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Promotion of Climate Resilience in Rice and Maize

Myanmar National Study

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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.

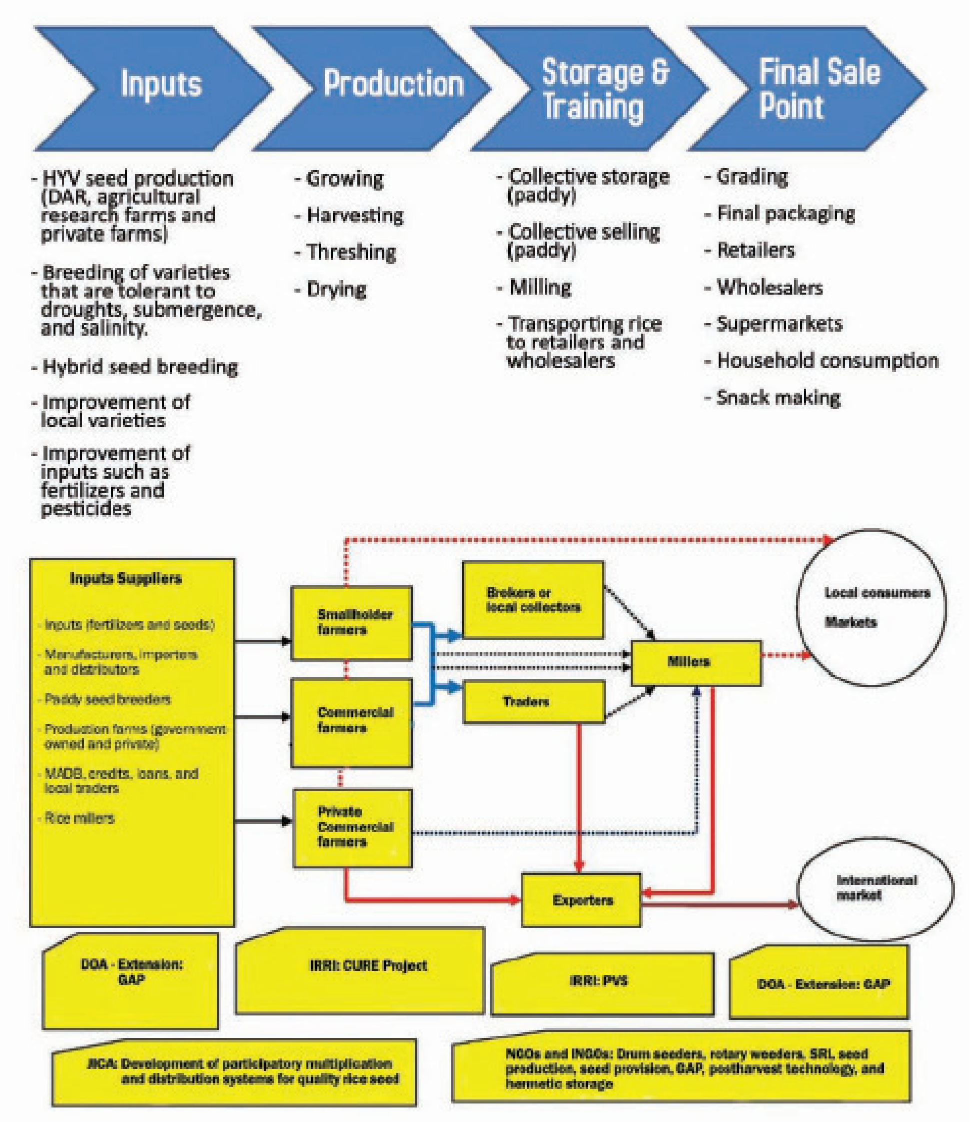

Figure 1. Rice production value chain (functions and operations along the value chain)

