Food and Agriculture Organization of the United Nations

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HANDBOOK

ON

CLIMATE SMART AGRICULTURE

Training of Trainers on Climate Smart Agriculture

in

Myanmar

HANDBOOK

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in

Myanmar

Sustainable Cropland and Forest Management in Priority Agro-ecosystems of Myanmar Project (GCP/MYA/017/GFF)

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Contents

Foreword

The Food and Agriculture Organization of the United Nations (FAO) is implementing a project entitled "Sustainable Cropland and forest management in priority agro-ecosystems of Myanmar (SLM-GEF)" in coordination with the Ministry of Natural Resources and Environmental Conservation (MoNREC) and the Ministry of Agriculture, Livestock and Irrigation (MoALI) with funding from the Global Environment Facility (GEF).

The project aims to build the capacity of farming and forestry stakeholders to mitigate climate change and improve land condition by adopting climate-smart agriculture (CSA), sustainable forest management (SFM) and sustainable land management (SLM) policies and practices. The project facilitates the adoption of climate smart agriculture (CSA) policies and practices that will help to sustainably increase productivity, enhance resilience, reduce/remove GHGs emission and enhance achievement of national food security and development goals.

The project intends to establish a national CSA/SLM training program mainstreaming CSA/SLM in the agriculture related academic courses and trainings conducted by Yezin Agricultural University (YAU), State Agricultural Institutes (SAI), Department of Agriculture (DoA) and Department of Agriculture Research (DAR). The project is working with DoA, SAIs, DAR and YAU to integrate CSA within their research, extension, training and development programs. The project has made efforts to revise/develop the curricula integrating CSA topics for example: i) CSA component integrated into the Masters and Bachelor level courses on Agriculture at YAU; ii) CSA component integrated into the Diploma in Agriculture course at SAIs; iii) one month training on CSA together with other subjects for the in-service or refresher course at Central Agriculture Research and Training Centre (CARTC) under DoA and iv) one-week intensive Training of Trainers (ToT) program aiming for the researchers, extension agents and teachers of DoA, DAR and YAU.

AVSI Foundation was contracted by FAO to develop the Climate Smart Agriculture Curricula for the above-mentioned courses and a CSA Handbook both in Myanmar and English languages. This CSA Handbook is intended to help the researchers, extension agents, teachers and farmers to learn and promote CSA in Myanmar.

Ms. Xiaojie Fan

FAO Representative in Myanmar

Acronyms

ACIAR	the Australian Centre for International Agricultural Research
ADS	Agricultural Development Strategy
AESA	Agro-ecosystem Analysis
AVSI	Association of Volunteers in International Service
AWD	Alternate wetting and drying
BMD	Burma Meteorological Department
CA	Conservation Agriculture
CARTC	Central Agricultural Research and Training Center
CCAFS	Climate Change, Agriculture and Food Security
CFI	Community Forestry Instruction
CIG	Common interest group
CIRAD	The French Agricultural Research Centre for International Development
CS	Certified seed
CSA	Climate Smart Agriculture
CSPM	Climate Smart Pest Management
CSV	Climate Smart Village
DAR	Department of Agricultural Research
DFID	Department for International Development
DMH	Department of Meteorology and Hydrology
DoA	Department of Agriculture
F2FE	Farmer-to-farmer extension
FAO	Food and Agriculture Organization
FARM	Fostering Agricultural Revitalization in Myanmar
FFS	Farmer Field School
FYM	Farm yard manure
GACSA	Global Alliance for Climate Smart Agriculture

GAP	Good Agricultural Practices
GDP	Gross Domestic Product
GEF	Global Environment Facility
GHG	Greenhouse Gas
IC-LS	Integrated Crop Management and Landscape Management
IDM	Integrated Disease Management
IMO	International Meteorological Department
IFS	Integrated Farming System
IIRR	International Institute of Rural Reconstruction
IPCC	International Panel of Climate Change
IPM	Integrated Pest Management
IPNM	Integrated Plant Nutrient Management
JICA	Japan International Cooperation Agency
MA 21	Myanmar's Agenda 21
MADB	Myanmar Agricultural Development Bank
MAPCO	Myanmar Agribusiness Public Company
MBRLC	Mindanao Baptist Rural Life Center
MCSAS	Myanmar Climate Smart Agriculture Strategy
MDG	Millennium Development Goals
MI	Micro irrigation
MoALI	Ministry of Agriculture, Livestock and Irrigation
MoNREC	Ministry of Natural Resources and Environmental Conservation
MRIA	Myanmar Rice Industry Association
NAPA	National Adaptation Programme of Action
NARES	National Agricultural research and Extension Services
NFTS	Nitrogen-fixing trees and shrubs
NICRA	the National Initiatives on Climate Resilient Agriculture
NGO	Non-government Organization

PRA	Participatory Rural Appraisal
QSEM	The Qualitative Social and Economic Monitoring.
RRS	River Forecasting Section
RIICE	Remote Sensing-Based Information and the Insurance for Crops in Emerging Economies
RRA	Rapid Rural Appraisal
SAI	State Agricultural Institute
SSB	Single Side Band
SCPI	Sustainable Crop Production Intensification
SALT	Sloping Agricultural Land Technology
SALT 2	Simple Agro-Livestock Technology
SALT 3	Sustainable Agroforest Land Technology
SALT 4	Small Agrofruit Livestock Technology
SDI	Subsurface Drip Irrigation
SFM	Sustainable Forest Management
SLM	Sustainable Land Management
SOC	Soil organic carbon
SRI	System of Rice Intensification
TNAU	Tamil Nadu Agricultural University
TVET	Technical, Vocational Training and Development
UNDP	United nations Development Programme
USGCRP	U.S. Global Change Research Program
YAU	Yezin Agricultural University

1. BASICS

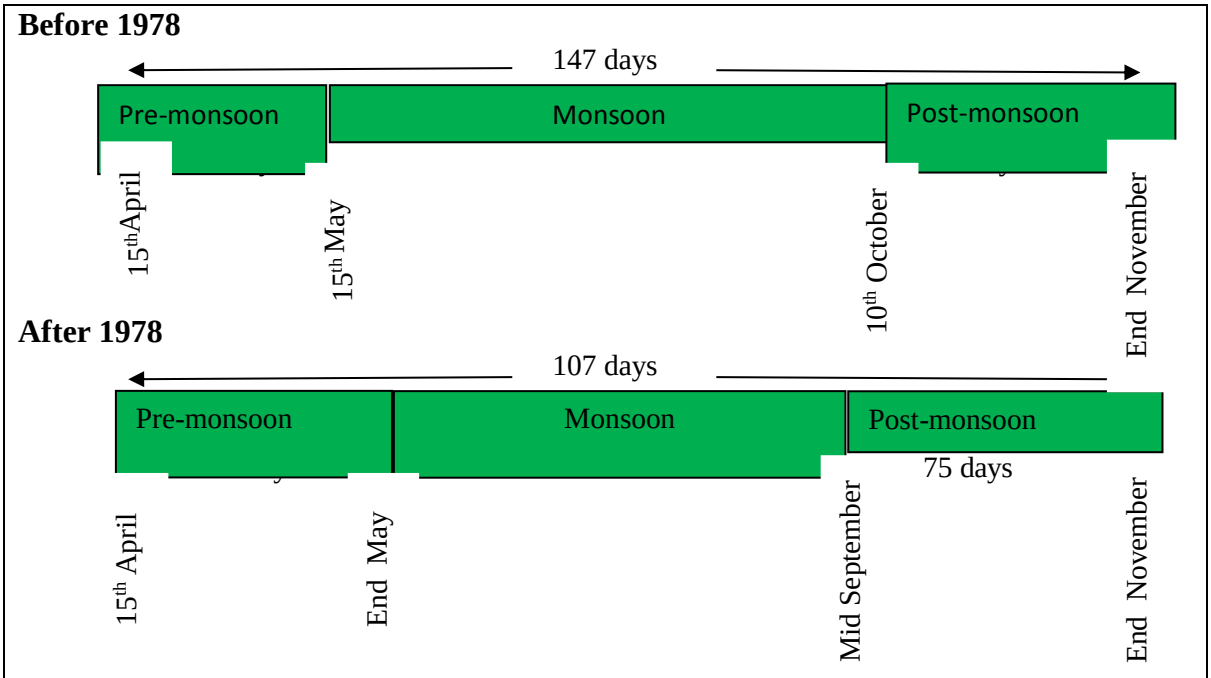
1.1 Agro-ecological Zones in Myanmar

Land area of Myanmar is 676,577 square kilometer and topographically, the country can be divided into five regions. They are the northern and western mountains, the eastern plateau (Shan plateau), the central basin and coastal strip. The country is mountainous, rising to more than 5 800 m above sea level in the far north, and reaching an elevation of well over 2 000 m over much of Shan state in the northeast, and in Rakhine and Chin states in the west.

The average annual rainfall of central dry zone is less than 30 inches (762 mm) but it may be 200 inches (5080 mm) in the coastal. The mean maximum temperature in central dry zone is about 100°F (37.8°C) in March and April but it may be 40°F (4.4°C) to 50°F (10.0°C) in the Northern part of Myanmar in January and February (Lai Lai Aung et al. 2017).

