transplanting by hand instead of using sticks. Some farmers did not follow the recommended spacing. Instead of transplanting just one seedling, some farmers planted 3–5 seedlings. Compared to the broadcasting method, the farmers observed that yields increased when the transplanting method was applied. Most of the expenditures (e.g., for seeds, chemical fertilizers, and pesticides) were also reduced. The assessment showed that SRI techniques can harvest an average of 85 baskets/ac, while broadcasting can harvest an average of 57 baskets /ac for monsoon rice.

According to the survey, the farmers faced some constraints with SRI such as flooding, labor problems, and insufficient investment. Approximately 80 percent of the respondents previously practiced transplanting with stick in 235 ac of paddy fields. After the project, only 18 percent of the respondents continued using the method, while the rest shifted to transplanting 2–3 seedlings per hole. All respondents from the freshwater area completely shifted to transplanting monsoon paddy by hand (Emilie 2010).

Intermittent irrigation can control weed growth and pest infestation. Economic analysis also showed that SRI techniques require a lower investment but generate a higher profit than broadcasting. Farmers previously used 3–4 baskets/ac for broadcasting, but now they can reduce their seed rate to less than 1 basket/ac through SRI. The number of households, cultivated acres, and yield per acre using different cultivation methods are presented in Table 6.

Table 6. Rice sowing methods in project villages in Bogale and Mawgyun Townships, monsoon season, 2011

Sowing method	No. of households	Acres	Yield (basket/ac)
SRI	198	509	56.34
Broadcasting	427	3,522	37.28
Transplanting by stick	416	2,980	43.80
Total no. of households	620	7,424	35.55

Source: BATWG-GRET (2012)

5.1.2 Changes in Crops and Cropping Patterns

In March 2014, the farmers in selected villages in the dry zones of Yamethin Township, Manadalay Region were surveyed about their CCA strategies. Many village community ponds, dams, and reservoirs were built in Myanmar during the Burmese king era to irrigate rice fields in the central dry zone, where it is impossible to produce rice without irrigation given their geographic characteristics. Rice production used to be very successful with these well-developed irrigation systems. As this region is often affected by drought, which is compounded by weak management and renovation, rice production dwindled. Many irrigated fields have been converted to rainfed fields because of low rainfall and degrading catchment areas, among others. These age-old dams and reservoirs have poor storage capacity because of long-term siltation. Rice production is now often less than the target values, and many areas are known to have saline soils.

There are 23 dams and ponds for rice irrigation in Yamethin Township, which has 68 village tracts and 246 villages. Thitsone Dam, Kyeni Pond, and Katin Pond, which are considerably large, can irrigate about 5,000 ac each. Other dams and ponds can irrigate affected areas of less than 500 ac. The water inflow in many of these dams and ponds has decreased significantly since 2010. Many of these dams no longer meet the irrigation needs of their targeted areas. From 2009 to 2010, farmers were provided with small-scale irrigation facilities (shallow and deep tube wells), sunflower seeds, and other inputs through a project funded by the Organization of the Petroleum Exporting Countries (OPEC). The Association of Volunteers in International Service (AVSI) provided five tube wells to each of the 25 villages of Yamethin Township, with each tube well covering five farmers. Some farmers have had their private shallow or deep tube wells for 10–15 years (DOA, Yamethin Township 2014).

The rainfall pattern in Myanmar's central dry zone is diurnal, with drought occurring in July. Based on 21-year data on annual rainfall in Yamethin Township, rainfall fluctuated between 1993 and 2013, while severe drought was observed in 1998, 2009, and 2012 (Figure 3). Based on a 20-year -average comparison of monthly rainfall in the area, the total rainfall was lowest in 2012 (5,260 mm) and highest in 2013 (9,454 mm). The lowest rainfall during monsoon season was recorded in July (521 mm in 2012 and 511 mm in 2013). The rainfall amount in 2012 and 2013 was lower than the 20-year average rainfall amount (820 mm).

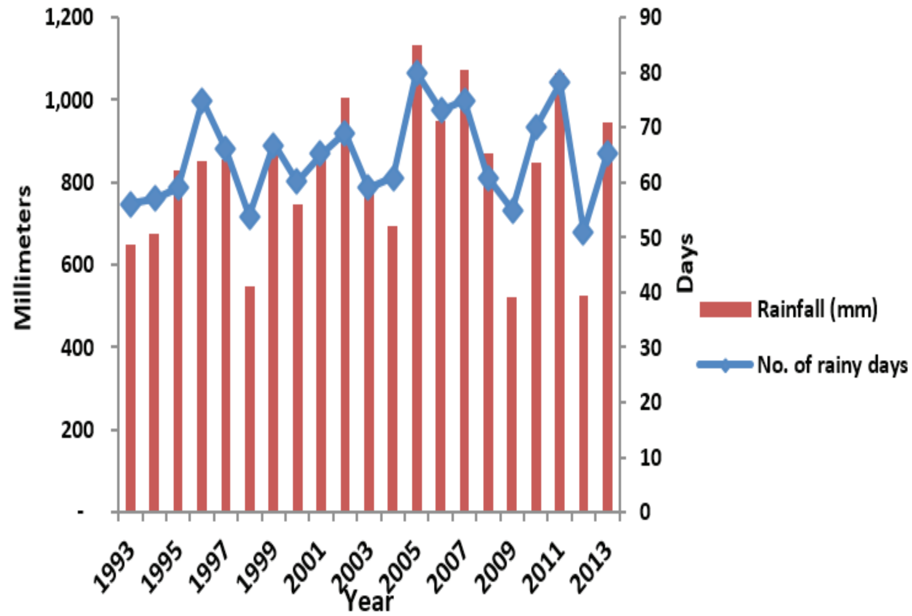

Figure 3. Annual rainfall and number of rainy days in Yamethin Township
Source: DOA, Yamethin Township (2014)

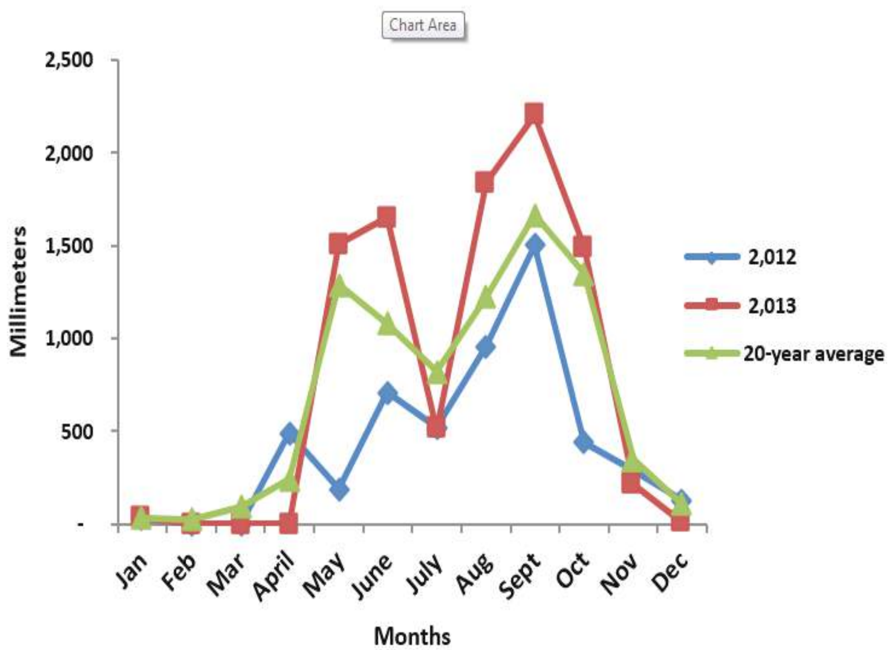

Figure 4. Comparison of monthly rainfall in Yamethin Township
Source: DOA, Yamethin Township (2014)

■ **Changing crops** – Data on crop production for 2000–2013 were recorded annually at DOA and SLRD offices in Yamethin Township, where the most common cropping pattern is rice-based (e.g., monsoon rice, sunflower, and mungbean). The monsoon rice harvested areas were smallest in 2009–2010 (8,705 ha ac) and 2010–2011 (11,034 ha in), and largest in 2007–2008 (24,548 ha) and 2008–2009 (22,852 ha). Similarly, rice production fluctuated during these years. These findings agree with the rainfall data of Yamethin Township, which show that drought was severe in 2009 and 2012. Farmers changed their crops because of infrequent rainfall and inadequate water from dams and ponds. They substituted paddy with sunflower or mungbean. Data on harvested area and production during the 13 years are presented in Figure 5.

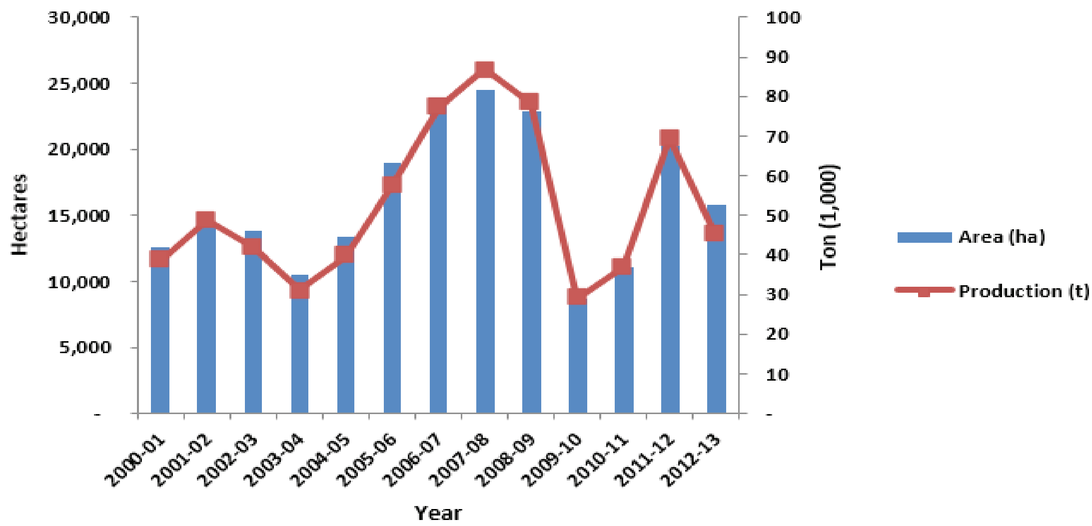

Figure 5. Annual monsoon rice production in Yamethin Township
Source: *DOA, Yamethin Township (2014)*

Mungbean areas during the monsoon season increased gradually from 356 ha in 2000–2001 to 18,554 ha in 2011–2012 (Figure 6). Mungbean production was also highest in 2010–2011 (20,064 t). Production declined significantly in 2011, 2012, and 2013, while harvested areas decreased in 2012–2013. The yield per acre decreased by approximately 50 percent (about 5–7 baskets from the normal yield of 10–14 baskets). According to the farmers, the monsoon came late and the area suffered severe drought in July, which disrupted the vegetative growth and seed setting of mungbean. These findings coincide with the very low rainfall in May and July in 2012 and 2013 (Figure 6).

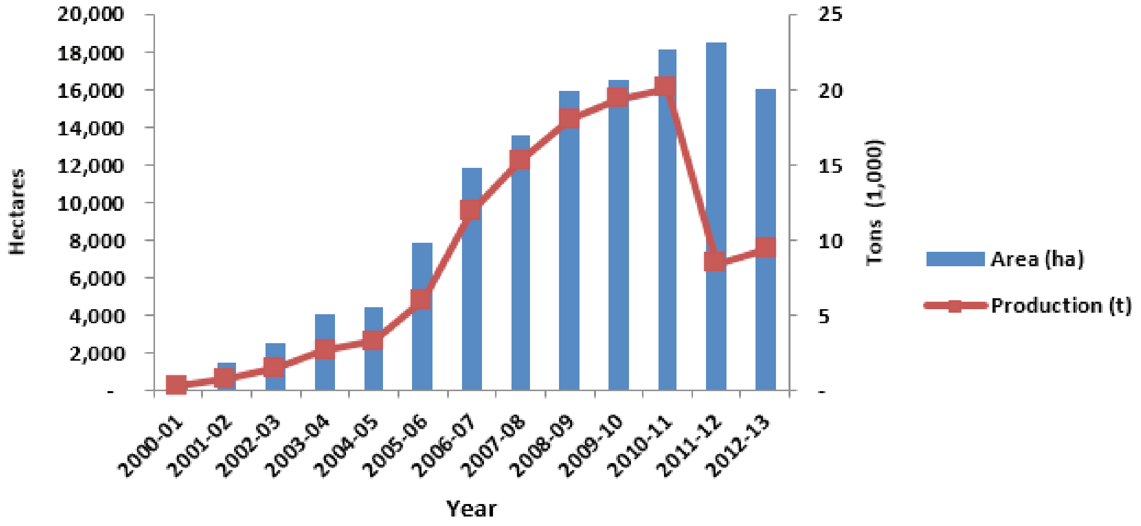

Figure 6. Annual monsoon mungbean production in Yamethin Township
Source: DOA, Yamethin Township (2014)

Mungbean production increased because of the high export demand for pulses in the open market economy of Myanmar and the farmers' conversion of many rice areas into mungbean areas. In years with regular rainfall before 2010, rice was grown during the monsoon season as a single crop. At present, rice areas are declining because some fields are left fallow and others are cultivated with sunflower or mungbean.

Sown and harvested sunflower areas during the monsoon season were more or less the same, except in 2004–2005 when the areas were smallest at 2,205 ha. Production after 2005–2006 increased significantly due to the use of quality seeds and improved farming technologies through the OPEC-funded project. However, production decreased significantly in 2011–2012 and 2012–2013 because of severe drought in July, which disrupted the vegetative growth and reduced the yield of sunflower (Figure 7).

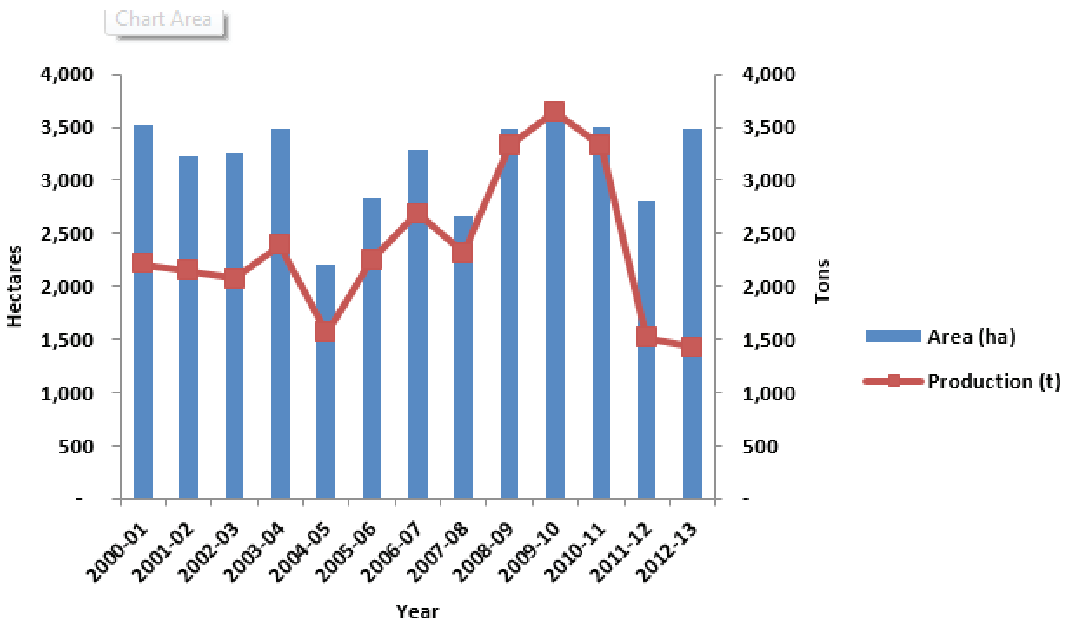

Figure 7. Annual monsoon sunflower production in Yamethin Township
Source: DOA, Yamethin Township (2014)

In a comparison of sown areas of three crops in Yamethin Township from 2000 to 2013, several patterns were observed. Rice area fluctuated and eventually declined, mungbean area constantly increased, and sunflower area almost remained constant (Figure 8).

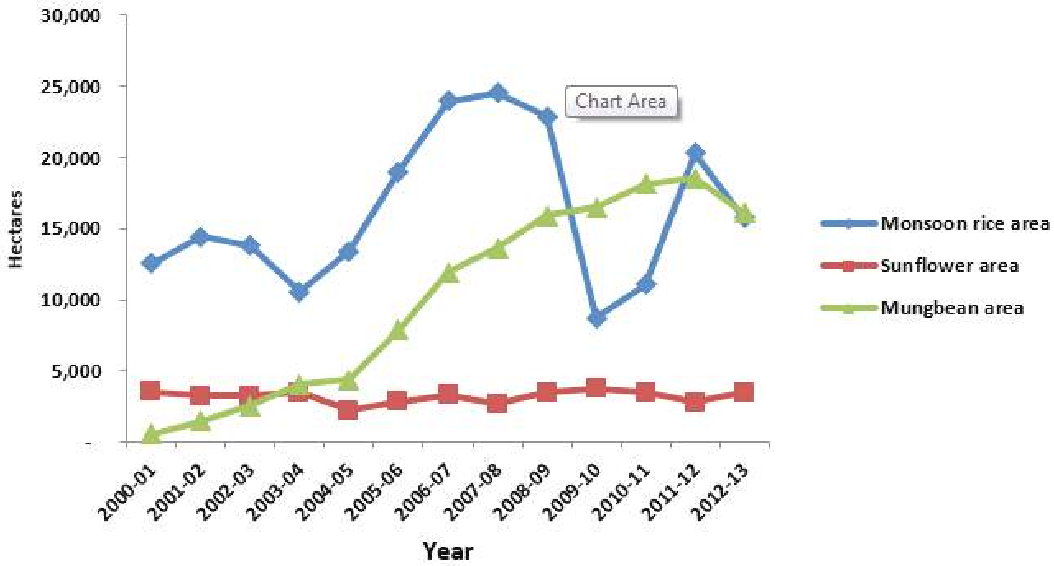

Figure 8. Annual sown areas of major monsoon crops in Yamethin Township
Source: DOA, Yamethin Township (2014)

- **Changing cropping patterns** – Intercropping, mix-cropping and double cropping are the traditional coping strategies of dry zone farmers to climate variability (Swe 2011). Double-cropping is a general cropping pattern in Yamethin Township. The first crop is grown during the early monsoon, while the second crop is grown during the mid- or late monsoon. The common cropping combinations include (1) rice and chickpea or sunflower; (2) mungbean and rice, chickpea, sunflower, or cotton; and (3) sesame and mungbean or groundnut, among others. Rice production was damaged successively from 2010 to 2013. Based on interviews with the farmers, it was found that rice was more severely damaged by drought compared to upland crops. Therefore, the farmers rely more on upland crops such as sunflower, mungbean, and chili.

The farmers in Yamethin Township usually practice about 10 cropping patterns in irrigated areas for all cropping seasons in a year. All cropping patterns in this area used to be rice-based; however, in 2013–2014, it was observed that only four of the cropping patterns were rice-based. The farmers said that they often experienced droughts, delayed monsoons, low rainfall, and irregular rainfall distribution during 4–5 successive years. As such, they were unable to grow rice during the monsoon season. In 2013–2014, upland crops (e.g., sunflower, mungbean, and groundnut) were planted instead of monsoon rice. The changes in cropping patterns for irrigated areas in Yamethin Township in 2013– 2014 are described in Table 7.

Table 7. Changes in cropping patterns for irrigated areas in Yamethin Township, 2013– 2014

Former cropping patterns	New cropping patterns (2013–2014)	Area (ha)
Monsoon sunflower – monsoon rice	Monsoon sunflower – monsoon rice	121.41
Monsoon mungbean – monsoon rice	Monsoon mungbean – monsoon rice	242.82
Monsoon rice – post-monsoon sunflower	Monsoon rice – post-monsoon sunflower	222.58
Monsoon rice – chickpea	Monsoon rice – chickpea	199.92
Monsoon mungbean – monsoon rice	Monsoon mungbean – cotton	1,704.57
Monsoon mungbean – monsoon rice	Monsoon mungbean – chickpea	2,832.86
Monsoon sesame – monsoon rice	Monsoon sesame – post-monsoon mungbean	3,399.43
Monsoon sesame – monsoon rice	Monsoon sesame – post-monsoon sunflower	4,127.88
Monsoon sesame – monsoon rice	Monsoon sesame – post-monsoon groundnut	1,785.51
Monsoon mungbean – monsoon rice	Monsoon mungbean – post-monsoon groundnut	885.47
TOTAL		15,522.46

Source: DOA, Yamethin Township, Mandalay Region (2013)

■ **Cropping patterns suggested by DOA** – In September 2013, the Cropping Pattern Section of DOA organized a meeting of extension staff from various states and regions at the Nay Pyi Taw Minister's Office to review the existing cropping patterns in specific agro-climatic regions in the 2013–2014 growing season (DOA, Nay Pyi Taw 2014). They discussed that under the climate change phenomenon, the farmers have experienced less rainfall (i.e., late arrival and early withdrawal of monsoon rains; and very erratic rainfall in terms of space, time, and distribution). In both irrigated and rainfed lowlands, a rice-based cropping pattern was dominant, whiledouble- and triple-cropping were practiced in some areas. It was noted that summer rice could not grow well even in irrigated areas. It should be substituted with sesame and mungbean, which have a shorter growth period and lower water requirement. Possible cropping patterns that were more suitable for current climatic conditions in irrigated, rainfed lowland, and rainfed upland areas were suggested.

The following are examples of cropping patterns in Mandalay Region (DOA, Nay Pyi Taw 2014):

(1) Current cropping patterns in irrigated areas: monsoon paddy – chickpea – summer paddy; monsoon paddy – black gram – summer paddy; and monsoon paddy – winter sesame – summer paddy

(2) Cropping pattern modifications required in irrigated areas: monsoon paddy – chickpea + sunflower – summer paddy; monsoon paddy –chickpea + sunflower – summer sesame; monsoon paddy – black gram – summer sesame; monsoon paddy – groundnut + sunflower – summer sesame; and monsoon paddy – chickpea – pre-monsoon + green gram;

(3) Suitable double-cropping or intercropping patterns in rainfed areas: monsoon paddy – sunflower; monsoon paddy – chickpea + sunflower; and monsoon paddy – groundnut + maize

(4) Suitable double-cropping or intercropping patterns in upland areas: monsoon sesame – chickpea + sunflower; pigeon pea – sesame; mungbean – post-monsoon cotton; and monsoon green gram – winter sunflower.

5.1.3 Production of Climate-resilient Varieties

DAR has carried out rice varietal development programs in Yezin, Nay Pyi Taw. The Rice Section, under the Rice and Other Cereal Crops Division of DAR, is responsible for these programs. IRRI has been introducing rice breeding materials to Myanmar since the late 1960s, when their collaboration began. The Rice Section staff is in charge of selecting which materials to use. The breeding methods applied are introduction, indigenous selection, hybridization and selection, mutation, and tissue culture. Systematic multiplication yield trials and dissemination of several HYVs and improved varieties are released yearly.

In 1975–1976, HYVs were gradually increased to substitute local varieties. In 2012 - 2013, HYV areas were 76.4 percent, while the local varieties were 23.6 percent of the total rice sown area of the country (Table 8) (DAR-MOAI 2014).

Table 8. Rice area changes by varietal group

Year	Total rice area (M ha)	HYVs (%)	Local varieties (%)
1967–1968	4.94	0.10	99.9
1975–1976	5.20	8.00	92.0
1979–1980	5.03	26.0	74.0
1980–1981	5.13	41.0	59.0
1986–1987	4.85	49.0	51.0
1988–1989	4.78	52.0	48.0
1999–2000	5.15	70.0	30.0
2001–2002	5.29	71.0	29.0
2010–2011	6.79	75.8	24.2
2011–2012	6.53	76.2	23.8
2012–2013	6.29	76.4	23.6

Source: Annual Reports, AED, DOA (2013)

Under IRRI's Consortium for Unfavorable Rice Environments (CURE) Project, DAR is currently producing climate-resilient varieties suitable for unfavorable ecosystems in Myanmar. The selection criteria are early to medium duration, medium plant height, medium tillering ability, tolerance to pests and diseases, and acceptable eating quality. Up until 2008, DAR released nine drought-tolerant and four salinity-tolerant rice varieties.

DAR is also developing submergence-tolerant rice varieties for flood-prone areas. The selection criteria are medium- to late-maturing varieties, with a yield of 60–70 baskets/ac; tolerant to 7–12 days of submergence; and resistant to logging. The introduced lines, such as Swarna, Swarna Sub-1, and local resistant varieties (e.g., Tharpound-meekauk and Meegauk- dume) were tested in on-station and on-farm trials. Swarna Sub-1 was tested on-station at Yezin, where it survived 100 percent at 10 days of submergence. Swarna Sub-1 and local variety Meegauk-dume survived flooding thrice on-farm at Pathein and Ngwesaung. As of 2012, DAR has released eight varieties of deepwater rice and one submergence-tolerant variety to these flood-prone regions (DAR-MOAI 2014).

DAR released 99 rice varieties through rice breeding and varietal development programs from 1967 to 2013 (DAR-MOAI 2014). Irrigated rice, followed by rainfed lowland rice, had the highest number of varieties (Table 9). Among irrigated and lowland rice varieties, it was noted that 12 varieties were widely grown on 56 percent of total rice sown areas in 2008.

Table 9. Rice varieties released by DAR for various rice ecosystems

Agro-ecosystems	No. of varieties released
Irrigated rice	36
Rainfed lowland rice	34
Upland rice	4
Quality rice	4
Drought-tolerant rice	8
Salinity-tolerant rice	4
Deepwater rice	8
Submergence-tolerant rice	1
Total	99

Source: Rice Section, DAR. MOAI, Nay Pyi Taw (2014)

DAR has ongoing collaborative projects with other organizations, including the CURE Project, wherein its Rice Section works primarily with IRRI; Irrigated Rice Research Consortium; International Network for Genetic Evaluation of Rice; and the project Development of Participatory Multiplication and Distribution System for Quality Rice Seed, which is funded by the Japan International Cooperation Agency (JICA) (JICA 2013). The following are current and recent R&D activities on rice seed production:

- **CURE Project** – The Rice Section of DAR has been striving to produce rice varieties that are suitable for unfavorable rice environments through IRRI's CURE Project since 2005. The program includes breeding better rice varieties with beneficial traits such as tolerance to drought, salt, and submergence. Through CURE, DAR is helping farmers upgrade their agricultural practices and find suitable varieties for their fragile ecosystems. DAR has conducted research within multidisciplinary working groups, covering critical drought-prone, submergence-prone, and salt-affected environments as well as upland systems.

Pilot site activities also include monitoring the performance of the submergence-tolerant variety Swarna Sub-1 distributed to farmers. Staff from DAR, DOA, Food and Agriculture Organization (FAO), AVSI, and Oxfam International, as well as farmers from various project villages, underwent Participatory Varietal Selection and Participatory Analysis (PVS-PA). PVS and Sensory Evaluation (PVS-SE) of selected rice varieties was conducted with the partners after the rice harvest. About 40–80 farmers actively participated in every activity. The varieties that the farmers selected during Participatory Varietal Selection (PVS) were further tested under farmer management in "baby" trials in the subsequent seasons. CURE supported the activities by assisting in planning and seed distribution to capture the salinity gradients as well as the likelihood of flooding. Results showed that Swarna Sub-1 produced better yield and was less affected by flooding than the farmers' variety. Swarna Sub-1 produced 4.45 t/ha and 3.01 t/ha at 4 days and 12 days of flooding, respectively. There was a 0.180 t/ha decrease per day in 4–12 days of flooding. The farmers' variety produced 3.97 t/ha and 2.14 t/ha at 4 days and 12 days of flooding, respectively. There was a 0.23 t/ha decrease for each extra day of flooding in 4–12 days, or a yield decline of 50 kg/ha/day more than Swarna Sub-1. The farmers generally appreciated the plant and grain type of the Swarna Sub-1. Swarna Sub-1 seeds amounting to 500 baskets (10.5 t) were distributed to 500 farmers in Ayeyarwady and Bago Regions for the monsoon season in 2014.

■ **Livelihoods and Food Security Trust Fund (LIFT)-IRRI Program (A)** – LIFT-IRRI has been implementing the program Reducing Risks and Improving Livelihoods in the Rice Environments of Myanmar through Better Targeting of Management Options in partnership with DAR, DOA, Welthungerhillfe, GRET, and Mercy Corps. The program began in 2012 and will run until 2015.

■ **LIFT-IRRI Program (B)** – From 2012 to 2014, LIFT-IRRI implemented the program Improving Livelihoods of Rice-based Rural Households in the Lower Region of the Ayeyarwady Delta in partnership with DAR, DOA, Welthungerhillfe, GRET, Mercy Corps, and Proximity Designs. It aimed to improve food security and livelihoods of 1,500 rice-producing households in the lower delta through the promotion of new practices and varieties of rice.

IRRI scientists worked closely with local and national government agencies and NGO partners to provide technologies for smallholder farmers in rice-based farming systems in the lower Ayeyarwady Delta. IRRI provided technical advice, assistance in establishing new cultivation techniques, and training support on adaptive research on these new techniques. DAR provided access to rice varieties developed previously through collaboration with IRRI rice breeders.

Improved rice varieties are poorly adopted because information on such varieties is lacking and good-quality seeds are difficult to access. LIFT-IRRI Program (B) has made information dissemination possible through the combined efforts of implementing partners, breeders, agronomists, social scientists, and agricultural extension workers in reaching farmers.

The new varieties tested via the PVS process are grown following the farmers' exposure to new and best practices. The farmers' role is a primary interest in this study as they are the target end-users of technologies being developed for unfavorable rice environments. Through their direct participation in the PVS and baby trials, there is a greater likelihood that they will adopt new varieties. The approach has potential environmental benefits because the new varieties will be more tolerant to salt stress, which will minimize the need for external chemical amendments (IRRI - Myanmar Report 2014).

■ **Development of Participatory Multiplication and Distribution System for Quality Rice Seed** – MOAI has been implementing the project, which started in 2011 and will run until 2015, in cooperation with JICA. The overall goal is for farmers to widely use the quality rice seed in Myanmar. Pilot project sites include Hinthada Seed Farm (DAR Satellite Research Farm), Myaungmya Research Center (DAR Satellite Research Farm), and Hmawbi Rice Research Center (under DOA). Through the project, participatory multiplication and a distribution system for quality rice seed will be established in the Ayeyarwady Delta area and the Ayeyarwady Region.

The activities include capacity building for DAR staff on BS and FS production; for extension staff on seed production, distribution, monitoring, and quality control; and for farmers on CS production techniques. The project also supports the improvement of facilities in the pilot Seed Farms (JICA 2013).

The outputs of the project are

- improving DAR's capacity in BS and FS production;
- improving DOA's capacity in planning the production and distribution of quality rice seed and quality control; and,
- improving project-site farmers' capacity in quality rice seed production (including some rice seed production companies).

For output A, DAR has been handling BS and FS purification programs since January 2012, when the grade of BS purity on nine varieties and the pedigree selection of Sinthukha and Yadanatoe varieties were conducted. Moreover, the project supported the improvement of facilities by providing laboratory equipment, agriculture machineries, and threshing floors (e.g., shelters and cement floors) to DAR, Yezin, and Myaungmya Research Center.

For output B, FS and RS purification programs have been conducted in Hmawbi Rice Research Center, wherein quality control measures were practiced. Field inspection trainings were undertaken from August to October in 2012, and extension staff inspected 150 farmers in three project townships. Moreover, training sessions on operation and maintenance of post-harvest machineries were conducted. Laboratory, equipment, and farm machineries were supplied to Gyogon seed laboratory, Hmawbi Rice Research Center and Hinthada Seed Farm.

For output C, aside from the staff of DAR, seed farms, and research centers, DOA extension staff from Myaungmya and Hmawbi participated in CS multiplication training in 2012. Approximately 60 staff members were trained in quality control measures. Under intensive guidance from newly trained extension staff, 150 selected farmers grew CS, of which 64 passed both field inspection and laboratory tests. Extension staff and farmers could share their experiences through training and feedback (DAR-MOAI 2014).

5.2 Maize

Next to rice, maize is the second most important cereal in Myanmar. It is mainly used for local animal feed and export. Maize sown areas increased to over 327,000 ha in 2007 from about 133,000 ha in 1999. Similarly, the production rose to 1 million t in 2007 from 194,000 t in 1999. This growth is explained by both area expansion and yield per acre, which are mostly attributed to the adoption of hybrid maize varieties. Hybrid maize has expanded rapidly in recent years in response to high demand for animal feed, notably from China and Thailand. However, overall maize productivity is still considered low as production faces several agronomic and input constraints common in many other countries, such as seed degeneration and unavailability, increased seed and fertilizer costs, and poor advisory and extension systems, among others.

In 2012–2013, the total maize sown area was 418,479 ha, with a yield of 3.64 t/ha and production of 1,524,298 t. Maize is commonly cultivated during the monsoon season in rainfed conditions. Maize cultivation is 364,983 ha (87% of the total sown area) in the monsoon season and 53,496 ha (13% of the total sown area) in the winter season. Cultivated areas of hybrid and local varieties are 84 percent and 16 percent of total sown areas, respectively. To date, there is no information regarding severe pest and disease infestation as well as serious weather-related yield loss in maize production (DOA-MOAI 2013).

5.2.1 Maize Production in the Lowlands/ Flatlands

This section describes maize production in Tatkone Township, Nay Pyi Taw Council Area. Maize production has increased during the last ten years due to high market demand. Most of the farmers prefer hybrid varieties of the CP Company, such as 888 (120 days), 301 (110 days), 101 (115 days), and 989 (120 days). The CP-888 variety is mostly cultivated because it is more tolerant to drought than the other varieties. According to a maize seed dealer, the demand for maize seeds is increasing, while that of foliar fertilizers for mungbean is decreasing. The market price and demand are more stable for maize than mungbean. Maize is exported to China through the Muse border trade. Therefore, farmers prefer to grow maize than pulses.

Tatkone Township was well known as a large producer of maize production up to 2004–2005. However, for approximately a decade, the sown area has been decreasing due to insufficient rainfall. Aside from the bad weather, farmers also focused on mungbean cultivation because the crop draws a good price and also has a high market demand. Farmers have now started to grow maize again because the price of mungbean is becoming low. Therefore, the farmers' choice of crops partly depends on the commodity price.

In Tatkone Township, the maize sown area declined significantly after 2004–2005 (Figure 9). The area increase was not substantial during the last three years, but production significantly increased. It was mainly due to the use of high-yielding CP varieties and proper technology, such as the use of appropriate amounts of chemical fertilizers. Maize sown in Naungcho gradually increased compared to the constant condition in Tatkone Township (Figure 10).