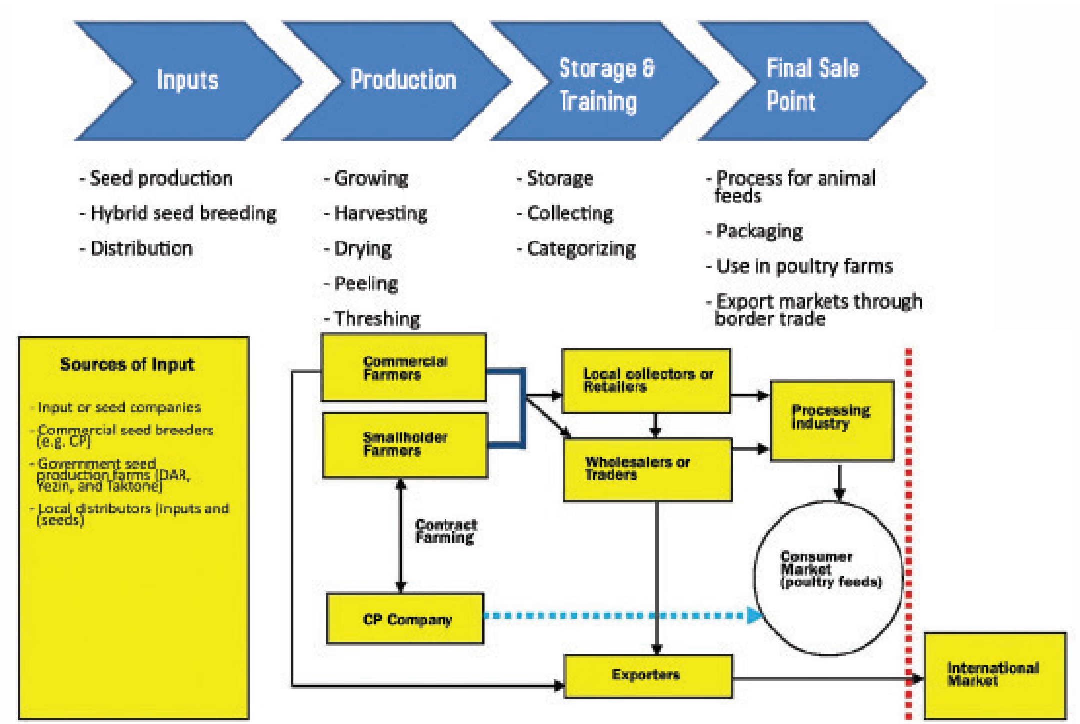

Figure 2. Maize production value chain (functions and operations along the value chain)

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).

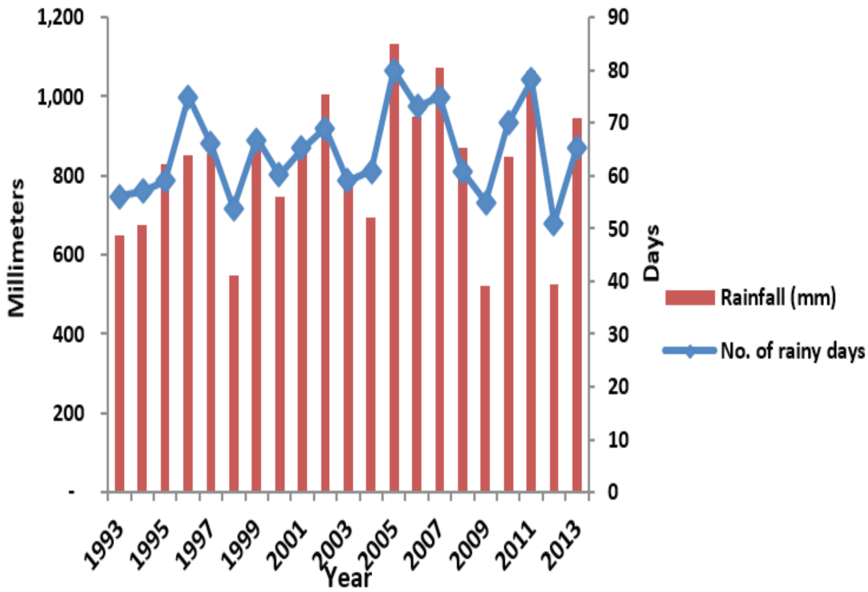

Figure 3. Annual rainfall and number of rainy days in Yamethin Township
Source: DOA, Yamethin Township (2014)