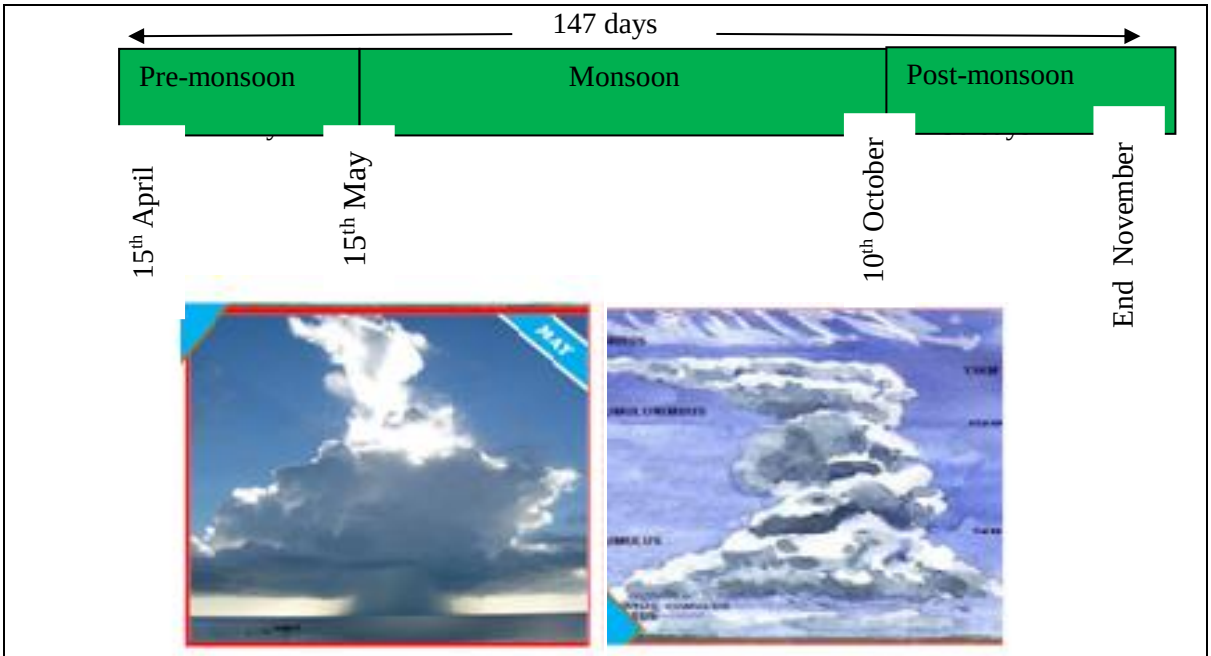
Myanmar is situated in the tropical climate region and highly vulnerable to impacts from climate change. From 1961-1990 to 1981-2010, the maximum temperature has increased whereas the minimum temperature has decreased. The normal annual mean maximum temperature increased by 0.5 °C from 1961-1990 to 1981-2010. Monthly normal rainfall was about 200 mm in May, > 300 mm in September, > 400 in June, July and August (Fig.1.1).

In the pre-monsoon and mid-monsoon seasons, the amount of rainfall has decreased over the whole country. The onset date of the monsoon is later and the withdrawal date is earlier. The duration of the rainy season has decreased. The normal duration of the monsoon period was 144 days in the period 1961-1990 and 121 days in the period of 1981-2010 (Lai Lai Aung et al. 2017). However, it was reported to be shorter than this (only 107 days) in some year (Fig. 1.1- 1.3).



Formation of cumulus nimbus becomes more and more as the duration of pre-monsoon and post-monsoon becomes longer. Thunderstorm, tornado, downburst, squall and lightning occur more.

Fig.1.1 The duration of pre-monsoon, monsoon and post-monsoon before and after 1978 (Source: Tun Lwin, 2010).



The clouds formed in pre-monsoon and post monsoon are cumulus. It shows the instability of atmosphere Thundershower will be scattered. Rain occurs only a few hours. Thunderstorm, tornado, downburst, squall, roll of thunder and lightning occur most.

Fig.1.2 The duration of pre-monsoon, monsoon and post-monsoon, and cloud formation before 1978 (©Tun Lwin, 2010).

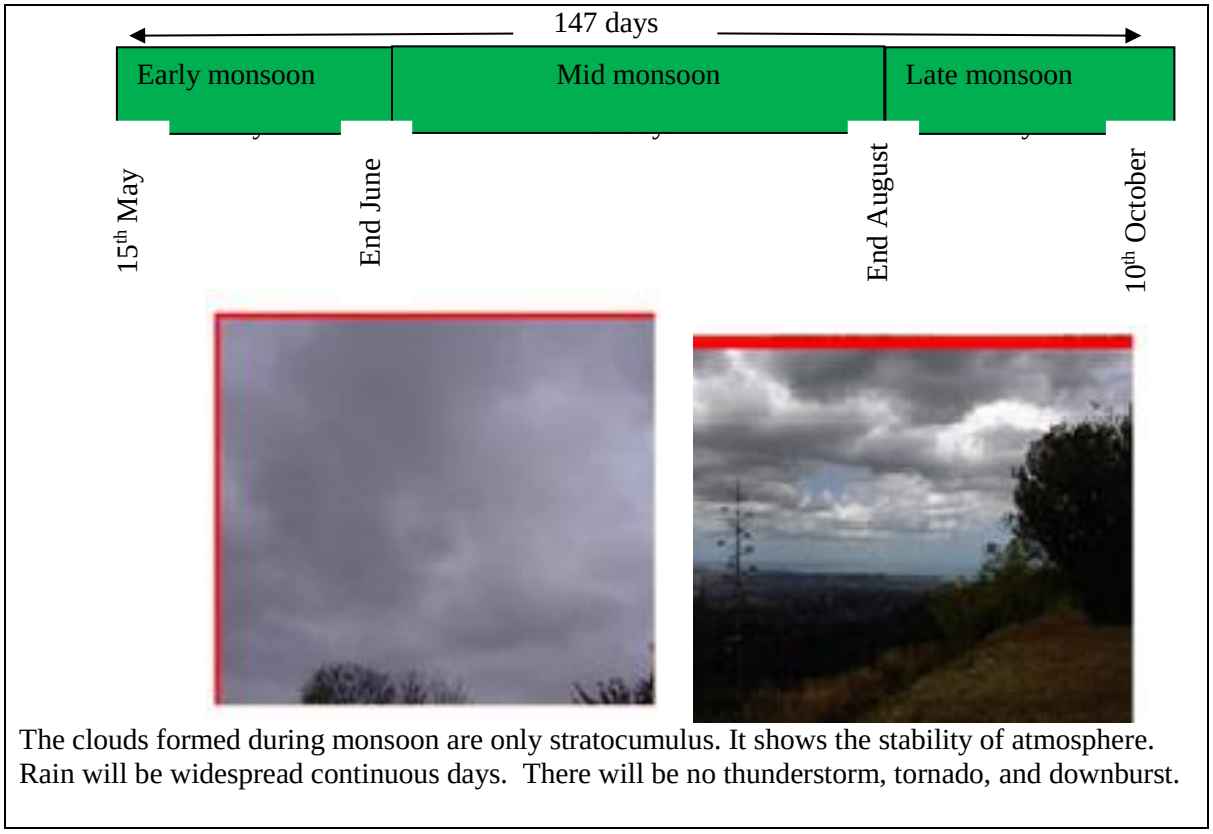


Fig.1.3 The duration of early monsoon, mid monsoon and late monsoon before 1978 (© Tun Lwin, 2010).

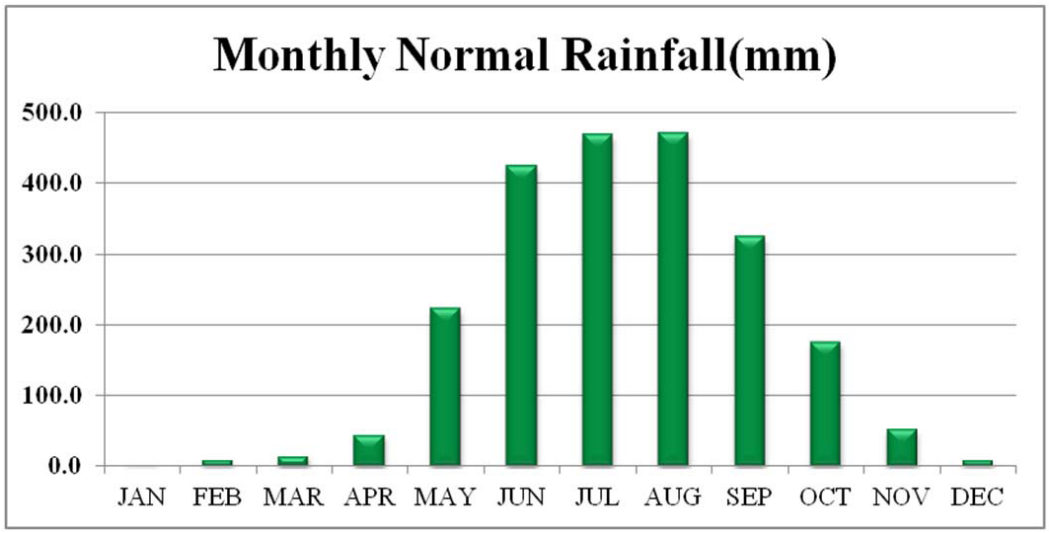


Figure.1.4 Monthly normal rainfall over Myanmar (1981-2010) (© Lai Lai Aung *et al.*, 2017).

1.1.1 Agricultural Zoning and Characteristics

The total cultivable area in Myanmar is almost 18.3 million ha. Total cultivated area in 2009 was around 12.1 million ha of which 11.0 million ha or 91 percent was for annual crops and 1.1 million ha or 9 percent for permanent crops. The cultivated areas are concentrated in the Ayeyawady river basin, while potential for further expansion lies mainly in upper Myanmar, in the Chin, Kachin and Shan states. Based on topography, land use, climate and sown crops the entire country can be divided into four agro-ecological zones: hilly and mountainous area, central dry zone, delta area and coastal area (Fig. 1.5) (FAO 2009; JICA, 2013). Topography, weather conditions, cultivated crops and population density varies with different ecological zone. Each and every zone suffered from the impacts of climate change but the severity and magnitude differed from one another. Agricultural characteristics of each zone are summarized as shown in Table 1.1.