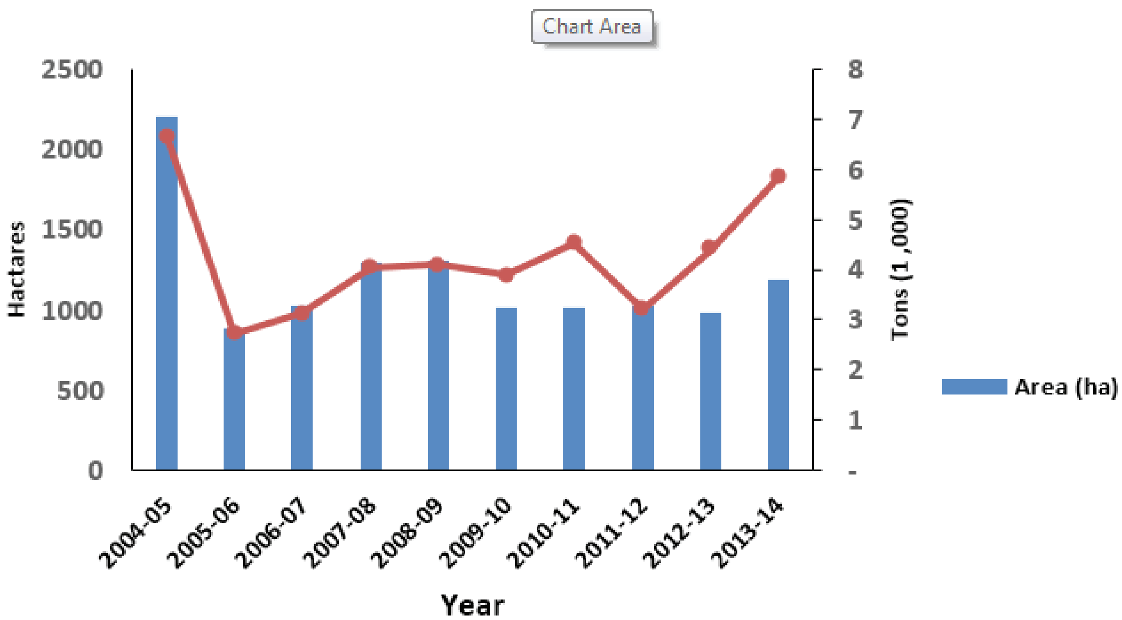

Figure 9. Annual maize production in Tatkone Township
Source: DOA, Tatkone Township (2014)

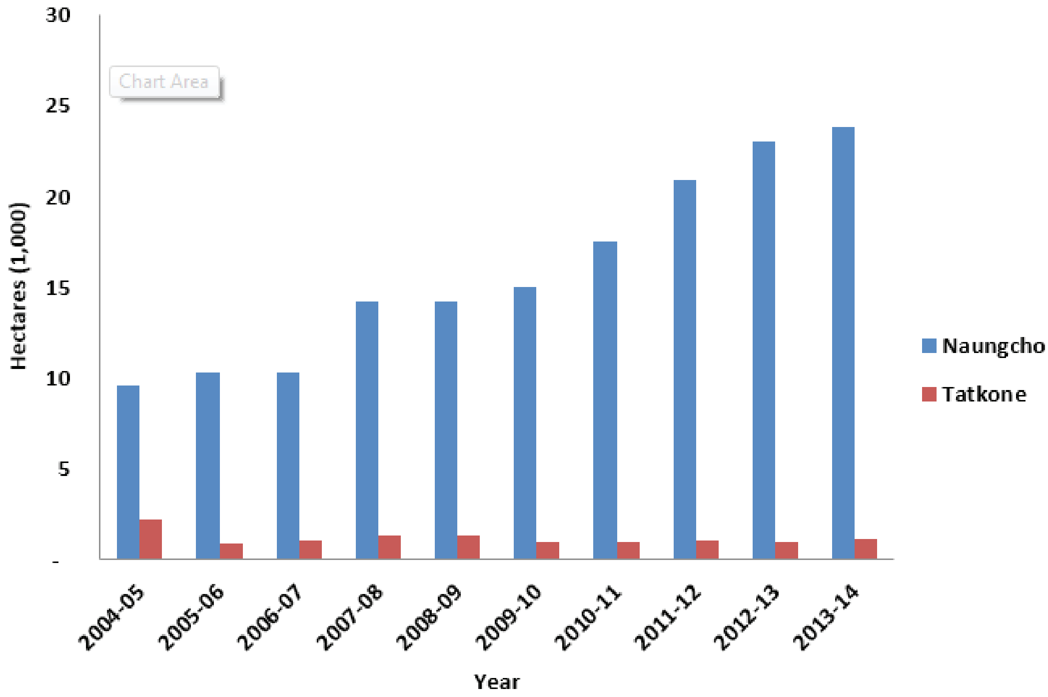

Figure 10. Comparison of maize sown areas in Naungcho and Tatkone Townships
Source: DOA, Naungcho and Tatkone Townships (2014)

Most farmers commonly use the CP-888 variety, while a few grow Yezin-6 and Yezin-10. Maize is cultivated in mid-May to June and is harvested in September for pre-monsoon cultivation. For post-monsoon cultivation, maize is cultivated in October and harvested in February until March. Yield decreased by 50 percent in 2013 because of drought. Farmers were not able to facilitate irrigation and the average yield was 50–60 baskets/ac.

Survey results showed that in the study villages in the lowlands, there have been frequent and persistent droughts during the last few decades. Drought has caused delayed sowing and changes in cropping pattern. Moreover, maize farmers profited less due to higher input prices, wages, and stagnation of output prices. In search of better job opportunities, several households in the study villages shifted to non-farm occupations or migrated to other places.

The following are good practices in Tatkone Township:

- **Cattle feed for maize residues**– To feed the cattle, the upper parts of the plants are collected at intervals before harvesting time. The stem residues are also gathered for animal feed. Cattle feeds are scarce in central Myanmar compared to other regions, where all maize residues are used. Burning of maize stems is uncommon in the field. Husks are burned nowadays, but 3–4 years ago they were sold to the local cigar enterprise or factory. Farmers buy seeds from the traders and sell their maize directly to traders in town, sometimes to the collector.

- **Using maize residues for compost** – At the Tatkone Agricultural Research Farm, maize cobs and husks are made into compost to be used as organic fertilizer. Instead of being burned, they are piled up for several weeks together with some amount of cow dung.

- **Hybrid maize production** – For several years, maize has been cultivated extensively using hybrid seeds produced by national research institutions and farms under MOAI, as well as seeds imported from other countries. A hybrid maize research and development program was initiated at the Tatkone Agricultural Research Farm in 1964 and the Maize and Other Cereal Crops Division of DAR in 1975. In the hybrid maize program, exotic germplasm and collaborative research play in a vital role for national breeding program. CIMMYT has been a main partner and source of germplasm since 1972. The program has a good relationship with international organizations, such as the Tropical Asia Maize Network and International Corn Foundation, among others. This program successfully released several hybrid varieties in 1990, 1993, 1996, 2000, and 2012. It is generally noted that these hybrids have a yield advantage in the 35-40 percent range over the existing open-pollinated varieties. The area under these hybrids increased from 5,300 ha in 1999–2000 to over 40,000 ha in 2007–2008, and currently amounts to about 20 percent of the total maize area of the country (Maize and Other Cereal Crops Division Report, DAR-MOAI 2014).

In collaboration with DAR, maize hybrid varieties such as Yezin-2, Yezin-3, and Yezin 5 were produced at the Tatkone Agricultural Research Farm in 2010. Yezin-3 and Yezin-5 were mostly cultivated in hilly region. Nowadays, new hybrid varieties, such as Yezin-6 and Yezin-10, were also produced in the farm. Yezin-6 is distributed to Magway, Mandalay, and Sagaing Regions, while Yezin-10 is mostly distributed to Shan State. Maize seeds are produced in early and late monsoon seasons. The total seed production is about 1,200 baskets per year. It can be distributed to almost 20,000 ac for cultivation.

5.2.2 Maize Production in the Uplands/ Hilly Region

This section describes maize production in Kyauktaw Village, Myitchin-nu Village tract, Naungcho Township, Northern Shan State. Maize is cultivated in early June and harvested in Mid-October. When CP hybrids were introduced to Myanmar more than 20 years ago, most farmers started using CP varieties instead of local varieties. In the Naungcho Township, double-cropping maize and wheat is very common. Wheat is cultivated in October immediately after the maize is harvested. Most farmers now prefer to prepare their land using power tillers, causing buffalo ownership to decline. The village cooperative bought three tractors in 2013. Commercial intensive farming, HYVs, and high inputs are becoming common in the Northern Shan State.

Lands are cultivated with maize, wheat, and sugarcane continuously for more than 50 years. Crops are usually planted in rotation, but this practice is not enough to enrich soil fertility. Farmers have noticed that lands are degrading and soil fertility is reduced. They now use more fertilizers than ever before for maize production. Moreover, current sugarcane rotation is possible for 1–2 years only, whereas 3 years was previously the norm.

As timely wheat cultivation is important, farmers do not process maize immediately after harvest. Soon after the maize harvest, the lands are prepared for wheat cultivation to minimize the loss of soil moisture. Wheat is widely grown after maize with the residual soil moisture. Many farmers, in a traditional way, cut the maize stalks and pile them up on a vacant plot for about a week to dry, and then they burn the residues. However, these days, there are many farmers who do not burn the maize stalk residues. They prepare their lands for next crops with tractors and power tillers, incorporating the maize residues into the soil. When wheat sowing has been finished, farmers start doing maize post-harvest processes. They peel maize husks and then remove the shell of maize kernels manually or with a sheller. After drying under the sun for 3–4 days, the maize kernels are ready for sale. The cob-residues are valuable cooking fuel in this region. Unusual rains sometimes occur at the time of harvest, which damage the quality of maize seeds. Some small-scale maize shellers have been started to apply in the study village. It will shorten the processing period as well as reduce the workload of women who are responsible for such tedious tasks of manual shelling.

Changes in cropping patterns are also evident. A few decades ago, there were enough spring water sources in the study area to irrigate rice

fields. However, as water sources dwindled, many farmers discarded rice cultivation and shifted to maize and sugarcane production. At present, only farmers with access to irrigated water grow rice. At the village level, the size of rice areas depends on sufficient rainfall, spring water sources, and farmers' interest. It was noted that about 75 percent of farmers had to change their crop cultivation patterns from paddy to maize and sugarcane. Only about 25 percent of farmers can cultivate paddy because they can access water easily.
Therefore, there was an increasing trend in maize production and sown area during the 10 years (2004–2005 to 2013–2014) in Naungcho Township (Figure 11).

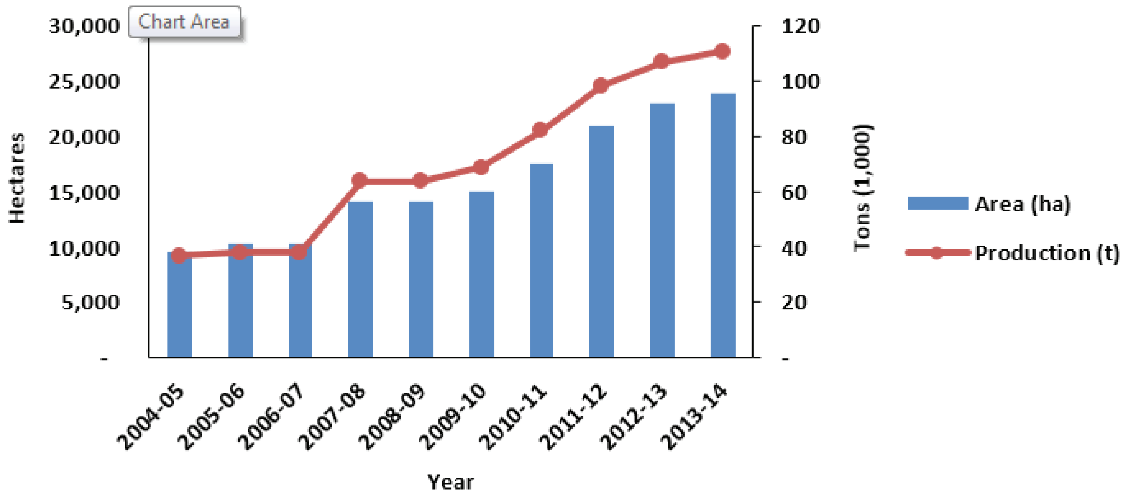

Figure 11. Annual maize production in Naungcho Township
Source: DOA, Naungcho Township (2014)

One of the major constraints for maize farmers is the uncertain arrival of monsoon rains, which has been the case in recent years. They occasionally arrive on time but at a low intensity and frequency after seeds have been sown. Insufficient moisture negatively affects the growth of maize seedlings, leading to a smaller plant population. In such cases, farmers often need to replant the field again.

In 2013, the sowing and harvesting of maize were delayed because of the late arrival of monsoon rains. Consequently, some farmers were unable to grow wheat on time. The absence of rain caused poor growth of small maize seedlings, which were at the vegetative stage, and low yield. Survey results revealed that smallholder farmers favored early-maturing maize varieties because they are more likely to survive drought, especially since maize is grown in drought-prone areas. Early maturity was the farmers' second most desired attribute of maize varieties after good yield potential. Plants of early-maturing maize varieties have a higher probability of completing flowering—the most drought-sensitive stage—before the onset of drought. As such, they are more likely to escape terminal drought.

The following are good practices in Naungcho Township:

- **Timely preparation for maize cultivation before the arrival of monsoon rains** – Given the unpredictable climate, farmers are now unable to estimate the arrival of monsoon rains. They have to be ready to sow seeds as soon as rainfall becomes sufficient. Before sowing, farmers need to prepare the land, collect seeds, and acquire fertilizers, among others, to ensure proper cultivation. Many farmers are unable to invest in the required inputs in advance. As such, they start to prepare only when the monsoon rains have arrived. This will delay their sowing by 3–5 days, after which the seedlings will no longer obtain enough soil moisture. Before 2010, advanced preparation was usually unnecessary because rainfall distribution was regular and not a limiting factor. However, in recent years, due to irregular rainfall distribution, only the industrious and resourceful farmers can expect successful harvests.

Large- and middle-scale farmers have the means to prepare before sowing, while smallholder farmers lack the investment capacity to make such efforts. The village has three tractors that help farmers for in plowing and harrowing more timely and conveniently. These tractors are owned by a cooperative of a village association. If there is rain, the weight of maize decreases. If the rain is sufficient, the vegetative period is longer than normal and the maize (kernels) weight increases.

■ **Site Specific Nutrient Management (SSNM) for fertilizer application** – In 2013, monsoon rainfall was less than usual and soil moisture was inadequate for fertilizer side dressing. Therefore, some farmers changed their fertilizer application method. Their conventional method of fertilization is placing the fertilizer (Urea) between maize rows. Instead, farmers carefully placed the fertilizers close to the maize plants, following SSNM. The fertilizers were then incorporated into the soil using an inter-cultivator with animal draught power. Many farmers were reluctant to apply fertilizers because of low soil moisture. However, some farmers applied fertilizers using the conventional method of placing them between maize rows just before inter-cultivation. It was found that these farmers' yields were lower than those of SSNM farmers. SSNM should be promoted among maize farmers because most smallholder farmers are unable to afford or sustain ample use of chemical fertilizers.

■ **Incorporation of maize residues** – The farmers in the study area have ceased burning maize residues because they now use them to make compost. With the introduction of tractors, maize stalks are cut and incorporated into the soil by the machines at the land preparing time. Farmers noticed that land productivity much improved. However, there are many farmers in the study village who do not have access to a tractor and thus are unable to follow this practice.

This section describes maize production in Kanpetlet Township, Southern Chin State. Chin State has the largest sown acreage for local maize varieties in Myanmar. From 2012 to 2013, the total sown area of maize in this state was 22,671 ha, of which local varieties comprised 81 percent. Only 19 percent of the total area was cultivated with hybrid varieties distributed by DAR and CP. As a tradition, the Chin nationals, especially those in rural areas, eat maize instead of rice. They believe that maize is more nutritious than rice for the people in highland areas. They prefer the soft and sticky grain quality of local varieties, which are suitable for human consumption, compared to other HYVs that are tough and hard. Nowadays, people in urban areas who can afford the cost of rice have shifted to eating it instead of maize. However, there remain many people in rural areas who consider maize as a staple food. Farmers are not interested in using HYVs because they think that it will not produce good yields due to the lack of high inputs. The difficulties in transportation make their products less competitive in the market, which is why they grow maize for home consumption. Local varieties give very lower yield (20–30 baskets/ac) compared to hybrid varieties (60–70 baskets/ac). Most farmers keep their maize seeds for planting in the next season. Cultivating the same varieties continuously for decades will cause seed quality degeneration and lead to poor yield potential. Varietal improvement of local maize varieties and improved growing techniques should be prioritized. Developing of quality protein maize (QPM) varieties should be encouraged to include in the national breeding programs. These programs will fulfill the specific local requirement of quality maize as a staple food for the Chin nationals.

Based on a survey conducted in Kanpetlet Township, Southern Chin State in May 2014, the villagers noticed that temperatures have become warmer. Crop production is mainly rainfed and based on subsistence agriculture with the shifting Taungya farming system in the hilly areas. The annual rainfall in 2013 in Kanpetlet was 2,316 mm (Figure 12).

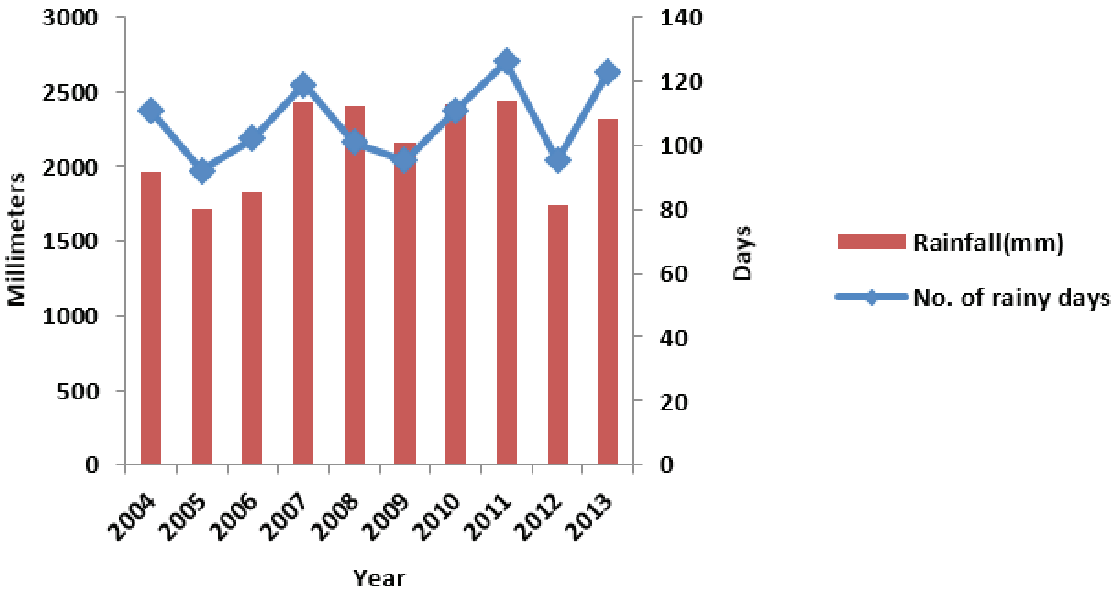

Figure 12. Annual rainfall in Kanpetlet Township
Source: DOA, Kanpetlet Township (2014)

The major crops consumed in the study area were rice and maize. Crop yields were lower in the uplands/hilly region than the lowlands/flatlands. It was observed that the sown areas of all crops decreased from 2009–2014, except for yam (Figure 13 and Table 10). Yam growing was introduced to Kanpetlet Township in 2009–2010. Farmers are interested in expanding yam areas because the crop garners profit from the export market to China.

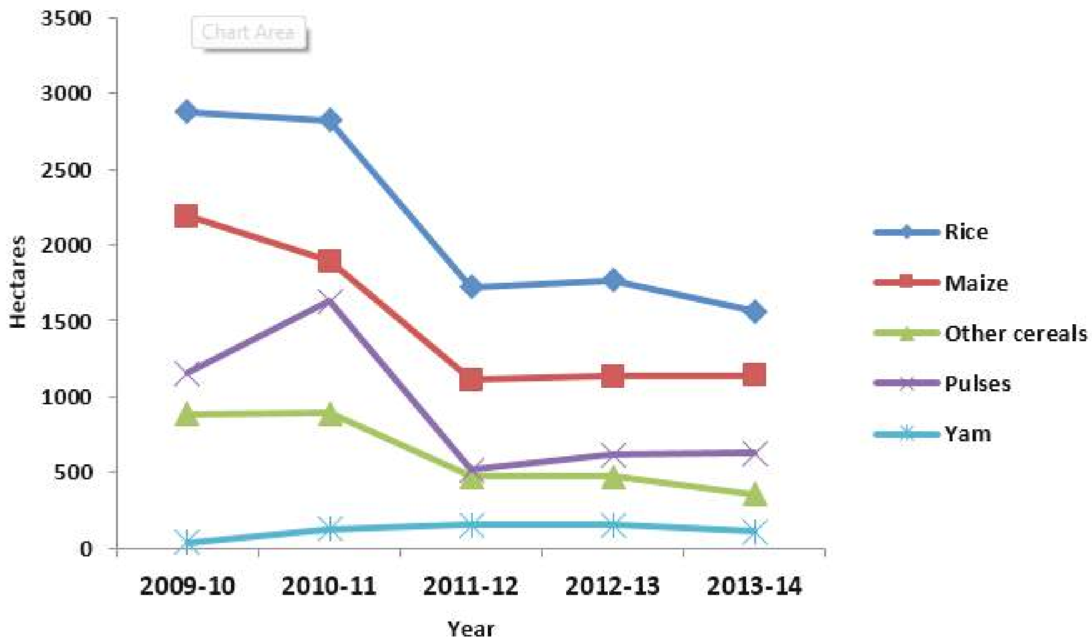

Figure 13. Annual sown areas of major crops in Kanpetlet Township
Source: DOA, Kanpetlet Township (2014)

Table 10. Crop sown areas during five years in Kanpelet Township

Crops	Annual sown area (ha)				
	2009–2010	2010–2011	2011–2012	2012–2013	2013–2014
Rice	2,877	2,820	1,720	1,767	1,562
Maize	2,188	1,892	1,112	1,134	1,138
Other cereals (e.g., sorghum, millet)	887	889	472	473	359
Pulses	1,157	1,625	515	617	624
Yam	38	124	153	155	109

Source: DOA, Kanpetlet Township, Southern Chin State (2013)

The following is a good practice in Kanpelet Township:

■ **Sustainable shifting cultivation (Shifting Taungya Farming System)** – After land clearing, local ethnic people (Chin nationals) in upland/hilly areas grow maize and rice in their Taungya farms. Plowing is not possible with cattle because of the topographical setting. They use hoe and axe for land preparation and sow the seeds by dibbling with sticks. After 1–2 years of cultivation on the same plot, they move to another place and let the previous fields fallow for 5–10 years for regeneration of the secondary forest. The shifting Taungya farming is a good sustainable land use system if the fallow periods are long enough for soil fertility enrichment. Compared to permanent farming, Taungya also sustains biodiversity and protects the land from erosion and degradation. It was observed that the Chin nationals have traditionally owned their lands by customary laws, which encourage land conservation. Given its topography and poor transportation, Chin State has a poor economy and weak infrastructure development. Its agriculture is not as well developed as agriculture in other regions in Myanmar. To date, the Chin nationals generally conserve natural resources by practicing traditional shifting Taungya farming.

The following are the challenges:

■ **Improvement of local varieties and introduction of QPM production** – Local varieties are widely grown in Chin State, Northern Shan State, and upland areas of Magway and Sagaing Regions, mostly by ethnic minorities under shifting cultivation. Low yields in this region are largely associated with drought stress, low soil fertility, weeds, pests, diseases, low input availability, low input use, and inappropriate seeds. The local varieties should be improved, and QPM should also be introduced to these areas. Reliance on rainfall increases the vulnerability of maize systems to climate variability. There is an urgent need to address CCA policies and management strategies in agriculture at both national and international levels.

■ **Greater Mekong Maize IPM project in Myanmar: Pest and disease occurrence in upland maize production** – The Development and Cooperation – EuropeAid has been funding this project since 2012 and will do so until 2015. It is being implemented by the Plant Protection Division, DOA, MOAI. It aims to improve livelihoods and market linkages of smallholder maize farmers in the Mekong sub-region (i.e., Myanmar, Lao PDR, and China) by facilitating the transfer of knowledge on a biologically based plant protection technology. It also helps in strengthening grassroots organizations and local capacity building. The mass production of the parasitic wasps (Trichogramma spp.) will be conducted to reduce the Lepidopterous pests on maize, including ACB. After the completion of the project, Trichogramma facilities will be installed in seven villages in Northern Shan State, providing bio-control to more than 1,000 ha of local farmers. Trichogramma will be used primarily to control ACB by reducing chemical pesticides and preventing crop losses in an environment-friendly manner. It will also conserve and promote the population of natural enemies of insect pests in maize production while preventing the outbreak of infestation.

The dynamics of insect pests are also strongly coupled with environmental conditions. Temperature is the single most important environmental factor influencing insect behavior, distribution, and reproduction. Increased temperature can speed up the life cycle of insects leading to a faster increase in pest populations. It has been estimated that a 2°C increase in temperature has the potential to increase the number of insect life cycles during the crop season by 1–5 times. Therefore, the increase in global warming and drought incidences will favor insect proliferation and herbivory, which will likely increase the incidence and severity of insect-related damages in maize in the near future.

Maize farmers rely solely on rainfed production. Previously, they used local varieties with limited input. By using high-yielding maize varieties and applying more chemical fertilizers, the farmers have amplified production levels. Changes in maize production technology increasingly augment the average yield across the country. However, farmers who rely on rain to grow maize could expect to see yields drop dramatically in the future. Research findings predict that maize yields for both commercial and small-scale farmers are expected to drop by up to 60 percent within the next century if farmers continue to depend on rainfed production. Therefore, improved water harvesting technology and irrigation facilities should be developed to sustain maize production.

Past experience has demonstrated that the combination of new varieties and improved management practices can substantially increase maize production. Current seed production was identified as the major bottleneck, especially for smallholder farmers. Since the maize sown area has been expanding significantly in Myanmar, the demands of hybrid CP seeds have also been increasing, along with soaring seed prices. On the other hand, the CP Company cannot produce sufficient amounts to fulfill the farmers' needs. At present, the seed policy environment is not conducive to facilitate smallholder farmers' access to the improved germplasm. With strong support from the concerned agencies, it is possible to overcome many of the obstacles within the seed production system. To overcome this constraint for future maize production, Myanmar should encourage the hybrid seed production of the Maize and other Cereals Division of DAR, as its most potential source, as well as the involvement of the private sector. It will help reduce the price of hybrid seeds as well as increase the amount to meet the maize
farmers' needs.

5.3 Structuring Good Practice Adaptation Options

Crop production in Myanmar is mostly rainfed (about 80% of the total sown area) and highly dependent on the southwest monsoon. Precipitation is confined to mid-May to October, while a dry cool spell occurs from mid-October to mid-February. The dry season begins in mid-February and ends in mid-May. In the last few decades, unusual droughts, abnormal rainfall patterns, high rainfall intensity, and flood events were observed. Farmers, who often face yield decline or loss, are striving to adapt to the adverse impacts of climate change by through their traditional practices. These include (1) changing crop or crop varieties, (2) altering cropping patterns, and (3) adjusting sowing time and crop management practices depending on the monsoon rains. In addition, MOAI encourages farmers to increase their crop production by introducing new farming practices, such as GAP and new varieties of flood- or drought-tolerant varieties. Since rice and maize are the most important cereals of the country, the current good practice adaptation options for rice and maize production are described in Table 11 and Table 12.

Table 11. Structuring good practice adaptation options for rice production

System of interest	Selected impacts leading to high/medium vulnerability and need for action	Adaptation options	Relevant actors/ stakeholders
GAP and SRI	There is infrequent rainfall, intense droughts, and high temperature. The rice sown area, as well as the harvested area, and yields decline almost every year.	Of the total sown area of monsoon rice in 2011–2012 (6,529,370 ha), about 3 percent (195,102 ha) were cultivated using GAP. MOA set the 14 guidelines for GAP in rice cultivation. The expenses, such as for seeds, chemical fertilizers, and pesticides, were reduced.	Agricultural extension workers (DOA) INGOs and NGOs DAR YAU Model farmers
Change of rice sowing practice; cropping patterns and diversifying crop varieties	Late arrival of monsoon rains, infrequent rainfall, unavailability of irrigation in the central dry zone	Instead of transplanting rice seedlings and using direct wet seeding, farmers in the central dry zone apply dry seeding to half of their land acreage. Traditional adaptation options include changing crops, increasing crop diversity, and altering cropping patterns.	Farmers in central Myanmar, particularly in the dry zone
Use of varieties that are tolerant to unfavorable rice ecosystems	Unfavorable rice ecosystems, such as drought-, flood-prone, and salt-affected areas in central Myanmar and coastal regions	Use of short-duration, drought-, submergence-, and salt-tolerant varieties in unfavorable areas	DAR YAU DOA and model farmers International organizations

Table 12. Structuring good practice adaptation options for maize production

System of interest	Selected impacts leading to high/medium vulnerability and need for action	Adaptation options	Relevant actors/ stakeholders
Lowland/flatland maize production (rainfed)	Cattle feeds are scarce, especially during the dry season, because of infrequent rainfall and poor soil fertility.	Production of hybrid maize seeds: In collaboration with DAR, the Tatkone Agricultural Research Farm has been producing hybrid maize varieties, such as Yezin-2, Yezin-3, and Yezin-5. It can be distributed to almost 20,000 ac for cultivation. Good crop residue management: Given the scarcity of cattle feeds in dry zones, farmers collect the upper portion of maize plants at appropriate intervals before or after the harvest. The husks, which were normally burned a few years ago, are now used for making compost.	Tatkone Agriculture Farm DOA extension service Farmers
Highland maize production (rainfed)	Late arrival of monsoon rains and severe droughts	Timely preparation of growing maize: Seeds should be sown as soon as rainfall becomes sufficient. Before sowing, seed collection and land preparation, among others, should be done in advance. Change the fertilizer application technique (SSNM): Instead of broadcasting, fertilizer should be placed in the burrows near the plants and covered with soil. Sustainable Taung-yar farming system in Chin State and QPM: Local maize varieties have been grown traditionally and maize is the staple food of Chin ethnic minorities in the uplands. The sustainable Taungya farming system should be encouraged. Traditional ownership through customary law should be improved.	Local ethnic people: Danu people in Northern Shan State Chin people in Southern Chin State

VI. CONCLUSION

Myanmar is one of the countries that are most vulnerable to the impacts of climate change. It is prone to the following climate-related hazards or extreme weather events: (1) cyclones/strong winds, (2) flood/storm surges, (3) intense rains, (4) extremely high temperatures, (5) droughts, and (6) sea level rise. Droughts are the most severe weather event in the country, followed by extremely high temperatures, cyclones/strong winds, intense rain, and flood/storm surges. For generations, farmers have had to adapt their production systems to climate variability. However, the severity of current climate change impacts is far from their previous experiences. Therefore, farmers cannot adapt to these challenges without assistance from private and public associations as well as international funding agencies.

Land degradation, forest degradation, and decreased crop productivity are huge ecological and social challenges in Myanmar. The emerging impacts of climate change will increase both the intensity and scope of these challenges. Some of the farmers' traditional adaptation technologies, such as changing crop or crop varieties, altering cropping patterns, and adjusting sowing practices to suit specific localities, are good practices that should be scaled up and shared among AMS. In areas that experience frequent flooding, prolonged droughts, and soil problems (e.g., salinity), farmers use local or traditional varieties with very low harvest. Crop varietal improvement programs are urgently needed, and they should be developed alongside enhanced crop management technologies.

Contract farming for rice and maize production have started in recent years, but it should be improved and scaled up to cover more states and regions across the country. Services, inputs, and technology for farmers should also be promoted. The role of DOA extension service personnel, DAR researchers, and YAU professionals should be upgraded in the rice and maize production value chains. Staff knowledge and skills should be enriched through capacity-building programs. The sharing of good practices as CCA strategies among AMS is essential in promoting climate resilience of rice and other crops in the region, and it will also improve agriculture in Myanmar.

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ANNEX

Rice Ecosystems in Myanmar

Rice can be grown in Myanmar throughout the year. The country's rice growing systems fall under three categories: irrigated, rainfed lowland, or upland. Irrigated rice is grown in bunded puddle fields with assured year-round irrigation for single-, double-, or triple-cropping. Irrigated rice ecosystems are subdivided into irrigated wet season (monsoon rice) and irrigated dry season (summer rice) on the basis of rainfall or water variability. Rainfed lowland rice is grown in bunded fields that are flooded for at least part of the cropping season to water depths that may exceed 50 cm for no more than 10 consecutive days. Rainfed lowlands are poorly managed in terms of controlling floods and droughts, which hamper stable rice production.

Rainfed lowland rice has no stable yield and is constrained by floods, droughts, pests, weeds, and poor soil fertility. Upland rice is grown in lands that vary from low-lying valley bottoms to undulating and steep slopes with high runoff and lateral water movement. Upland rice has low yield (1–3 t/ha) and is constrained by droughts; weeds; blast disease; brown spots; stem borer, rice bugs, and birds; and soil fertility problems, such as phosphorus deficiency as well as aluminum and magnesium toxicities.

Rice agro-ecosystems in Myanmar can be classified as favorable lowland areas (68%) or unfavorable rainfed areas (32%), depending on water availability and topography (Table A). Many regions in the country have unfavorable agro-ecosystems because they are prone to floods and droughts as well as vulnerable to soil salinity. Many farmers work in rice environments with saline, flood-prone soils that rely on unpredictable rains. They usually grow traditional varieties with very few external inputs, leading to very low productivity.

Table A. Rice ecosystems in Myanmar

Agro-ecosystems	% of Total sown area
Favorable lowland	68
Irrigated lowland	20
Rainfed lowland	48
Unfavorable rainfed area	32
Drought-prone	12
Deepwater	5
Submerged	9
Salt-affected	3
Upland-Taungyar	3

Source: Annual Report, AED, DOA (2012–2013)

Unfavorable Rainfed Lowland Rice Ecosystem

Drought-prone Areas

Crop production in Myanmar is mostly rainfed (about 80% of the total sown area) and highly dependent on the southwest monsoon. Precipitation is confined to mid-May to October, while a dry cool spell occurs from mid-October to mid-February. The dry season begins in mid-February and ends in mid-May.