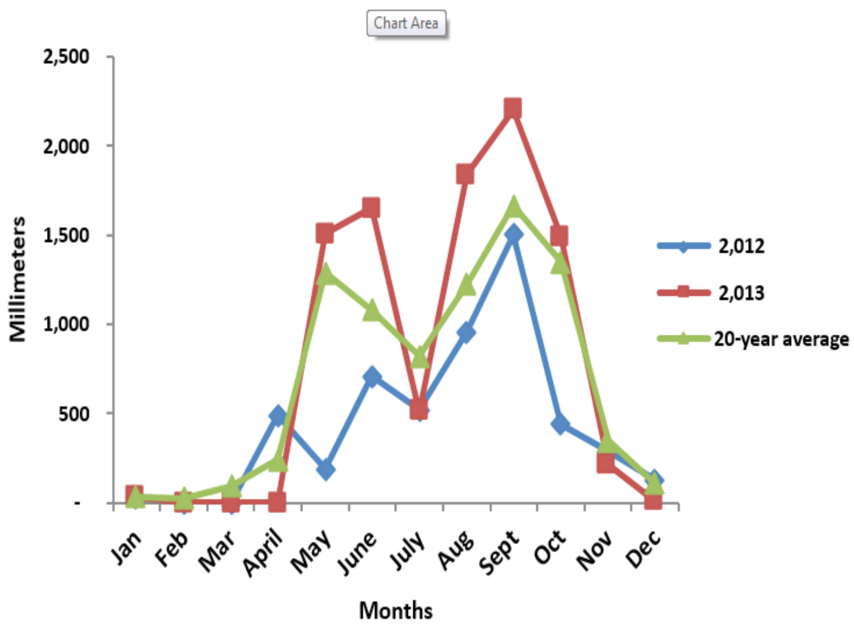

Figure 4. Comparison of monthly rainfall in Yamethin Township
Source: DOA, Yamethin Township (2014)

■ **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.

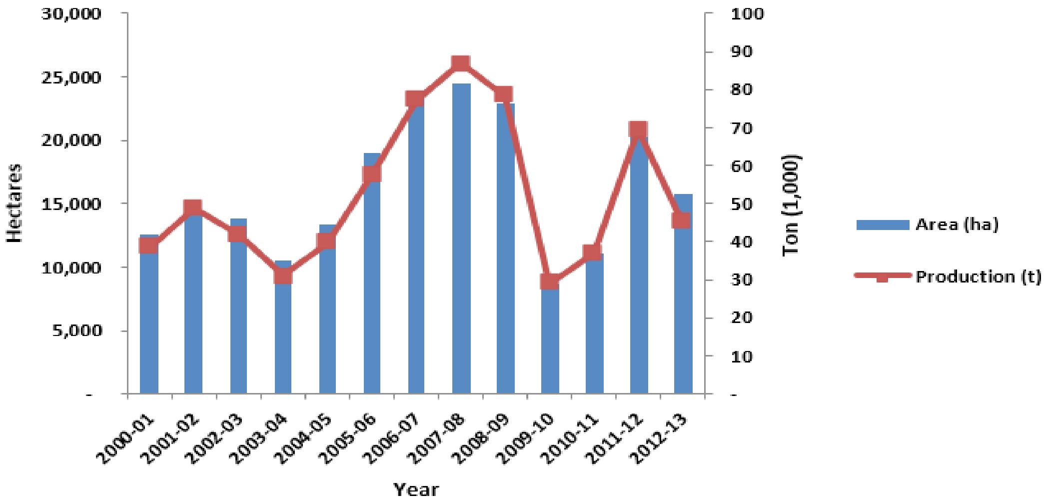

Figure 5. Annual monsoon rice production in Yamethin Township
Source: *DOA, Yamethin Township (2014)*

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).

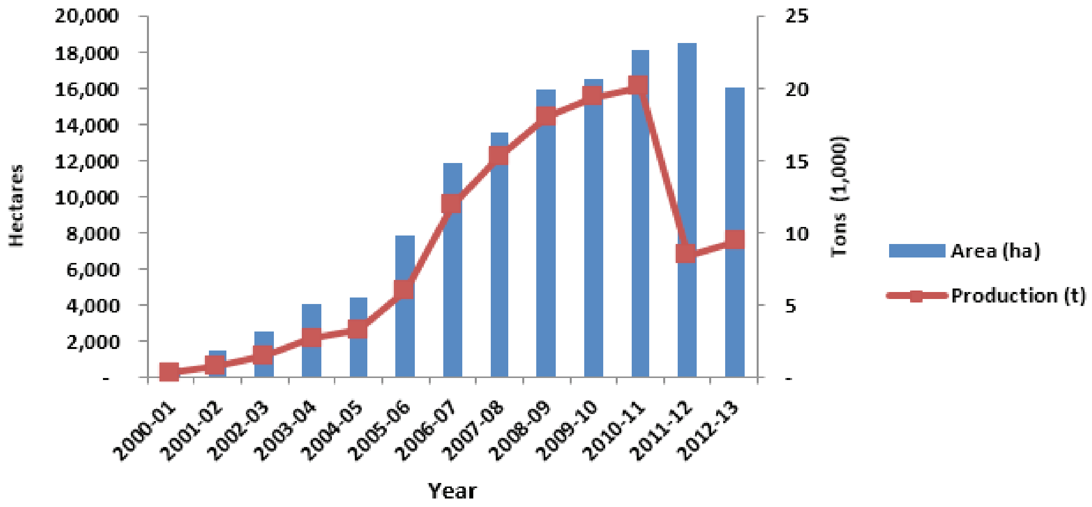

Figure 6. Annual monsoon mungbean production in Yamethin Township
Source: DOA, Yamethin Township (2014)

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).