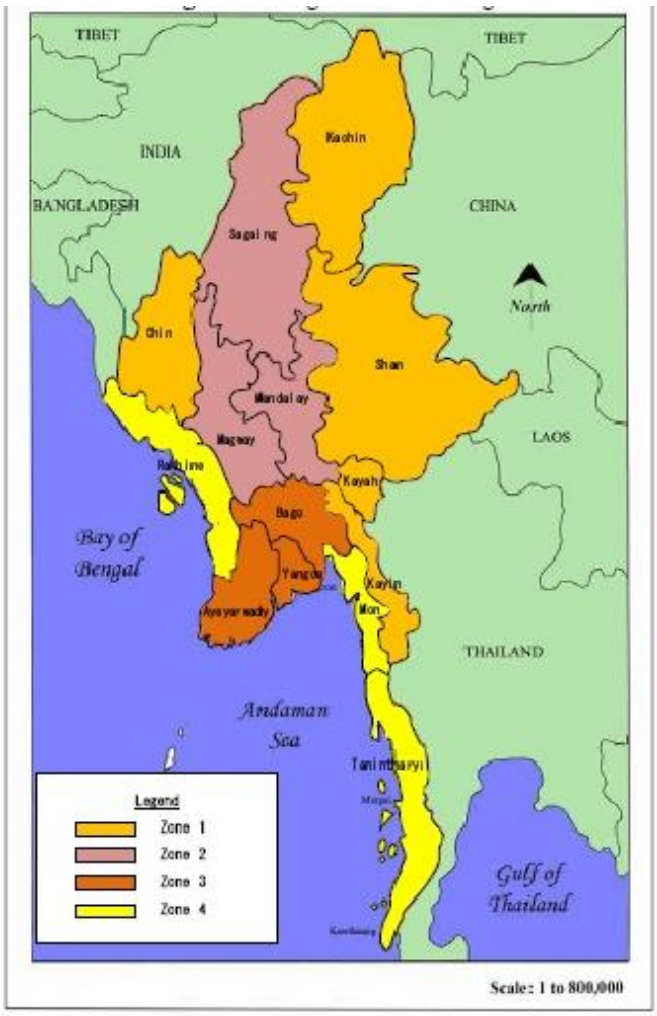


Fig.1.5 Agro-ecological zones of Myanmar) (© FAO 2009; JICA, 2013).

Table.1.1 Agricultural Zoning and Characteristics

Item	Zone I Hilly and Mountainous Area	Zone II Central Dry Zone Area	Zone III Delta Area	Zone IV Coastal Area
Administrative Area	Kachin State Kayah State Chin State Shan State	Sagaing Region Magway Region Mandalay Region	Ayeyarwady Region Yangon Region Bago Region	Mon State Tanintharyi Region Rakhine State
Climate	-Rainy season (Mid-May to Mid-Oct.) -Dry season (Mid-Oct.to Mid-May) - Annual Rainfall (1,000 to 2,000mm)	-Summer (Mar. to May -Rainy season (Mid-May to Oct.), -Winter (Nov. to Feb.) -Annual rainfall (700 to 1,000 mm)	-Rainy season (Mid-May to Mid-Oct.) -Dry season (Mid-Oct. to Mid-May) -Annual rainfall (2,200 to 28,000 mm)	- Annual rainfall (3,000 - 5,000 mm)
Topography and Land Use	- High mountains, range and forests -Some areas high rainfall, rivers developed -Crop cultivation in valley areas, shift-cultivation in hilly areas	-Flat topography, semi-dry to dry condition -Paddy cultivation by irrigation water. Rain-fed paddy lands are found in some areas.	-Low land consists of Ayeyarwady delta and Sittaung delta -Area 3.1 million ha, paddy monoculture	-Cultivated areas of coastal regions of Mon, Tanintharyi, Rakhine
Major Crops and Potential	-Rice wheat, maize, sorghum vegetables, sugarcane -Soil types and topography is suitable for agro-forestry	-Rice, groundnut, sesame, pulses, oil seeds etc., various crops are sown.	-Rice, pulses -60% of total rice production is produced in this zone	-Rice, rubber, oil palm oil -Rice sufficiency area -Potential area for development rubber, coconut and oil palm
Issues for Agricultural Production	Forest land is degraded by shifting cultivation. Soil erosion, sediment and	To increase crop production depend upon the improving exist- ing irrigation	This zone cannot be classified as problematic one for agricultural production, but	Flood protection and drainage improvement are required.

	deficit of water resources are found. Few fertile land and low potential to manage the . large scale farming	networks and maintenance canals Production of sesame depends on weather condition. Rice deficit is observed in some areas	more renovation on flooding and drainage protection becomes necessary	

(Source: JICA, 2013).

1.1.2 Climate Change and Vulnerability in Myanmar

Myanmar is highly vulnerable to climate change and extreme weather conditions. According to the Global Climate Risk Index, Myanmar ranks among the top three countries most affected by weather related events, which has led to massive displacement of people and the destruction of livelihoods, crops and other food sources. In the recent years, the change in the climate has been characterized by changing rainfall patterns, increasing temperatures and extreme weather throughout the country and some examples are presented below.

1. Drought commonly occurs in the dry zone (Sagaing, Mandalay, Magway regions).
2. Cyclones, storm surges, heavy winds, floods were usually observed in the coastal areas, mainly the Rakhine Coastal State, Ayeyarwady Delta and Mon State.
3. High temperatures happened in flat regions in Central Dry Zones/arid-semi-arid belts.
4. Intensive rains occur in Tanintharyi, Yangon, Rakhine, Ayarwady and Mon state/Region and other parts of the country. Sea level rise was observed in coastal regions/ Ayayarwady Delta.

The country has experiences with meteorological, hydrological and seismic hazards. The Great Sittwe Cyclone of 1968, the Pathein Cyclone of 1975, the Gwa Cyclone 1982, the Maungdaw Cylone of 1994, the Cyclone Mala of 2006, the Cyclone Nargis of May 2008, the effect of the Cyclone Koman (crossed Bangladesh coast) and the historical flood of year 2004, 2010 and 2015 were all extreme meteorological and hydrological events.

The extent of damage

The flooded areas of crop increased year after year from 2015-16 to 2016-17. In 2018, the rain started earlier and the crop damage becomes more severe (Table 2). In this year, Kayin and Mon states became vulnerable to climate change. The flooded area in Mon State was about

73462 acres and 26760 acres was damaged. This situations call for taking action immediately to prevent further damage in the following years.

Table.1.2 Submerged and damaged acres of crops in selected regions and states in different years

Sr no	Region/ State	2015-2016		2016-2017		2017-2018		2018 (till Aug)	
		Submerge	Damage	Submerge	Damage	Submerge	Damage	Submerge	Damage
1	Kachin	33552	12959	11757	4164	30051	13452	8082	1488
2	Sagaing	248599	152901	66385	31416	171858	51699	108492	67800
3	Bago	376446	152847	167273	111906	240577	72854	497706	192865
4	Magway	98646	65912	62706	24032	135712	83188	259902	169892
5	Rakhine	291219	217246	4872	-	-	-	5525	-
6	Yangon	116894	56486	77849	56207	32996	4584	55279	19858
7	Ayeyawady	318843	224515	327495	223941	142471	79348	132415	41449
	Total	**1520226**	**889376**	**763445**	**460633**	**850328**	**329535**	**1233557**	**563527**

Source: DoA (2018).

1.2 What is climate change?

1.2.1 Introduction to climate change

The primary cause of climate change is the burning of fossil fuels, such as oil and coal, which emits greenhouse gases into the atmosphere—primarily carbon dioxide. Agriculture and deforestation, also contribute to the proliferation of greenhouse gases that cause climate change. These greenhouse gases include carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). Increases in average global temperature (global warming) is one of the main characteristics of climate change. The gases trap heat within the atmosphere, which can have a range of effects on ecosystems, including rising sea levels, severe weather events, and droughts that render landscapes more susceptible to wildfires.

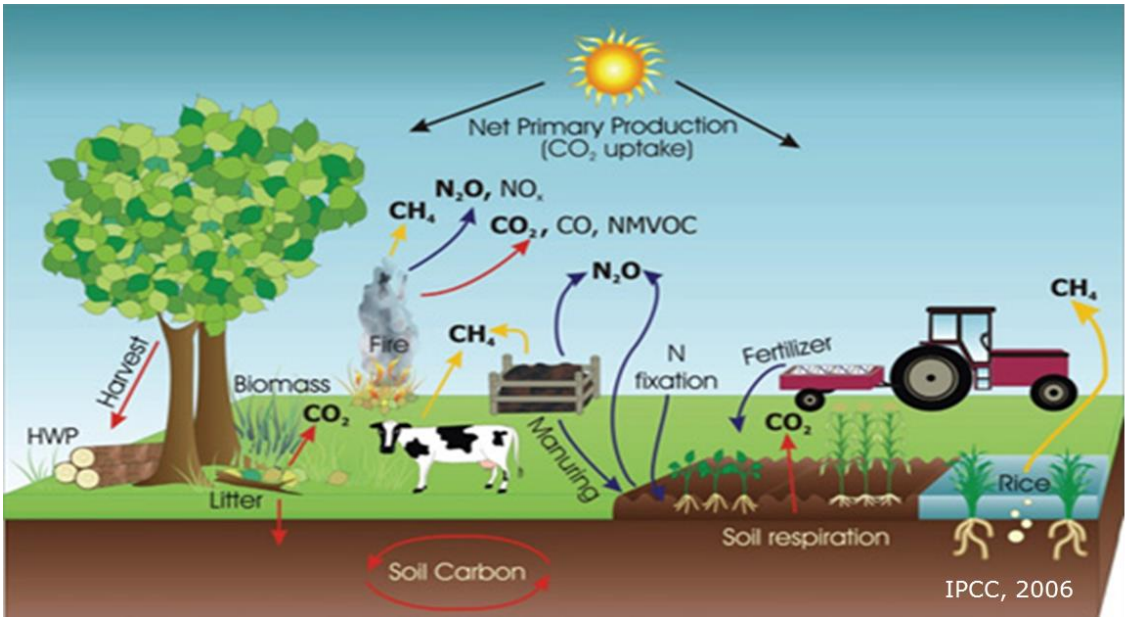


Fig.1.6 The nature of greenhouse gas emission (© IPCC, 2006).