The central dry zone, which is situated in the lower Sagaing, Mandalay, and Magway Regions, is highly susceptible to droughts. It covers about 8.7 million ha or 13 percent of the country's total land area. Based on mean annual precipitation, the central dry zone includes 57 townships in 13 districts. The topography is generally undulating. On the average, annual precipitation is less than 750 mm, with very erratic time and space. Temperature ranges from a minimum of 12ºC to a maximum of 42ºC during the warmest period of the year. The common problems in these areas are low productivity because of droughts and soil degradation, and irrigation-induced salinity.

Rice sown areas have increased substantially during the last few decades. Similarly, the unfavorable areas for rice production have expanded. There were more drought-prone areas throughout the country in 2010–2011 than in 2002–2003 (Table B).

Table B. Drought-prone areas in various states and regions in Myanmar

State/Region	Year	Total sown area (ha)	Drought area (ha)	% of Drought area
Mandalay	2002–2003	275,902	58,482	21.2
	2010–2011	307,800	94,402	30.7
Sagaing	2002–2003	652,357	45,741	7.0
	2010–2011	739,665	211,513	28.6
Magway	2002–2003	240,277	44,868	18.7
	2010–2011	361,048	175,565	48.6
Rakhine	2002–2003	406,264	39,854	9.8
	2010–2011	412,134	49,010	11.9
Bago (East)	2002–2003	629,285	35,985	5.7
	2010–2011	720,007	65,140	9.0
Bago (West)	2002–2003	407,851	28,956	7.1
	2010–2011	512,428	88,886	17.3

Source: Annual Reports, AED, DOA (2002–2003 and 2010–2011)

Flood-prone Areas

Myanmar has been experiencing changing river flows and unpredictable flooding events. The late onset and early withdrawal of the monsoon season has led to large quantities of rain falling over short periods. Consequently, vast lowlands are inundated regularly. Regular inundation occurs in the upper reaches of river systems, coastal areas, and low-lying areas along major river systems like the Ayeyarwady Delta. In 2010, about 2 million ha of land were flooded and 3.25 million ha were moderately inundated. It was observed that severely flooded or inundated land left damaged riverbanks and irrigation systems (Htay 2011).

There were more flood-prone areas throughout the country in 2010–2011 than in 2002–2003 (Table C). Kayin State, Tanintharı Region, and Mon State exhibited the largest increase in flood-prone areas.

Table C. Flood-prone areas in various states and regions in Myanmar

State/Region	Year	Area (ha)				
		Total sown area	DeepWater	Submerged	Total flooded area	% of Flooded area
Kachin	2002–2003	-	NA	NA	NA	
	2010–2011	260,297	-	8,681	8,681	3.300
Kayin	2002–2003	174,579	14,636	4,947	19,583	3.260
	2010–2011	218,447	17,695	20,370	38,066	17.420
Sagaing	2002–2003	652,357	-	33,288	33,288	5.540
	2010–2011	739,665	-	35,752	35,752	4.800
Tanintharyi	2002–2003	130,603	19,167	10,935	30,102	5.000
	2010–2011	143,148	11,505	19,850	31,335	21.900
Bago (East)	2002–2003	629,285	98,264	55,900	154,164	25.600
	2010–2011	720,007	123,543	46,931	170,474	23.700
Bago (West)	2002–2003	407,851	-	48,168	48,168	8.000
	2010–2011	512,428	32,816	60,265	93,081	18.200
Magway	2002–2003	240,277	-	2,200	2,200	0.004
	2010–2011	361,048	-	2,059	2,059	0.600
Mandalay	2002–2003	275,902	-	5,549	5,549	0.920
	2010–2011	307,800	-	9,677	9,677	3.100
Mon	2002–2003	284,048	34,998	17,674	52,672	8.800
	2010–2011	357,776	49,028	38,516	87,545	24.500
Rakhine	2002–2003	406,264	-	36,884	36,884	6.140
	2010–2011	412,134	-	32,485	32485	7.900
Yangon	2002–2003	481,323	21,740	83,978	105,718	17.600
	2010–2011	485,635	15,178	83,416	98,594	20.300
Shan (East)	2002–2003	97,235	-	117	117	0.020
	2010–2011	-	NA	NA	NA	
Shan (North)	2002–2003		NA	NA	NA	
	2010–2011	189,981		1,172	1,172	0.600
Ayeyarwady	2002–2003	2,094,363	91,089	20,909	111,998	18.700
	2010–2011	1,501,726	107,573	221,788	329361	21.900

Source: Annual Reports, DOA (2002–2003 and 2010–2011)

Salt-affected Areas

Rice lands in the coastal areas of Myanmar are prone to salinity because of tidal seawater intrusion. Imbalances in phosphorus and zinc are common in rice grown in saline areas, where drought and submergence can compound problems. Salt-affected coastal areas are most common in Tanintharyi, Ayeyarwady, Yangon, and Rakhine State.

There were more salt-affected areas throughout the country in 2010–2011 than in 2002–2003 (Table D). In Rakhine State, salt-affected areas comprised 5.8 percent and 11.5 percent of the total sown area in 2002–2003 and 2010–2011, respectively.

Table D. Salt-affected coastal land areas in various states and regions in Myanmar

State/Region	Year	Total sown area (ha)	Salt-affected area (ha)	% of Salt-affected area
Tanintharyi	2002–2003	130,603	2,041	1.6
	2010–2011	143,148	4,943	3.5
Rakhine	2002–2003	406,264	23,505	5.8
	2010–2011	412,134	47,519	11.5
Yangon	2002–2003	481,323	5,735	1.2
	2010–2011	485,635	5,815	1.2
Ayeyawady	2002–2003	1,420,361	15,189	1.1
	2010–2011	1,501,726	56,027	3.7

Source: Annual Reports, DOA (2002–2003 and 2010–2011)

During the monsoon season, farmers in freshwater zones of Ayeyarwady Delta usually sow seeds of long-duration rice varieties (more than 130 days) in the last week of May. During the dry season, they sow short-duration varieties in December. Flooding caused by spring tides is a serious concern because it produces standing water, which causes the plants to lodge at harvest time. Lodging is more severe during the monsoon season because the fields are exposed to prolonged and continuous standing water, frequent rains, and strong winds.

Some farmers in the intermediate saline or brackish water areas can grow two salt-tolerant rice crops per year, during the monsoon and summer seasons. In 2012, late-maturing monsoon rice varieties (long duration rice varieties) were transplanted in July and harvested in November, while summer rice (short duration varieties) was sown by broadcasting (direct seeding method) in December. The soil salinity level generally increases around January due to the intrusion of seawater into this brackish area. It is important to plant the summer rice as early as possible to prevent salinity stress among young seedlings. The average electrical conductivity (EC) of these areas, tested by the Land Use Division of the Ayeyarwady Region, was about 5.5 dS/m in March 2013 (DOA-MOAI 2014).

In saline areas, rice can be grown only during the monsoon season because fields are mostly fallow during the dry season. Most rice areas are not protected from flooding and saline water intrusion from rivers in the intermediate saline and saline zones. Varietal tolerance is an effective management option in such areas, while advancing the cropping calendar can aid in circumventing salinity problems in the intermediate saline zones.

Inland Salinity in Mandalay Region

Inland salinity or irrigation salinity is caused by over-watering, seepage from irrigation channels, and impaired natural drainage. It is also influenced by a high water table and an increase in the frequency of drought events, which will also increase utilization pressures on groundwater for expanding irrigated agriculture. This type of salinity is more common in central dry zone regions, such as Mandalay and Sagaing Regions. The level of salinity is highest during the summer. Rainwater dilutes the salt during the monsoon season and thus reduces the intensity of salinity; however, the salt cannot be flushed out because of low rainfall in recent years.

In 2012–2013, the total saline area of 16 townships in Mandalay Region was 6,357.4 ha (Table E). Meiktila, Nwahtogyi, and Myithar Townships had the largest salt-affected areas.

Table E. Salt-affected areas in Mandalay Region, 2012–2013

District	Township	Salt-affected area (ha)
Mandalay	Patheingyi	35.6
	Amayapuya	44.1
Pyinoolwin	Sintgu	49.8
	Madaya	151.4
Kyaukse	Tadaoo	378.4
	Myithar	616.8
	Kyaukse	129.9
Myingyan	Myingyan	173.6
	Nahtogyi	939.7
	Taungthar	232.7
	Kyaukpadaung	184.1
Meiktila	Meiktila	2,107.2
	Tharzi	334.3
	Wuntwin	437.1
	Mahlaing	166.7
Yamethin	Pyawbwe	376.0
	TOTAL	6,357.4

Source: Land Use Division, DOA, Mandalay Region (2013)

A research team from YAU visited Tharzi Township, Mandalay Region in March 2014. The team found that farmers in salt-affected areas have been cultivating suitable rice varieties for several decades. These varieties grow in specific localities, e.g., Kun-war in Tharzi Township, Shwe-phoe variety in Wunttwin Township, and Manaw-htun in Meiktila Township. Most of the HYVs, such as Manaw-thukha, are short- or medium-duration varieties that do not grow well in these areas. Short day-old seedlings, which must be used for transplanting, are very sensitive to salinity. It was found that seedlings up to 25–30 days old are not tolerant to salinity. Farmers avoid salinity problems by using old seedlings of local varieties (45–60 days) for transplanting. Local varieties are long-duration varieties (more than 150 days), and the use of long day-old seedlings does not affect the yield.

The local variety Khun-war has a lower yield (30–40 basket/ac) than HYVs (60–70 basket/ac), but it provides more rice straw than long-stem and long-duration HYVs. Rice straw is the main animal feed in dry zones where cattle feed is scarce, especially during the summer. Farmers believe that these local varieties are more adaptable and suitable to saline areas, although they offer lower yields than HYVs.

Case Study: Kone Doung Village, Tharzi Township

Kone Doung Village has a population of about 3,400, with 313 households and 265 farmers. It has a total sown area of 1,688 ac. Farmers in the study village were aware that salinity is a natural occurrence, and they used sand from saline areas as detergent. Based on the SLRD land use map, the most serious areas are (1) Block/Kwin Number 1813/2087, which has a total area of 250 ac and a saline area of 30 ac; (2) Block/Kwin Number 1813, which has a total area of 386 ac and a saline area of 70 ac; and (3) Block/Kwin Number 180, which has a total area of 300 ac and a saline area of 40 ac.

According to some of the farmers, the soil has been saline since 1964, and Khun-war rice cultivation started about 50 years ago. At present, Pokali, Thukha-htun, Khun-war, and Man-ngasein are commonly grown in this area. These varieties are tolerant to climate variability and salinity to some extent. Farmers prefer them because they have long stems and more straw yield for fodder.

Farmers in this area prepare the land differently from farmers in non-saline areas. They first till the soil using a harrow because saline land requires very shallow plowing. If the soil is plowed deeply, the salt will rise to the surface and the salinity level will increase. After puddling, farmers grow rice by transplanting or direct wet seed broadcasting.

Farmers in Myanmar usually plow the soil after harvest, which is known as Nwe-hta-ye in Myanmar language, meaning “summer plowing.” The main purpose of this practice is to reduce the infestation of weeds, pests, and diseases at the time of monsoon rice growing. Farmers in the study village do not practice “summer plowing.”

Some rice fields in Kone Doung Village are irrigated using Theinkone Dam, which obtains its water supply from Meiktila Lake. In the past, Theinkone Dam could irrigate about 200 ac; nowadays, it could irrigate only about 50 ac. Farmers believe that rainwater passes through saline soil along the streams and transports salt to the dam. The water in the dams and ponds consist of salt and sodium carbonate, which can increase salinity in rice fields. When the rainfall is sufficient to drain the salts 3–4 times in some years, salinity is reduced. However, since rainfall has become less frequent in recent years, the water in the dams and ponds are insufficient for irrigation. This makes salinity a serious constraint in rice production in this area.

About 10–15 years ago, the weather was favorable and rainfall was abundant. Triple-cropping (i.e., sesame – rice – chickpea in paddy land) was also a common practice. In recent years, single-cropping of upland crops, particularly pulses and watermelon, became the trend. By using water from tube wells and ponds for irrigation, farmers noticed that the lands have been degrading gradually because of due to poor fertility and increased salinity.

Irrigation Practices

Tube Wells Irrigation

In 2000, WRUD installed about 800 tube wells in Yamethin and Meiktila Districts, most of which are currently damaged. It installed 50 tube wells in Kone Doung village. The FAO Environmentally Sustainable Food Security Programme (ESFSP), which was also initiated in 2010, provided 23 tube wells to Kone Doung village. The installations in Kone Doung are currently damaged, except for six tube wells.

Based on an interview with a technical staff from ESFSP in Meiktila township, the program was created to support special rice production in four townships in central Myanmar: Meiktila, Thazi, Yemathin, and Pyawebwe. FAO, in collaboration with the Irrigation Department of DOA and WRUD, supervises the program and provides technical support along with its implementing partner, AVSI. Twenty-five villages were selected from the four townships, and one Farmers Field School was established in each village with 25 farmers as participants in the school. In each village, 1–2 tube wells for irrigation and drinking water were installed. The community tanks and ponds were also renovated. The project also provided threshers, compressors, drum seeders, seeds (e.g., rice, sunflower, and mungbean), and fertilizers. Over 100 shallow tube wells, seven deep tube wells, and seven community tanks were installed in the four selected townships.

(1) Special Rice Production Program by FAO and IRRI – A research team from YAU visited farmer U Aung Din, 80 years old, in Kone Doung village. In 2009, an Artesian tube well was installed near his land, where he has been growing local salt-resistant varieties. Staff from Rice Section, DAR conducted an experiment on PVS, wherein 13 varieties/lines were grown and tested. It was found that Shwe-pyihtay, a salt-tolerant variety released by DAR, gave the highest yields with the value of 200 baskets from 2.5 acre. Pokali, an introduced variety, was also successful in this experiment. The yield was almost the same with Shwepyihtay. The plant height of Pokali is about 4–5 feet, higher than other varieties tested, which farmers prefer for cattle feed.

(2) Crop compensation by the regional government – Myingyan District, Mandalay Region is one of the areas that are most seriously affected by drought every year. Based on an interview with a technical staff from the Land Use Division in DOA, Mandalay region, in 2013, the Mandalay Regional Government provided financial support to farmers in areas that were seriously affected by low rainfall and drought. Farmers of 25,000 ac in Myingyan, Taungthar, Nahtogyi, and Ngazun Townships received a compensation of MMK 7,000 per acre for their yield loss.

Published by
giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

In cooperation with

Promotion of Climate Resilience in Rice and Maize

Philippines National Study

Imprint

This publication is a joint undertaking by the ASEAN Technical Working Group on Agricultural Research and Development (ATWGARD) and the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH
through the ASEAN-German Programme on Response to Climate Change (GAP-CC).

In partnership with the Southeast Asian Regional Center for Graduate Study and Research in Agriculture (SEARCA).

Published by the
Deutsche Gesellschaft für
Internationale Zusammenarbeit (GIZ) GmbH

Registered offices
Bonn and Eschborn, Germany

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As at
April 2015

Printed by/design and layout
SEARCA
College, Los Baños
Laguna - 4031

Photo Credits
Arnold Cordero (SEARCA Photo Contest)

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German Federal Ministry for Economic Cooperation and Development (BMZ)
Alternatively: German Federal Foreign Office

Promotion of Climate Resilience in Rice and Maize

Philippines National Study

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
AIFS	ASEAN Integrated Food Security
AMS	ASEAN Member States
ASEAN	Association of Southeast Asian Nations
AWD	Alternate Wetting and Drying
BAR	Bureau of Agricultural Research
BSWM	Bureau of Soils and Water Management
CCA	Climate Change Adaptation
CCC	Climate Change Commission
DA	Department of Agriculture
FAO	Food and Agriculture Organization
GAP-CC	German-ASEAN Programme on Response to Climate Change: Agriculture, Forestry, and Related Sectors
GHG	Greenhouse Gas
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
ICM	Integrated Crop Management
IPB-CA	Institute of Plant Breeding – College of Agriculture
IPCC	Intergovernmental Panel on Climate Change
IRRI	International Rice Research Institute
MDG	Millennium Development Goals
NEDA	National Economic Development Authority
OPV	Open Pollinated Varieties
PhilRice	Philippine Rice Research Institute
QPM	Quality Protein Maize
QTL	Quantitative Trait Loci
SCOPSA	Sustainable Corn Production in Sloping Areas
SEARCA	Southeast Asian Regional Center for Graduate Study and Research in Agriculture
SSNM	Site-specific Nutrient Management
UPLB	University of the Philippines Los Baños

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Foreword

The Bureau of Agricultural Research of the Department of Agriculture is proud to endorse this national study of promotion of resilience of rice and maize (corn). We are happy to be able to contribute to this exercise through the ASEAN Technical Working Group on Agricultural Research and Development (ATWGARD) with the support of GIZ through the German-ASEAN Programme on Response to Climate Change (GAPCC). This initiative allowed us to review adaptive practices that ensure impacts of climate change to food security is minimized.

Climate change affects the Philippines through the increase in frequency and intensity of extreme weather conditions such as droughts, floods and tropical cyclones that will place large populations and key sectors in the region at risk, especially the agriculture sector. Climate change adaptation best practices for commodities such as rice and maize were considered for this study. For irrigated rice, the following are considered as good practices: PalayCheck, Palayamanan Plus, and controlled irrigation or Alternate Wetting and Drying (AWD); while for rainfed rice are Palayamanan Plus, controlled irrigation/ AWD, and use of climate resilient varieties. For yellow corn are: Site Specific Nutrient Management (SSNM), village type drier, and Sustainable Corn Production in Sloping Areas (SCOPSA); while for white corn, white corn for food and village type white corn mill.

We hope that the practices from the Philippines will be upscaled in several areas, and shared with our neighboring countries at ASEAN through regional collaboration of joint measures such as research and information exchange to benefit the people of the Philippines and the nearby countries within the region.

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Acknowledgment

This document is a product of a series of consultations with a team of technical experts and research managers from the Philippine Department of Agriculture (DA) and its attached agencies, Bureau of Agricultural Research (BAR) and Bureau of Soils and Water Management (BSWM); National Economic Development Authority (NEDA); Philippine Rice Research Institute (PhilRice); Food and Agriculture Organization (FAO) – Manila; Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH – Philippines; International Rice Research Institute (IRRI); and University of the Philippines Los Baños (UPLB). We are grateful to the experts and the participants for sharing their knowledge and expertise in developing this material. We would also like to extend our sincerest appreciation to everyone who contributed to the completion of this report in one way or another.

Executive Summary

In Southeast Asia, climate change has augmented the frequency and intensity of extreme weather conditions such as droughts, floods, and tropical cyclones. As an additional stressor on livelihoods, ecosystems, and infrastructure, it will place large populations and key sectors in the region at risk (USAID 2010). As climate change vulnerability varies substantially across the region of the Association of Southeast Asian Nations (ASEAN), it is imperative to strengthen the resilience of people and ecosystems, and enhance the adaptive capacity of farmers and fishermen to cope with the imminent threat of climate change (AFCC 2009).

A team of technical experts and research managers from the Philippine DA and its attached agencies, BAR and BSWM; NEDA; PhilRice; FAO – Manila; GIZ – Philippines; IRRI; and UPLB was consulted to determine regional and national climate change vulnerabilities as well as climate change adaptation (CCA) in the Philippines. Four national consultative meetings were held on 11 and 17 February 2014 at DA-BAR, Quezon City and 20 March 2014 and 14 April 2014 at the Southeast Asian Regional Center for Graduate Study and Research in Agriculture (SEARCA), Los Baños.

Lessons learned, good practices to be adopted or adapted and scaled up, and new collaborative initiatives to be undertaken were discussed to ensure environment and food security in Southeast Asia, as well as other regions that are experiencing the adverse impacts of climate change (SEARCA 2012).

This study focused on rice and corn, which are the two most important grain crops in the Philippines. Rice, the major staple food in the country, is grown mainly in irrigated and rainfed ecosystems. In 2013, irrigated lowland rice was grown to about 3.2 million hectares (ha) with a total production of 13.82 million tons (t) and an average grain yield of 4.27 t/ha, while rainfed lowland rice was grown to about 1.4 million ha with a total production of 4.39 million t and an average yield of 3.15 t/ha. Yellow corn is the major source of feed materials for the livestock sector, while white corn is also a staple food in the country. In 2013, yellow corn was grown to 1.3 million ha with a total production of 5.24 million t and an average yield of 3.86 t/ha, while white corn was grown to 1.27 million ha with a total production of 4.87 million t and an average yield of 1.67 t/ha.

Climate hazards affecting rice and corn production include increase in temperature; increase in frequency, intensity, and duration of extreme climate events such as droughts, floods, and tropical storms; changes in the intensity, timing, and spatial distribution of rainfall; warming temperatures; soil degradation; increase in weather variability; and sea level rise resulting in saltwater intrusion and loss of agricultural land (PhilRice 2011, 2012).

The following case studies on good practices in CCA options for rice and corn were prioritized: for irrigated rice, (1) PalayCheck System, (2) Palayamanan Plus, and (3) controlled irrigation or alternate wetting and drying (AWD) technique; for rainfed rice, (1) Palayamanan Plus, (2) controlled irrigation or AWD technique, and (3) climate-ready varieties; for yellow corn, (1) Site-specific Nutrient Management (SSNM), (2) village-type dryer, and (3) sustainable corn production in sloping areas (SCOPSA); and for white corn, (1) promoting wider adaptation of white corn for food or alternative staple food, and (2) village-type white corn mill. These case studies are described in detail in subsequent sections of this document.

This report presents the results of the study, discusses climate change vulnerability, reviews CCA and mitigation practices, and evaluates existing policy responses to and initiatives on climate change.

I. INTRODUCTION

Climate change is one of the greatest development challenges of today. It requires immediate attention because it has discernible and worsening effects on communities, including increasing severity of droughts and floods, rising sea level, displacement of large populations, and changes to growing seasons (IPCC 2007). In addition, climate change will compound existing obstacles to development and exacerbate the divisions between men and women in communities that are already vulnerable (UNDP 2011).

The International Panel on Climate Change (IPCC) (2007) defines the phenomenon as a statistically significant variation that persists for an extended period, typically decades or longer. It includes shifts in the frequency and magnitude of sporadic weather events, and a slow yet continuous rise in global mean surface temperature that may include cooling or warming. It may also result from natural factors (e.g., volcanic eruption and changes in solar energy), natural processes within the climate system (e.g., changes in ocean and wind circulation), and human activities (e.g., agriculture and burning of fossil fuels) (Landicho et al. 2010; PhilRice 2011).

According to the Fourth Assessment Report of the IPCC, sea levels have risen rapidly in the past century, especially in the last 25 years (IPCC 2007). Climate change and climate variability are among the top issues that pose real threats to the environment and human systems, specifically agricultural production, biodiversity, and health, among others (IPCC 2007). Extreme climatic events (e.g., more frequent and destructive typhoons, prolonged wet and dry seasons, and higher incidence of pest and disease outbreaks) affect agricultural production systems negatively, leading to food and livelihood shortages that threaten environment and food security. This phenomenon has and will continue to affect Southeast Asia where the project focuses on seven ASEAN Member States (AMS), namely, Cambodia, Indonesia, Lao PDR, Myanmar, the Philippines, Thailand, and Vietnam, to ensure long-term food security and improve farmer livelihoods.

ASEAN leaders adopted the ASEAN Integrated Food Security (AIFS) Framework to ensure long-term food security, which has long been an important agenda of ASEAN, and improve farmer livelihoods. Within the AIFS Framework, ASEAN established the ASEAN Multi-Sectoral Framework on Climate Change: Agriculture, Fisheries, and Forestry towards Food Security (AFCC). The AFCC aims to contribute to food security through the sustainable and efficient use of land, forest, water, and aquatic resources by minimizing the risks to and impacts of their contributions to climate change.

During the 8th ASEAN Technical Working Group Meeting held in Singapore in 2013, the Thai DA endorsed a proposal entitled Production System Approach for Sustainable Productivity and Enhanced Resilience to Climate Change. The proposal was approved by the German-ASEAN Programme on Response to Climate Change: Agriculture, Forestry, and Related Sectors (GAP-CC). The proposal was further developed, and the title was changed to Promotion of Climate Resilience of Rice and Other Crops. This national study is based on the GAP-CC implementation proposal.

GAP-CC strives to support ASEAN in advancing the implementation of regionally coordinated strategies and policies for food security and climate protection in agricultural and forestry sectors within AMS. It developed a regional food security index, which includes climate change effects, to provide ASEAN decision-makers with a comparable regional overview of food security vulnerability for the three most important food crops: rice, corn, and cassava. It is based on the regional food security index that the staples have been selected to support Thailand's project proposal at the regional level.

As a member of ASEAN, the Philippines is committed to address and act on climate change by integrating it systematically in all phases of policy formation, development planning, and research and development (R&D). The general goal is to build the country's adaptive capacity, strengthen its resilience to climate change, and optimize its mitigation opportunities.

In 2009, the Philippine Congress passed the Climate Change Act. The Climate Change Commission (CCC) was then established to develop policies and coordinate government programs on climate change. The CCC formed the National Climate Change Action Plan that serves as a road map for all climate change programs in the Philippines. Strengthening reforms to fully integrate the climate change agenda in the planning and budgeting of the government will bolster the country's resilience to the impacts of a warming world, and make communities less vulnerable to sea level rise, degradation of marine ecosystems, and extreme weather events (CCC 2011; DA 2013b; PAGASA 2011).

The Climate Change Act of 2009 (R.A. 9729) mandates the "mainstreaming of climate change in policy formation, such that policies and measures that address climate change are integrated in development planning and sectoral decision-making." To fulfill the mandate, the DA came up with four strategic objectives to make its plans and programs climate-proof or compliant to climate change. DA programs and projects across all functions and agencies should take the necessary steps to migrate from the usual planning framework (DA 2013b).

All general circulation models predict an enhanced hydrological cycle and an increase in area-averaged annual mean rainfall in Asia. This is expected to exacerbate pressure on the region's natural resources that are already under severe stress from increasing population. Developing countries will be the most vulnerable as they have limited resources and capacity to adapt to the effects of climate change (Lasco et al. 2010).

1.1 Climate Change in Southeast Asia

Growing evidence of climate change around the world and in Southeast Asia compels all sectors to act and ensure the sustainability of lifelines, which include natural systems and food resources, rural livelihoods, and human resources. Southeast Asia, particularly AMS (Figure 1), is therefore challenged to increase its capacities and expertise to attain the Millennium Development Goals (MDG), specifically those that pertain to eradicating extreme poverty and hunger, and ensuring environmental sustainability (SEARCA 2012).

Figure 1. Map of the ASEAN region

The Fourth Assessment Report of the IPCC (2007) states that Southeast Asia is expected to be seriously affected by adverse climate change impacts, since most of the economies in the region rely on agriculture and natural resources (IFAD 2009). Annually, Southeast Asia experiences climate extremes, particularly floods, droughts, and tropical cyclones, making large areas in the region highly prone to flooding and influenced by monsoons. Such climatic forces will severely threaten the livelihoods of poor rural dwellers, who have limited adaptive capacity.

Climate change is expected to affect agriculture in Southeast Asia in several ways. For example, irrigation systems will be affected by changes in rainfall and runoff. Subsequently, water quality and supply will be altered. The region already faces water stresses; hence, future climate change impacts on regional rainfall will have both direct and indirect effects on agriculture (IFAD 2009).

The Philippines is facing an increase in temperature from 2°C to 4°C, and studies suggest both potential gains and losses. For example, at less than 2°C, agricultural losses are predicted to occur in the Philippines, while rice yields are projected to increase in Indonesia and Malaysia. In fact, although climate change impacts could result in significant changes in crop yields, production, storage, and distribution, the net effect of the changes around the region is uncertain because of local differences in growing season and crop management, among others (IFAD 2009).

In general, climate studies indicate increasing rainfall throughout the region. However, despite increases in rainfall, a rise in temperature may threaten agricultural productivity, stressing crops and reducing yields.

In particular, scientific studies have documented that major cereal and tree crops are highly sensitive to changes in temperature, moisture, and carbon dioxide (CO_2) concentration of the magnitudes projected for the region. For example, projected impacts on rice and wheat yields suggest that any increase in production associated with CO_2 fertilization will be more than offset by reductions in yield resulting from temperature and/or moisture changes (IFAD 2009). Such agricultural impacts particularly affect low-income rural populations that depend on traditional agricultural systems or marginal lands.

1.2 Climate Change in the Philippines

The Philippines, which has a total land area of 300,000 square kilometers, is an archipelago composed of 7,100 islands that are clustered into the three major island groups of Luzon, Visayas, and Mindanao (Jose and Cruz 1999). The country is susceptible to the harsh impacts of climate change because its population and economic activity are highly concentrated in coastal areas; it relies heavily on agriculture in providing livelihoods for a large segment of its population; and it depends greatly on natural resources (NEDA 2013).

The Philippines is one of the countries that are considered highly vulnerable to climate change. It has experienced numerous weather-related disturbances and disasters. In recent years, the typhoons have been unusually heavy and devastating to the country. In its analysis of natural disaster hotspots, the Hazard Management Unit of the World Bank (2005) found that the Philippines is among the countries where a large percentage of the population resides in disaster-prone areas. Many highly populated areas are exposed to multiple hazards: 22.3 percent of the land area is exposed to three or more hazards, and in that area, 36.4 percent of the population is exposed. Areas where two or more hazards are prevalent comprise 62.2 percent of the total area where 73.8 percent of the population is exposed (Rudinas et al. 2013).

Based on the report of the Philippine Atmospheric, Geophysical, and Astronomical Services Administration from 1951 to 2006, maximum, minimum, and mean annual temperatures increased by 0.35°C, 0.89°C, and 0.61°C, respectively. Minimum temperatures rose to as high as thrice the increase in maximum temperatures. From 1961 to 2003, there was a significant increase in the frequency of hot days and nights, and a decrease in the number of cold nights and days (PAGASA 2011; PhilRice 2011).

The annual mean rainfall and number of rainy days, as well as the inter-annual variability of the onset of rainfall, have been rising. Increasing occurrences of extreme rains have caused flash floods, landslides, and inundation of low-lying areas. In addition, typhoons have become increasingly frequent. In the last few decades, about 15 to 20 typhoons per year entered the Philippines' area of responsibility (PAGASA 2011). Droughts, normally associated with El Niño, have also become more intense.

The outcomes of climate change threaten to undermine the Philippines' development prospects and exacerbate the vulnerability of its poorer communities. With projected changes in precipitation, temperature, intensity of tropical cyclones, and frequency of extreme weather events, considerable efforts are required to prepare the Philippines in dealing with climate change consequences on different climate-sensitive sectors. Adaptation will be an integral part of the country's response to the threats of climate change (PAGASA 2011).

Central to achieving the outcomes of the Philippines' implementation of the MDG Fund Joint Programme, Strengthening the Philippines' Institutional Capacity to Adapt to Climate Change, is developing the capacity of local government units to mainstream CCA in their development plans, programs, and activities. CCA planning and implementation will require detailed information on plausible future climates (e.g., changes in temperatures, rainfall, and frequency of extreme weather events). Referred to as climate change scenarios, this type of climate information is generated from climate simulations (PAGASA 2011).

As in most parts of the globe, the Philippines has also exhibited increasing temperatures (Figure 2). The graph of observed mean temperature anomalies (or departures from the 1971 to 2000 normal values) from 1951 to 2010 indicate an increase of 0.648°C or an average increase of 0.0108°C annually (Cinco et al. 2013; PAGASA 2011).

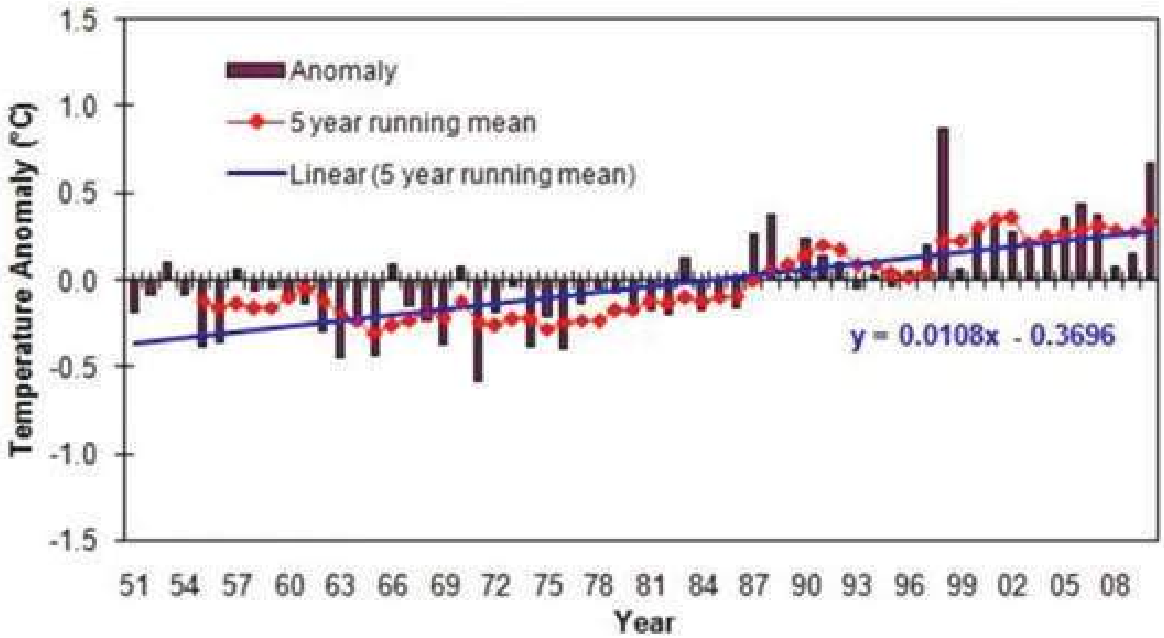

Figure 2. Observed mean annual temperature anomalies in the Philippines, 1951–2010

Note: The values from 1951 to 2010 were compared with the normal values from 1971 to 2000.

Source: PAGASA-DOST (2011)

Studies have shown that climate change threatens the stability and productivity of agricultural production. In many areas of the world where agricultural productivity is already low and the means of coping with adverse events are limited, climate change is expected to reduce productivity to even lower levels and make production more erratic (Cline 2007; Fisher et al. 2002; IPCC 2007; Stern 2006).