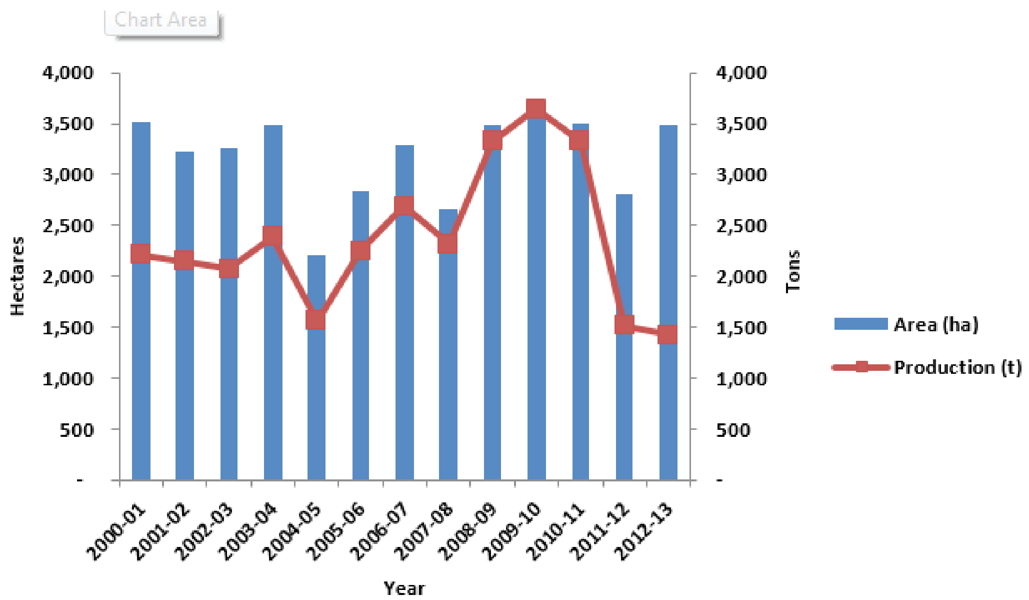

Figure 7. Annual monsoon sunflower production in Yamethin Township
Source: DOA, Yamethin Township (2014)

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).

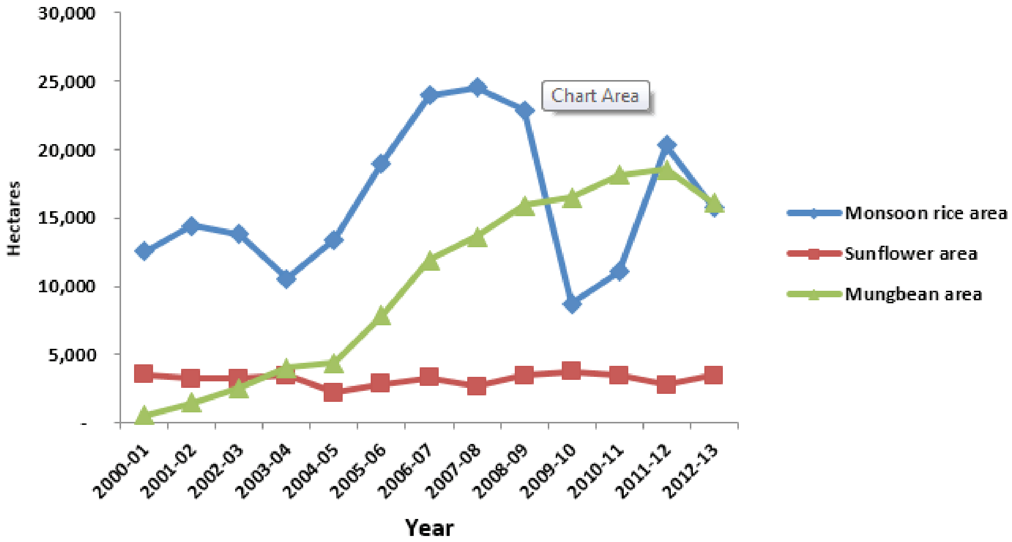

Figure 8. Annual sown areas of major monsoon crops in Yamethin Township
Source: DOA, Yamethin Township (2014)

- **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).