Detailed break-down of GHG emission from different sectors is given in Fig. 1.7 and global agricultural land use emission in Fig.1.8). Agriculture is the largest contributor (56 percent) of non-CO_2 GHGs. Livestock contributes 14.5 percent and food systems 19-29 percent of global GHG emission (Fig. 1.9). There is more than one way agriculture's greenhouse gas emissions can be reduced. The mitigation process involves implementation of new practices that enhance the efficiency of input use so that the increase in agricultural output is greater than the increase in emissions (Smith *et al.* 2014).

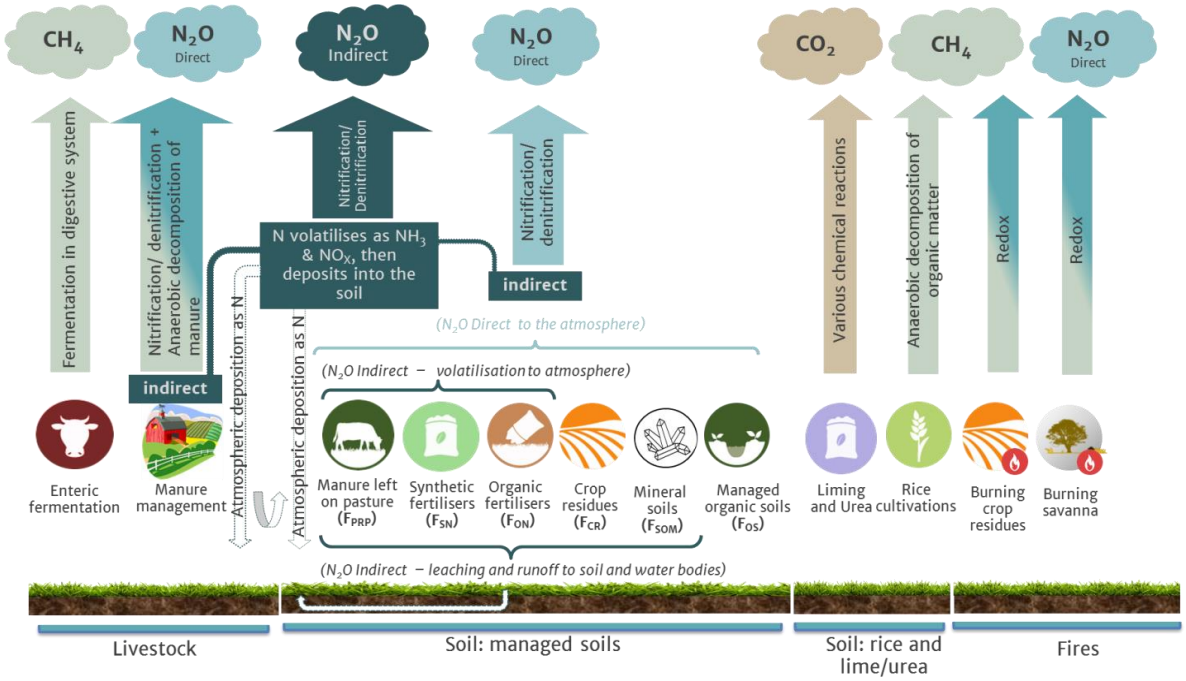


Figure 1.7. Detailed diagram of greenhouse gas emission

(Source:www.fao.org/climatechange).

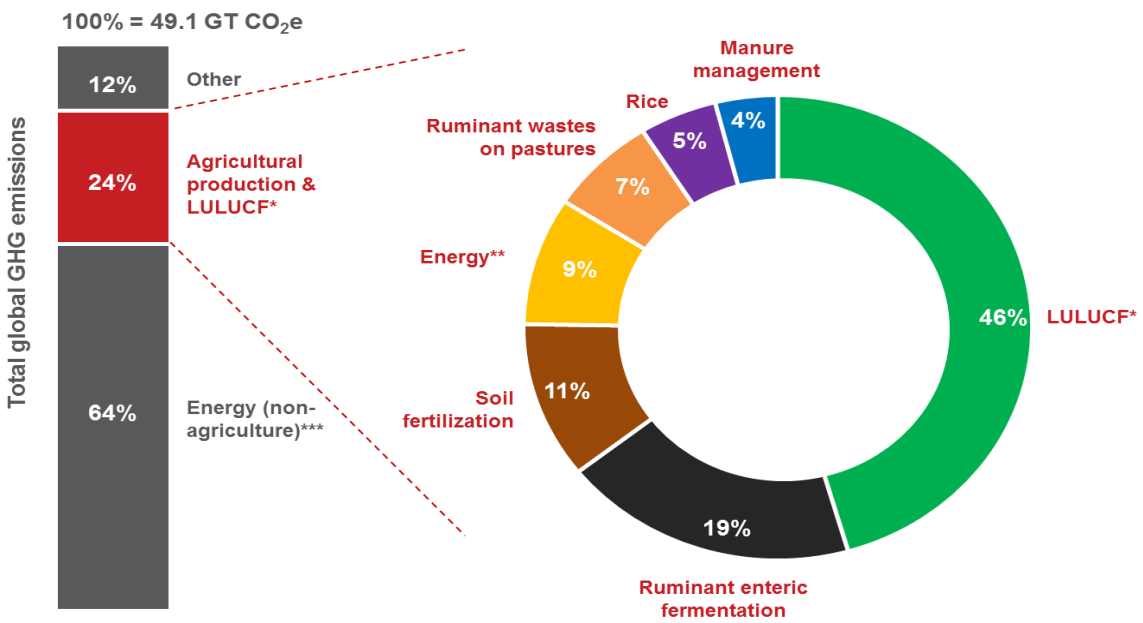


Fig.1.8 High global agriculture and land use emission (2010) (© Delgado and Negra, 2014).

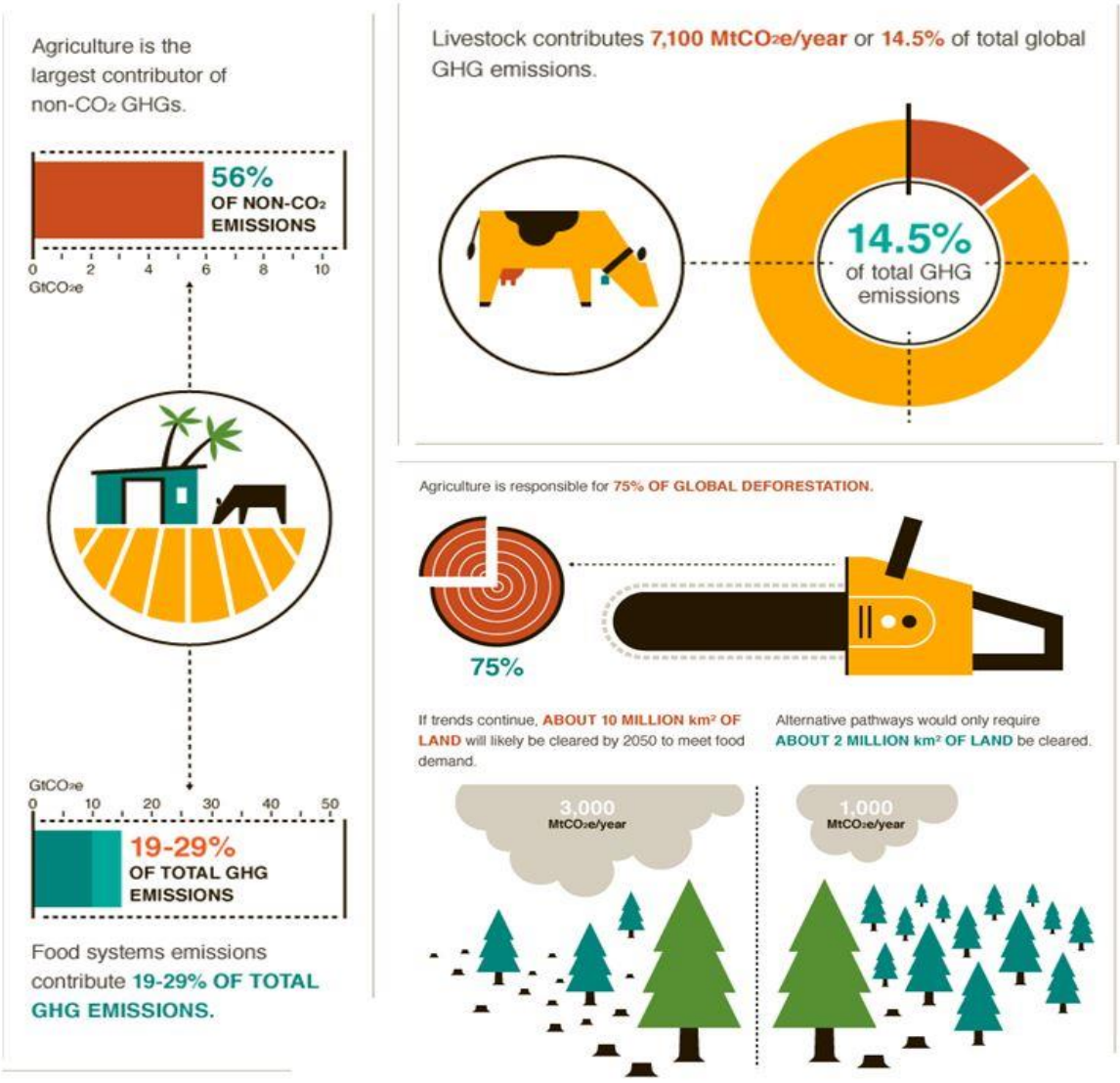


Figure 1.9: Share of agricultural greenhouse gas emission in a 2°C world in a BAU scenario (Source: [CCAFS Big Facts: Food emissions]).