1.3 Rice and Corn Production in the Philippines

Rice (Oryza sativa L.) and corn (Zea mays L.) are the two most important grain crops in the Philippines. Rice is the country's major staple food, while corn is the primary source of feed materials for the country's livestock industry. In 2004, the areas devoted to rice and corn production were 4.1 million ha and 2.5 million ha, respectively, amounting to an annual production of 14.5 million t and 5.4 million t, respectively (BAS 2004). Based on official statistics, the projected population of the country for the year 2005 was 85.2 million (NSO 2005). This population consumed about 8.2 million t of rice and 0.3 million t of corn for food alone (FAO 2006). Hence, it is important to quantify the effects of climate change on productivity for these two crops (Lansigan and Salvacion 2007). Data on the quantity of rice and corn production in the last 50 years showed an increasing trend (FAO 2014) (Figure 3). Rice harvested area decreased at some point, particularly during the early 1980s and late 1990s, but eventually increased, while corn harvested area followed a decreasing trend since the 1990s (FAO 2014) (Figure 4).

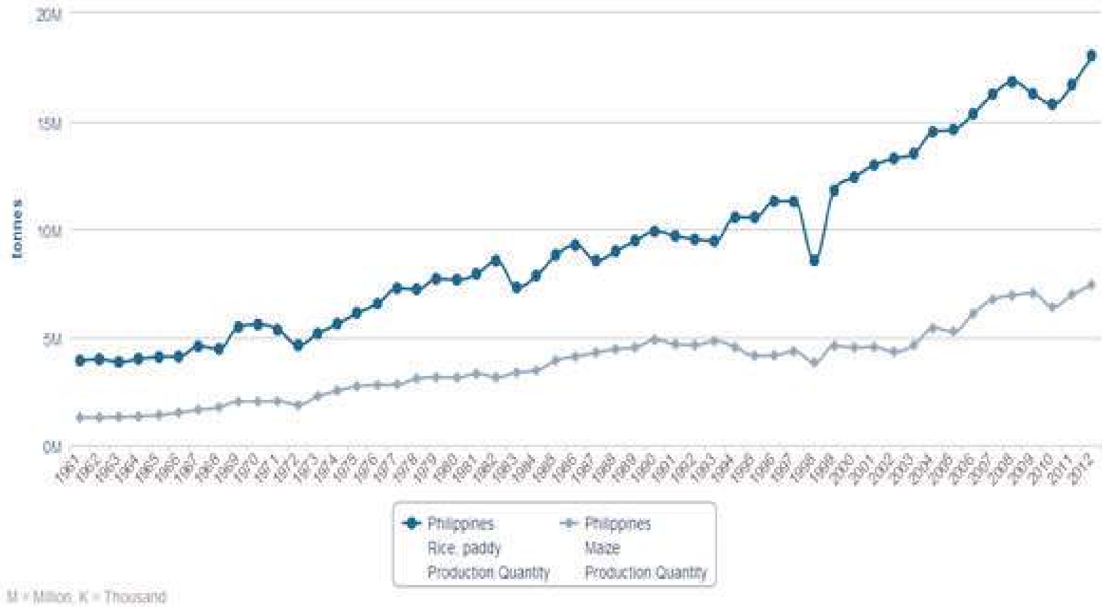

Figure 3. Production quantity of rice and corn, 1961–2012
Source: FAOSTAT (2014)

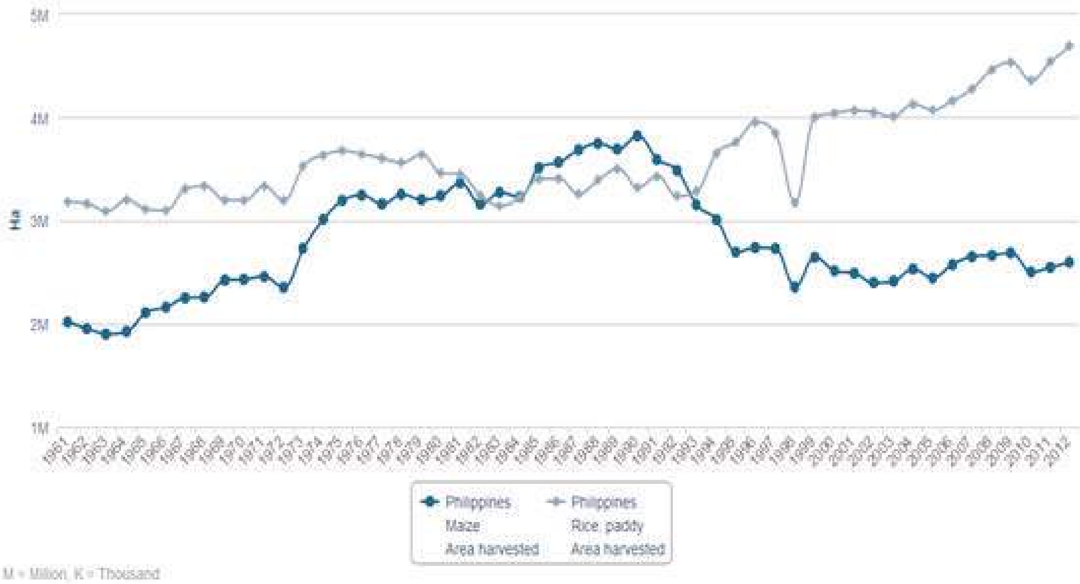

Figure 4. Area harvested of rice and corn, 1961–2012
Source: FAOSTAT (2014)

The Philippines is a large rice producer, but it is forced to rely on imports to compensate for the difference as demand outpaces supply. In fact, the country is one of the largest rice importers in the world, leaving it particularly vulnerable to high and volatile rice prices.

Corn is the second most important crop in the Philippines. Yellow corn is mainly used and traded as raw material for animal feeds (almost 70% of the annual national corn production). White corn serves as the main staple food for about 15 percent of the country's total population, mostly in Visayas and Mindanao (DA 2013a). Some 600,000 farm households depend on corn as a major source of livelihood, in addition to transport services, traders, processors, and agricultural input suppliers who directly benefit from corn production, processing, marketing, and distribution.

As of 2013, the total production for irrigated, rainfed, and upland rice were 13,823,145 t, 4,392,864 t, and 223,398 t, respectively (PSA-BAS 2014) (Table 1). The total production for yellow corn and white corn were 5,248,020 t and 2,129,056 t, respectively (PSA-BAS 2014) (Table 2).

Table 1. Major rice production systems in the Philippines

Production system type	National production volume			National production value (PHP 44.14 = USD 1)	Assessment of impact on national/ regional consumption (1–3)	Indication/ estimate of relative vulnerability to climate change (1–3)
	Production (t)	Area harvested (ha)	Yield (million t/ha)			
Irrigated	13,823,145[a] 12,730,856[b]	3,236,336[a] 3,107,249[b]	4.27[a] 4.09[b]	PHP 314,022,000.98[a] USD 7,113,729.04[a]	High	High
Rainfed	4,392,864[a] 4,128,953[b]	1,395,367[a] 1,375,376[b]	3.15[a] 3.00[b]		Low	High
Upland	223,398[a] 223,896[c]	114,379[a] 111,508[c]	1.95[a] 2.01[c]		Low	High

Source: [a]BAS Data (2013), [b]BAS Data (2009–2013), [c]BAS Data for Upland Rice (2010–2013)

Table 2. Major corn production systems in the Philippines

Production system type	National production volume			National production value (PHP 44.14 = USD 1)	Assessment of impact on national/ regional consumption (1–3)	Indication/ estimate of relative vulnerability to climate change (1–3)
	Production (t)	Area harvested (ha)	Yield (million t/ha)			
Yellow	5,248,020[a] 4,847,127[b]	1,285,029[a] 1,253,865[b]	4.08[a] 3.86[b]	PHP 90,221,000.69[a] USD 2,043,973.74[a]	High	High
White	2,129,056[a] 2,186,064[b]	1,278,606[a] 1,323,135[b]	1.67[a] 1.65[b]	PHP 33,830,700[b] USD 766,440.87[b]	High	High

Source: [a]BAS Data (2013), [b]BAS Data (2009–2013)

During the last quarter of 2013, corn was among the crops sub-sector with big output increment, along with pineapple, mango, and tobacco. Rice production, on the other hand, reached 11.36 million t in the first nine months of the year (PSA-BAS 2014). Crop simulation modeling showed that rice productivity is expected to decline because of climate change (Peñalba et al. 2012).

1.4 Objectives of the Study

In support of promoting climate resilience of rice and other crops, the project provides a national and regional platform to enhance cross-sectoral knowledge-sharing and cooperation among Ministries of Agriculture, other relevant ministries, and the scientific community. The objective is to identify areas of collaboration and priorities for the development of ASEAN regional coordinated strategies to address climate change in agriculture and selected crops to increase food security.

The main goal of the consultative meetings was to bring together researchers, academicians, policy-makers, and planners to exchange information towards enhanced capacity in rice and corn production in the Philippines in the face of climate change and its impacts, particularly on food security.

The goals included exchanging knowledge on climate change and adaptation strategies, gathering information and experiences into an integrative body of knowledge, identifying location-specific knowledge and adaptation strategies that may be scaled up to other regions, and promoting partnerships and linkages among different sectors for collaborative activities on CCA.

In general, the study aimed to provide information on the status of national-level vulnerability of AMS, which are among the countries that are most susceptible to the impacts of climate change.

1.5 Methodology

The methodology used in this study was developed as part of the GAP-CC project, which seeks to review and develop the adaptive capacity of stakeholders and identify priority areas for selected AMS. Overall, the program aimed to facilitate a process of regional agreement among AMS on where adaptive capacity should be prioritized and addressed through cooperation.

The methodology sought to cover the following objectives:

- To identify good practices in the ASEAN region that address climate change-related vulnerabilities that could lead to food insecurity in critical regional food crops (i.e., rice, corn, and cassava) using a value chain mapping approach

Output A: Good practice case studies on improving the adaptive capacity of rice, corn, and cassava supply in AMS

- To identify where vulnerabilities exist or are likely to exist in the supply of the identified food crops, focusing primarily on production and related inputs and secondly on post-production activities, specifically drawing out where regional collaboration will be most valuable

Output B: List areas of vulnerability related to the production of rice, corn, and cassava, as well as regional mechanisms for cooperation and action to address the identified vulnerabilities

- To use the lessons learned from the abovementioned points to stimulate and spread meaningful action across the region

Output C: Targeted dissemination of research outputs to stakeholders across the AMS to facilitate knowledge-sharing, cooperation, and communication on building adaptive capacities

At the AMS level, the following methodology highlighted the proposed support from GAP-CC as input to the regional platform. Research institutions that are experts in value chain analysis in selected sectors and climate change were selected to undertake these studies. Further capacity-building and technical guidance were provided by GIZ, resource persons, and other institutions involved.

This study applied a six-step process in assessing where adaptive capacity is needed in the value chain now and in the climate-affected future, as well as what level of adaptive capacity currently exists in the country (Figure 5).

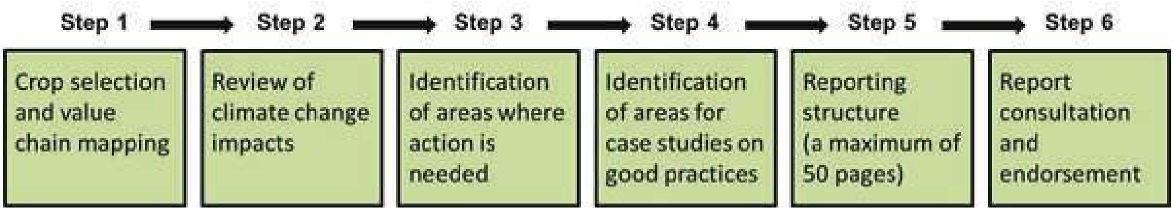

Figure 5. Six-step methodology for scoping the adaptive capacity of value chainst

The study was implemented in consultation with relevant stakeholders at the national level to obtain relevant input. The nature of climate change impacts and respective responses requires leadership at the highest level, and close collaboration and coordination between sectors. Since climate change impacts and potential adaptation and mitigation responses can be very site-specific, respective action should be taken at sub-national and local levels. The framework was set to promote cross-sectoral and inter-departmental coordination and cooperation.

The methodology used was designed to maximize existing information, studies, and experience in the Philippines. There was no primary research intended as each step of the methodology involved literature review, particularly the compilation of past studies on climate change impacts, adaptation strategies, and measures (i.e., good practices); the judgment of the stakeholders; and the judgment of other experts that participated in the consultative meetings.

Four national consultative meetings were held on the following dates in the following venues, and with the following number of participants:

- 11 February 2014 at DA-BAR with 30 participants (19 males and 11 females)

- 17 February 2014 at DA-BAR with 30 participants (20 males and 10 females)

- 20 March 2014 at the Southeast Asian Regional Center for Graduate Study and Research in Agriculture (SEARCA) with 20 participants (13 males and 7 females)

- 14 April 2014 at SEARCA with 33 participants (22 males and 9 females)

These meetings, which were attended by experts who are involved in rice and corn programs, were held to identify rice and corn issues related to climate change as well as good agricultural practices for adaptation and mitigation of climate change impacts (Figures 6 to 9).

Figure 6. First national consultative meeting on 11 February 2014 at DA-BAR, Quezon City

Figure 7. Second national consultative meeting on 17 February 2014 at DA-BAR, Quezon City

Figure 8. Third national consultative meeting on 20 March 2014 at SEARCA, Los Baños

Figure 9. Fourth national consultative meeting on 14 April 2014 at SEARCA, Los Baños

II. VALUE CHAIN MAPPING

2.1 Rice Value Chain Map in the Philippines

The value chain of rice is the sequence of events from its production to processing, to its marketing and consumption. Rice input suppliers, producers, and marketing channels usually constitute the basic value chain processes for a rice sub-sector (Figure 10). Seed variety is the most important input of the rice industry (Regalado and Romero 2012). The rice value chain uses wide-ranging labor. In the rice supply chain, the logistics are identified as drying, transporting, milling, packaging, and storage.

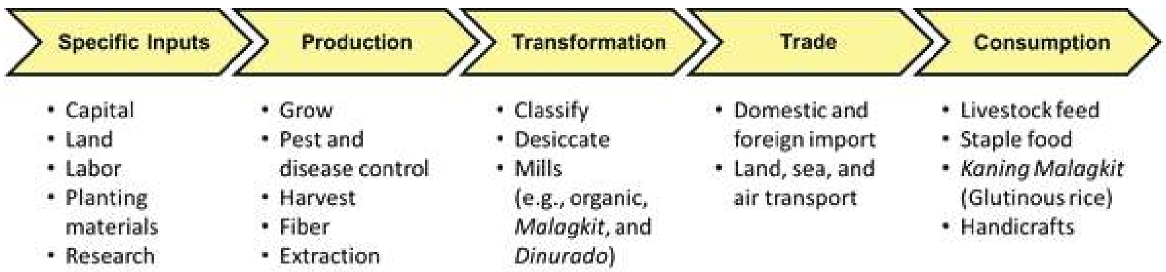

Figure 10. Basic functions in a rice sub-sector value chain
Source: GTZ (2005)

In the Philippines, studies on the rice value chain are scarce. Recently, a study was conducted on the rapid appraisal that was based on an interview with selected players in various levels of the rice value chain, specifically from Pangasinan and Nueva Ecija to Metro Manila. Findings revealed that the paddy rice supply chain is multi-layered, with many competing players in each layer and no evidence of any cartel-like behavior in the areas studied. Margins are limited to 2 percent or less of raw materials at all levels before retail. The profits are enhanced by volume, fast turnover of stocks, integration of operations across levels, and investments for quality consistency. The greatest threats to current players are weather risks and continuing tight local paddy supplies that spawn greater competition and raise management costs. The increased costs also highlight the lower-cost option of bringing in foreign rice that manifests in rampant smuggling given the government's quantitative restrictions on rice imports (Dela Peña 2014).

2.2 Corn Value Chain Map in the Philippines

A clearer understanding of the Philippines' corn industry is possible by separating yellow corn from white corn (flint type). Yellow corn and white corn are mainly used for animal feeds and human food, respectively. Most of the white corn produced by marginal farmers is consumed at the household level. There are very few seed companies working on white corn hybrid because of lack of market. The marginal farmers could not afford to buy hybrid seeds or fertilizers. Native varieties are mostly early maturing, low yielding, and tolerant to stresses, but they exhibit good eating quality (Salazar 2011).

Excess yellow corn production from the southern parts of the Philippines used to be shipped to the majority of feed mills in the central and northern parts of the country. The government had instead intensified production in the northern parts due to high transport cost from the south (Salazar 2011).

In the yellow corn value/supply chain, the players commonly involved are input suppliers, farmers, traders and processors, big traders and contributors, and consumers (Figure 11). The same set of key players constitutes the value/supply chain for white corn (Figure 12).

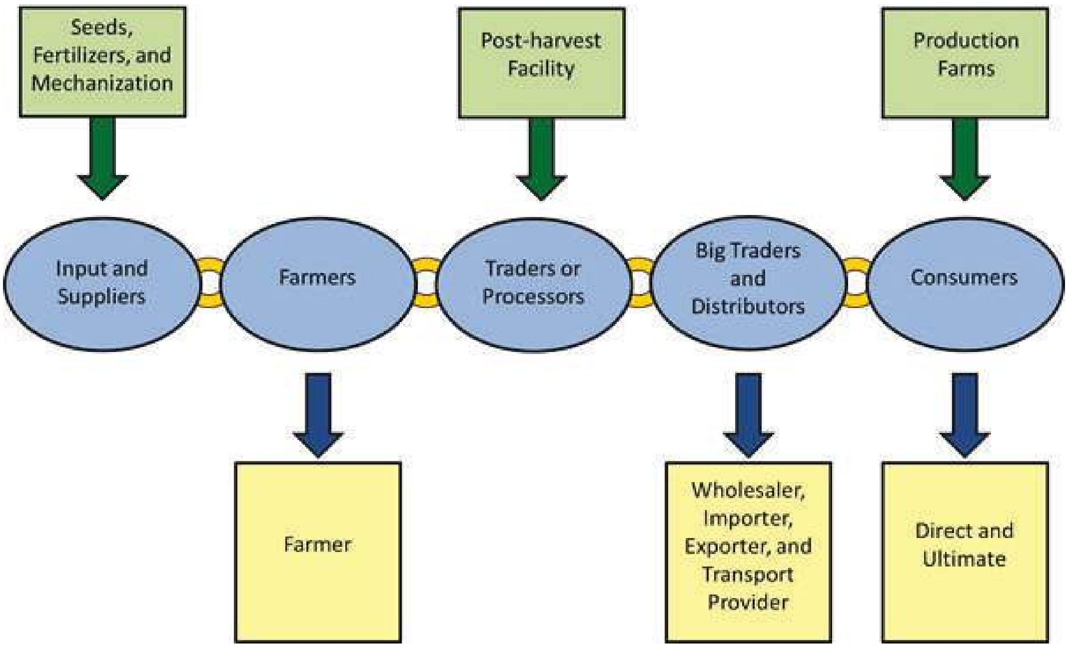

Figure 11. Yellow corn value/supply chain in the Philippines
Source: Salazar (2011)

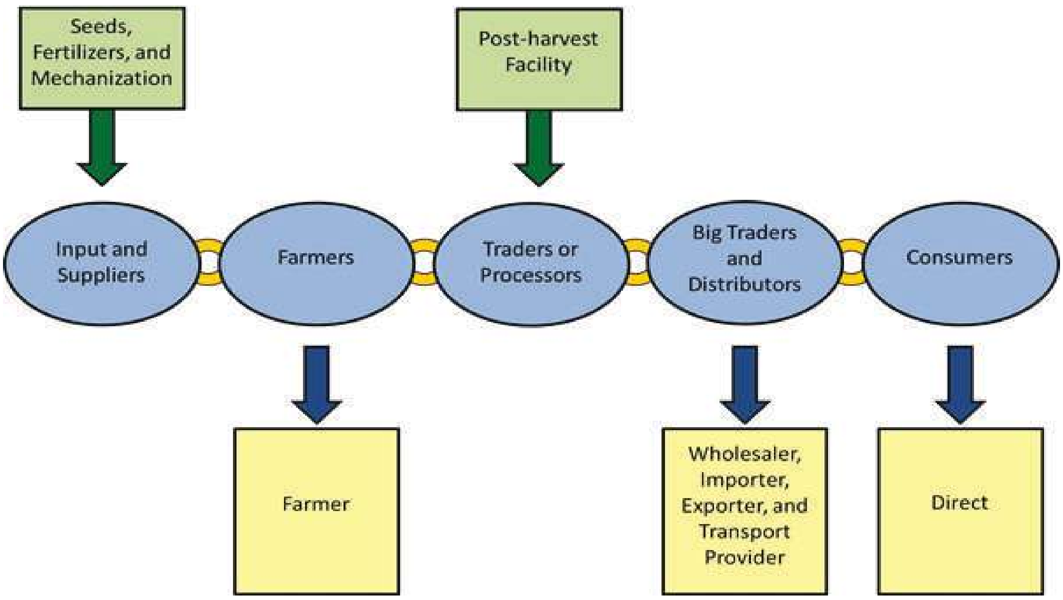

Figure 12. White corn value/supply chain in the Philippines
Source: Salazar (2011)

The end of the chain will largely determine the beginning of the chain. A total of 1, 282,045 ha of land are devoted to yellow corn farming. It is mainly a component of feeds for the livestock industry.

As a consequence of the impending increase in demand for meat, yellow corn production will intensify. However, the supply of yellow corn in the world market is uncertain because the grain is used for ethanol production by the world's biggest corn supplier: the United States. Also, climate change prohibits the reliance on the supply and price of feed wheat in East Europe and Australia.

According to Salazar et al. (2012), the pressing need to be self-sufficient in yellow corn opens areas for research, development, and extension (RDE) based also on the above supply/value chains. Common RDE needs for corn include enhancing the quality of yellow corn and post-harvest processing facilities, particularly for drying, shelling, and storage, since the high amount of rainfall during the wet season from May to August has serious implications to corn grain quality. Aflatoxin contamination is common in areas with no mechanical dryer. Until the requisite affordable and efficient drying and storage facilities become available, most of the productivity increase will go to post-harvest losses. This will be detrimental to the producers and users. Another RDE need is on grain pest and disease control, which can be addressed through appropriate pest control measures (e.g., chemical and biological) as well as genetic improvement (e.g., development of resistant cultivars).

Knowing what other countries, suppliers, and consumers are doing and will be doing will aid in determining what direction the local corn industry should take for the benefit of the consumers, producers, and all the stakeholders in the yellow corn supply chain (Salazar et al. 2012).

The situation for white corn is different. White corn is produced mostly by marginal corn farmers and consumed at the household level. There are also very few seed companies working on white corn hybrids because of lack of market. White corn farmers are usually poor and could not afford to buy hybrid seeds or fertilizers. The R&D thematic areas are similar to yellow corn, but projects such as the development of white corn open pollinated varieties (OPV) that are tolerant to biotic (e.g., pests and diseases) and abiotic (e.g., droughts) stresses should be highlighted. Such studies will definitely show the nutritional advantage of corn as food to enhance the market of white corn, which will be advantageous to consumers and producers; farming system studies to augment the income of white corn farmers; and post-harvest processing technologies, especially since the product is consumed directly by humans (Salazar et al. 2012).

III. CLIMATE CHANGE IMPACTS AND VULNERABILITIES

3.1 Climate Change Impacts on Agriculture in the Philippines

Agriculture is an important driver of the Philippines' economy. More than one-third of the country's inhabitants depend on agriculture and fishing for a living. There are already trends of increasing number of hot days and warm nights, but decreasing number of cold days and cool nights. Both maximum and minimum temperatures are generally getting warmer. Other extreme weather or climate events like intense rains have become more frequent.

Agricultural crop production and post-production are highly influenced by climate (Chalinor et al. 2007; Hoogenboom 2003; Lansigan et al. 2007; Lansigan and Salvacion 2007; Sivakumar and Hansen 2007a). Farmers rely on existing weather conditions to implement different farm activities, starting from pre-production to post-harvest. At the crop level, the existing weather pattern determines not only the rate of crop growth and development but also the rate and development of different pests and diseases (Shapiro et al. 2007; Zhao et al. 2005). According to Moeletsi et al. (2013), the vulnerability of agricultural production is higher today than ever before because of increasing population, high input cost, and changing climate across the globe.

In the Philippines, the effects of global climate change include increase in temperature; increase in frequency, intensity, and duration of extreme climate events such as droughts, floods, and tropical storms; changes in the intensity, timing, and spatial distribution of rainfall; warming temperatures; soil degradation; increasing weather variability; and sea level rise resulting in saltwater intrusion and loss of agricultural land (PhilRice 2011, 2012).

Long-term changes in temperature and precipitation patterns that are caused by climate change are expected to shift production seasons, pest and disease patterns, and modify the set of feasible crops. In turn, these will affect production, prices, incomes, and ultimately, livelihoods and lives. Climate change impacts include increased floods and droughts, soil degradation, water shortages, and possible increases in destructive pests and diseases. Agriculture must become central to future discussions on climate change because it contributes a significant proportion of greenhouse gas (GHG) emissions (Rudinas et al. 2013).

Soil erosion that will lead to soil nutrients mining, lower soil productivity, and consequently, lower crop yields are some of the impacts of climate change on Philippine agriculture (Perez 2009). The identified adaptation strategies such as crop diversification, change of crop or crop variety, and crop insurance are anticipatory. Providing subsidies is another adaptation strategy.

Impacts on water resources are water shortages and water quality degradation. Adaptation practices would be to reiterate existing policy to prioritize abstraction from surface water to remove the pressures from groundwater sources (e.g., Natural Water Resources Board, Metropolitan Waterworks and Sewerage System, and other agencies). The adoption of new environment-friendly technology for efficient water use and water conservation (e.g., small water impounding projects, small farm reservoirs, and AWD technique) should also be encouraged.

Changes in weather patterns because of anticipated climatic change will exert huge impact on agricultural production systems. Such impacts were already demonstrated in different climate change impact studies (e.g., Chalinor et al., 2007; Lobell et al. 2007; Mearns 2000; Olesen and Bindi 2002; Reddy et al. 2000; Reynolds 2010; Thorton et al. 2006; Yadav et al. 2011). In the Philippines, the works of Buan et al. (1996), Centeno et al. (1995), Lansigan and Salvacion (2007), and Salvacion (2013a; 2013b) show that climate change will affect the yield and suitability of rice and corn negatively. This can be a serious threat to the country's food security. According to De los Santos et al. (2007), rice and corn production losses from El Niño events alone range from USD 0.5 million to USD 0.76 million. Therefore, it is imperative to develop different measures and systems to minimize such negative effects and economic losses.

Advances in information technology, cropping systems modeling, geographic information systems, and field sensors can be combined to develop decision-support models and early warning systems that will help farmers and policy-makers develop sound, science-based judgment under uncertain situations brought about by climate change. The development of a "smarter Forestry Agricultural Resource Management System" that integrates different decision-support models into a single setup is the realization of the needed early warning systems. Sivakumar and Hansen (2007b) showcased the uses of different decision-support models and early warning systems in addressing the impacts of climate variability in agriculture in different countries across the globe.

3.2 Climate Change Impacts on Rice Production and Post-production

Climate change will devastate the rice production and post-production sectors if it is not addressed properly. Low rice supply, along with increasing rice demand, affects both food security and national economy (PhilRice 2011). The historical and projected trends in rice in selected climate variables in the Philippines are shown in Table 3.

PhilRice established the Climate Change Center in 2011 by virtue of PhilRice Administrative Order No. 2011–04. Its mandate is to "develop and extend a comprehensive and judicious understanding of the current and future impacts of climate change, including variability and extremes on the Philippine rice farming system, and to cushion its possible negative effects on the realization of rice self-sufficiency" (PhilRice 2012). Droughts affect all stages of rice growth and development. The strong effects on grain yield are largely due to the reduction of spikelet fertility and panicle exertion. Frequent droughts not only reduce water supplies but also increase the amount of water needed for plant transpiration. The most significant drought occurrence was the 1997–1998 El Niño, during which rice yield declined considerably (Table 4).

Table 3. Historical and projected trends in rice in selected climate variables in the Philippines

Variable	Specific climate risk/opportunity	Historical trend	Projections	Confidence	References
Evapotranspiration	Amount of irrigation Frequency of irrigation	Slight increase Shift with season			IPCC (2007)
Temperature	High temperature Extreme heat days (highly correlated with yield)	Increasing temperatures Increasing frequency of extreme temperature	Projected increase of 1ºC–1.1ºC in the next 50 years	High	DOST-PAGASA (2011) IPCC (2007) PhilRice (2012)
Solar radiation (SR)	High SR increases yield during flowering stage	Constant but with seasonal variation			DOST-PAGASA (2011) IPCC (2007) IPCC (2001) NASA (2013)
Precipitation by season (rainfall)	Typhoons Floods Droughts Soil erosion Salinity	Increasing in total average Occurrences of extremes	Increasing frequency of occurrences of extremes Rainfall intensity increase Mid-season temporal drought Increase of 3–5 percent by 2020 Rainfall variability Rainfall intensity increase (during rainy season) Prolonged droughts (during dry season)	High	DOST-PAGASA (2011) IPCC (2007)
Relative humidity (RH)	High RH, high occurrence of new and emerging pest and disease High RH, high risk on seed deterioration	Minor increase Almost constant	Slight shift with season following changes in rainfall and temperature pattern	High	DOST-PAGASA (2011) IPCC (2007)
Wind speed	Typhoons	Occasional Year-round Increasing frequency of destructive typhoons	Increasing frequency of destructive typhoons Typhoon occurrences not limited to wet season but distributed throughout the year	High	DOST-PAGASA (2011) IPCC (2007)
Surface water level (sources)	Increasing runoff causes increased soil erosion Decreasing levels cause a decrease in irrigation Low cropping intensity	Decreasing sources and water levels due to prolonged droughts	Continuous decrease in water level unless high intensity rainfall (during wet season) can be collected and stored	High	Experts' opinion Personal communication
Groundwater level	Increasing runoff causes increased soil erosion Alternative source of irrigation Saltwater intrusion in coastal areas	During dry season, especially with El Niño		Medium	Experts' opinion Personal communication

Table 4. Impacts on rice production and the vulnerability rating

System of interest	Geographical location	Climate change trend/signal	Biophysical impact	Socio-economic impact	Exposure	Sensitivity	Ability to respond	Vulnerability rating	References
Rainwater harvest (R) Small farm reservoir or rainfall interceptor pond Small water impounding project Diversion dam	National	Erratic rainfall	Lack of irrigation for production	Lower rice yield	High	High	Medium	Very high	Experts' opinion Personal communication
Irrigation (I)	National	Extremely high temperature Temperature rise High variability (erratic) rainfall	Decreased cropping intensity (decreased irrigated area during dry season, floods during wet season)	Decreased total yield Poor performance Degradation of irrigation systems	High	High	Medium	Very high	PhilRice (2011)
Varieties more resilient to salinity, drought, and submergence (I&R)	National	Susceptible to abiotic stresses	Lack of suitable tolerant varieties	Lower yield Lower grain quality	High	High	Medium	Very high	PhilRice (2011, 2012)
Varieties more resilient to pest and diseases (I&R)	National	Susceptible to biotic stresses	Lack of suitable tolerant varieties	Lower yield Lower grain quality	High	High	Medium	Very high	PhilRice (2011, 2012)
Nutrient management (I&R)	National	Symptoms of deficiency	Declining soil fertility	Lower yield Lower grain quality	High	High	High	High	IRRI (2010) PhilRice (2012)

Rice diseases (e.g., rice blast, sheath, and culm blight) could become more widespread. Altered wind patterns may change the spread of wind-borne pests, bacteria, and fungi that are agents of crop disease. Crop-pest interactions may shift as the timing of development stages in both hosts and pests are altered. The possible increases in pest infestations may bring about greater use of chemical pesticides to control them. Climate change may also affect weed ecology, the evolution of weed species over time, and the competitiveness of C3 versus C4 weed species (PhilRice 2011).

The combined effects of increases in temperature and rainfall on rice production vary depending on time, location, eco-zone, cropping season, and planting schedule. Rainfed upland rice production during the wet season proved to be the most vulnerable to climate change, disrupting the cropping calendar and thus resulting to greater loss in rice production in this eco-zone (Peñalba et al. 2012).

Peñalba et al. (2012) recommended adjustment of cropping calendar; rotation and diversification of crops; construction of small farm reservoirs; zero tillage for more effective water infiltration; and prevention of soil erosion, especially for upland rainfed conditions. In addition, the study also recommended the use of drought-resistant and submergence-tolerant varieties as appropriate. The researchers also pushed for farmers' education to improve the acceptability of alternative conservation farm technologies and help them make informed decisions on technologies that they can adopt to respond to projected climatic changes.

3.3 Climate Change Impacts on Corn Production and Post-production

Corn is the second major cereal crop in the Philippines. It provides 75 percent of the calories the world consumes, along with rice, soybean, and wheat. Climate scientists, especially in the United States, agree that long-term weather patterns will continue to change, but there is great uncertainty and very minimal research regarding how these global climate changes will influence cropping systems.

As identified during the consultative meetings, temperature, solar radiation, rainfall, relative humidity, wind speed, and groundwater level are among the climate variables that may affect corn production and post-production (Table 5). Such climate variables will heavily affect corn productivity in marginal and unfavorable growing areas. As such, climate-ready varieties, an integrated farming systems approach, soil and water conservation measures, and post-production technologies may be needed to address these variables (Table 6).