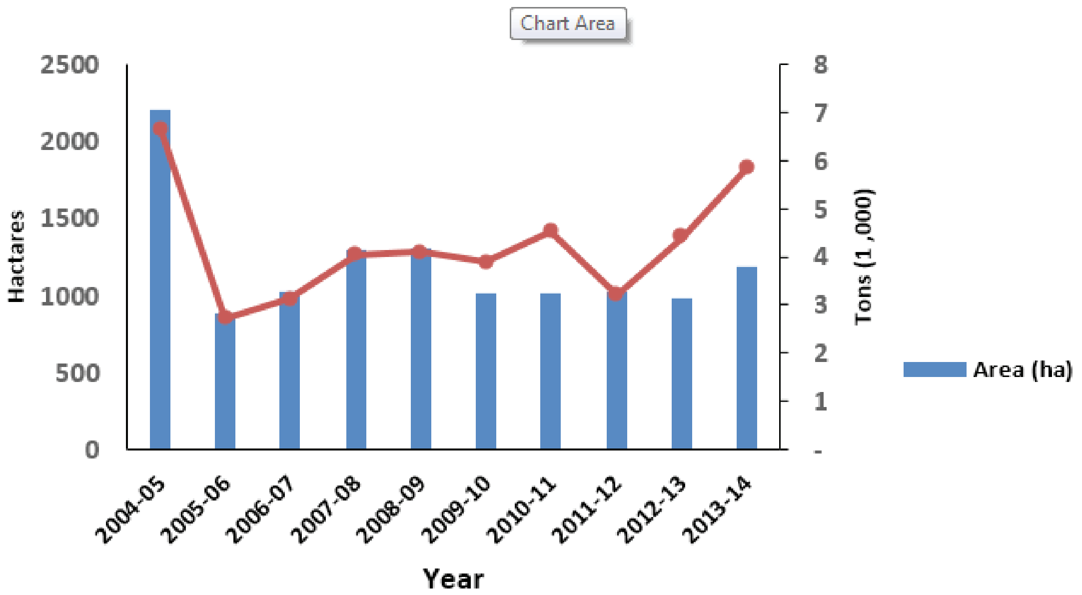

Figure 9. Annual maize production in Tatkone Township
Source: DOA, Tatkone Township (2014)

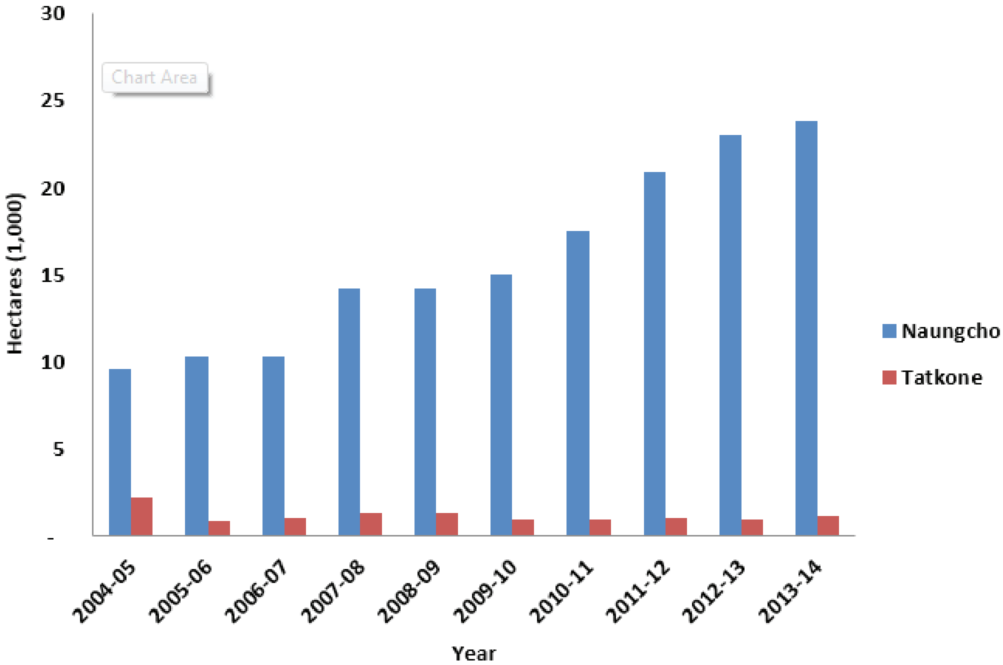

Figure 10. Comparison of maize sown areas in Naungcho and Tatkone Townships
Source: DOA, Naungcho and Tatkone Townships (2014)

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).