Livestock and manure is the main direct source of agricultural emissions

- 30% of direct agriculture emissions
- 7% of all global GHGs
- Up to 14.5% if livestock related land use change is counted as livestock caused
- Ruminants = 80% of livestock GHG issue (Beef= 6 X as many GHG/protein as chicken, eggs or pork)

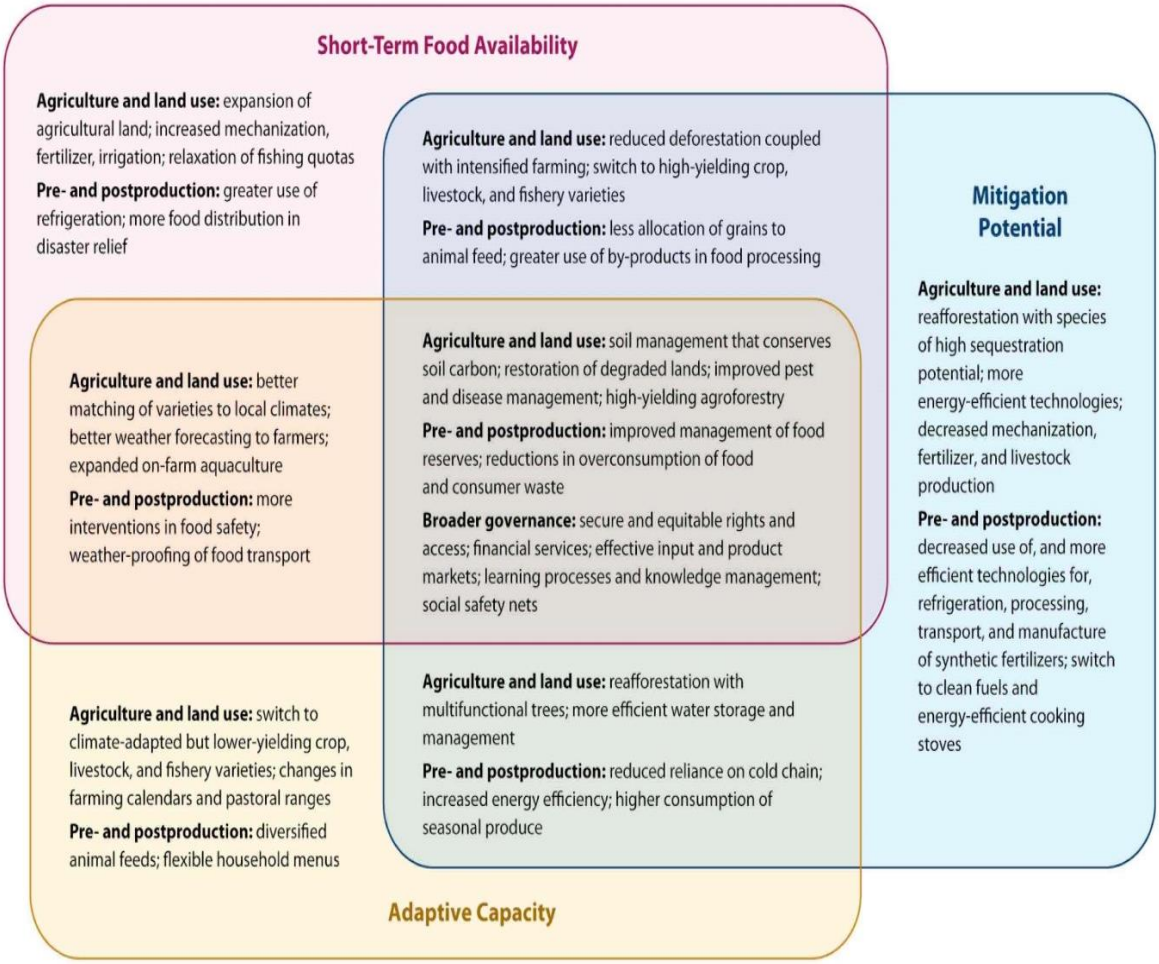


Figure 1.10 Synergies and trade-offs for adaptation, mitigation and food security (Source; Vermeulen *et al.*, 2012, p. C-3).

Another important emissions reduction pathway is through increasing the carbon-sequestration capacity of agriculture. Plants and soils have the capacity to remove CO_2 from the atmosphere and store it in their biomass – this is the process of carbon sequestration. Increasing tree cover in crop and livestock systems (e.g. through agro-forestry) and reducing soil disturbance (e.g. through reduced tillage) are two means of sequestering carbon in agricultural systems. However, this form of emissions reduction may not be permanent – if the trees are cut or the soil plowed, the stored CO_2 is released. Despite these challenges, increasing carbon sequestration represents a huge potential source of mitigation, especially since the agricultural practices that generate sequestration are also important for adaptation and food security.

Global mean temperatures have increased 0.2°C per decade since the 1970s, and global mean precipitation increased 2% in the last 100 years with a high probability of warming of more than 2°C over the next century (IPCC 2007). In the short term, the frequency of extreme weather events such as cyclones, drought, heat waves and floods is expected to increase.

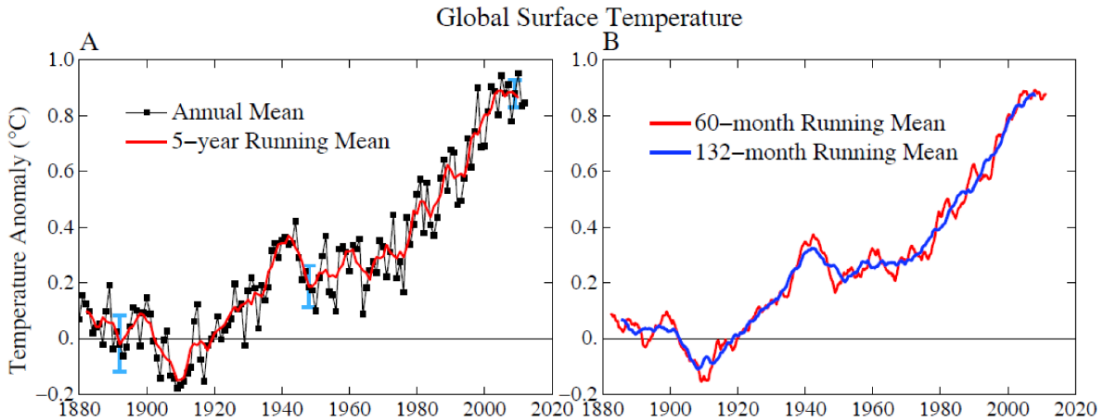


Figure 1.11 Global surface temperature relative to 1880–1920 mean.

(Source: https://doi.org/10.1371/journal.pone.0081648.g003).

Climate change is a global problem and it has negative impact on the people in different parts of the world. It can severely affect the livelihoods of farmer, and is fundamentally changing the way agriculture is practiced. Drastically different weather patterns, shorter growing seasons, extreme weather, and many other changes pose serious problems for smallholder farmers around the world—especially in the tropics. Developing countries are the most vulnerable to climate change impacts because they have fewer resources to adapt: socially, technologically and financially. Consequently, governments of many developing countries have given adaptation action a high, even urgent, priority. Myanmar is no exception and she also suffered a lot from the climate change and finding its way to tackle the problem.

In this case, the problems caused by climate change must be tackled so that the sustainable increase in production of crop could be achieved. People especially farmers, should be educated to get awareness of climate change and its consequences or impact on agriculture. After that farmers should be trained to be able to cope with climate change in performing their farming practices.

The Government of Myanmar has initiated economic reforms to achieve a higher per capita income for the rural populace, whose major source of livelihood is agriculture, and Myanmar's

economy was growing at 7.3% in 2012 to 2013. However, these economic gains are being threatened by climate change. Myanmar is annually affected by climate extremes, particularly floods, droughts, and tropical cyclones, threatening the livelihoods of poor people living in rural areas, as well as the food security in the country. In 2008, category 4 cyclone Nargis hit the country. According to a World Bank report, Nargis severely affected the country's agriculture sector with losses equivalent to 80,000 tons and damaging 251,000 tons of stored crops, across 34,000 hectares of cropland.

Examples of observed changes in climate related hazards in Myanmar and their consequences include:

- An increase in the prevalence of drought events
- An increase in intensity and frequency of cyclones/strong winds
- Rainfall variability including erratic and record-breaking intense rainfall events
- An increase in the occurrence of flooding and storm surge
- An increase in extreme high temperatures

According to the Germanwatch Global Climate Risk Index 2018, Myanmar ranked third as one of the countries most affected by extreme weather events from 1997 to 2016 (Eckstein et. al 2018). German Watch's index is based on the ability of governments to adapt and mitigate to the already changing climate. 'Adaptation' refers to efforts on working around the impacts of climate change (i.e. floodwalls and other infrastructure). 'Mitigation' refers to lessening causes of climate change, mainly by curbing emission. The intensity and regularity with which cyclones make landfall have increased with every year, with the delta region affected by tropical storms and the dry zone impacted by debilitating droughts.

1.2.2 Impact of climate change on crops/farmers

The long-term effects of climatic change will seriously impact agricultural production and food security, requiring substantive adaptation of agricultural systems over time. Moreover agriculture significantly contributes to greenhouse gas (GHG) emissions. Therefore, the vulnerability of agriculture to climate change and food security is an issue of major importance that needs the attention of the national authority as well as local community. For achieving food security to offset the impacts of climate change, the implementation of climate smart

agriculture through the sustainable crop production, adaptation and mitigation measures will be the solution.