Table 5. Historical and projected trends in corn in selected climate variables in the Philippines

Variable	Specific climate risk/opportunity	Historical trend	Projections	Confidence	References
Temperature	High temperature Extreme heat days (highly correlated with yield)	Increasing temperatures Increasing frequency of extreme temperature	Projected increase of 1ºC–1.1ºC in the next 50 years	High	DOST-PAGASA (2011) IPCC (2007) PhilRice (2012)
Solar radiation (SR)	High SR increases yield during flowering stage	Constant but with seasonal variation			DOST-PAGASA (2011) IPCC (2001, 2007) NASA (2013)
Precipitation by season (rainfall)	Typhoons Floods Droughts Soil erosion Salinity	Increasing in total average Occurrences of extremes	Increasing frequency of occurrences of extremes Rainfall intensity increase Mid-season temporal drought Increase of 3–5 percent by 2020 Rainfall variability Rainfall intensity increase (during rainy season) Prolonged droughts (during dry season)	High	DOST-PAGASA (2011) IPCC (2007)
Relative humidity (RH)	High RH, occurrence of new and emerging pest and disease High RH, high risk on seed deterioration	Minor increase Almost constant	Slight shift with season following changes in rainfall and temperature pattern	High	DOST-PAGASA (2011) IPCC (2007)
Wind speed	High wind speed during wet season, particularly during flowering stage, leads to corn barrenness (infertility) Typhoons	Low High	Increasing frequency of destructive typhoons Typhoon occurrences not limited to wet season but distributed throughout the year	Medium High	IPCC (2007)
Groundwater level	Increasing runoff causes increased soil erosion Alternative source of irrigation Saltwater intrusion in coastal areas	During dry season, especially with El Niño		Medium	Experts' opinion Personal communication

Table 6. Impacts on corn production and the vulnerability rating

System of interest	Geographical location	Climate change trend/signal	Biophysical impact	Socio-economic impact	Exposure	Sensitivity	Ability to respond	Vulnerability rating	References
Corn production in sloping areas	National	Soil erosion Landslides Loss of top soil Siltation	Land degradation Decreased soil fertility and productivity	Lower yield Increased poverty incidence	Medium	High	Low	Very high	Experts' opinion Paredes (2014) Personal communication Rola et.al. (2008)
Varieties more resilient to pest and diseases	National	Increasing occurrences of extreme weather conditions (e.g., drought and typhoons) during critical growth stages	Worsening of pest and disease problems	Lower yield Increased production cost	Low	Low	High	Very low	Experts' opinion Personal communication
Poor productivity in marginal areas (drought, water logging, acidity, and salinity)	National	Increasing occurrences of extreme weather conditions (e.g., drought and typhoons) during critical growth stages	Declining soil productivity in stress-prone areas	Lower yield and income for the farmers	High	High	Low	Very high	Experts' opinion Personal communication
Farming systems	National	Unpredictable weather extremes during the cropping season	Declining overall farm productivity	Lower yield and income for the farmers	High	Medium	Medium	High	Experts' opinion Personal communication
On-farm crop storage	National	Unpredictable weather	Increasing mycotoxin occurrence	Post-harvest losses	High	Medium	High	Medium	Experts' opinion Personal communication

Climatic variability, pests, and diseases are the main challenges confronting local farmers. Since most corn-producing areas are rainfed, they depend greatly on rains to experience a good cropping season. Those without supplemental irrigation will face a greater risk of getting their standing crop wiped out during prolonged dry spells or droughts. Excessive rains and flooding could also destroy the season's crop easily. When the two most economically significant pests of the corn crop—the Asiatic corn borer and weeds—are included in the mix, the concerns become magnified.

In the United States, a study conducted and headed by Morton (2011) focused on a regionally coordinated functional network developing science-based knowledge that addresses climate mitigation and adaptation; informs policy development; and guides on-farm, watershed-level, and public decision-making in corn-based cropping systems. One of the objectives was to apply models to research data and climate scenarios to identify impacts and outcomes that could affect the sustainability and economic vitality of corn-based cropping systems. Knowledge gains of farmer beliefs and concerns about climate change, attitudes toward adaptive and mitigating strategies and practices, and decision support need to inform the development of tools and practices that support long-term sustainability of crop production.

Results showed that climate and climate-related information were undoubtedly among the major factors being considered by farmers in their crop production activities. Climate change was observed to affect corn prices. Researchers also found that climate change is likely to have far greater influence on the volatility of corn prices over the next three decades than factors that have been recently blamed for prices swings (e.g., oil prices, trade policies, and government biofuel mandates) (Jordan 2012).

IV. INSTITUTIONAL CHALLENGES AND AREAS FOR REGIONAL COLLABORATION

4.1 Institutional Challenges

The following institutional challenges were identified during the consultative meetings:

(1) Enhancing RDE programs at the national level to include breeding climate-ready rice and corn varieties using best management production and post-production practices

(2) Intensifying the conduct of documentation studies and other relevant research to further generate information, lessons, and experiences that will strengthen CCA in rice and corn

(3) Addressing the intimate connections between climate change, agriculture, and rural poverty to understand gender and climate financing in the Philippines

4.2 Areas for Regional Collaboration

The following are areas of regional collaboration that may need support:

(1) Strengthening regional centers and information networks to support CCA initiatives and projects

(2) Strengthening South to South collaboration through the following:

a. Germplasm exchange between partner countries in Southeast Asia

b. Building capacities on CCA

c. Information/technology/expert exchange

V. CASE STUDIES OF GOOD PRACTICES

Given the apparent effects of climate change on agricultural production, scientists and researchers are exerting sizeable efforts to identify the best adaptation measures to combat them.

McCarthy et al. (2001) and Smit and Wandel (2006) define adaptation as an adjustment in ecological, social, and economic systems in response to climate stimuli and their effects. More specifically, adaptation refers to process, action, or outcome in a system (e.g., household, community, sector, region, and country) to better cope with, manage, or adjust to some changing condition, stress, hazard, risk, or opportunity. An example of CCA is maintaining biological diversity (PhilRice 2011).

Mitigation, on the other hand, is a human intervention or action aimed at lowering the level of GHGs in the atmosphere, or enhancing GHG "sinks" or carbon storage. Planting trees is an example of a mitigation strategy as it avoids GHG emission by increasing carbon storage (PhilRice 2011). CCA involves changing behavior at various levels: individuals, groups, organizations, institutions, and governments.

5.1 Rice

Table 7 shows the prioritized good practices for rice in the Philippines: PalayCheck, Palayamanan Plus, controlled irrigation or AWD technique, and climate-ready varieties.

Table 7. Structuring good practice adaptation options in rice

Case study	Brief description	Criteria satisfied	Regional relevance	Impact on women (-ve/+ve / neutral)	References
Irrigated rice					
1	PalayCheck	Adaptation (refer to manual)	Very high	+	PhilRice (2011)
2	Palayamanan Plus	Adaptation (HH food and income, food security)	High	+	Corales et al. (2005) PhilRice (2011)
3	Controlled irrigation or AWD technology	Adaptation (water shortage) Mitigation (reduce GHG emission)	High	Neutral	Siopongco et al. (2013)
Rainfed rice					
1	Palayamanan Plus	Adaptation (HH food and income, food security)	High	+	Corales et al. (2005) PhilRice (2011)
2	Controlled irrigation or AWD technique	Adaptation (water shortage) Mitigation (reduce GHG emission)	High	Neutral	Siopongco et al. (2013) IRRI Technical Bulletin
3	Climate-ready varieties	Adaptation (biotic and abiotic stress tolerance)	Very high	+	Brar et al. (2009) Gamuyao et al. (2012) Gregorio (2010) Gregorio et al. (2002) Ismail et al. (2010) Islam et al. (2011) Ismail et al. (2012) Mackill et al. (2012) Manzanilla et al. (2011) Singh et al. (2009) Thomson et al. (2010) Wassman et al. (2009a, 2009b) Ye et al. (2010, 2012)

Note: The practices identified in this table were sourced from a series of consultations with the heads of the DA and its attached agencies, especially those involved in climate change, rice, and corn programs; and R&D focal persons from DA regional offices. The criteria in the third column refer to the criteria and indicators for Appraisal of Adaptation Measures (Annex 7) based on/adopted from the Guidance Manual for Climate Change Adaptation Case Studies- ASEAN.

5.1.1 PalayCheck System

Rice production, which can offset major impacts of climate change by increasing farmers' productivity and profitability, can be improved through the adoption of an integrated crop management (ICM) system for rice. PalayCheck is a dynamic ICM system that presents easy-to-follow practices to achieve respective key checks as well as improve crop yield and input efficiency. In addition, this promising technology has high potential for climate change mitigation in irrigated lowland rice farming systems (PhilRice 2011, 2012).

PalayCheck is similar to Australia's Ricecheck, which helped increase the country's yield from about 6 t/ha in 1987 to almost 10 t/ha in 2000. In 2004, the Philippines' version of Ricecheck was developed through a series of workshops and consultations with rice experts, extension workers, and farmers. Palaytandaan served as base material. From its inception in 2004, PalayCheck was tested in some 30 sites with almost 1,000 farmers nationwide eventually recommending it for scaling up. The average yield increased by at least 1 t/ha in pilot sites. The results showed that the more checks achieved, the higher the yield. PalayCheck served as the platform for the Location-specific Technology Development project of PhilRice.

PalayCheck encourages farmers to manage crops based on targets, and provides recommendations on how to attain the targets based on best management practices for a particular agro-ecological condition. The recommendations are localized at the farmer level, taking into account the interactions among practices and other factors affecting yield, grain quality, and environment. In addition, PalayCheck provides a collaborative learning framework for farmers to improve their understanding of production principles and management skills to enable technology localization, with facilitation from technically competent resource persons.

5.1.2 PalayamananPlus

One of the possible strategies to reduce the impacts of climate change on rice production is the adoption of a diversified integrated rice-based farming system. Recent studies showed that income from one hectare of rice monocropping is insufficient to meet even the financial requirements of a family of five. At present, it is projected that a farming family should earn at least PHP 90,000 or farm two hectares of land to sustain the family's financial needs. As a response, PhilRice has embarked on Palayamanan, a term coined from palay (rice) and kayamanan (wealth), to help the farmers meet their needs.

PhilRice developed Palayamanan, a model to help farmers in rainfed and upland areas sustain their livelihoods and better cope with adverse impacts of climate change. Palayamanan is a farming system that highlights the purposive integration of various farm components such as rice and other crops, livestock, aquaculture, biomass waste recycling, and other income-generating means (PhilRice 2011, 2012).

Palayamanan is the modern concept of bahay-kubo or nipa house, but it is elevated to a higher level of integration. It combines rice with other high-value crops, trees, fish, poultry, livestock, and biomass recycling. It espouses the efficient use of available farm resources and highlights the interconnectivity between each resource and by-product through available modern technologies. It is not a new system of farming but an old paradigm that many farmers have been practicing for a long time. However, despite its benefits to the farmers and the environment, most farmers have not adopted it because of the popularity of the monoculture system (rice-rice) and the lack of knowledge on how to implement it.

Palayamanan, along with AWD and PalayCheck, are included in the technologies and practices in rice identified by PhilRice (2012). It is considered a strategy to diversify the farmers' sources of food and income to enhance their resilience to climate change (Appendix 1).

5.1.3 Alternate Wetting and Drying (AWD) Technique

AWD is one of the key climate change mitigation strategies that benefit small farmers. It is a water-saving technique for use in rice production, especially during drought conditions. It also minimizes GHG emissions in paddy fields. Water-saving techniques provide ways to change practices to improve the livelihoods of many farmers. It is regarded as one of the more important rice cultivation methods that can dramatically save freshwater irrigation in this century (Siopongco et al. 2013). In addition to AWD, other water-saving techniques include controlled irrigation, small farm reservoir, and rainwater harvesting.

Irrigation has become a very costly input in rice production because of the rising cost of fuel. In producing one kilogram (kg) of paddy, it is estimated that a farmer has to use 3,000–5,000 liters of water to keep ponded water during the growth stage of plants. Therefore, farmers irrigate frequently and keep the field flooded at all times.

IRRI, in cooperation with national research institutions, developed the AWD technique. The ample adoption of this technique can improve the use of irrigation water so that the cropping intensity could be increased from 119 percent to 160 percent (related to the maximum of 200% in double cropping systems) (IRRI 2014; Siopongco et al.2013).

In this practice, the crop is intermittently submerged and dried from 20 days after sowing until two weeks before flowering, which means that fields are allowed to drain until water below the surface reaches down to 15 centimeters before re-flooding. In this controlled drainage setup, the crop is still spared from the debilitating effects of droughts. Compared with conventional flooding, water savings in AWD could be as much as 25 percent. This will result in a reallocation of saved water to nearby fields or other purposes (e.g., household use). Moreover, AWD technique has been proven to mitigate methane emissions. The GHG methane is pro-duced anaerobically by methanogenic bacteria that thrive well in paddy rice fields. Flooded rice fields are a large source of methane emissions. In fact, they are the second largest anthropogenic source after ruminant livestock. AWD can reduce methane emissions by up to 50 percent because periodic aeration of the soil inhibits methane-producing bacteria (Siopongco et al. 2013).

5.1.4 Climate-ready Rice Varieties

The Philippines' rice productivity losses are compounded by biotic (e.g., pests) and abiotic (e.g., droughts, heat, erratic rainfall patterns, increasing risks from typhoon- and rainfall-induced floods, sea level rise, and saltwater intrusions) stresses brought about by the changing climate (Wassman et al. 2009a, 2009b). To mitigate losses caused by abiotic stress, IRRI developed rice breeding lines that are tolerant to submergence, salinity, heat, and droughts. The SUB1A gene, derived from FR13A (a rice variety from Odisha, India), confers tolerance of up to two weeks of complete submergence. Varieties with the SUB1A gene have the same yield and other characteristics as the original varieties, and they can be used to replace these varieties in flood-prone areas (Mackill et al. 2012; Manzanilla et al. 2011; Singh et al. 2009). Saline-tolerant rice, aided by the Saltol gene, can survive in saline-prone environments with salt of at least EC 4 dS/m (0.3% salt) (Gregorio 2010; Gregorio et al. 2002; Islam et al. 2011; Ismail et al. 2010; Thomson et al. 2010). Combining Saltol and SUB1 in one genetic background seems feasible with no apparent negative impacts on agronomic traits, and this will help develop more stable varieties adapted to coastal zones (Gregorio et al. 2002). Rice breeding lines with tolerance of drought conditions conferred by drought quantitative trait loci (QTL) are also available, and some materials have been released as varieties in India and the Philippines. QTL for heat tolerance at the flowering stage have been mapped (Ye et al. 2010, 2012). For direct seeding, particularly where water is applied to suppress weeds, tolerance of anaerobic germination can improve early seedling establishment (Ismail et al. 2012). Materials with stronger tolerance for adverse soil conditions of excess Fe, deficient P, and deficient Zn are also in the pipeline. The isolation of the Pstol1 gene (Phosphorus starvation tolerance 1) from variety Kasalath has shown its role in improving root growth and distribution in phosphorus-deficient soils and increasing yield by as much as 20 percent (Gamuyao et al. 2012). However, all these important traits can help farmers only through smart breeding by fast-tracking introgression into high-yielding rice, and evaluating their adaptation at target sites in the country.

Marker-assisted breeding allows breeders to introduce a gene of interest into a commercial variety in two backcross generations, thereby speeding up product development by two to three years. Aside from the traits mentioned above, markers have been available for resistance to biotic factors. For planthoppers, the genetics of resistance to brown planthopper, white-backed planthopper, green leafhopper, and other leafhoppers has been studied and many resistance genes have been identified (Brar et al. 2009).

In spite of flashfloods or submergence and long-term inundation in rice-producing areas in Southeast Asia, rice productivity can be sustained and even improved. This can be achieved by applying systematic and participatory methods in identifying and selecting appropriate and adopted rice varieties under local conditions, along with best management practices.

5.2 Corn

Table 8 shows the prioritized good practices for corn in the Philippines: SSNM, village-type corn dryer, SCOPSA, white corn for food, and village-type white corn mill.

Table 8. Structuring good practice adaptation options in corn

Case study	Brief description	Criteria satisfied	Regional relevance	Impact on women (-ve/+ve / neutral)	References
Yellow corn					
1	SSNM	Mitigation (increase nutrient efficiency, reduce GHG emission)	High	+	DA-BAR (2013) Ocampo (2010) Pasuquin et al. (2010) Witt et al. (2008, 2009)
2	Village-type dryer	Adaptation and mitigation (erratic rainfall, grain quality efficiency	High	+	
3	SCOPSA	Adaptation and mitigation (conserve soil moisture, reduce GHG emission)	High	+	BSWM
White corn					
1	White corn for food Village-type white corn mill	Adaptation (corn grits as product serve as staple food)	High	+	UPLB Horizon (2014)
2	SCOPSA	Adaptation and mitigation (conserve soil moisture, reduce GHG emission)	High	+	BSWM

Note: The practices identified in this table were sourced from a series of consultations with the heads of the DA and its attached agencies, especially those involved in climate change, rice, and corn programs; and R&D focal persons from DA regional offices. The criteria in the third column refer to the criteria and indicators for Appraisal of Adaptation Measures (Annex 7) based on/adopted from the Guidance Manual for Climate Change Adaptation Case Studies- ASEAN.

5.2.1 Site-specific Nutrient Management (SSNM)

SSNM is an approach that advocates the use of available organic nutrient sources (e.g., crop residue and manure) and inorganic fertilizers.

There is a growing demand for corn not only in the Philippines but in the whole of Asia. There is significant potential for corn production in the favorable irrigated and rainfed environments, although knowledge on yield potential, exploitable yield gaps, and constraints to improving productivity at the field level are still limited. With SSNM, farmers strive to adjust fertilizer use to optimally fill the deficit between the nutrient needs of a high-yielding crop and the nutrient supply from naturally occurring indigenous sources (e.g., soil, crop residue, manure, and irrigation water). The principles of SSNM for corn were developed through a series of researcher-managed on-farm and on-station experiments covering a wide range of biophysical and socioeconomic conditions. Experimental data were obtained and updated as more data became available, and used to develop site-specific fertilizer recommendations for evaluation at project sites (DA-BAR 2013; Pasuquin et al. 2010; Witt et al. 2008; Witt et al. 2009).

Specifically, SSNM aims to (1) utilize indigenous nutrient sources available on-farm; (2) apply adequate amounts of fertilizer containing nitrogen (N), phosphorous (P), potassium (K), and other nutrients to minimize nutrient-related constraints and achieve high yield; (3) achieve high profitability in the short and medium term; (4) avoid the luxury uptake of nutrients by the crop; and (5) minimize depletion of soil fertility (Pasuquin et al. 2010; Witt et al. 2008; Witt et al. 2009).

A new, computer-based decision support tool was developed to assist local experts in formulating fertilizer guidelines for tropical hybrid corn based on the principles of SSNM. The software, The Nutrient Expert for Hybrid Maize, allows scientists and extension experts to jointly develop novel nutrient management strategies for evaluation (DA-BAR 2013).

The SSNM approach further advocates the sufficient use of fertilizer P and K to overcome deficiencies (fertilizer use based on yield response like for N), accounting to some extent for the nutrient removal with harvested products to avoid the mining of soil P and K. Site-specific adjustment of nutrient management guidelines and robust approaches to an improved quantitative understanding of nutrient requirements to fill the deficit between plant demand and soil indigenous nutrient supply seem crucial in achieving high yield and profit. Wider scale evaluation of SSNM has begun using farmer participatory approaches at existing project sites, which is an important step towards wider scale delivery of more knowledge-intensive technologies like SSNM for corn in the research-extension continuum of the International Plant Nutrition Institute and its partners in Southeast Asia (DA-BAR 2013; Ocampo et al. 2010; Pasuquin et al. 2010; Witt et al. 2008; Witt et al. 2009).

5.2.2 Village-type Dryer

The three national strategic areas to spur the development of the corn industry in the Philippines include the (1) expansion of production area; (2) improvement of productivity through the provision of high-yielding varieties, appropriate cultural practices, and full mechanization, among others; and (3) reduction of post-harvest losses.

Thirty-seven percent of post-harvest losses in corn are caused by drying. This is followed by storage, which comprises 24 percent of the total loss. Part of the government's program objectives is to reduce the national average post-harvest loss by decreasing drying loss and improve milling recovery, since high post-harvest losses coupled with the limited post-harvest facilities were identified as part of major problems in the Philippine corn industry (Amongo 2011; De Luna 2013; Gragasin 2013).

In spite of the various advancements in mechanization technologies, the level of agricultural mechanization in the Philippines in terms of available mechanical power in the farm is still low compared to other

Asian countries. In corn production, land preparation and threshing are done using a manually operated mechanical power source, while milling is highly mechanized. The bulk of the cost of production, particularly in yellow corn, goes to labor, which includes post-production activities such as harvesting, drying, and shelling (Amongo 2011; De Luna 2013).

5.2.3 Sustainable Corn Production in Sloping Areas (SCOPSA)

GHG emissions can be significantly reduced and carbon sequestered through the adoption of climate-friendly agronomic practices (e.g., crop-residue management and no-tillage farming) and improved use of organic and chemical fertilizers.

Conservation tillage, particularly zero tillage, was introduced in the area to offset the production cost during land preparation. It is one of the technology interventions tested on-farm to evaluate its performance versus conventional tillage and the farmers' practice of growing corn after rice in the area. Generally, the conservation tillage trial aims to aid in the formulation of location-specific and ecologically sound management practices and technology options for sustained corn-based productivity. Specifically, it aims to evaluate the effect of various tillage practices on the growth and yield of yellow and green corn (Labios et al. 2002).

Corn has become an emerging cash crop in the last five years due to the introduction of various corn production technologies. Many idle or barren lands were used to cultivate corn. It was observed that the expansion of corn areas in sloping lands and protected areas augmented the farmers' income, but appropriate soil and water conservation measures were absent. Combined with high rainfall intensities, unsustainable farming practices, and other human-induced factors, impacts to land and soils became very apparent in recent years. These include top soil removal through erosion, formation of gullies, and nutrient depletion. Consequential damage or off-site impacts include siltation and pollution of dams, lakes, rivers, and other waterways; flooding; and water scarcity. Essentially, there is a need to "balance" targets on corn production, as well as conservation and management of soil and water resources, by adopting soil and water conservation measures in sloping lands (Contreras 2013; DA-BSWM 2013).

Therefore, it is important for various sectors to work together and promote SCOPSA through raising awareness, building capacity, and demonstrating technology. It will involve the adoption of a land use management approach that integrates technologies within the socio-economic conditions and biophysical limitations of upland areas for the sustainable development of soil and water resources for corn production. It will consider a farming system that adopts appropriate land use management options and the right mix of soil and water conservation practices (Contreras 2013; DA-BSWM 2013).

The goal is to enhance the productivity level of corn farmers utilizing sustainable adaptive corn-based technologies in sloping areas. The program covers corn areas vulnerable to soil erosion in various locations in the country (Baccay 2014; Rola et al. 2011). The specific details of this approach, which were drafted by DA-BSWM, can be found in Guidelines on the Promotion and Implementation of SCOPSA (DA-BSWM 2013) (Appendix 6).

5.2.4 White Corn for Food and Village-type White Corn Mill

In the Philippines, yellow and white corn varieties are generally planted. Yellow corn (e.g., young corn, popcorn, and sweet corn) are edible, but most of this variety is intended for industrial use (e.g., feeds and raw materials for industrial products). The yellow corn variety is favored as feeds over white corn because it gives poultry and livestock meat a good color.

White corn, on the other hand, is used as a substitute for rice in times of hardship. In places where rice is the main staple, white corn is consumed as vegetable or snacks. White corn is commonly referred to as the "poor man's rice." In the Philippines, white corn is favored as a staple or a substitute for rice because of its taste and eating quality, while hybrid yellow corn is produced primarily for 50 percent of livestock mixed feeds. Other colored corn (e.g., purple) is not grown widely in the Philippines.

From 2000 to 2011, corn consumption ranged from 1 million t to 1.7 million t, whereas white corn production ranged from 1.8 million t to 2.5 million t. More white corn was produced than consumed. This is probably part of the reason why DA started promoting white corn as an alternative to rice in 2010. Apart from surplus production, it is thought that diversifying the diet (i.e., consuming white corn in particular) will help in curbing the country's rice shortfall and help reduce rice imports (DA 2013a).

DA is also promoting white corn as a healthier staple than rice because of its low glycemic index. White corn is slower to digest, resulting in a gradual release of glucose into the bloodstreams and lessening the risks of diabetes, which is a major cause of death in the Philippines (DA 2013a).

White corn also contains more protein, lysine and tryptophan, dietary fiber, minerals, and antioxidants than rice. Lysine aids in building muscle tissue, recovery from injury or surgery, and effective calcium absorption. It also helps the body produce antibodies, enzymes, and hormones, while tryptophan is needed for normal growth in infants (Jamias 2014).

After recognizing the value of white corn as a staple food, several government programs have promoted it as an alternative to rice. For example, the program Adaptation and Dissemination of Newly Developed and Improved White Corn Varieties as Alternative Source as Staple Food was established to support the production of white corn and expand its promotion at the national level, including establishing a more stable supply of white corn and producing varieties to suit different regional preferences (Labios et al. 2013a, 2013b).

Filipino farmers traditionally plant OPV of white corn that allow them to save seeds from their harvest for the next planting season. Traditional OPV planting also makes it possible for farmers to exchange seeds and breed varieties that are better adapted to the environment.

Corn has been touted as "poor man's rice" for years. The rice shortage in the 1960s that forced many Filipinos to eat inferior rice mixed with rough corn grits left a harsh memory. With the exception of those living in Visayas, where white corn is a staple food for 14 million or 20 percent of the population, many Filipinos will eat corn as rice only if rice is unavailable.

The demand for rice increases significantly each year. With demand superseding supply, the government imports stocks from other countries to fill in the gaps and keep prices at stable rates. Given this, the government exerts effort to look into other potential sources of staple food crops to lessen the demand for rice and achieve food security in the midst of climate change. Next to rice, white corn has been the most potential source of staple food in the Philippines, where about 20 percent of the population uses white corn for food. It is a food staple considered second to rice and even more favorable for its health benefits (Balangen 2012; Battad 2012; Cabrera 2013; DA 2012; Jamias 2014).

Plant breeders from the Institute of Plant Breeding of the Crop Science Cluster, College of Agriculture (IPB-CA) at UPLB have also been transforming white corn. They have developed Quality Protein Maize (QPM) Var 6, a variety that contains high-protein for feeding poor, malnourished children and with traits that can sustain a healthy lifestyle for athletes and health aficionados. Developed in 2006, QPM Var 6 contains 66.2 percent more lysine than the normal white corn. QPM Var 6 has 0.374 grams (g) of lysine, while white corn has 0.225 g. Protein is needed to balance the often high carbohydrate intake of most marginalized families because they cannot afford viands. Further, the QPM also has more dietary fiber, minerals, and antioxidants than rice alone (Jamias 2014). Aside from its nutritional values, QPM Var 6 has benefits for ordinary farmers. As an OPV, farmers do not have to buy seeds every time they need to plant because they can save their seeds for the next season (Jamias 2014).

QPM Var 6 has relatively high yields compared to other corn varieties: 5.84 t/ha in Luzon, 5.45 t/ha in Visayas, and 4.47 t/ha in Mindanao. A farmer can harvest in 105 days during the dry season or in 100 days during the wet season. Further, the variety is resistant to diseases such as rust and stalk rot. The shelling recovery from the cobs is 76 percent (Jamias 2014). Another important trait is that corn needs less water than rice, which eases the pressure on irrigation needs. With rice shortages and the crop becoming an expensive commodity in the country, these scenarios offer an opportunity to show that corn could be the staple food (Jamias 2014).

To eat QPM Var 6, the corn kernels are milled into grits. Based on numerous taste tests conducted by the Institute of Human Nutrition and Food of the College of Human Ecology at UPLB, the best mix of rice and corn is 70 percent rice and 30 percent corn grits, making the rice-corn blend taste and look like pure rice (Jamias 2014).

Small farmers were kept in mind about the milling of corn grits. In 2008, UPLB, through the College of Engineering and Agro-Industrial Technology, designed a portable mini corn miller that can be operated by a cooperative or women, especially in the uplands. The grit size of the white corn is crucial to allow it to cook well with rice. DA, through the AgriPinoy Corn Program, allocated about PHP 1 million per region for the purchase and distribution of the improved mini rice corn mill to allow more farmers to produce corn grits (Jamias 2014).

Hunger is more prevalent in rural areas than in urban areas. Farmers in distant locations still have to travel far to buy staple food. Farmers in remote areas have the opportunity to grow corn, but commercial corn mills are very expensive and found only in commercial centers. Therefore, farmers trade their meager produce to survive. By making an inexpensive corn mill that could produce good quality grits available to them, farmers could have ready access to food using their own produce (Jamias 2014). The machine can mill 150 kg of grains per hour with 64.8 percent recovery. In one day, the mill can generate an adequate amount of corn grits to feed more than 1,000 people at 300 g per person consumption per day.

In promoting QPM seed planting, developing and utilizing improved mini white corn mills and eating the rice-corn blend go hand in hand. DA, a long-time partner of the IPB-CA, poured funds into the project to produce and distribute IPB Var 6 seeds around the country and promote it in multimedia platforms. White corn was included in the Food Staples Sufficiency Program of DA to mitigate rice importation (Balangen 2012; Battad 2012; Cabrera 2013; DA 2012; Jamias 2014).

Most of the good practices identified were designed without considering the impacts of climate change.

5.3 Gender Component

Women are expected to be particularly vulnerable to future changes in climate, but they also have certain knowledge and skills that can contribute to climate solutions. Integrating a gender perspective into CCA planning and decision-making is important because of the critical roles women play in supporting households and communities.

Women are often the main actors in managing natural resources such as agriculture, forestry, and fisheries, which are sectors that will be seriously affected by droughts, variable precipitation, and flooding, among others (Laddey et al. 2011; Peralta 2008). Noting that 70 percent of the world's farmers are women, and in Asia women are responsible for 65 percent of food security, women contribute significant labor in cultivating rice and collecting products from the natural environment (e.g., shellfish) (Laddey et al. 2011).

Gender and climate financing in the Philippines can only be understood by addressing the intimate connections between climate change, agriculture, and rural poverty.

5.3.1 Coping Strategies

It is women who have led their households and communities in developing agricultural coping strategies, including food preservation, mixed cropping and cropping diversification, water harvesting and irrigation, growing reliance on wild fruits and forest products, and cultivating at higher levels. Financial coping strategies include shifting from crop production, taking out loans, selling off livestock, seeking government financial assistance, reducing food consumption, and migrating to other sources of work and income (Laddey et al. 2011).

5.3.2 Making Climate Finance Gender-sensitive

At the national level, successful climate strategies, policies, and programs must link with efforts to combat poverty and land degradation as well as enhance food security and access to safe water. Thus, financing to deal with climate change must be situated within the broader context of development financing and development goals: gender equality, poverty eradication, and sustainable development (Peralta 2008). Gender-responsive climate finance at the national level requires sufficient and appropriate global funds and mechanisms that have so far lacked gender considerations.

According to Peralta (2008), the study on gender and climate change finance in the Philippines concluded that proposals for ensuring women and gender is adequately addressed in national climate-financing policies, programs, and frameworks. These include the following:

(1) Creating mechanisms that guarantee women's equal access to negotiating, developing, managing, and implementing adaptation and mitigation financing

(2) Including disaggregated indicators on mitigation and adaptation funds targeting and monitoring benefits to women

(3) Developing principles and procedures to protect and encourage women's access to national adaptation programs and projects

(4) Conducting gender impact assessments of adaptation and mitigation strategies

(5) Implementing the "polluter pays" and "shared but differentiated" principles

(6) Ensuring that mitigation strategies include financing new, green technologies as well as developing and enforcing necessary regulations on GHG emissions

Any effective, long-term response to the climate crisis will require fundamental transformations in production and consumption patterns, particularly in the developed world but also for developing countries like the Philippines. Change lies within the rural and coastal communities and women's organizations that are already facing up to the challenges and risks posed by climate change through a wide range of actions: agricultural adaptation, awareness-building, community organization, and political advocacy (Peralta 2008).

V. CONCLUSION

The following institutional challenges were identified during the consultative meetings:

(1) Enhancing RDE programs at the national level to include breeding climate-ready rice and corn varieties using best production and post-production management practices

(2) Intensifying the conduct of documentation studies and other relevant research to further generate information, lessons, and experiences that will strengthen CCA in rice and corn

(3) Addressing the intimate connections between climate change, agriculture, and rural poverty to understand gender and climate financing in the Philippines

The following are areas of regional collaboration that may need support:

(1) Strengthening regional centers and information networks to support CCA initiatives and projects

(2) Strengthening South to South collaboration through the following:

a. Germplasm exchange between partner countries in Southeast Asia
b. Building capacity on CCA
c. Information/technology/expert exchange

In addition, crop insurance can serve as a guarantee for climate risk needs of farmers, agricultural workers, and other stakeholders.

Climate change is a complex problem that requires a multitude of solutions with sustainable development at the core. An integrated mitigation-adaptation framework should be anchored on a sustainable agenda, which would translate into "no regrets" options and serve the long-term interests of the country regardless of the ultimate impacts of climate change. This framework should involve the following:

(1) Activating CCA policies to mitigate adverse effects and increase resilience in field crop production

(2) Breeding new varieties of pest- and disease-resistant crops that are adapted to heat, salinity, and droughts, and with a short growing season to reduce their water requirements

(3) Active participation in climate change-related international agreements and programs

(4) Increased interest in climate change research

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Published by

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

In cooperation with

SEAMEO SEARCA

Promotion of Climate Resilience in Rice and Maize

Thailand National Study

Imprint

This publication is a joint undertaking by the ASEAN Technical Working Group on Agricultural Research and Development (ATWGARD) and the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH through the ASEAN-German Programme on Response to Climate Change (GAP-CC).

In partnership with the Southeast Asian Regional Center for Graduate Study and Research in Agriculture (SEARCA).

Published by the
Deutsche Gesellschaft für
Internationale Zusammenarbeit (GIZ) GmbH

Registered offices
Bonn and Eschborn, Germany

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As at
April 2015

Printed by/design and layout
SEARCA
College, Los Baños
Laguna - 4031

Photo Credits
Hansa Tangmanpoowadol (SEARCA Photo Contest)

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German Federal Ministry for Economic Cooperation and Development (BMZ)
Alternatively: German Federal Foreign Office

Promotion of Climate Resilience in Rice and Maize

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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

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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.

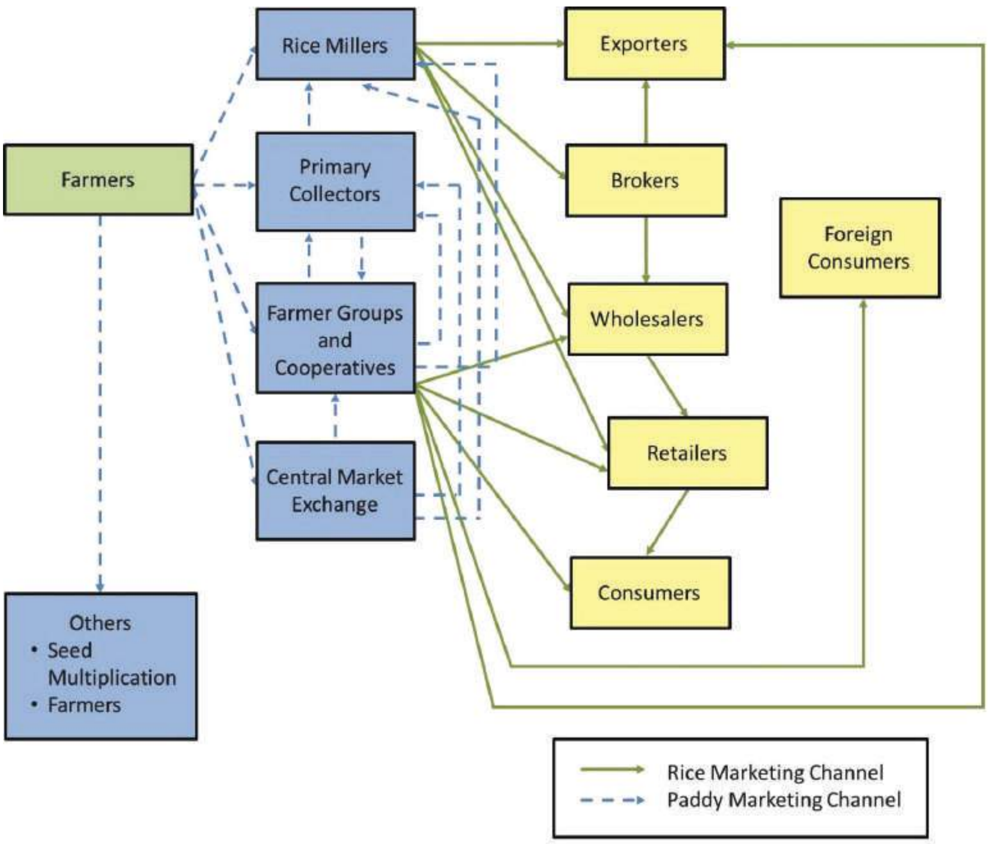

Figure 1. Rice value chain in Thailand.
Source: Agrifood Consulting International (2005)

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.