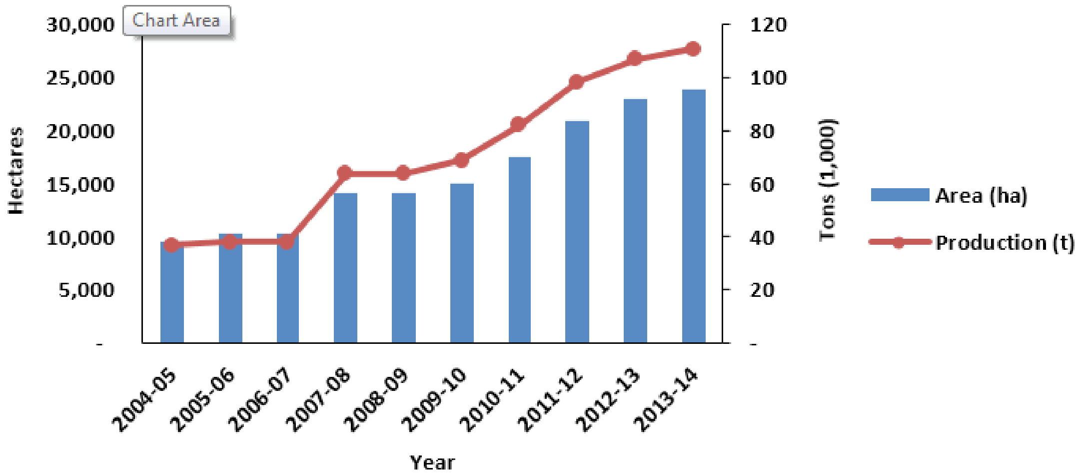

Figure 11. Annual maize production in Naungcho Township
Source: DOA, Naungcho Township (2014)

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).

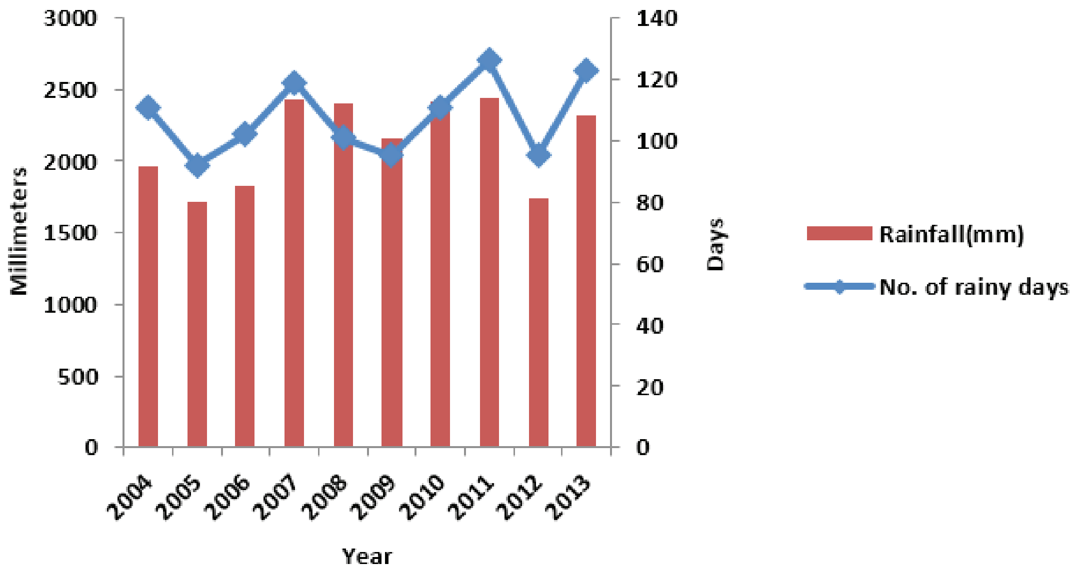

Figure 12. Annual rainfall in Kanpelet Township
Source: DOA, Kanpetlet Township (2014)

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.