Rapidly rising levels of carbon dioxide (CO_2) and other GHGs in the atmosphere have direct effects on agricultural systems due to increased CO_2 and ozone levels, seasonal changes in rainfall and temperature, and modified pest, weed, and disease populations. In general, the flux of agro-climatic conditions can alter the length of growing seasons, planting and harvesting calendars, water availability and water usage rates, along with a host of plant physiological functions including evapo-transpiration, photosynthesis and biomass production, and land suitability.

Scarce rainfall and droughts

Droughts mostly occur in the early monsoon period causing a shortage of soil moisture adversely affecting crop productivity. In the Central Dry Zone area, drought years have significantly affected the production of crops, leading to food shortages for both people and livestock. In 2010, severe drought depleted village water sources across the country and destroyed agricultural yields of peas, sugar cane, tomato and rice. Short spurts of excessive precipitation are expected to alternate with longer periods of drought. This will make it even more challenging for the country's largely rural population to grow crops and earn a living.

Heavy rains and floods

After 1978, the rain days during monsoon season becomes less, about 30 days shorter than before which is about 147 days. However, the intensity of rain was heavier and flood is a common phenomenon in rainy season across Myanmar. In many regions and states flash floods due to heavy rain have been observed. In 2008, it got worse and the spillway of some dams collapsed and paddy field were flooded. The sand covered the whole area and it needed to be removed for growing another crop. Irregular and erratic rainfalls also create problems.

Fig 1.12 A flooded paddy field (left) (Source: myanmarwaterportal.com) and a parched paddy field due to lack of rain (right) (© Kyaw Ko Ko / The Myanmar Times).

Temperature

For any particular crop, the effect of increased temperature will depend on the crop's optimal temperature for growth and reproduction. In some areas, warming may benefit the types of crops that are typically planted there, or allow farmers to shift to crops that are currently grown in warmer areas. Conversely, if the higher temperature exceeds a crop's optimum temperature, yields will decline (USGCRP, 2014).

Depending on future emissions of greenhouse gases, climate change will increase global temperatures by 2°C and 4 °C within the next century, change rainfall patterns and will result in more frequent and severe floods and droughts. Not only the average annual or seasonal rainfall will change, there will also be an increase in the number of extreme events resulting in more frequent and severe floods and droughts.

Developing countries are most vulnerable to climate change and the poor are likely to suffer most from climate change. Without serious adaptation, climate change is likely to push millions further into poverty and limit the opportunities for sustainable development and for people to escape from poverty.

Climate change is likely to reduce economic growth in developing countries and hence, significant investments in climate change adaptation are necessary. Through its impacts on agriculture, climate change is likely to have a significant impact on reducing severe poverty and hunger. Climate change policies for the rapidly developing countries should focus on mitigation and the policies for the least developed countries should focus on adaptation.

Salt intrusion

This is the main problem in delta area. Due to the salt intrusion, crop production could be no longer profitable in most area of the delta region after Nargis Cyclone occurred in 2008. The improvement of soil fertility and structure may take many years costing a lot of money.

Table 1.3 Summary of the most important projected impacts of climate change on the different sectors in developing countries (Asia).

Water	• Disappearing glaciers reduce summer stream flow of most large rivers affecting more than one billion people • Snowmelt earlier in the season will increase risk of spring floods • Increased water shortages during the dry season in South and East Asia • Higher flood risks during the monsoon season in South East Asia and the Indian subcontinent • Likely increase of water stress due to a combination of increased population growth, higher per capita water demands and climate change.
Agriculture	• Increased climate variability will generally increase the number of crop failures due to either floods or droughts. • In areas where rainfall is predicted to increase agricultural production is likely to improve. • Irrigated agriculture which depends on run-off from snowmelt and/or glaciers is likely to be affected; snow will melt earlier in the season which will reduce water availability during the (late) summer when irrigation is most needed. • Agricultural production in low lying coastal areas such as large parts of Bangladesh will be affected by increased flooding and salt water intrusion. • o Likely increase of diseases and pests affecting both plant and animal production systems.
Ecosystem	• Large parts of the biodiversity at risk, although detailed analyses are lacking for most countries. • Forest fires have been observed to increase over the last 20 years due to higher temperatures; this trend could increase into the future. • Grasslands are likely to see a reduction in productivity due to higher temperatures and increased evaporation; desertification will increase if land use remains unchanged. • In Mountainous regions such as the Himalaya different vegetation zones will move higher into the mountains. • Species with low migration rates could become (locally) extinct and vegetation zones could disappear

(Source: Ludwig et. al, 2007).

1.2.3 Efforts of Government to tackle the problems caused by climate change

In response to climate change, Ministry of Agriculture, Livestock and Irrigation (MOALI) has developed Myanmar Climate Smart Agriculture Strategy in 2015. Myanmar's CSA strategy has been designed socially, culturally and politically appropriate, environment-friendly and economically feasible to promote sustainable agriculture with maximized food security and nutrition, development, climate change adaptation and mitigation.

At the same time, the Ministry has developed the Agricultural Development Strategy (ADS) with the consensus of all stakeholders and officially launched it in June 2018. Food and Nutrition Security is one of the 12 principles laid down in ADS. Agricultural development contributes to food and nutrition security through different channels including increasing farm and rural household income; nutrition behavioral change communication, initiatives such as home economics and backyard gardening, and agricultural diversification; the comprehensive inclusion of women in development programs (including the application of a minimum quota for women's participation where necessary), social mobilization, and group formation.

Government of Myanmar is trying its best to cope with the adverse effects of climate change with a National Adaptation Program of Action (NAPA) covering eight sectors, namely: 1) agriculture, 2) early warning systems, 3) forests, 4) public health, 5) water resources, 6) coastal zones, 7) energy and industry, and 8) biodiversity. Agriculture, early warning systems and forests have the highest priority. However, it is critical to get awareness of the climate change impact among the farmers who are the main stakeholder for food crop production. On the other hand, the extension staffs as well as the policy makers need to be educated to help tackle the problems of climate change. The final solution is the knowledge and adoption of CSA practices.

In this case, all the stakeholders from the agricultural sectors need to be trained to get familiar with climate smart agriculture. The duration of the training course and the content involved in the training will vary with the level of target group and type of organization as the training course is designed to address the need of individual institution and target groups. For in-service training, only basic concept will be introduced but it will be extended for ToT, diploma level, bachelor level and master's level one step after another.

Firstly, the awareness on climate change and its impact should be raised among the farmers using different media. On the other hand, a course on CSA should be introduced to the institutions for the students and extension staff working with Department of Agriculture. CSA has never been introduced as a subject at the university or training centers in Myanmar. Therefore, it is time to develop curricula for different levels of agricultural institute and university.

The CSA training curriculum will provide students with the skills and tools for developing agricultural practices, policies and measures addressing the key challenges that global warming poses for agriculture and food security worldwide.

There are a number of constraints (physical, policy, and institutional and governance) for each sub-sector of agriculture (food crop, water resource and environment). The physical constraints that commonly affect crop production in Myanmar like other developing countries are: rural infrastructure deficiencies, inadequate irrigation, limited and unreliable electrification, and inadequate flood, drainage and salinity control structures. Government of Myanmar is to relieve policy constraints and institutional and governance constraints (see Mir 2013 for detail).

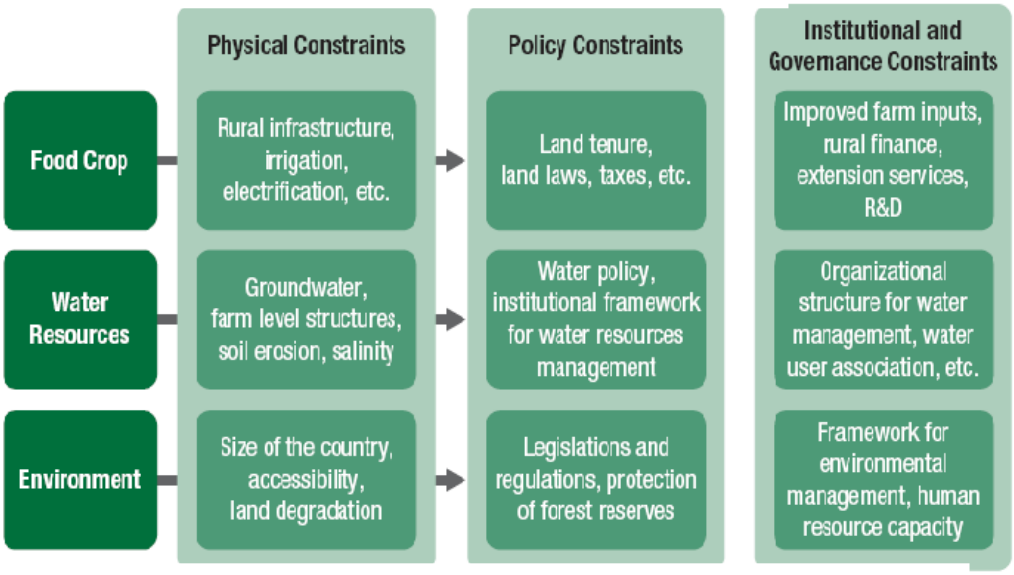


Fig. 1.13 Key constraints in agricultural development (© Mir, 2013).

1. 3 What is climate-smart agriculture?

Introduction

Climate-smart agriculture (CSA) is an approach for developing actions needed to transform and reorient agricultural systems to effectively support development and ensure food security under climate change. CSA aims to tackle three main objectives: sustainably increasing agricultural productivity and incomes; adapting and building resilience to climate change; and reducing and/or removing greenhouse gas emissions, where possible (http://www.fao.org/climate-smart-agriculture-sourcebook/concept/en/).