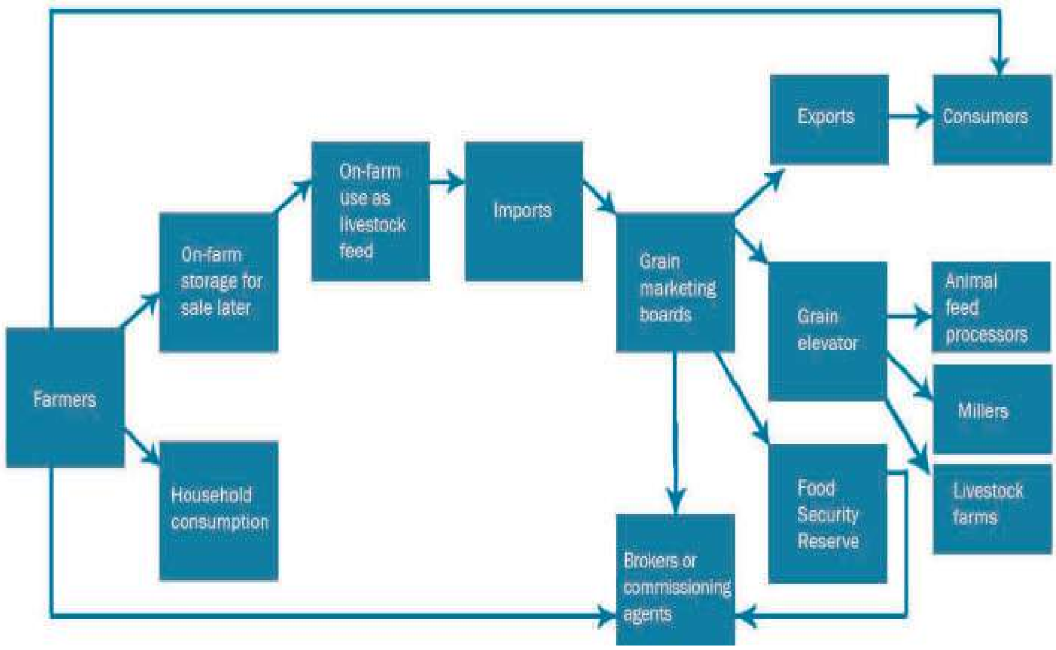

Figure 2. Maize value chain in Thailand.
Source: FAO (2014)

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).

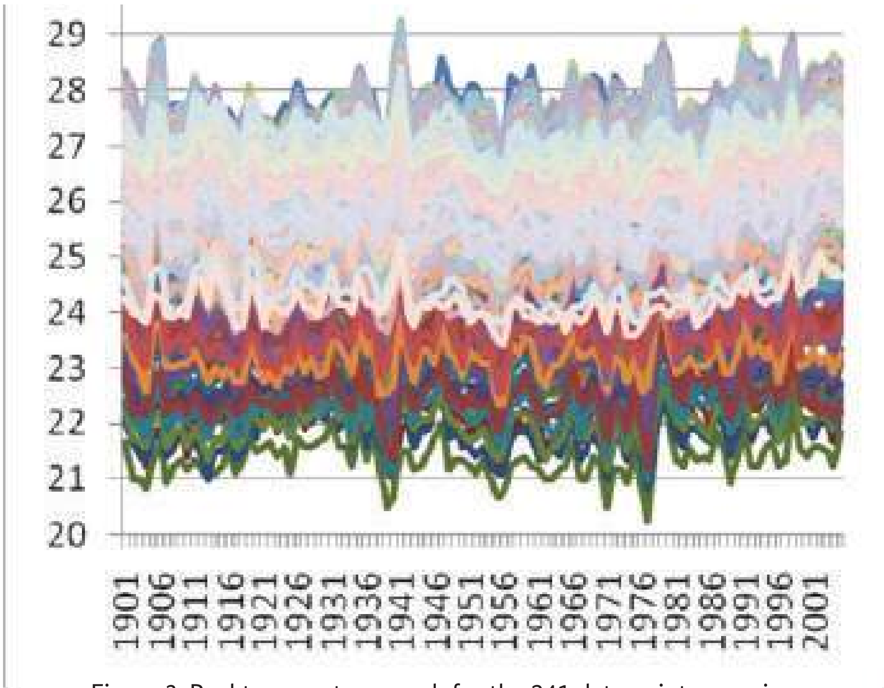

Figure 3. Real temperature graph for the 241 data points covering Thailand's territory.
Source: *OAE, CIAT, and GIZ (2012)*

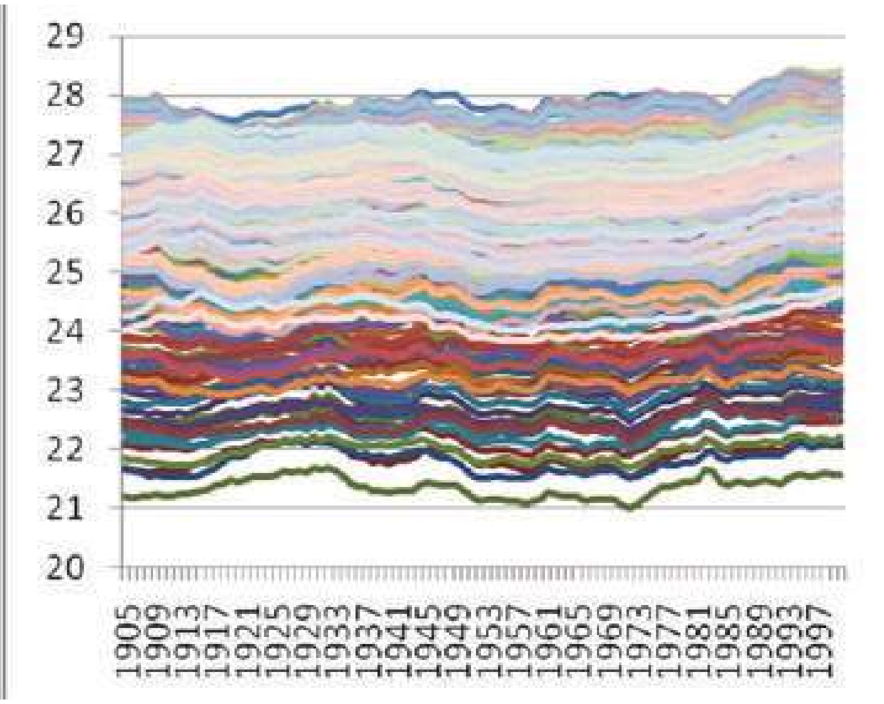

Figure 4. Smoothed temperature graph for the 241 data points covering Thailand's territory.
Source: *OAE, CIAT, and GIZ (2012)*

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.

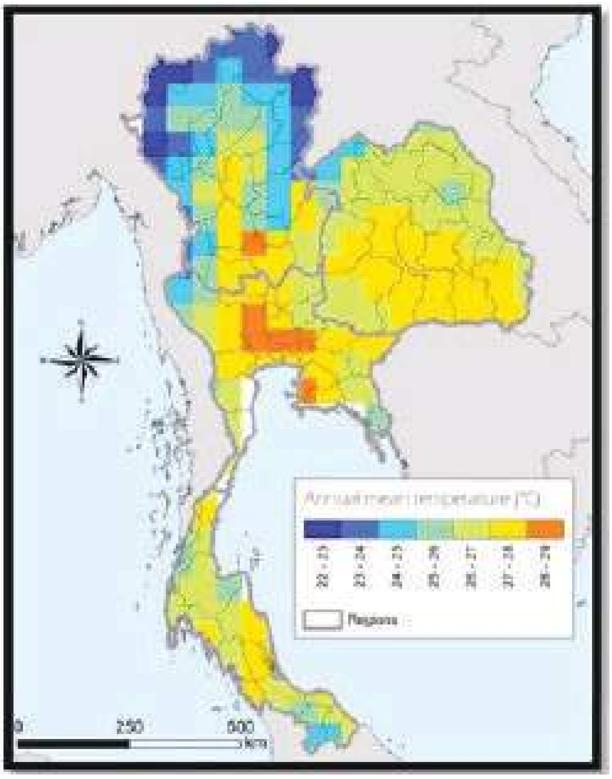

Figure 5. Average annual mean temperature, 1985–2005.
Source: OAE, CIAT, and GIZ (2012)

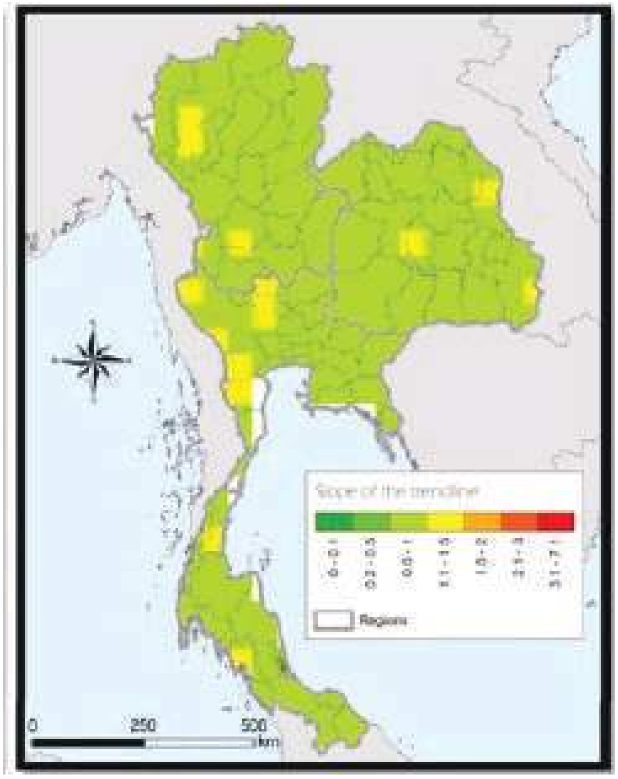

Figure 6. Change in annual mean temperature, 1901–2005.
Source: OAE, CIAT, and GIZ (2012)

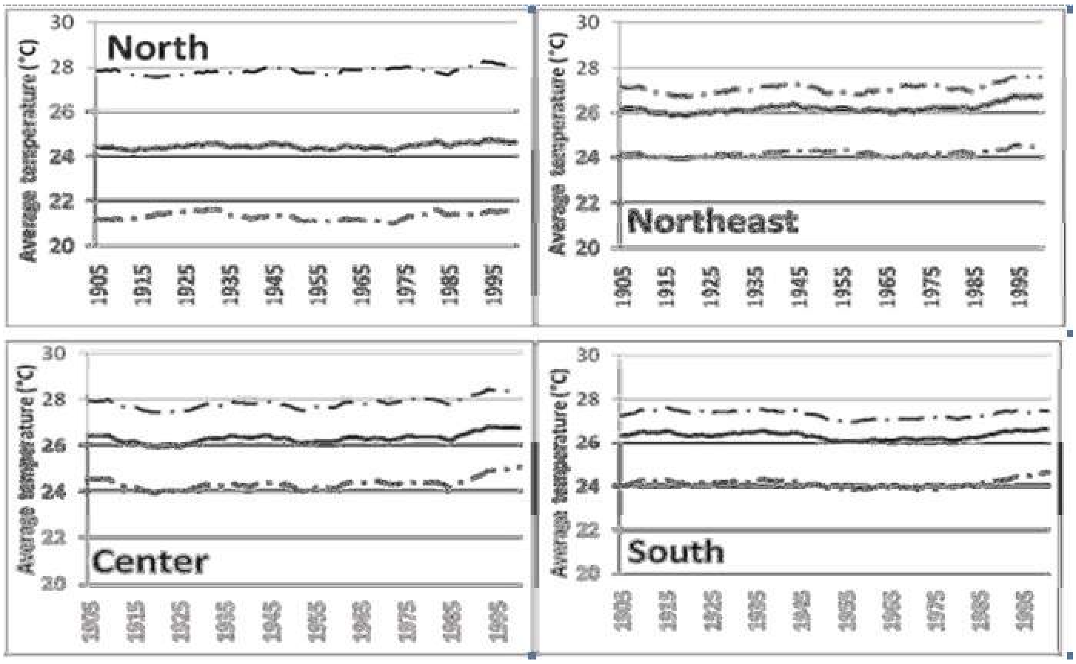

Figure 7. Smoothed annual mean temperature for the four regions of Thailand, 1905–2000.
Note: The solid line represents the average value for the region. The broken lines represent the minimum and maximum values.
Source: OAE, CIAT, and GIZ (2012)

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.

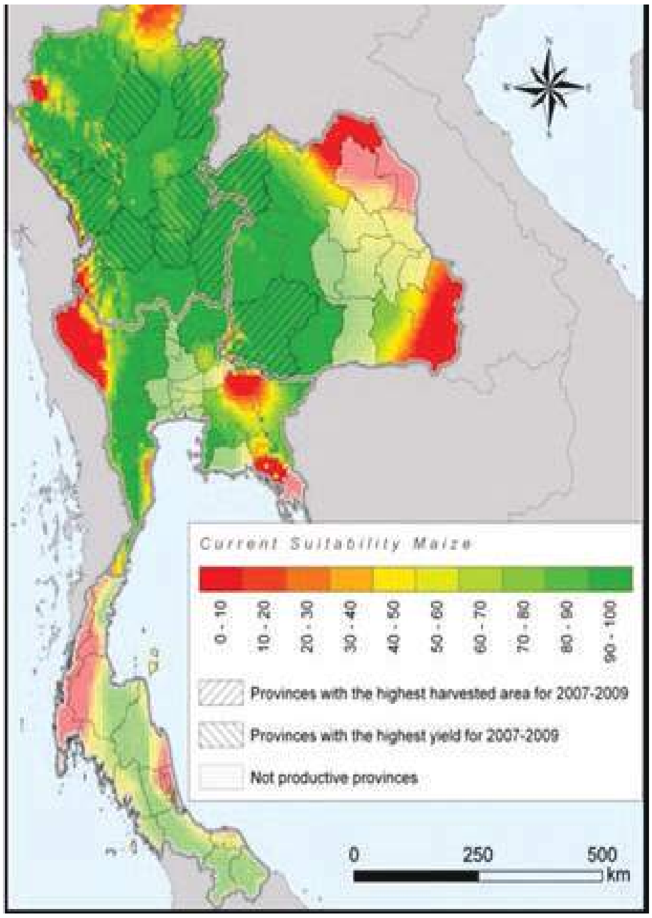

Figure 8. Suitability of maize in the current environment, Ecocrop assessment.
Source: OAE, CIAT, and GIZ (2012)

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).

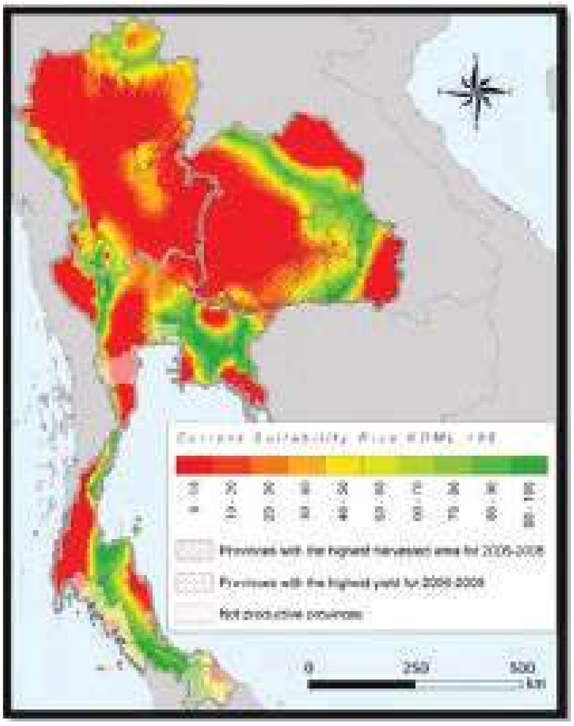

Figure 9. Suitability of rice in the current environment, Ecocrop assessment.
Source: OAE, CIAT, and GIZ (2012)

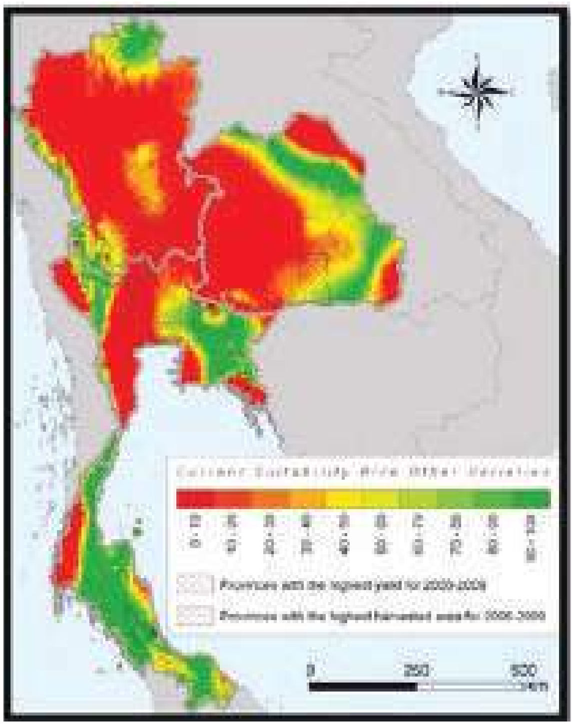

Figure 10. Suitability of other varieties in the current environment, Ecocrop assessment.
Source: OAE, CIAT, and GIZ (2012)

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).

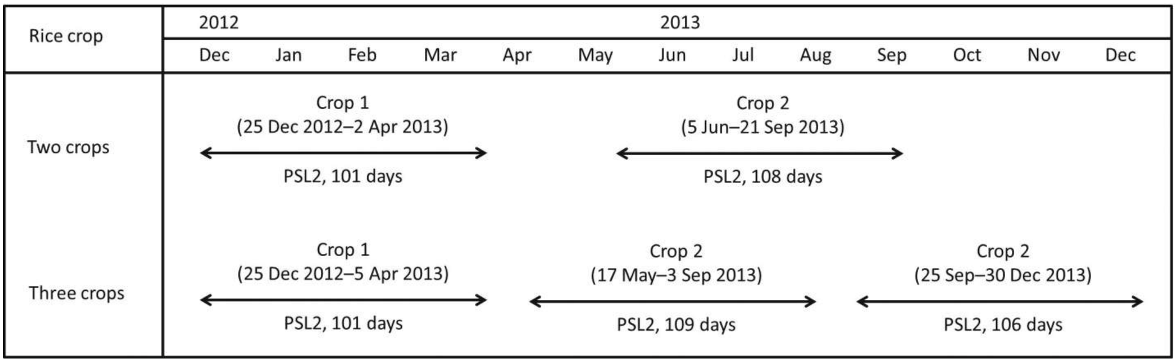

Figure 11. Growing the same rice varieties twice and thrice a year in Lamlookka.

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 (CH4) 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 CH4 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 CH4 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.

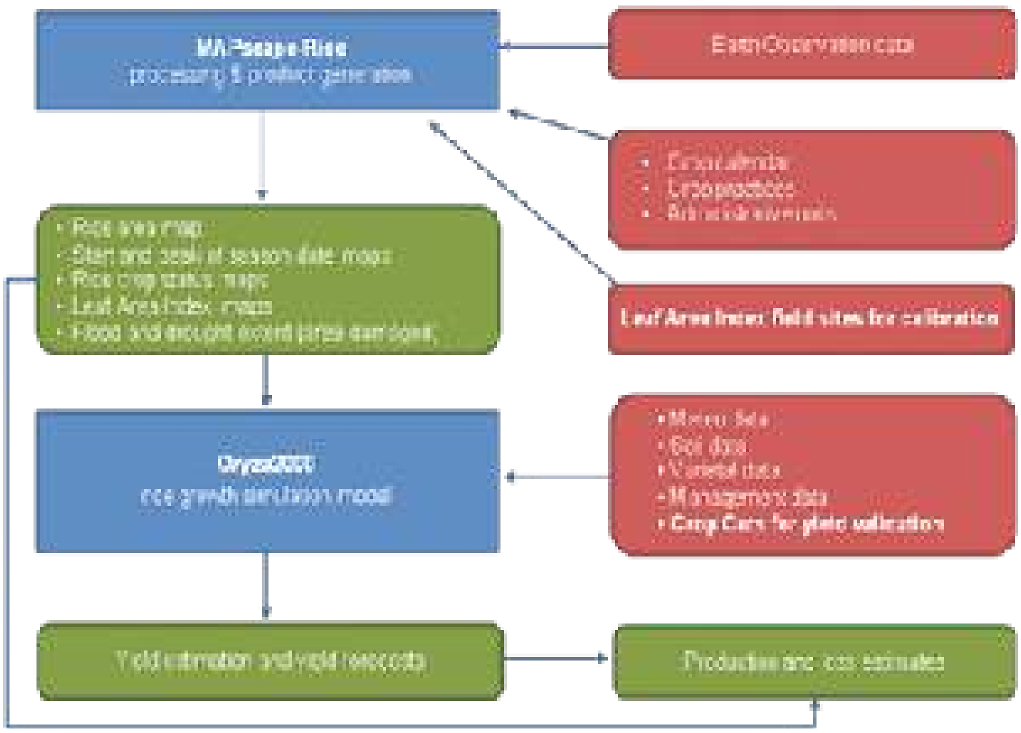

Figure 12. RIICE Conceptual Framework and Technologies.

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.

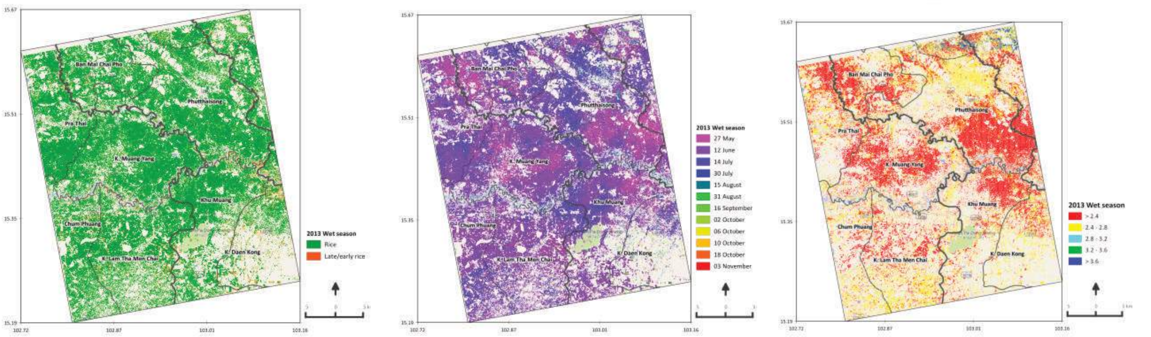

Figure 13. Area, Planting Date, and Yield for Rice in
Source: Nakorn Ratchasima (2013

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.

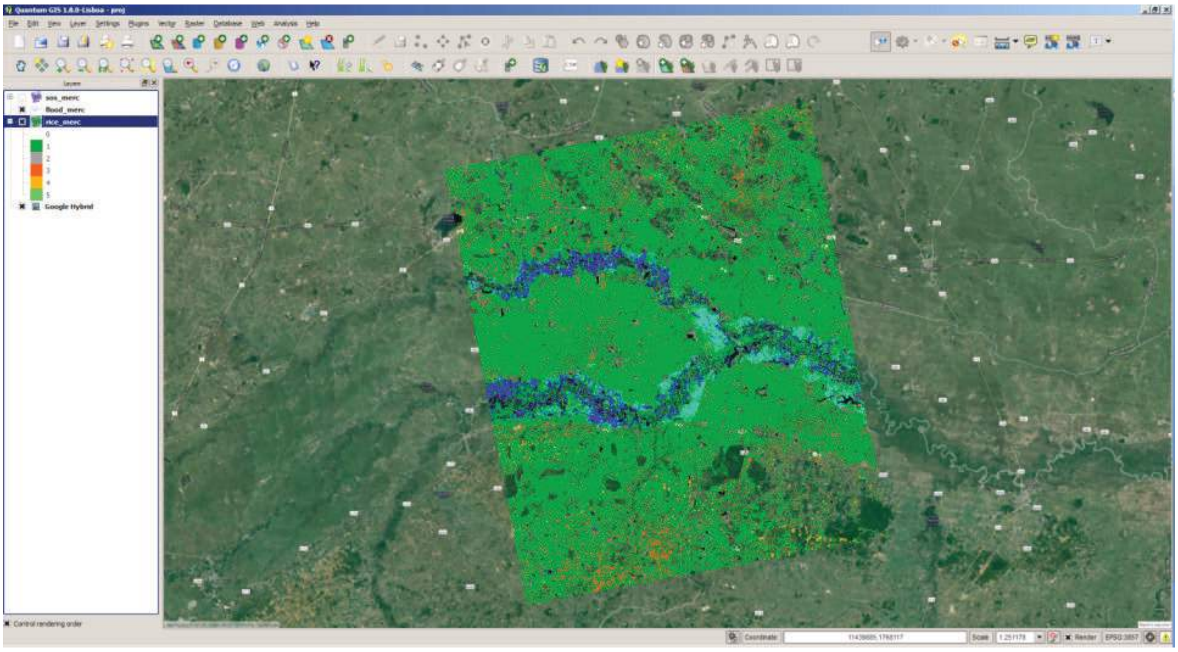

Figure 14. [Flood Affected Rice Area.
Source: Nakorn Ratchasima (2013)

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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german cooperation
DEUTSCHE ZUSAMMENARBEIT

Published by

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

In cooperation with

SEAMEO SEARCA

Promotion of Climate Resilience in Rice and Maize

Vietnam National Study

Imprint

This publication is a joint undertaking by the ASEAN Technical Working Group on Agricultural Research and Development (ATWGARD) and the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH
through the ASEAN-German Programme on Response to Climate Change (GAP-CC).

In partnership with the Southeast Asian Regional Center for Graduate Study and Research in Agriculture (SEARCA).

Published by the
Deutsche Gesellschaft für
Internationale Zusammenarbeit (GIZ) GmbH

Registered offices
Bonn and Eschborn, Germany

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As at
April 2015

Printed by/design and layout
SEARCA
College, Los Baños
Laguna - 4031

Photo Credits
Ly Hoang Long (SEARCA Photo Contest)

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On behalf of the
German Federal Ministry for Economic Cooperation and Development (BMZ)
Alternatively: German Federal Foreign Office

Promotion of Climate Resilience in Rice and Maize

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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

AMS	ASEAN Member States
ASEAN	Association of Southeast Asian Nations
AWD	Alternate Wetting and Drying
CCA	Climate Change Adaptation
DAS	Days After Sowing
IRRI	International Rice Research Institute
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH
MRD	Mekong River Delta
NGO	Non-government Organization
NMMA	Northern Midlands and Mountainous Areas
RRD	Red River Delta

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Foreword

Vietnam is one of the countries that is dramatically affected by climate change. Key climate risks are sea level rise, extreme weather events, rising temperature and changes in precipitation, which could severely affect the agriculture production. Therefore, it is highly necessary for Vietnam to have proper climate change adaptation measures to mitigate the impacts and ensure food security, agricultural production and development in the long term.

In this context, the regional study through the ASEAN Technical Working Group on Agricultural Research and Development (ATWGARD) with the generous support of GIZ through the German-ASEAN Programme on Response to Climate Change (GAPCC), which seeks to promote resiliency of rice and other crops is highlight appreciated. Vietnam has knowledge on climate adaptive practices in the region, and through this project, we are happy to be given the opportunity to share and also learn from our neighbors at ASEAN.

Under this project, five good case studies are highly recommended which include three for rice, namely: Alternate Wetting and Drying (AWD) technique, rice-shrimp farming, and adjustment of rice crop cultivation timing and use of short growing duration rice varieties; and two for maize production, namely: an appropriate planting density with adequate row spacing and plant spacing within rows in flat areas, and improving cultivation practices in sloping areas for maize.

This body of work is not only beneficial to our work in Vietnam, but to other relevant entities in the ASEAN region, which work with farmers and climate change. Therefore, the highlighted practices need to be encouraged and replicated in similar areas, through regional collaboration of joint measures such as research and information exchange.

Dr. Nguyen Thi Thanh Thuy
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Executive Summary

The Intergovernmental Panel on Climate Change (2007) considers Vietnam as one of the countries that are most vulnerable to climate change. Key climate change risks in the country are sea level rise, extreme weather events, rising temperature, and changes in precipitation. Climate change has caused great human and property losses, substantially influenced socio-economic and cultural infrastructure, and imposed negative effects on the environment nationwide. Agriculture is expected to be the most vulnerable sector as agricultural production depends more heavily on climate than on other factors. Therefore, it is imperative for Vietnam to devise proper climate change adaptation (CCA) and mitigation measures to ensure long-term food security, agricultural production, and development.

This report reviews climate change impacts on rice and maize, the two main food crops in Vietnam. It also presents good examples of CCA measures for these crops. Practices are considered good examples if they are effective in limiting the negative effects of climate change and have the potential for regional replication.

The following good practices in CCA options for rice and maize are highly recommended: for rice, (1) alternate wetting and drying (AWD) technique, (2) rice-shrimp farming, and (3) adjusting rice crop timing and using short-duration rice varieties; and for maize, (1) applying appropriate planting density with adequate row spacing and plant spacing within rows in flat areas, and (2) improving cultivation practices in sloping areas. These procedures, which have been applied across the country, have shown promise in reducing the harsh consequences of climate change and being replicated in other geographic regions experiencing the same impacts. They can also be disseminated to other countries in Southeast Asia through technical and financial collaboration.

I. INTRODUCTION

1.1 Context

Climate change is one of the biggest challenges of today. It has become increasingly serious and is mainly manifested by global warming and sea level rise. This phenomenon attracts significant global interest, and countries worldwide are striving to identify measures for CCA and mitigation.

The annual average temperature in Vietnam has increased by 0.5ºC–0.7ºC and continues to intensify. The rate of sea level rise was about 3 millimeters (mm) per year from 1993 to 2008, which coincides with the global tendency. Precipitation has been inconsistent, but it decreased by about 2 percent in the 50 years following 1958. Extreme weather events, such as typhoons, floods, and droughts, have been increasing in number and density (MONRE 2009).

Climate change has caused great human and property losses, substantially influenced socio-economic and cultural infrastructure, and imposed negative effects on the environment nationwide. Since 2001, natural disasters, such as floods, flash floods, landslides, droughts, soil and water salinity, and other calamities, have resulted in 9,500 deaths and unrecovered people as well as damaged about 1.5 percent of annual gross domestic product.

As stated in Decision No. 2139/QD-TTg (2011), food security and agricultural development are the most threatened among the sectors that have been strongly affected by climate change. Agricultural lands have decreased, especially a significant area of low-lying coastal lands, and the Red River Delta (RRD) and the Mekong River Delta (MRD) are flooded with saltwater because of sea level rise. As a result, crop growth, productivity, and cultivation schedules have changed; pestilent insects now pose greater risks; the adaptability period of tropical and subtropical plants has expanded and diminished, respectively; and the reproduction and growth of domestic animals, including their resistance to epidemics, have been negatively influenced (Decision No. 2139/QD-TTg 2011).

It is predicted that Vietnam is one of several countries that will be most adversely affected by climate change. It has been dubbed a "natural disaster hotspot," ranking 7th on economic risk, 9th on the percentage of land area and population exposed, and 22nd on mortality from multiple climate hazards (e.g., sea level rise, floods, and typhoons) (IFAD 2011, 1; IPCC 2007). Vietnam is also considered a "hotspot of key future climate impacts and vulnerabilities in Asia" and an "extreme risk" country, ranking 13th among 170 countries in terms of vulnerability to climate change impacts over the next 30 years (IFAD 2011, 1; IPCC 2007).

Recognizing potentially remarkable outcomes, the government of Vietnam has made a strong commitment to confront climate change. It has carried out a series of actions to combat, adapt to, and mitigate the effects of climate change. In agriculture, CCA measures include (1) increased spending on research, development, and extension to raise average crop yields by 13.5 percent by 2050 relative to the baseline; and (2) extending irrigated land area by about 688,000 ha by 2050 (World Bank 2011, p.76). The total costs of adaptation measures are substantial and were estimated at USD 8.8 billion in 2009; however, despite the prices (without discounting) estimated for 2010–2050, which covers agricultural research and extension (USD 4.05 billion) as well as irrigation expansion (USD 4.76 billion), the benefits of adaptation outweigh its costs (IFPRI 2009).

Adaptation measures will improve both crop yield and areas compared with no-adaptation scenarios, improving all economic indicators.

Compared with no-adaptation scenarios, adaptation measures will improve not only overall welfare but also income equality between different types of households, which are classified as urban or rural and expenditure quintile. Poorer households will gain more from adaptation than richer households. Adaptation measures will also make climate change impacts more evenly distributed across Vietnam's eight agro-ecological regions (CoPS/MONASH 2012).

The rice sector is a key player in ensuring national food security in Vietnam. Rice is the staple food of the majority in the country, and rice production is the main livelihood of about 50 percent of the country's total population. The rice sector also contributes to production value and export turnover, but rice production is forecasted to be severely disrupted by sea level rise and temperature increase. Rice yield in the MRD, the main rice bowl in Vietnam, will decrease by 6.3 percent to 12 percent under different scenarios because of higher temperature. Paddy land will be exposed to extensive inundation and saltwater intrusion because of sea level rise, which will also lead to a decline in rice area and production. It is estimated that a sea level rise of 30 centimeters (cm) by 2050 will result in rice area losses of 193,000 hectares (ha) and 294,000 ha because of inundation and saltwater intrusion, respectively. Consequently, rice production in MRD will decline by about 13 percent (IFPRI 2010).

Maize is the second most important food crop in Vietnam. It is used commonly as a substitute staple in periods of rice shortage and extensively for human consumption in some rural areas and mountainous regions. Maize is considered the primary source of feed for livestock production and thus an important source of income for many farmers. As with rice, climate change is likely to reduce maize productivity and production by 18.71 percent, which is higher than that of rice.