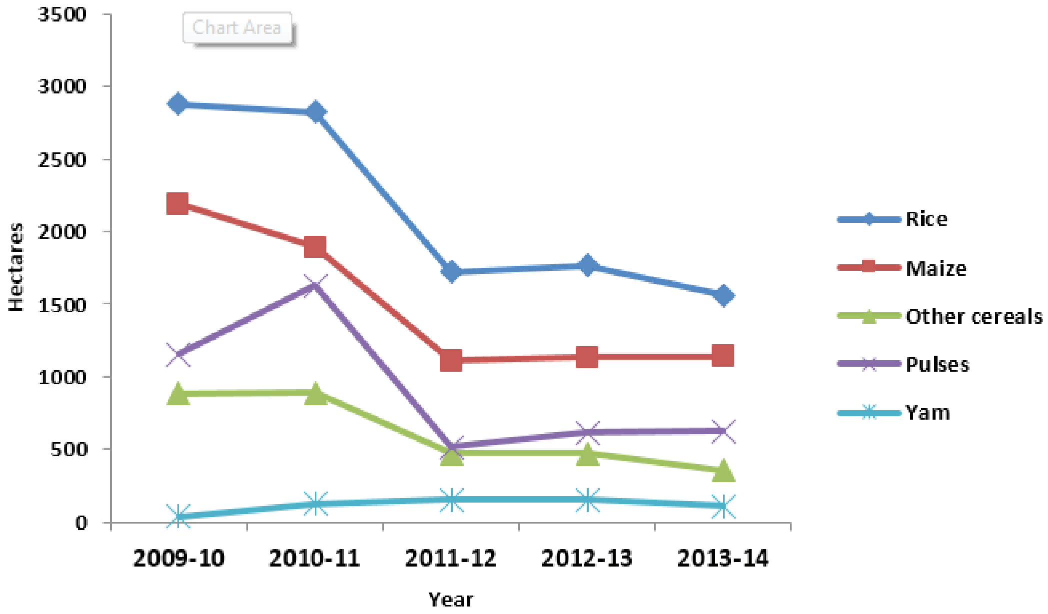

Figure 13. Annual sown areas of major crops in Kanpelet Township
Source: DOA, Kanpetlet Township (2014)

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.

References

ARDC (Agribusiness and Rural Development Consultants). 2012. "Study on Variations in Support Activities in Different Agro-Ecological Zones and Socio-Economic Situation of Myanmar." **Consultancy Report to the United Nation Development Programme, Myanmar.** Yangon, Myanmar.

BATWG-GRET (Bogale Agriculture Technical Working Group, Groupe de Recherches et d'Echanges Technologiques). 2012. "Rainy Season Rice Bogale & Mawgyun Townships." **A Full Report on Assessment Survey of 2011.** Bogale, Ayeyarwady Region, Myanmar

CSO-MNPED (Central Statistical Organization, Ministry of National Planning and Economic Development). 2010. **Statistical Year Book 2010.** Nay Pyi Taw, Myanmar.

DAP-MOAI (Department of Agricultural Planning, Ministry of Agriculture and Irrigation). 2013a. **Myanmar Agriculture at a Glance.** Nay Pyi Taw, Myanmar.

DAP-MOAI. 2013b. Myanmar Agriculture in Brief. Nay Pyi Taw, Myanmar.

DAR-MOAI (Department of Agricultural Research, Ministry of Agriculture and Irrigation). 2014. **Annual Report.** Nay Pyi Taw, Myanmar.

DOA-MOAI (Department of Agriculture, Ministry of Agriculture and Irrigation). 2014. **Annual Report.** Nay Pyi Taw,

DOA-MOAI. 2013. **Annual Report.** Nay Pyi Taw, Myanmar.

DOA-MOAI. 2012. **Talking Figures: Some Statics in Agriculture of Myanmar and Asia-Pacific Region**. Nay Pyi Taw, Myanmar.

DOP-MIP (Department of Population, Ministry of Immigration and Population). 2014. "Population and Housing Census of Myanmar 2014." **Census Report Volume 1.** Retrieved August 2014. http://www.dop.gov.mm/

DTP-MOC. (Department of Trade Promotion, Ministry of Commerce). 2013. T**he Commerce Journal,** Page 5. Vol.13. No.27. Retrieved August 2014. http://www.commercejournal.com.mm

Ferrero A., and V.N. Nguyen. 2004. "The Sustainable Development of Rice-Based Production Systems in Europe." **International Rice Commission (IRC) Newsletter** 54: 115–124. Agriculture and Consumer Protection, Food and Agriculture Organization of the United Nations, Rome.

FAO (Food and Agriculture Organization). 2004. **Agricultural Sector Review and Investment Strategy: Volumes I and II, and Background Studies.** Yangon, Myanmar.

Htay, T.T. 2011. "Review of Flood Occurrence in 2010 in Myanmar". Presentation at the Monsoon Forum: A Stakeholders' Meeting for Enhancing the Utility of Climate Forecasts, Department of Meteorology and Hydrology, Ministry of Transport, Nay

Pyi Taw, Myanmar, February 15, 2011.