FAOs CCA foresee a broader approach, working to build synergies among social protection and climate change to achieve sustainable growth and eliminate rural poverty. FAO uses a "twin-track" approach, on the one hand taking immediate steps to protect and support agriculture, food and nutrition, and on the other addressing in the longer term the underlying factors driving risks, disasters and crises. FAO's work focuses on developing, protecting and restoring sustainable livelihoods so that the integrity of societies that depend on farming, livestock, fish, forests and other natural resources is not threatened by crises. CSA uses a comprehensive approach in seeking to improve rural livelihoods, increasing the productivity and resilience of poor communities, including rural women and girls, while also providing mitigation benefits.

Climate-smart agriculture is a holistic system applicable to big farms cultivating thousands of acres as well as smallholder farmers who live and work on fewer than 10 acres of land. The principles can have positive effects for farmers, the land, water, and wildlife. It helps reduce the negative impacts of climate change to agriculture and boost positive ones, protecting agro-ecosystems, and promoting healthier, more resilient landscapes, which in the aggregate, contributes to climate change mitigation and food security.

Being an agricultural country, Myanmar economy mainly relies on agriculture. In Myanmar, most of the people consider "Agriculture" as the production of crops. However, it has a wider scope not only crop and livestock production but also covers fisheries and forest management. Agriculture sector contributed to 28.6 % of total export earnings in 2015-2016 and employed 61.25 % of the labour force (MOALI, 2017).

CSA is not a new production system – it is a means of identifying which production systems and enabling institutions are best suited to respond to the challenges of climate change for specific locations, to maintain and enhance the capacity of agriculture to support food security in a sustainable way.

The Myanmar Climate-Smart Agriculture Strategy (MCSAS) has been elaborated in response to the adverse effects of climate change that Myanmar suffers from, such as "scarcity of rainfall, irregular rainfall, heat stress, drought, flooding, seawater intrusion, land degradation, desertification, deforestation and other natural disasters".

1.3.1 Three pillars of CSA

CSA has three main pillars (Fig.1.14):

1. Sustainably increasing agricultural productivity and incomes
2. Adapting and building resilience to climate change and
3. Reducing and/or removing greenhouse gas emissions, where possible.

1. Sustainably increasing agricultural productivity and incomes

The world population is expected to reach 9 billion by 2050, and the need to provide enough nutritious food in the future will be crucial (United Nations 2015). To feed an expanding population, the annual world food production will need to increase by 60 percent over the next three decades (Bruinsma, 2009). Diets need to be balanced with nutrients such as: vitamins, trace elements and amino acids. Diet must also take into account factors such as energy requirements, age and pregnancy. An additional challenge for the future is the growing demand for animal products such as milk, dairy, and meat, particularly in developing countries. Food security is not only a matter of increasing production, but also avoiding spoilage or waste of food along the value chain, i.e.- the range of activities that are necessary to deliver the product to the customer. The amount of food produced only counts – if it reaches the individual consuming it. Ensuring food security for future generations relies in increasing productivity in a sustainable manner.

CSA aims to sustainably increase agricultural productivity and incomes from crops, livestock and fish, without having a negative impact on the environment. This, in turn, will raise food and nutritional security. A key concept related to raising productivity is sustainable

intensification. Increasing productivity as well as reducing costs through increased resource-use efficiency is important means of attaining agricultural growth. Reducing yield gaps by enhancing the productivity of agro-ecosystems and increasing the efficiency of soil, water, fertilizer, livestock feed and other agricultural inputs offers higher returns to agricultural producers, reducing poverty and increasing food availability and access. These same measures can often result in lower greenhouse gas emissions compared with past trends (FAO, 2014).

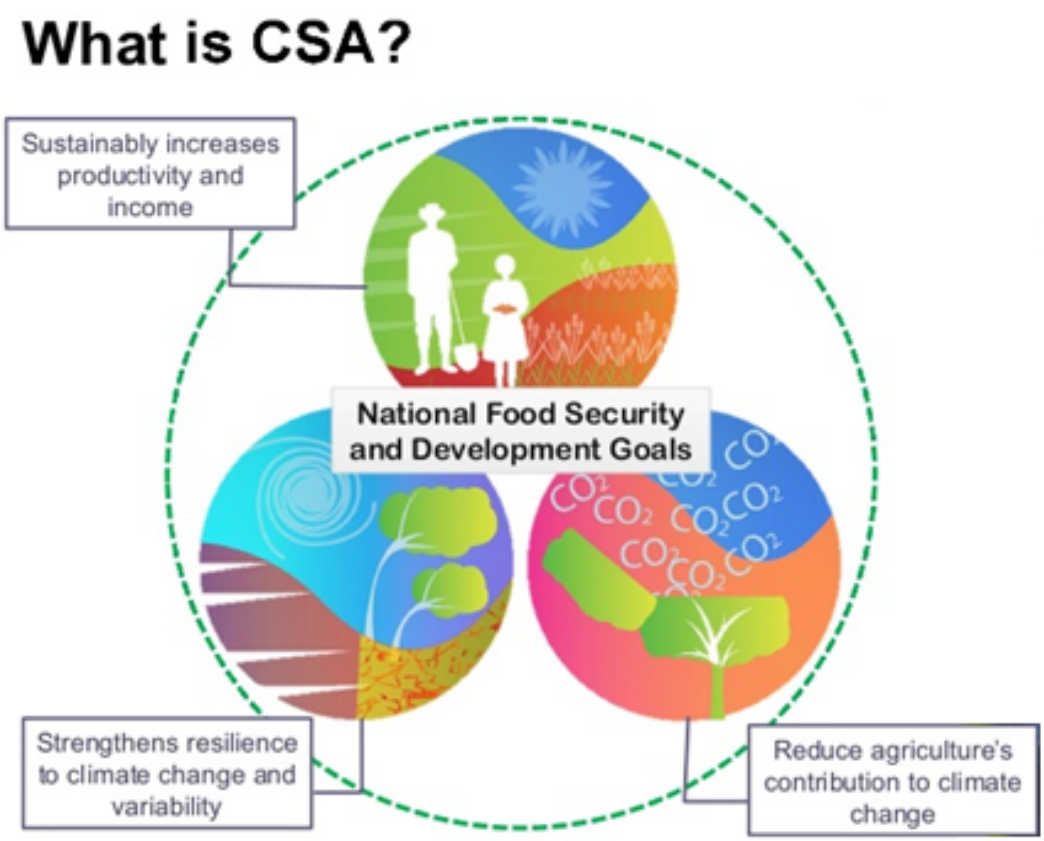


Fig. 1.14 Three pillars of climate smart agriculture (© Papuso and Faraby, 2013).

2 Adapting and building resilience to climate change

Agriculture is affected by numerous challenges in a changing climate including extreme weather events such as: severe rainfalls, storms, high temperatures, droughts and floods. Rising sea levels are a challenge for agriculture in coastal areas. Globally there are changes in seasonality and average temperatures. In some countries climate change might favour agriculture, for example, by longer growing seasons or higher temperatures. In many countries however, the effects of climate change on agriculture will be negative. There is an inevitable

need to adapt farming in order to ensure the resilience of agricultural systems to the changing climate. Adaptation can involve changes in practice such as: changing the crops or livestock that are farmed, use of new technologies and, applying climate or weather data to make decisions for the future.

There is already an increase in the frequency and intensity of extreme events, such as drought, heavy rainfall and subsequent flooding and high maximum temperatures. The increased exposure to these climate risks, already being experienced in many parts of the world, poses a significant threat to the potential for increasing food security and reducing poverty amongst low-income agricultural-dependent populations.

CSA aims to reduce the exposure of farmers to short-term risks, while also strengthening their resilience by building their capacity to adapt and prosper in the face of shocks and longer-term stresses. Particular attention is given to protecting the ecosystem services which ecosystems provide to farmers and others. These services are essential for maintaining productivity and our ability to adapt to climate changes.

It is possible to reduce and even avoid these negative impacts of climate change – but it requires formulating and implementing effective adaptation strategies. Given the site-specific effects of climate change, together with the wide variation in agro-ecologies and farming, livestock and fishery systems, the most effective adaptation strategies will vary even within countries. A range of potential adaptation measures, for example, enhancing the resilience of agro-ecosystems by increasing ecosystem services through the use of agro-ecology principles and landscape approaches, can be applied depending on the local situations. Reducing risk exposure through diversification of production or incomes, and building input supply systems and extension services that support efficient and timely use of inputs, including stress tolerant crop varieties, livestock breeds and fish and forestry species are also examples of adaptation measures that can increase resilience.

3. Reducing and/removing greenhouse gases emissions where possible

Adapting agriculture to climate change and maintaining food production could help to solve the current problems. However, with rising levels of GHGs, climate change and its consequences will continue to impact our lives and pose new challenges. Currently agriculture (and related sectors) contributes about a quarter of human-induced GHG emissions, so there is

a lot of potential to reduce these emissions, and to mitigate other detrimental effects of agriculture on the environment.

Very often, mitigating resource input and increasing efficiency goes hand in hand with mitigating emissions. Wherever and whenever possible, CSA should help to reduce and/or remove greenhouse gas (GHG) emissions in producing for each calorie or kilo of food, fibre and fuel, avoid deforestation from agriculture and manage soils and trees in ways that maximizes their potential to acts as carbon sinks and absorb CO_2 from the atmosphere. The more the concentration of GHGs in our atmosphere can be reduced, the less likely the extreme climate scenarios will be for the future, and the easier it will be to adapt to climate change.