The potential impacts of climate change on rice and maize are presented in Table 1.

Table 1. Potential impacts of climate change on rice and maize under the MONRE medium emissions scenario, 2030

Crop	Quantity (1,000 t)	Rate (%)
Rice	-2,031.87	-8.37
Impacts of natural disaster	-65.27	-0.18
Impacts of change in potential yield	-1,966.60	-8.10
Maize	-500.40	-18.71

Source: Nguyen Van Viet (2011)
Note: Negative values indicate negative impacts, which denote a reduction in quantity and rate.

This study was conducted to identify good practices in CCA options for rice and maize in Vietnam, and to determine areas for regional cooperation to improve and spread CCA measures across the region of the Association of Southeast Asian Nations (ASEAN).

The methodology sought to cover the following objectives:

1. To identify climate change-related vulnerabilities in rice and maize that could lead to food insecurity

2. To identify where vulnerabilities exist or are likely to exist in the supply of rice and maize, focusing primarily on production and related inputs and secondly on post-production activities, specifically drawing out where regional collaboration could be most valuable

3. To use the lessons learned from the abovementioned points to stimulate and spread meaningful action across the region.

1.2 Approaches and Methodologies

This study made full use of existing information and data from official sources in Vietnam, such as government agencies that are responsible for or related to climate change policy formulation, implementation, and assessment; research institutions; and local and international non-government organizations (NGOs) that focus on climate change issues as well as CCA and mitigation measures. The research team also conducted in-depth interviews with experts on rice and maize production as well as discussions with specialists on climate change to gather more detailed information and develop a deeper understanding of the subject matter.

The study used the value chain analysis as a visualization tool to highlight phases that are vulnerable to climate change and likely to have good mitigation activities. Among many phases along the value chain, production and inputs supply are the main concerns, followed by post-production activities.

II. VALUE CHAIN MAPPING

2.1 Value Chain Selection

Rice is cultivated throughout Vietnam, mainly in RRD and MRD. Among six different agro-ecological zones, MRD accounts for the largest proportion of the total paddy rice planted area and is the biggest contributor to the total paddy production in the country (GSO 2013) (Table 2).

Table 2. Paddy planted area and production, 2012

Particulars	Paddy planted area		Paddy production	
	1,000 ha	%	1,000 t	%
Red River Delta	1,139.1	14.7	6,872.5	15.7
Northern midlands and mountainous areas	674	8.7	3,264.4	7.5
North central and central coastal area	1,235.9	15.9	6713	15.4
Central highlands	228.1	2.9	1,129.4	2.6
Southeast	294.8	3.8	1,389.5	3.2
Mekong River Delta	4,181.3	53.9	24,293.0	55.6

Source: GSO (2013)

Among rice production systems in the country, the irrigated lowland system is the most dominant, covering more than 80 percent of the national production volume (Table 3). It is vital to national consumption because it sustains both domestic demand and export supply. However, without proper and timely intervention, irrigated lowlands will deteriorate because of climate change impacts such as floods and salinity. The rice value chain in irrigated lowlands, specifically in MRD, was selected for analysis in this report.

Table 3. Rice production systems in Vietnam

Production system type	National production volume (1,000 t)	National production value (USD)	Assessment of impact on national/regional consumption	Indication/ estimate of relative vulnerability to climate change
Irrigated lowland	20,171.9	N/A	3	2
Rainfed lowland	2,420.0	N/A	1	2
Upland production	2,600.8	N/A	2	2

Source: GSO (2013)
Note: In the assessment of impact on national/regional consumption, the production system is estimated to represent the following values of domestic rice consumption for national food security: 1 – Low (less than 30 percent), 2 – Medium (from 30 percent to 55 percent), and 3 – High (greater than 55 percent).

Unlike rice, maize production is concentrated in upland areas. Upland maize production contributes nearly 60 percent of the total production and meets about 45 percent of domestic demand for maize as a food source (Table 4). Similar to rice production in MRD, upland maize production faces several climate change impacts that should be addressed immediately.

Table 4. Maize production systems in Vietnam

Production system type	National production volume (t)	National production value (USD)	Assessment of impact on national/ regional consumption	Indication/ estimate of relative vulnerability to climate change
Irrigated lowland	1,317.4	N/A	1	2
Rainfed lowland	597.7	N/A	1	2
Upland production	2,691.7	N/A	3	2

Source: GSO (2013)

Among agro-ecological regions, the northern midlands and mountainous areas (NMMA) is the main production area, where maize planted area and production comprise about 42 percent and 35 percent of the total, respectively (Table 5). NMMA is followed by the central highlands. The maize value chain in NMMA was selected for analysis because of the significance of maize production in the area.

Table 5. Maize planted area and production, 2012

Particulars	Maize planted area		Maize production	
	1,000 ha	%	1,000 t	%
Red River Delta	86.6	7.7	404.3	8.4
Northern midlands and mountainous areas	466.8	41.7	1,696.2	35.3
North central and central coastal area	202.3	18.1	826	17.2
Central highlands	243.9	21.8	1,214.3	25.3
Southeast	79.3	7.1	445.3	9.3
Mekong River Delta	39.4	3.5	217.5	4.5

Source: GSO (2013)

2.2 Value Chain Mapping

2.2.1 Rice Value Chain in the Mekong River Delta

There have been several studies on the rice value chain in MRD. The first and seemingly most detailed rice value chain was done by Agrifood Consulting International in 2002, which mentions five key actors along the chain: input providers, farmers, collectors, millers/polishers, and traders and retailers/ end-users. Below is the most updated rice value chain (Figure 1).

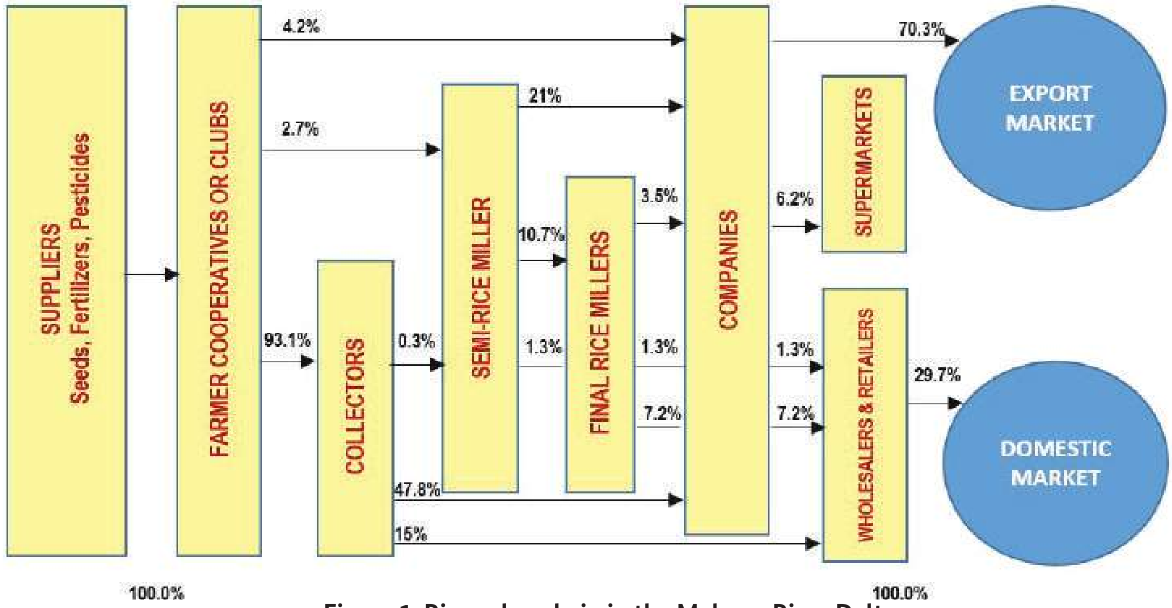

Figure 1. Rice value chain in the Mekong River Delta

Compared with the value chain in 2001, the number of actors along the rice value chain has more or less remained the same over time. In the export value chain, the key actors are still input suppliers, which include seed, fertilizer, and pesticide suppliers; farmers; collectors; millers; and exporters. In the domestic value chain, wholesalers and retailers replace exporters. One outstanding feature of the chain is that while various actors carry out post-production activities, farmers (as individuals or as members of cooperatives or clubs) and input providers are solely responsible for production and input.

2.2.2 Maize Value Chain in the Northern Midlands and Mountainous Areas

Maize is the staple food of people in the NMMA. This crop has become increasingly important to national food security because it is also important to the feed industry. More than 80 percent of maize production is used for animal and aqua feed industries.

The maize value chain shown in Figure 2 was drawn from a study in 2002. In the current maize value chain, which is similar to the traditional value chain, many actors participate in post-production activities. Such participation is also visible in the rice value chain. Only farmers are involved in production, and the lack of cooperatives is striking. Another noticeable feature of the value chain is the lack of input providers. Input providers are available, but they are not mentioned because of their very limited role in the whole value chain. Farmers mainly use their own seeds and hardly use other inputs such as fertilizers and insecticides. This will be reviewed in more detail in the case studies.

Unlike the rice value chain in MRD, where all stages are almost done in the zone, only some actors (e.g., farmers, assemblers, and local wholesalers) in the maize value chain operate in NMMA, which is vulnerable to climate change impacts. Other actors in the maize value chain operate in RRD.

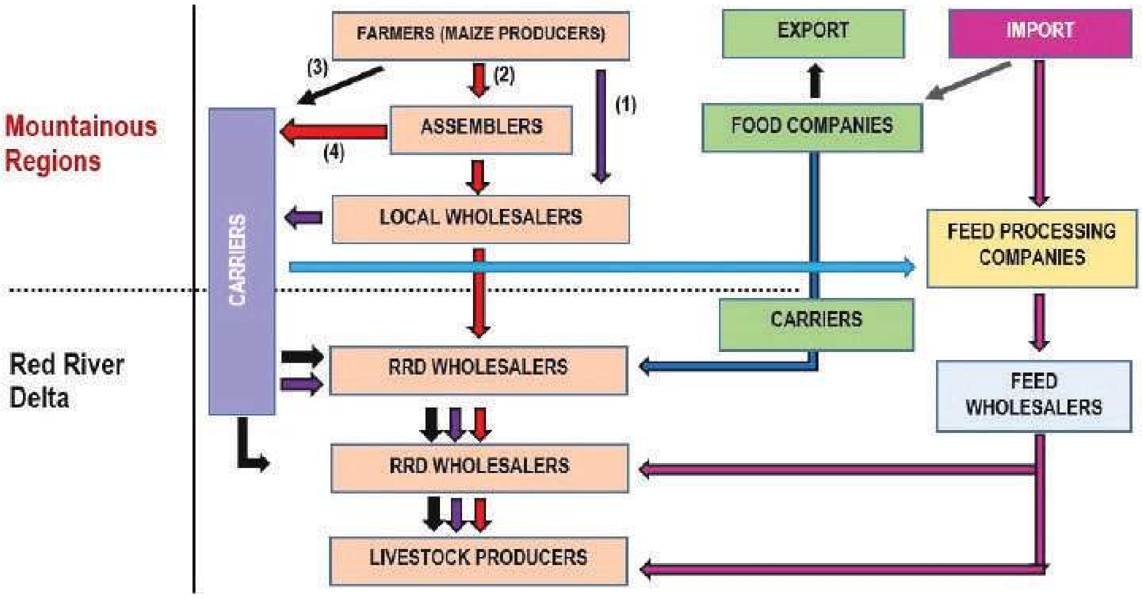

Figure 2 . Maize value chain in the northern midlands and mountainous areas in Vietnam
Source: CIRAD (2014)

III. CLIMATE CHANGE IMPACTS AND VULNERABILITIES

3.1 Review of Climate Change Variables

Vietnam is considered one of the countries that are most vulnerable to climate change. The following climate change variables considerably influence agriculture in general and selected crops and regions in particular:

- Based on historical data from 1958 to 2008, temperature increased nationwide (MONRE 2009). This rising trend will continue and the northern part of the country will experience a faster increase rate, especially during winter.

- Typhoons, which barely affected the southern part of the country in the past, have recently moved southward. Typhoons of extremely high density and abnormal movement have caused substantial damages and losses.

- Sea level rise is considered the most serious climate change risk in the country. It has already negatively affected the largest areas of agricultural production and dense population. Sea level rise is associated with inundation and saltwater intrusion, which have reduced production area as well as weakened the productivity and quality of agricultural products, especially rice.

- Historical data on production show a decrease in precipitation and the number of rainy days per year. It is anticipated that rainfall will increase but highly fluctuate between the rainy and dry seasons. There will be a higher rate of increase in the northern region than in the southern region.

These trends are presented in Table 6.

Table 6. Historical and projected trends in climate variables in Vietnam

Variable	Specific climate risk/opportunity	Historical trend	Projections	Confidence	References
Mean temperature	Increase	Increased by 0.5ºC–0.7 ºC from 1958 to 2007	Increase of about 0.5 ºC by 2020 but faster in winter and northern areas than summer and southern areas	High	MONRE (2009)
Rainfall	Increase High fluctuation between dry and rainy seasons	Decreased by 2 percent from 1958 to 2007	Decrease and increase in rainfall during the dry and rainy seasons, respectively By 2020, rainfall will increase by about 1.5 percent in the north and 0.5 percent in the south	High	MONRE (2008, 2009)
Cold fronts	Decrease	Reduced dramatically but anomalous events seem more frequent and extreme	Decrease in frequency and intensity	High	MONRE (2008, 2009)
Typhoons	Increase	More frequent and moved southward with higher density and abnormal movement	Increase in frequency and intensity in the north and no changes in the south Increase in southward movement between September and November	High	MONRE (2003, 2009)
Number of rainy days	Decrease	Decreased gradually	Gradual decrease	High	MONRE (2009)
Sea level	Increase	Increased by about 3 mm/year	Increase of 11 cm by 2020	High	MONRE (2009)

Climate change variables vary among climate zones, resulting in diverse consequences. In NMMA, the average temperature will increase, leading to higher evaporation and lower relative humidity. Rainfall will also increase, primarily during the peak rainy season, while the number of rainy days per year will decrease. The NMMA will be more prone to droughts during the dry season and floods during the rainy season. In addition to higher temperature and precipitation, MRD will face sea level rise and tropical cyclones. Cyclones of higher frequency and density during September and November may cause severe floods, resulting in substantial losses and damages in both agricultural production and infrastructure. Sea level rise, which will severely affect this region, will be manifested by the inundation and saltwater intrusion of vast areas.

These trends are presented in Table 7.

3.2 Impacts on Selected Crops and Vulnerabilities

3.2.1 Impacts on the Rice Sector

In Vietnam, rice production in RRD and MRD constitutes about 70 percent of the total paddy planted area and production. Among the three rice production systems in the country, irrigated lowland is the most common and also the most vulnerable to climate change impacts in terms of exposure and sensitivity.

Seedling or sowing in RRD and MRD seems to be severely influenced by the drop in precipitation during the dry season. This results in water shortage or even drought, especially during the dry season. As a coping mechanism, farmers have to either delay the current crop to wait for supplemental water supply, thus delaying the subsequent crops; or find ways to supply adequate water on time, thus increasing rice production cost. Another negative impact is lower rice yield due to insufficient water supply during sowing, resulting in lower production and smaller income earned by farmers from selling rice.

Flowering is also highly dependent on water supply. Increase in temperature and a decrease in rainfall during the dry season will trigger a decline in available water. Consequently, rice productivity will decrease and farmers' income will drop due to lower production.

Agriculture in Vietnam has used water extensively and wastefully. Up to 85 percent of annual freshwater withdrawals is from agriculture compared to 40 percent in other countries (Table 8). Moreover, the rate of evaporation is considerably high and continues to increase. As such, water shortage caused by evaporation under high temperature and rainfall fluctuation between seasons will hamper the development of agriculture, especially the rice sector, in the near future.

Table 7. Historical and projected trends in climate variables by climate zones in Vietnam

Climate zone	Year	Change in		Narrative
		Temp (°C)	Rainfall (%)	
Sea level rise in coastal Vietnam: 11–12 cm in 2020 and 28–33 cm in 2050				
Northwest	2020	0.5	1.4–1.7	**Cold fronts:** Lower frequency, with the northwest region more affected; increased variability of occurrence; mid-winter peaks diminish **Temperature:** Increased occurrence of hot spells in mid and lower elevations; longer hot season and shorter cold season at lower elevation; higher evaporation and lower relative humidity **Rainfall:** Increased variability during the dry season; increased incidence of severe droughts, especially in the final months of the dry season; increased incidence of extreme rainfall events (e.g., intensity, scale, duration, and rainy periods); decrease in "drizzly" rainfall between the dry and rainy seasons in northeast mountains; increased variability of the onset and/or end of the dry and rainy seasons; increased rainfall concentration in peak months
Northeast	2050	1.2–1.3	3.6–3.8	
Red River Delta and Quang Ninh (a coastal province in the northeastern region)	2020	0.5	1.6	**Tropical cyclones:** May increase frequency and intensity; inter- and intra-annual variability increase; typhoon season starts earlier and/or ends later **Cold front:** Lower frequency and intensity; inter- and intra-annual variability increase **Temperature:** Higher normal and maximum values; increased occurrence, intensity, and duration of hot spells; warmer and shorter cold season; longer and more severe warm season; higher evaporation **Rainfall:** Long-term increase in rainfall during the rainy season; increased rainfall variability during the dry season; increased variability of the onset and/or end of the dry and rainy seasons; increased incidence of extreme rainfall events (e.g., intensity, scale, duration, and rainy periods); increased incidence of droughts; decrease in "drizzly" rain **Sea level:** Increased rate of rise (5–6 mm/year)
	2050	1.2–1.3	3.9–4.1	
North central coast	2020	0.5–0.6	1.5–1.8	**Tropical cyclones:** May increase frequency and intensity; inter- and intra-annual variability increase; typhoon season starts earlier, ends later, and becomes shorter **Cold front:** Decreased incidence; shorter seasons and longer intervals between fronts **Temperature:** Higher normal values; the windy season (dry, hot, and westerly winds) arrives earlier and/or ends later; increased number and duration of hot spells; shorter cold season in the north; southern boundary of the cold season will move to higher latitudes; ceased occurrence of hoarfrost in the north (now rare); higher evaporation **Rainfall:** Long-term increase in rainfall during the rainy season; rainfall will increasingly be concentrated in months with higher precipitation; minimal changes in the south during the dry season, but the north may be permanently dry and hot like in the south in May and June; decrease in "drizzly" rain in the north; increased daily/monthly/annual maximum values in the central coastal strip; increased incidence and severity of droughts **Sea level:** Increased rate of rise (5–6 mm/year)
	2050	1.4–1.5	3.8–4.0	
South central coast	2020	0.3	0.7	
	2050	0.9–1.0	1.6–1.7	
Central highlands	2020	0.4	0.3	**Cold front:** Decreased incidence (rate is already increasing) **Tropical cyclones:** May penetrate deeper inland **Temperature:** Higher normal and maximum values, especially in lower elevations and mid or lower reaches of major rivers; increased occurrence of hot spells in lower elevations, hollows, and river valleys; longer hot season in mid or lower elevations and shorter cold season in mid or high elevations; higher evaporation contributing to severe droughts in early months of the year **Rainfall:** Long-term increase in rainfall during the rainy season; strong increase in variability during the dry season; overall increase in variability with increased maximum daily/monthly/annual rainfall; increased incidence and severity of droughts in the latter half of winter; increased variability of the onset and/or end of the dry and rainy seasons
	2050	0.8	0.7	
South (Southeast and Mekong River Delta)	2020	0.4	0.3	**Tropical cyclones:** May remain unchanged but will increase in southward movement between September and November **Temperature:** Higher normal and maximum values; increased incidence and severity of hot spells in the early months of the year; higher evaporation with increased dryness, especially in April and May **Rainfall:** Long-term increase in rainfall during the rainy season; increased rainfall variability during the dry season; distribution across southern areas will change significantly; inter-annual and intra-seasonal variability in rainy seasons; increased rainfall intensity and maximum daily/weekly/monthly amounts (equal or nearly equal to south central) **Sea level:** Increased rate of rise (5–6 mm/year)
	2050	1.0	0.7–0.8	

Source: ISPONRE (2009), MONRE (2010)

Table 8. Annual freshwater withdrawals from agriculture (% of total)

Country	Year	Annual freshwater withdrawals from agriculture (% of total freshwater withdrawal)
Cambodia	2011	94.0
China	1987	86.3
	1997	77.6
	2011	64.6
Indonesia	1997	93.1
	2011	81.9
Laos	2011	93.0
Malaysia	1997	60.2
	2011	34.2
Myanmar	1987	98.6
	1997	98.6
	2011	89.0
Thailand	2011	90.4
Vietnam	1987	89.8
	2002	89.8
	2007	94.8
	2011	94.8

Source: World Bank (2014).
Note: Annual freshwater withdrawals refer to total water withdrawals, excluding evaporation losses from storage basins. Withdrawals also include water from desalination plants in countries where they are a significant source. Withdrawals can exceed 100 percent of total renewable resources where extraction from non-renewable aquifers or desalination plants is considerable or where there is significant water reuse. Withdrawals for agriculture are total withdrawals for irrigation and livestock production.

In contrast to sowing and flowering, harvesting activities are exposed to high risks, especially floods, due to higher rainfall during the rainy season. Farmers in RRD and MRD have experienced higher post-harvest losses during the rainy season, or partial or full damages or losses because of floods. They manage the risks by using submergence-tolerant or short-duration rice varieties, or adjusting the cropping calendar to ensure that the crops are harvested before the rainy season begins.

Typhoons tend to be more frequent and abnormal, and they cause similar problems in harvesting activities. Typhoons or floods also affect post-harvest activities (e.g., processing or drying) because storage capacity and processing facilities at the household level are limited.

Sea level rise is the biggest challenge for MRD because of its adverse effects. Inundation and saltwater intrusion caused by sea level rise will reduce rice production in MRD from 5.2 percent to 8 percent by 2050 (Table 9). Production losses may increase if productivity decrease is incorporated in this calculation.

Table 9. Effects of sea level rise on rice production and area in the Mekong River Delta, 2050

Particulars	Rainy season (Inundation)	Dry season (Saltwater intrusion)
Affected area (1,000 ha)	276.00	420.00
Affected rice area (1,000 ha)	193.00	294.00
Production loss (million t)	0.89	1.77
Production loss (%)	5.20	8.00

Source: IFPRI (2010)

For RRD, more frequent and extreme anomalous cold fronts are likely to have adverse effects on winter-spring crops, reducing productivity.

A decrease in the number of rainy days will also cause water shortage, leading to lower productivity and higher production cost because of higher water supply cost. However, it will be easier for rice farmers to manage a decline in rainy days than other climate change impacts.

To locate points in the value chain that are vulnerable to climate change impacts, vulnerability was estimated by considering various aspects, including exposure, sensitivity, and ability to adapt. For rice in MRD, production activities, especially seedling, flowering, and harvesting, have medium vulnerability. For sea level rise, both exposure and sensitivity are high because of the current substantial impacts on rice production and the increasing number of potential impacts. Ability to respond is at the medium level, which means that to some extent, rice production can respond to climate change. However, its ability to respond should be strengthened to improve its capacity to cope. Responses can be done in different ways, but a more manual approach is required for some activities or stages that have a low level of mechanization. Plowing, watering, and transportation have a higher level of mechanization than drying and sowing in rice production nationwide and in MRD. The level of mechanization in harvesting is only 30 percent compared to 90 percent or more in other activities. The mechanization in rice production for the whole country and MRD is presented in Table 10.

Table 10. Mechanization in rice production

Stage	Degree of mechanization
Whole country	
Plowing	75%
Sowing	20%
Watering	85%
Drying	39%
Transporting	70%
Mekong River Delta	
Harvesting	30%
Threshing	90%
Husking	95%

Source: MARD (2010)

The level of mechanization is diverse among different types of production organizations. Enterprises have the highest level of mechanization, followed by cooperatives and households. Approximately 14.8 percent of enterprises own tractors and ploughs, 74 times higher than the average of the whole agricultural sector (0.2%). The number of engines and generators is 9–38 times higher than the average of the agricultural sector. The number of water pumps and pesticide sprayers is 6–17 times higher and the level of mechanization of cooperatives is also higher than the average of the agricultural sector. Given the large number of small households, the level of mechanization in agricultural production in Vietnam remains low (GSO 2012).

Women are active in harvesting activities and some post-harvest activities such as drying. As such, using machines during these activities will reduce the work load of women. Climate change impacts on and vulnerability rating for rice production are synthesized in Table 11.

3.2.2 Impacts on the Maize Sector

As the main production system for maize is rainfed upland, maize production is extremely sensitive to water availability. Rainfall decrease or droughts during the dry season will lead to a shortage of water for maize production. The absence of rain at sowing time will push farmers to delay cropping, which will most likely delay the planting of maize or other crops. Similarly, rain is the primary prerequisite during flowering for maize to grow and mature. Otherwise, productivity will be drastically reduced or farmers may suffer from absolute losses.

Water shortage makes all production activities before harvesting more difficult, but an increase in rainfall at harvesting time is the main cause for higher post-harvest losses in maize production. Harvesting activities are mainly done manually and highly vulnerable to bad weather conditions. Storage as well as processing facilities and technologies (e.g., drying after harvesting) are not available in NMMA.

Applying the same vulnerability rating method, sowing, flowering, harvesting, and post-harvest activities have medium vulnerability. These processes have medium ability to respond, but they have high exposure and sensitivity to climate change because maize production in NMMA is naturally rainfed. It is completely dependent on rain and the application of CCA measures has been very limited.

Unlike rice production in MRD, maize production is mainly done manually in all stages of production. Challenging geographic conditions (i.e., small farm size with different slopes in NMMA), as well as limited technical and financial capacity of farmers in NMMA, make it difficult to use machines. Almost all maize farmers are ethnic minorities from low income quintiles and with low educational levels. Therefore, with the intensive participation of women in sowing and harvesting activities, it is likely that improvements in maize production will increase income-generating opportunities for women and girls. Climate change impacts on and vulnerability rating for maize production are synthesized in Table 12.

Table 11. Climate change impact assessment and vulnerability rating for rice production in Vietnam

System of interest	Geographic location	Climate change trend	Biophysical impact	Socio-economic impact	References	Exposure	Sensitivity	Ability to respond	Vulnerability rating
Irrigated lowland rice flowering	MRD	Increasing mean temperature	Water shortage caused by high evaporation	Lower productivity Higher production cost for water supply	Experts on climate change and rice	M	M	M	M
	RRD					M	M	M	M
Irrigated lowland rice seedling/ sowing	MRD	Increasing rainfall, highly fluctuating between the dry and rainy seasons	Water shortage in dry season Droughts	Lower productivity Higher production cost for water supply Delayed cultivation of current and subsequent crops		M	M	M	M
	RRD					M	M	M	M
Irrigated lowland rice flowering	MRD	Increasing rainfall, highly fluctuating between the dry and rainy seasons	Water shortage in dry season Droughts	Lower productivity Higher production cost for water supply		M	M	M	M
	RRD					M	M	M	M
Irrigated lowland rice harvesting	MRD	More frequent and abnormal typhoons	Damage crop Higher post-harvest losses	Lower rice productivity and quality Partial or total losses		M	M	M	M
	RRD					L	L	M	L
Irrigated lowland rice post-harvest activities (e.g., storage and processing)	MRD	More frequent and abnormal typhoons	Damaged crops Higher post-harvest losses	Lower rice quality Partial or total losses		M	M	M	M
	RRD					L	L	M	L
Irrigated lowland rice production	MRD	Sea level rise	Soil quality affected by saltwater intrusion and inundation Paddy land diminishes	Lower rice productivity and quality Decrease in farmers' income		H	H	M	M
Irrigated lowland rice flowering	RRD	More frequent and extremely anomalous cold fronts	Damaged crops	Lower rice productivity and quality or total losses		M	M	M	M
Irrigated lowland rice production	RRD	Decreasing number of rainy days	Water shortage	Lower productivity Higher production cost for water supply		L	L	M	L
	MRD					L	L	M	L

Sources: ISPONRE (2009), MONRE (2010), and author's synthesis of results from meetings with various experts on rice and climate change

Table 12. Climate change impact assessment and vulnerability rating for maize production in Vietnam

System of interest	Geographic location	Climate change trend	Biophysical impact	Socio-economic impact	References	Exposure	Sensitivity	Ability to respond	Vulnerability rating
Rainfed upland maize seedling/ sowing	NMMA	Decreasing rainfall during the dry season Increasing incidence of severe droughts	Water shortage	Lower maize productivity Delayed cultivation of current and subsequent crops Bigger workload for farmers	Experts from NMRI	H	H	M	M
	Central highlands					H	M	M	M
Rainfed upland maize flowering	NMMA	Increasing mean temperature Decreasing rainfall during the dry season	Water shortage	Lower maize productivity and quality		H	H	M	M
	Central highlands					L	L	M	L
Rainfed upland maize harvesting	NMMA	Increasing rainfall	Damaged crops or higher post-harvest losses	Lower rice productivity and quality Total losses Bigger work load for farmers		H	H	M	M
	Central highlands					L	L	M	L
Rainfed upland maize production	Central highlands	More frequent and abnormal typhoons	Damaged crops	Lower rice productivity and quality		L	L	M	L
Rainfed upland maize harvesting	Central highlands		Damaged crops or higher post-harvest losses	Lower rice productivity and quality Total losses		L	L	M	L

Sources: Author's synthesis of results from meetings with various experts on maize and climate change

IV. AREAS OF REGIONAL COLLABORATION

Regional cooperation can be done through either technical assistance or financial support, or a combination of both. It is difficult to determine which is more important, but technical support will be more useful than financial support because it will generate more sustainable results and opportunities to expand and multiply good practices.

Technical assistance should focus heavily on issues or activities that require high expertise. Vietnam has minimal experience in research and development of new varieties, technology transfer, and capacity building. Technical support and technology transfer for post-harvest activities such as drying and processing; sharing experiences on storage and processing to reduce post-harvest losses and augment value added for rice and maize; and technology transfer for storage and processing that have been successfully applied in other countries will be very useful in rice and maize production in Vietnam.

Financial support is necessary to develop and improve infrastructure for production, but it may have several unwanted side effects. One of the disadvantages of financial support is self-dependency, where recipients usually become reliant on the support, lose their influence, and sometimes make unnecessary decisions. Financial support for irrigation systems or dike systems should be limited. After it has been carried out, community participation should be monitored to ensure the appropriateness, effectiveness, and sustainability of the investment.

The combination of technical and financial support seems more appropriate as it will provide technical assistance as well as pilot and promote application. For example, designing an intercropping model between rice or maize and other crops is the initial step. This could be backed up by piloting in specific locations to transfer technologies to farmers, which will give farmers opportunities to test and further understand the model, thus proving the benefits of the model.

Regional collaboration should also focus on improving climate change awareness at different levels, especially at the household level. Rural households should be properly informed about climate change and its impacts. In addition, efforts to mainstream climate change issues in plans and activities of different stakeholders at different levels should also be generated. This requires both technical and financial support.

From Vietnam's perspective, the issue of agro-insurance should be raised. Vietnam has just finished its pilot program for agro-insurance, and many concerns and problems should be answered. The most important issue is the significance of agro-insurance in terms of managing the risks related to agricultural production. To successfully implement agro-insurance, technical and financial support from multilateral donors and other ASEAN Member States (AMS) are essential. Regional collaboration should also focus on disseminating advanced technology to risk monitoring and management (e.g., affordable remote sensing technology).

4.1 Stakeholder Analysis

After assessing climate change impacts, vulnerabilities, and adaptation and mitigation measures that require regional collaboration, this section analyzes the main stakeholders that are involved in different stages along the selected value chains, which can be seen below (Figure 3).

[1] Read more about community participation from http://www.ilo.org/public/english/employment/recon/eiip/download/irap_laos4.pdf

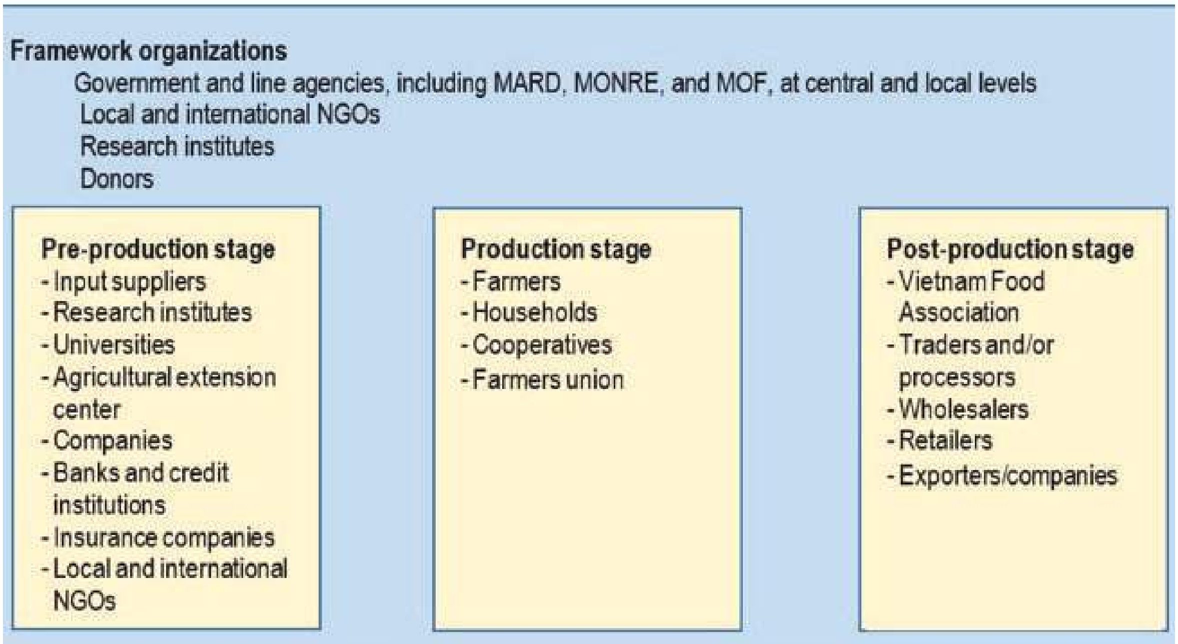

Figure 3. Stakeholder mapping

Input suppliers include individuals or companies that are very active in promoting the use of seeds, fertilizers, and chemicals for agricultural production. They have extensive networks as well as direct and long-standing contacts with farmers. However, as they work for profit, it is impossible to ensure that they will promote inputs that are good in terms of CCA or mitigation but offer them limited margins. Therefore, the activities of input suppliers should be controlled to harmonize their own benefit and the sustainability of agricultural production.

Research institutions, universities, local and international NGOs, and agricultural extension centers primarily work on researching new varieties, improving production techniques, and designing and piloting models. However, as they are non-profit agencies, they can only carry out a few pilot models. The widespread application of CCA-related practices is particularly difficult because proving their effectiveness takes time. Such application may also require farmers to make large financial investments.