Htwe, M.M. 2011. "From Special Yield Model Paddy Farm of Nay Pyi Taw to Farmlands of Myanmar." **New Light of Myanmar. Volume XIX, Number 115.** News and Periodicals Enterprise, Ministry of Information, Union of Myanmar.

IFPRI (International Food Policy Research Institute). 2009. "Food Policy Report." **Climate Change Impact on Agriculture and Costs of Adaptation.** Washington, D.C., U.S.A. Retrieved August 2014. http://www.ifpri.org/sites/default/files/publications/os11_climatechange.pdf

IRRI (International Rice Research Institute). Retrieved October 2014. http://www.irri.org

IWMI (International Water Management Institute). 2007. **IWMI Publication 2007:14: Rice Feeding the Billions.** Colombo, Sri Lanka. Retrieved August 2014. http://www.iwmi.cgiar.org/issues/climate-change/publications/

JICA (Japan International Cooperation Agency). 2013. "Development of Participatory Multiplication and Distribution System for Quality Rice Seed." Presentation at the 3rd Joint Coordination Committee, MOAI and JICA, Nay Pyi Taw, Myanmar, July 4, 2013.

Lampayan, R. M., R. M. Rejesus, G.R. Singleton, B.A.M. Bouman. 2015. "Adoption and economics of alternate wetting and drying water management for irrigated lowland rice." **Field Crops Research** 170: 95-108.

Matsushima, S., and K. Tsunoda. 1958. **Analysis of Developmental Factors Determining Yield and Application of Yield Prediction and Culture Improvement of Lowland Rice XLV. Effects of temperature and its daily range in different growth stages upon the growth, grain yield, and constitutional factors in rice plants.** Proc. Crop Sci. Soc. Jpn, 26: 243–244. Crop Science Society of Japan, Tokyo, Japan.

MOAI (Ministry of Agriculture and Irrigation). Retrieved August 2014. http://www.moai.gov.mm

Mury, E. 2010. "The Ayeyarwady Delta: Agriculture between Land and Sea". Master's thesis, Institute of the Warm Regions of Montpellier and Polytechnique Institute LaSalle Beauvais.

NECC-MOECAF, and DMH-MOT (National Environmental Conservation Committee, Ministry of Environmental Conservation and Forestry, and Department of Meteorology and Hydrology, Ministry of Transport). 2012. **Myanmar's National Adaptation Program of Actions (NAPA) to Climate Change.** Yangon, Myanmar

Nguyen, N.V. 2004. **Global Climate Changes and Rice Food Security. Ed., Vol.** FAO, Rome: Italy. Retrieved May 2014. http:// www.fao.org/climatechange/

Peng, S., J. Huang, J.E. Sheehy, R.C. Laza, R.M. Visperas, X. Zhong, G.S. Centeno, G.S. Khush, and K.G. Cassman. 2004. "Rice Yields Decline with Higher Night Temperature from Global Warming." **Proceedings of the National Academy of Sciences of the United States of America** 101 (27): 9971–75.

Richards, M., Sander, B.O. 2014. “Alternate Wetting and Drying in Irrigated Rice”. **Climate Smart Agriculture Practice Brief.** CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). Copenhagen, Denmark. http://ccafs.cgiar.org/publications/alternate-wetting-and-drying-irrigated-rice

Shifflette, A. 2011. **Cyclone Nargis in Myanmar: Support to PONJA and Post-Nargis Periodic Review.** Retrieved June 2014. http://eeas.europa.eu/ifs/publications/articles/rep2/reportage_vol2chapter7_myanmar-cyclone_nargis_in_myanmar_en.pdf

Shwe, T. M. 2011. “Agriculture Development Issues and Strategies, Myanmar: Background Paper for the Development Policy Options, Agribusiness and Rural Development Consultants (ARDC).”N**ational Consultancy Report.** FAO, Myanmar.

SRI International Network and Resources Center. Retrieved October 2014. http://www.sririce.org

Swe, K.L. 2011. “Coping Strategies with Drought and Agricultural Development in Dry Zone, Myanmar.” **Journal of Agroforestry and Environment, Vol.5, Special Issue.** Official publication of Agroforestry Society of Bangladesh.

TCG (Tripartite Core Group). 2008. “Post-Nargis Joint Assessment.” A report prepared by TCG comprised of representatives of the Government of the Union of Myanmar, the Association of the Southeast Asian Nations (ASEAN) and the United Nations (UN). United Nations Information Center (UNIC), Yangon. Myanmar.

YAU (Yezin Agricultural University). Retrieved October 2014. http://yaummr.org

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, Taninthari 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.