In principle, banks, credit institutions, and insurance companies should be important stakeholders. Their limited contribution, which has gradually improved, is due to several reasons. Firstly, Vietnam has a limited state budget for rural credit and insurance activities. Of the total investment from various sources, investment from the state budget accounts for 39 percent and is spent mainly on infrastructure (more than 30 percent), whereas only 6 percent is for the agricultural sector and remains unchanged over time (GSO 2012).

Secondly, the improper implementation of policies on agriculture and rural development limits the efficiencies. Taking the credit policies in Vietnam as an example, Decree No. 41/2010/ND-CP is the most important legal document issued on the credit policy for agricultural and rural development, in which the most prominent provision is about providing loans without collateral at the following levels:

(i) Up to VND 50 million for individuals and households engaged in agricultural sub-sector, forestry, fishery, or salt production

(ii) Up to VND 200 million for households carrying out business or production activities or providing services for agriculture and rural areas

(iii) Up to VND 500 million for cooperatives and farm owners

The efficiency of policy implementation became debatable when the agricultural and rural dwellers were required to submit their land-use rights certificates, or the confirmation about non-dispute plot from the People's Committee, to approach credit sources. Such requirements pose more obstacles to finding funds for agricultural production.

Farmers and households are main stakeholders responsible for production, and they normally suffer bigger losses from climate change impacts than other stakeholders. Farmers can boost their capacity to apply CCA measures by joining cooperatives and forming clubs. Such groups will give farmers more power and a stronger voice in dealing with other stakeholders, thus reducing climate change risks and vulnerabilities.

Stakeholders in post-production stages are those who have hardly been affected by climate change impacts. Therefore, their importance in promoting and applying CCA measures is limited.

In addition to the stakeholders that are directly involved in various stages, there are others that facilitate the development of the value chains and thus enhance climate change mitigation measures. Government and other line agencies, such as Ministry of Finance, Ministry of Agriculture and Rural Development, and Ministry of Industry and Trade, are responsible for formulating policy and supervising policy implementation. Multi-level local authorities that are in charge of policy implementation mainly receive policy responses and propose amendments or new policies.

Research institutions, donors, and NGOs are very helpful in providing valuable inputs such as primary data from surveys, data analysis, and worldwide experiences. Recently, they have worked actively in policy advocacy, which contributes to policy formulation, and more importantly policy mainstreaming at different levels. Policy mainstreaming is vital especially for CCA, which is a relatively new concept in Vietnam.

V. CASE STUDIES ON GOOD PRACTICES

5.1 Selection of Case Studies

Vulnerability rating is the first criteria for selection. From the list of impacts on rice and maize, only those that are rated medium or high vulnerabilities are selected for next step. As discussed at the beginning, this report mainly focused on rice in MRD and maize in NMMA because of their importance to food security. Crop production systems were assessed to determine good case studies. (Table 13).

To ensure that the highlighted case studies have the potential to be replicated and scaled up within the region, the following criteria were used for the second round of selection:

(1) Whether adaptation measures will be carried out through both technical and financial support

(2) Whether adaptation measures will be carried out without the need for a big investment, since developing better infrastructure for production will significantly dent the state budget

(3) Whether adaptation measures will require limited technical understanding and thus be easily applicable for farmers, and can be replicated with minor adjustments in other areas for rice and maize production

(4) Whether the benefits of adaptation measures will be easily noticed and visually measured in terms of increases in productivity and income for farmers. This is a very important feature that makes them attractive to farmers. Moreover, they can have spillover effects, such as reduction in greenhouse gas emissions, because of lower water consumption for rice crops or better environment because of lower fertilizer or chemical application for crop production.

Selected CCA measures with areas for regional collaboration are presented in Table 14; while good practices as CCA measures in Vietnam are presented in Table 15.

In addition to the abovementioned measures, setting up a risk management scheme appears to be the most integrated solution in dealing with climate change impacts. Increasing climate change awareness and mainstreaming CCA into action plans at different levels, especially at the commune level, will also increase farmers' understanding of climate change and its consequences. It will also encourage their participation in planning local action on CCA and mitigation.

In Vietnam, mainstreaming CCA is very important because it is the prerequisite to mobilizing efforts from all related stakeholders and funds from sources at different levels. Some pilot programs gained initial success, but efforts to ensure that they will bring sustainable results and be made applicable to other geographic areas should be furthered.

Farmers have also benefitted from the pilot agro-insurance program in the country because of the active participation of three stakeholders (i.e., government, farmers, and enterprises) that formed a rationale for scaling up agro-insurance programs in the future. However, running an agro-insurance program smoothly and applying it nationwide with or without limited subsidy call for more time and effort. Agriculture in the country offers low income and high risks, which is why enterprises are not interested in agro-insurance without government subsidy. Income diversification has been considered a good scheme for farmers to reduce their high vulnerabilities; however, given the farmers' low levels of education and professional training, there is no example of successful income diversification for farmers in Vietnam.

Table 13. Crop production systems and their vulnerabilities

System of interest	Geographic location	Climate change trend	Biophysical impact	Socio-economic impact	References	Exposure	Sensitivity	Ability to respond	Vulnerability rating
Irrigated lowland rice flowering	MRD	Increasing mean temperature	Water shortage caused by high evaporation	Lower productivity Higher production cost for water supply	Experts on climate change and rice	M	M	M	M
Irrigated lowland rice seedling/sowing	MRD	Increasing rainfall, highly fluctuating between the dry and rainy seasons	Water shortage during the dry season or drought conditions	Lower productivity Higher production cost for water supply Delayed cultivation of current and subsequent crops		M	M	M	M
Irrigated lowland rice flowering	MRD	Increasing rainfall, highly fluctuating between the dry and rainy seasons	Water shortage during the dry season or drought conditions	Lower productivity Higher production cost for water supply		M	M	M	M
Irrigated lowland rice harvesting	MRD	More frequent and abnormal typhoons	Damaged crops Higher post-harvest losses	Lower rice productivity and quality Partial or total losses		M	M	M	M
Irrigated lowland rice post-harvest activities (e.g., storage and processing)	MRD	More frequent and abnormal typhoons	Damaged crops Higher post-harvest losses	Lower rice quality Partial or total losses		M	M	M	M
Irrigated lowland rice production	MRD	Sea level rise	Soil quality affected by saltwater intrusion and inundation Paddy land diminishes	Lower rice productivity and quality Decrease in farmers' income		H	H	M	M
Rainfed upland maize seedling/ sowing	NMMA	Decreasing rainfall during the dry season Increasing incidence of severe droughts	Water shortage	Lower maize productivity Delayed cultivation of current and subsequent crops Bigger workload for farmers	Experts from NMRI	H	H	M	M
Rainfed upland maize flowering	NMMA	Increasing mean temperature Decreasing rainfall during the dry season	Water shortage	Lower maize productivity and quality		H	H	M	M
Rainfed upland maize harvesting	NMMA	Increasing rainfall	Damaged crops Higher post-harvest losses	Lower rice productivity and quality Total losses Bigger workload for farmers		H	H	M	M
Rainfed upland maize post-harvest activities	NMMA	Increasing rainfall	Damaged crops Higher post-harvest losses	Partial or total losses in farmers' income Bigger work load for post-harvest activities		H	H	M	M

Table 14. Highlighted areas for regional collaboration

Adaptation measures	Good practices	Areas for regional collaboration	Support needed
Improved irrigation techniques	AWD for rice production	Research on the techniques to fit local conditions	Technical + Financial
		Design detailed technical guidelines	
Adjustments in cropping pattern	Rice-shrimp farming in MRD	Develop rice varieties of better quality for this farming system	Technical + Financial
		Research on measures/technical options to ensure the sustainable development of this system such as specific types of fertilizers/ chemicals for rice and safe medicines/ chemicals for shrimp	
Better adaptive varieties and crop timing	Adjustment of rice crop timing and use of short-duration rice varieties	Weather forecast activities and climatic data collection/analysis/sharing	Financial + Technical
		Develop rice varieties of short duration and better quality	
Better cultivation practices	Application of appropriate planting density with adequate row spacing and plant spacing within rows in flat areas for maize	Modifying rice crop timing and using short-duration varieties are very useful in avoiding possible floods and unusual weather events.	Technical + Financial
	Use of quality varieties and fertilizers, optimal rotation of crops or cropping systems, and adjustment of crop timing for maize production etc.	Develop maize varieties of high tolerance and better quality for this farming system Research on measures/technical options to ensure the sustainable development of this system such as specific types of fertilizers/ chemicals for maize	Technical + Financial

5.2 Detailed Description of Case Studies

5.2.1 Alternate Wetting and Drying Technology

AWD is a water-saving farming technique developed by the International Rice Research Institute (IRRI) to help rice farmers maintain yield despite water shortage. According to IRRI guidelines, AWD application in Bac Lieu was adjusted and implemented with the following steps (GIZ 2013):

1. **Wetting period**

a. From 10 to 30 days after sowing (DAS): In this period, the field requires adequate water. The water level is maintained at a height of 3–5 cm for the first and second time of manure.

b. From 40 to 55 DAS: In this period, the water level is maintained at a height of 3–5 cm for the third time of manure.

c. From 65 to 75 DAS: Before and after flowering, rice plants need water. The water level is maintained at a height of 3–5 cm for the fourth time of manure (if any).

Table 15. Good practices as CCA measures in Vietnam

Adaptation measures	Good practices	Regional relevance	Impacts on women	References
Improved irrigation techniques	AWD for rice production	IRRI developed the AWD technique to help rice farmers maintain rice yield despite water shortage.	Neutral	GIZ (2013)
Adjustments in cropping patterns	Rice-shrimp farming in MRD	In the last 30–40 years, many rice farmers in salt-affected areas have adapted to natural conditions by growing rice during the rainy season, subsequently using the rice fields for shrimp farming during the dry season.	Neutral	FAO (2001)
More adaptive varieties and better crop timing	Adjustment of rice crop timing and use of short-duration rice varieties	Modifying rice crop timing and using short-duration varieties are very useful in avoiding possible floods and unusual weather events.	Reduce workload for women	Experts on climate change and rice
Better cultivation practices	Application of appropriate planting density with adequate row spacing and plant spacing within rows in flat areas	Following the correct planting density in maize production can maximize productivity and improve adaptation to drought conditions in flat areas.	Increase workload for women	Phan (2011)
	Use of quality varieties and fertilizers, optimal rotation of crops or cropping systems, and adjustment of crop timing	Following these procedures in maize production can maximize productivity and improve adaptation to drought conditions in sloping areas.	Increase workload for women	Experts on climate change and maize

2. Water-saving or drying period

a. From 1 to 10 DAS: In this period, the field can be kept dry for pesticide and molluscicide application.

b. From 30 to 40 DAS: In this period, rice is growing. The field can be kept dry to help rice get more nutrition and be robust.

c. From 55 to 65 DAS: In this period, the paddy rice grows. The field can be kept dry.

d. From 85 to 100 DAS: In this period, the field can be kept dry for easy harvesting.

The differences between AWD recommended by IRRI and its application in Bac Lieu province are as follows:

1. AWD recommended by IRRI

a. Safe AWD: Irrigate when water is 15 cm below the surface.

b. Keep the field continuously flooded (3–5cm) 20 days after sowing and during flowering.

2. AWD application in Bac Lieu

a. Safe AWD: Irrigate when water is 10 cm below the surface.

b. Four water-saving stages: seedling, panicle initiation, panicle formation, and ripening.

According to farmers, AWD is a suitable technique that can be easily applied to farming. Farmers said that applying AWD and the "One Must Five Reductions"[2] (2012) technique helped them gain more benefits. In particular, they were able to obtain a higher income because of lower costs for water pumping and agriculture material. The amount of savings increased yearly. Compared with the traditional method, AWD application helped strengthen the rice stem and increase plant resistance to pest and diseases. Most of the farmers believed that AWD was an appropriate measure for coping with the abnormal weather. Some of the farmers mentioned that there were still a few disadvantages in using the technique.

Observing field water level using field tubes is time-consuming, and this may discourage farmers from practicing AWD. They may also be constrained by insufficient irrigation systems, especially inner field watering systems. In reality, without a suitable irrigation system, it will be difficult for farmers to apply AWD. The results revealed that AWD was increasingly applied during the winter-spring seasons. After one year, the proportion of AWD farmers who continuously applied AWD during winter-spring seasons increased from 51 percent in 2011–2012 to 93 percent in 2012–2013. In addition, AWD was applied not only to winter-spring crops but also to summer-autumn crops. However, it is difficult and not efficient to apply AWD during the summer-autumn seasons because heavy, high-frequency rainfall inhibits the monitoring of water level. As such, AWD during this season is not recommended.

There was a difference between what farmers learned from the training workshop on AWD funded by Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH and what they practiced. A large proportion of AWD farmers did not use a tube to observe the water level in the field. Instead, they hollowed out a hole in the field for observation.

Most of the farmers were satisfied with their training on AWD, but their assessment of its suitability to different conditions was different. They indicated that AWD application suited the natural, financial, and workplace conditions in their location, but not the existing infrastructure, particularly irrigation systems, and social conditions in some areas. The results of the survey also revealed that there was a difference in the suitability of the technique to different agro-areas during practical application. AWD is more suitable for soil with light acid concentration than soil with high acid concentration. It is also more suitable for elevated areas than inundated areas.

Almost half of non-AWD farmers said that they learned about the technique through

[2] **1 must:** forcing farmer to plan originated seeds, qualified by the authority. The planting seeds must be in local authority's list of recommendation.

5 reductions:

-Reduction in the quantity of sowing seeds: sowing with appropriate density: 80 – 120 kg/ha

-Reduction in the amount of nitrogen fertilizer: balanced and rational fertilizer. Using the colour chart to control the nitrogen excess.

-Reduction in plant protection drug: Applying IPM, ICM. Only use chemical drugs in plant protection when highly necessary and must comply with 04 RIGHT rules.

-Reduction in water irrigation: Rice plants do not always need to be flooded. Farmer can apply the method of "flooding, alternat ing dry" to save water, help the rice root growth, and prevent lodging, increase productivity and decrease pumping /irrigation cost.

-Reduction in post-harvest losses:

-Harvesting: Standard degree (85-90% of the seeds turn yellow straw) should use combine harvester-thresher…)

-Drying: Not drying in the field, not drying on traffic axis

-Heat drying: For seeds, heat drying temperature is not over 40°C; for commercial rice, it is not over 45°C

-Storage: For seeds, it is stored in anaerobic bags with moisture of no more than 13%; for commercial rice, it is / not over 14%.

media such as television, newspaper, and brochures issued by the plant protection sub-department, as well as AWD farmers, friends, and agricultural technicians. The majority of the respondents said that they were willing to join any training program or workshop on new farming techniques if they were invited. This showed that there is great potential for designing new training programs in Bac Lieu. Farmers wanted to learn many new techniques, which they could learn in training programs or workshops, such as cultivation of new rice varieties; use of fertilizer and insecticides; and application of new techniques in farming, water control, and irrigation, Three Reductions Three Increases[3] (NCAE 2014), One Must Five Reductions, and Integrated Pest Management.

The following are recommendations to facilitate the transfer of the AWD technique in Bac Lieu:

(1) AWD, as part of the farmers' water-saving measures, should be integrated in training programs or workshops for farmers. For example, AWD should be integrated into training programs like "One Must Five Reductions" and "Three Reductions Three Increases." AWD application should be considered an example of a rural vocational training activity. Given the success of the GIZ training program, AWD should be officially included in extension programs at the local level.

(2) Irrigation systems, including inner field watering systems, should be suitably prepared. In addition, the paddy fields should be flattened before AWD application. A good irrigation systems and a flat field will help farmers apply the technique more efficiently as they can monitor the water level.

(3) AWD is recommended for winter-spring season, which gains the highest efficiencies among all seasons. The technique can be used in areas with water shortage, but not in areas with severe saltwater intrusion.

(4) AWD should be promoted to sustain its application. Media involvement should be enhanced to support the dissemination of information on AWD. This GIZ-sponsored water-saving technique can be extended through outreach programs covering agro-areas in all administrative units in Bac Lieu. To scale up the technique in the province, more dissemination and training activities are recommended. The establishment of demonstration sites should be implemented at a larger scale. To do this, active participation of local government, department of agriculture and rural development, plant protection department and mass organizations is highly important.

5.2.2 Rice-shrimp Farming

The description of rice-shrimp farming in coastal areas of Vietnam below is drawn from the study by FAO (2001). It is a way to utilize paddy fields during the dry season which were often left fallow, thus helping increase farmers' income.

Tidal flats in coastal areas are periodically flooded during high tides. Salinity is usually higher than 5 parts per thousand (ppt) during the dry season, which is why most paddy fields are left fallow. Salinity declines during the rainy season, making rice cultivation possible. The living standards of farmers in the coastal areas of southern Vietnam are lower than those of their counterparts in freshwater regions. Integrating freshwater prawn culture with rice during the rainy

3 reductions:
o decline volume of seed
To decrease the amount of pesticide
To decrease the amount of fertilizer
3 increases
To rise crop productivity
To rise quality of product
To rise economical effectiveness

season, as well as marine shrimp mono-culture during the dry season, is one way of increasing their incomes. Integrating freshwater prawn culture with rice during the rainy season is described as below.

Site selection

-The field should be close to a river or channel
-Choose a low and flat place so it is easy to get water during high tide
-Avoid high acid sulphate soils

Dike and trench construction

-Surface area of field: 1 000-3 000 m²
-Trench is 2-3 m wide and 0.8- 1.0 m deep with trench-to-rice field rate of 10-20 percent.
-Peripheral dikes should be at least 20 cm higher than the annual flooded level.
-Install 2-3 inlet and outlet pipes (at least 20 cm diameter) made of coco nut trunk or wood. The inlet pipe should be installed so as to let water into the paddy field at high tide; the outlet pipe should allow water to drain from the trench when opened.
-Inlet and outlet pipes should be screened to prevent the intrusion of predators.
-Cover the trench surface with tree branches or plant water hyacinths, etc., along the trench to discourage poaching.

Stocking

-Stock juveniles of giant freshwater prawn (Macrobrachium rosenbergii) at a density of 1.2/m² (at least 4-5 g each).
-Stock 10-15 days after transplanting.
-Criteria for juveniles: vigorous, strong and uniform in size
Note: If stocking density is higher than 1/m², supplementary feeding should be done and trench-to-rice field rate should be higher than 10 percent. If water exchange is poor, do not stock higher than 1/m².

Feeding

-Prawn can subsist on natural food in the paddy field, especially if it is load ed with manure.
-The following supplementary feed can be given: rice bran, rice grain, copra, oil cake, cassava root, bro ken maize, fiddler crab (Uca spp.), shrimp or prawn head wastes and trash fish.
-Feeds can be given daily at 5 percent of the prawn's body weight (if no manure loading) or 2-3 percent (with manure loading). Mix ingredients thoroughly, form them into balls and put them in feeding trays. The use of feed ing trays controls consumption of feeds and prevents wastage.
-Feed twice a day: one-third of the quantity in the morning and the rest in the afternoon.
-Check feed consumption daily to ad just the feeding regime as necessary.
Below is a recommended formula for prawn in rice paddies
50 percent - rice bran, broken rice or rice grain
20-30 percent - cassava root or broken maize
20-30 percent - trash fish, shrimp or prawn head wastes or oil cake

Predator prevention

Predators include sea bass, tilapia, snakehead and other wild fish that compete with the prawn for feeds. Predation can result in very low prawn yields. Before stocking prawn, use any of the following measures:

-Drain rice fields and apply lime at the rate of 10 kg/100 m² (15-20 kg for acid sulphate soils).
-Apply Derris root (Derris elliptica), 1-1.5 kg soaked in 10 liters water/1 000 m².
-Release ducks into the rice fields for

several days.

Within the culture time, put gill nets in the trenches to catch the predators going to the rice fields.

Care and maintenance

-Water exchange is essential to supply oxygen to the prawn and to remove detrimental substances in the water. This should be done at least twice a month. The more fre quent the water is changed, the more suitable it is for the prawn's growth and development.

-Water exchange also improves the pH value in the fields especially in sulphate acid soils.
-Dikes should be repaired yearly.
-Cover crab holes along the dikes to prevent leakage.
-Check daily the screen mesh on the outlet and inlet pipes.

Harvesting

-Harvest prawn 5-6 months after rice harvest.
-Open the outlet pipe at low tide and drain the field and trench.
-Hand-collect prawn in the rice field and use a net to harvest in the trench.
-Harvest only the big (more than 15 g) prawn. The small ones are reserved for the next culture season.
Note: Transfer small prawn immediately to a hapa (net cage) to keep them alive for the next culture. Bring harvested prawn as soon as possible to the dealer or keep them in ice so that they stay fresh.

Land preparation and transplanting for rice

-Local varieties are recommended.
-Transplanting should be done when the salinity is lower than 5 ppt.
-Plough and harrow thoroughly be fore transplanting.
-Transplant 3-40 days after seeding.

Fertilizing

-Apply 50 kg diammonium phosphate and 5 t manure/ha before ploughing.
-Use 50 kg urea/ha for top-dressing.

Pest control

-No pesticide or herbicide is applied in integrated prawn-rice culture.
-Use brown planthopper-resistant varieties of rice.
-Release one-month old ducks into rice field to feed on insects, especially hoppers.
Note: In case the above measures cannot control pests, pesticide application can be an alternative. Before applying the pesticide, drain water in the field to let prawn take refuge in the trench for 3-5 days.

5.2.3 Adjustment of rice crop cultivation timing and use of short duration rice varieties

As different rice production areas suffer from different impacts of CC, they adjust their rice crop cultivation timing in different ways to reduce risks. Here below is an example of changes in rice planting calendar that uses some specific short duration rice varieties in Quang Nam province (Ngo et al, 2014) to avoid adverse effects from abnormal climatic events such as floods and storms.

Rice planting calendar

Before the period of 2001-2005, Quang Nam farmers planted three rice crops (winter-spring, spring-summer, autumn-winter) per year. For winter-spring crop season, farmers have to sow early so that the ear appearance and flowering stage of winter-spring rice coincides with the coldest period of the year (January-February) with very low temperature (18-20oC), low humidity (<55 percent) and drizzling rain. Accordingly, rice yield earnings could reduce by 30 to 50 percent because of empty or half-filled ears. For summer-autumn, prolonged drought occurred (from May to July)

and high temperatures of over 37°C during the reproductive stages reduced rice production, especially when the rice plant flowered, causing low seed setting and yield losses (rice plants are most sensitive at the flowering and ripening stages and both of yield and grain quality are adversely affected by high temperatures.

Extremely high temperatures during the vegetative growth reduce tiller number, and plant height and negatively affect panicle and pollen development, thereby decreasing rice yield potential. High temperature is of particular importance during flowering, which typically occurs at mid-morning. Exposure to high temperatures (>35°C) can greatly reduce pollen viability and cause irreversible yield loss because of spikelet sterility. Last crop season (autumn-winter) coincided with the rainy season which typically starts in September and lasts until November. Due to the effects of tropical depression and seasonal storms from the late September to December, the last crop season of the year had low yield and productivity or was even lost completely from flooding. Thus, from the practical rice production in recent years, Quang Nam province has a large transition area from three rice crops to two crops per year in order to avoid climate disadvantages and negative impacts of climate change. Under the guidance of the province's authorities, from 2001, farmers began to remove the spring-summer rice season and change its cropping calendar to winter-spring (from December-April instead of November-March) and summer-autumn (from May-September instead of May-August) to be more suitable to any abnormal changes in climate. Farmers have been encouraged to grow short-term rice varieties in summer-autumn crop season in less than 105 days so they can harvest the summer-autumn rice before September 15 to avoid the flooding season.

■ Rice varieties

Survey statistics showed that rice varieties Xi23, Xiec13.2 (long growth duration varieties), QN1, VL20, NhiUu 838, TBR1 (medium growth duration varieties), and HT1, Q5, GL102, IR325 (short growth duration varieties), etc., were popular at the study sites. Today, most farmers in Quang Nam have realized the importance of paddy seed for good results in cultivation. They shifted to growing high-yielding rice varieties, usually nitrogen-responsive varieties. Most of these have medium or short growth duration, ranging from 85 to 110 days. However, long-duration rice still makes up (45 percent) the rice varieties mostly used by farmers, especially in hilly midland areas

Thanks to the re-arrangement of the cultivation calendar, new rice varieties and appropriate crop structure, production of two rice crops has been higher than three rice crops, although the cultivated area reduced nearly one third. As a result, the cost of investment reduced by 30 percent and economic efficiency increased by 30 to 50 percent. Cultivation calendar was completely changed to avoid rain and storms in rainy season. In general, the impact of climate change on Quang Nam's agricultural production activities clearly changed the structure of crops.

5.2.4 Optimal Row Spacing and Density

Row spacing and plant density are the most important cultural practices to determine maize yield. High populations heighten interplant competition for light, water and nutrients. Therefore, optimal row spacing and density are easy ways to improve productivity especially in the context of water shortage (Phan, 2014). According to Phan, the planting density should be 65,000–75,000 seeds/ha with 1 seed/hole. Planting less than 65,000 plants/ha should be avoided because a 10 percent loss of plants is not uncommon under rainfed field conditions. The planting density at harvest should be at least 60,000 plants/ha to achieve high yield. A more uniform crop stand is reached with 1 seed/hole (and narrower plant spacing within rows) than 2 seeds/hole (and wider plant spacing within rows). Densities of more than 75,000 seeds/ha will not increase the yield unless the growing conditions are very favorable, with a yield potential of over 13 t/ha. In drought-prone environments, a planting density of more than 75,000 seeds/ha should be avoided.

Row spacing that works well with othermanagement practices should be selected. For optimal row spacing, rows should be 50–75 cm apart (the narrower the better). The required plant spacing within rows should be determined to achieve the desired planting density. For optimal plant spacing within rows, plants should be 20–30 cm apart (the wider the better) (Figure 4).

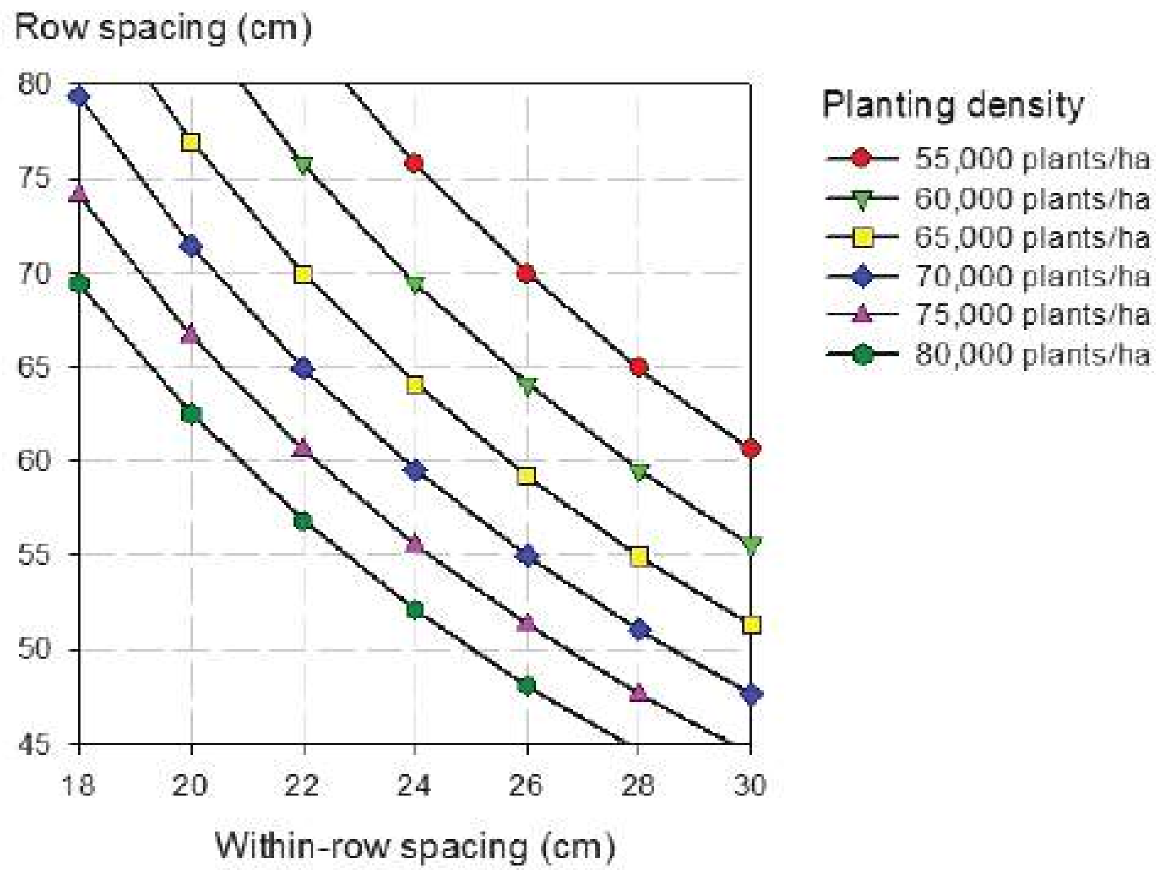

Figure 4. Row spacing and within-row spacing for different planting density

Source: Phan (2014)

Uneven row spacing should be considered to ensure that plants within rows are not planted too close to each other to avoid stress.

Appropriate planting density (e.g., 75,000 seeds/ha) and optimal row spacing (e.g., 70 cm and 50 cm rows alternating) should be selected. The average row spacing should then be calculated ([70+50]/2 = 60 cm). After determining the average row spacing, the required spacing within rows should be identified (e.g., about 22 cm) (Figure 5).

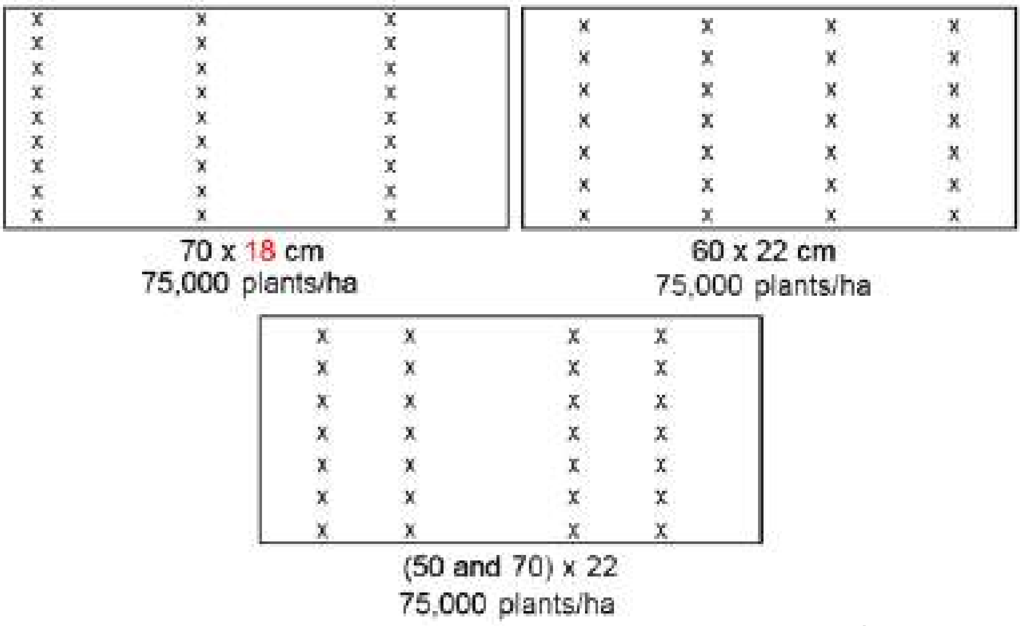

Figure 5. Uneven row spacing for planting density of 75,000 plants/ha
Source: Phan (2014)

5.2.5 Improvements of cultivation practices in sloping areas for maize

As mentioned, drought is the main problem in maize production in NMMA. Intercropping maize with legume crops (soybean, groundnut, and mung bean) proves to be a good measure to reduce evaporation from the soil surface, increase profit, and improve soil conditions and water holding capacity. Vietnamese farmers have practiced intercropping for a long time but their success has been limited when unsuitable combinations of species are planted together or when they planted at inappropriate intercropping ratios. (Ngo, 1996). A recent study by the Agriculture and Forestry Research and Development Center for Northern Mountainous Region of Thai Nguyen University of Agriculture and Forestry (Rural Economy, 2014) concluded that intercropping maize with mungbean instead of maize and mung bean mono-culture is a model that adapts well to climate change because the system works well in severe drought, improving soil fertility, sustaining and increasing farmers' income.

Adoption of stress tolerant and short/ medium duration varieties is another way to reduce adverse effects. of climate change. Early-maturing maize varieties are widely used to curve drought impacts during critical development stages of maize. Early-maturing OPVs such as 'TSB-2', 'MSB-49', 'MSB-49B' (a yellow version of MSB-49), and 'Q-2' are favored by farmers even in unfavorable growing conditions as their yields were as high as some hybrids' (Ngo, 1996). The National Maize Research Institute (NMRI) under MARD has been paying high attention on developing new hybrids which are early-maturing, have high yield potential and improved resistance to diseases. LVN25 and SB099 are some examples of such new hybrids (NMRI, 2011).

VI. CONCLUSION

This report highlighted five case studies on CCA measures that can be scaled up regionally to provide solutions for ensuring food security, sustainable agricultural production, and higher income for farmers. Although they are good practices, several issues should be taken into consideration and confronted through regional cooperation. These matters call for further sharing of knowledge and experiences among AMS.

Firstly, the framework conditions for the massive application of good practices should be examined. At national and regional levels, there are sufficient legal documents and strong institutional frameworks to enhance climate change awareness and mainstream climate change issues in annual national and regional action plans. Raising awareness on climate change and promoting CCA measures at the grassroots level should be strengthened to increase national and regional understanding of climate change impacts, adaptation, and mitigation.

Secondly, regional collaboration should be carried out through both technical and financial support instead of either technical assistance or financial support to safeguard the success and sustainability of results.

Thirdly, large-scale adjustments and pilot models should be done. Technical issues require more careful examination to prevent adverse side effects, especially on the environment.

Fourthly, the institutional framework for the application of CCA measures should be improved. The role of actors who are participating in post-production activities remains very limited, although they capture a large portion of profit along the value chain with low risks while farmers suffer from high risks with small profit.

Therefore, it is necessary to develop solutions to encourage these actors to participate more actively in this field.

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This publication is a joint undertaking by the ASEAN Technical Working Group on Agricultural Research and Development (ATWGARD) and the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH through the ASEAN-German Programme on Response to Climate Change (GAP-CC).

In partnership with the Southeast Asian Regional Center for Graduate Study and Research in Agriculture (SEARCA).

April 2015

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