1.4 Key characteristics of CSA

- **CSA addresses climate change:** Contrary to conventional agricultural development, CSA systematically integrates climate change into the planning and development of sustainable agricultural systems (Lipper *et al.*, 2014).
- **CSA integrates multiple goals and manages trade-offs:** Ideally, CSA produces triple-win outcomes: increased productivity enhanced resilience and reduced emissions. But often it is not possible to achieve all the three. Frequently, when it comes time to implement CSA, trade-offs must be made. This requires us to identify synergies and weigh the costs and benefits of different options based on stakeholder objectives identified through participatory approaches.
- **CSA maintains ecosystems services:** Ecosystems provide farmers with essential services, including clean air, water, food and materials. It is imperative that CSA interventions do not contribute to their degradation. Thus, CSA adopts a landscape approach that builds upon the principles of sustainable agriculture but goes beyond the narrow sectoral approaches that result in uncoordinated and competing land uses, to integrated planning and management.
- **CSA has multiple entry points at different levels:** CSA should not be perceived as a set of practices and technologies. It has multiple entry points, ranging from the development of technologies and practices to the elaboration of climate change models and scenarios, information technologies, insurance schemes, value chains and the strengthening of institutional and political enabling environments. As such, it goes beyond single technologies at the farm level and includes the integration of multiple interventions at the food system, landscape, value chain or policy level.

- **CSA is context specific:** What is climate-smart in one-place may not be climate-smart in another, and no interventions are climate-smart everywhere or every time. Interventions must take into account how different elements interact at the landscape level, within or among ecosystems and as a part of different institutional arrangements and political realities. The fact that CSA often strives to reach multiple objectives at the system level makes it particularly difficult to transfer experiences from one context to another.
- **CSA engages women and marginalized groups:** To achieve food security goals and enhance resilience, CSA approaches must involve the poorest and most vulnerable groups. These groups often live on marginal lands which are most vulnerable to climate events like drought and floods. They are, thus, most likely to be affected by climate change. Gender is another central aspect of CSA. Women typically have less access and legal right to the land which they farm, or to other productive and economic resources which could help build their adaptive capacity to cope with events like droughts and floods. CSA strives to involve all local, regional and national stakeholders in decision-making. Only by doing so, is it possible to identify the most appropriate interventions and form the partnerships and alliances needed to enable sustainable development.

There are five actions to implement a CSA approach successfully; i) Expanding the evidence base; ii) supporting enabling policy frameworks; iii) Strengthening national/local institutions; iv) Enhancing financing options; and v) Implementing practices at field level. 'Expanding the evidence base' acts as the *foundation* to the whole approach, as it informs and expands the actions to strengthen national/local institutions, enhance financial options and support policy frameworks. These three actions then support and inform the implementation of CSA practices at field level. The CSA practices on the ground inform and expand, through monitoring and evaluation, the evidence base (Fig. 1.15).

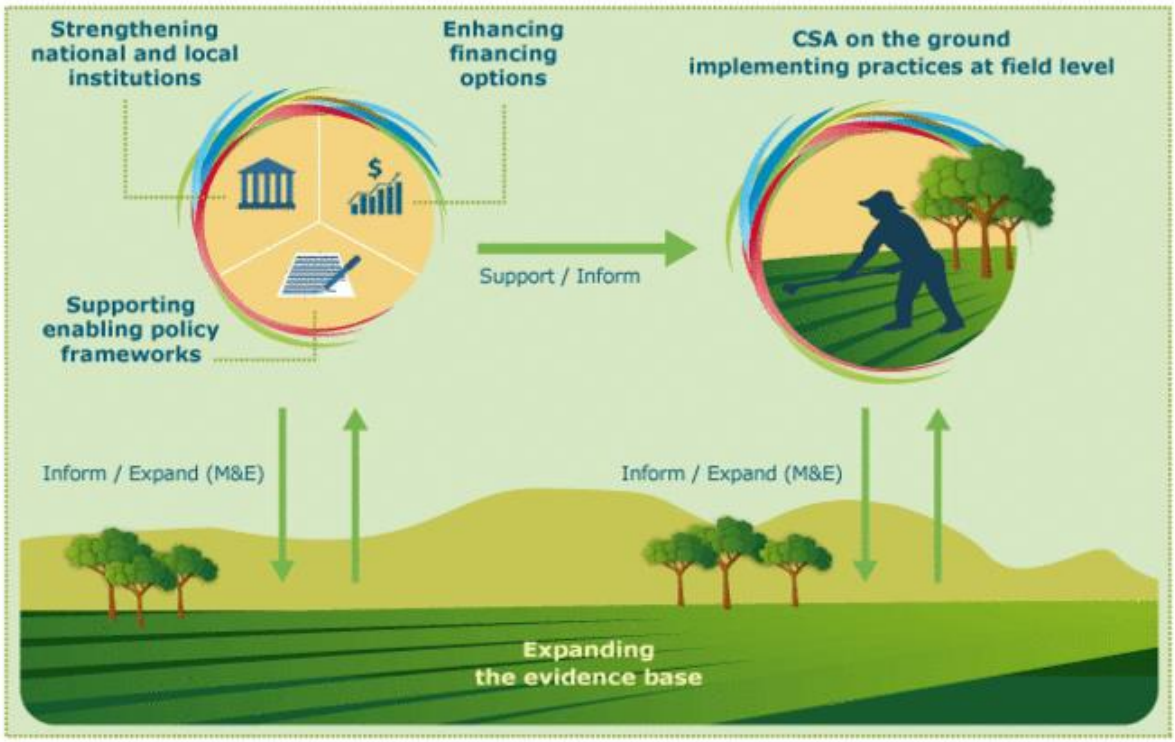


Fig 1.15 Climate-smart agriculture implementation in agricultural production systems and food systems (© Rima Al-Azar, 2018).

1.5 Why climate-smart agriculture?

Climate-smart agriculture (CSA) helps address a number of important challenges:

1. CSA addresses food security, misdistribution and malnutrition

Despite the attention paid to agricultural development and food security over the past decades, there are still about 800 million undernourished and 1 billion malnourished people in the world. At the same time, more than 1.4 billion adults are overweight and one third of all food produced is wasted. Before 2050, the global population is expected to swell to more than 9.7 billion people (United Nations 2015). At the same time, global food consumption trends are changing drastically, for example, increasing affluence is driving demand for meat-rich diets. If the current trends in consumption patterns and food waste continue, it is estimated we will require 60% more food production by 2050 (Alexandratos and Bruinsma 2012). CSA helps to improve food security for the poor and marginalized groups while also reducing food waste globally (CCAFS 2013).

2. CSA addresses the relationship between agriculture and poverty

Agriculture continues to be the main source of food, employment and income for many people living in developing countries. Indeed, it is estimated that about 75% of the world's poor live in rural areas, with agriculture being their most important income source. As such, agriculture is uniquely placed to propel people out of poverty. Agricultural growth is often the most effective and equitable strategy for both reducing poverty and increasing food security as Myanmar's economy heavily relies on agricultural sector.

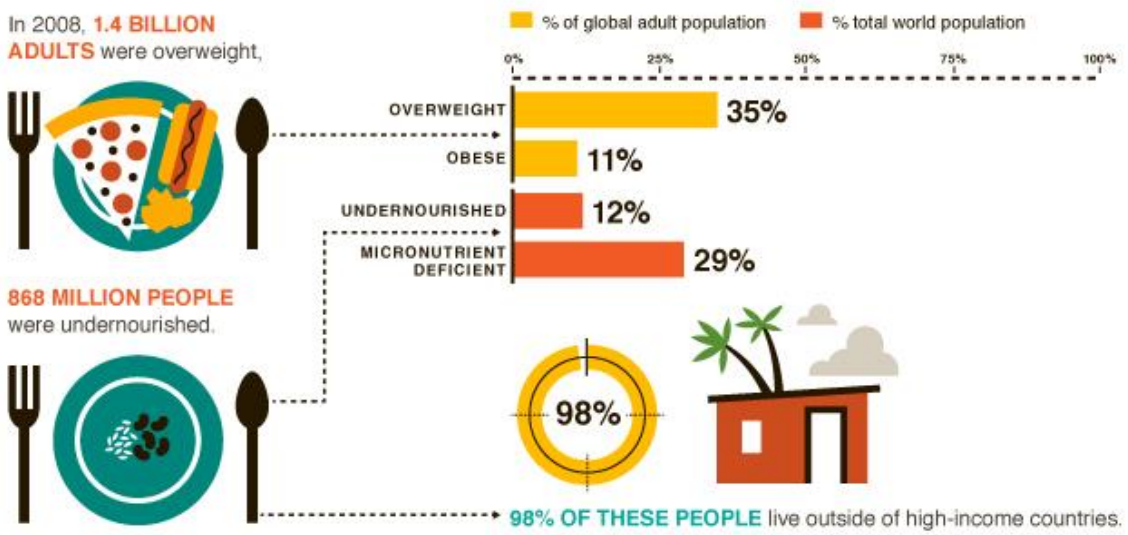


Figure 1.16 Food security, malnutrition and misdistribution (Source:CCAFS Big Facts: Food security).

3. CSA addresses the relation between climate change and agriculture

Climate change is already increasing average temperatures around the globe and, in the future, temperatures are projected to be not only hotter but more volatile too. This, in turn, will alter how much precipitation falls, where and when. Combined, these changes will increase the frequency and intensity of extreme weather events such as hurricanes, floods, heat waves, snowstorms and droughts. They may cause sea level rise and salinization, as well as perturbations across entire ecosystems. All of these changes will have profound impacts on agriculture, forestry and fisheries (FAO 2013).

The agriculture sector is particularly vulnerable to climate change because different crops and animals thrive in different conditions. This makes agriculture highly dependent on consistent temperature ranges and water availability, which are exactly what climate change threatens to undermine. In addition, plant pests and diseases will likely increase in incidence and spread into new territories (Grist 2015), bringing further challenges for agricultural productivity. In this case, it is necessary to observe the impact of climate change on the infestation insect pests

and diseases on the crops in order to take immediate action to avoid any effect on crop production. Otherwise, agricultural productivity will be reduced and will consequently threaten the food security.

2. PRACTICES

Global alliance for climate smart agriculture (GACSA) has developed a number of compendium concerning with CSA practices. They include Compendium on Site-Specific Nutrient Management, Integrated Soil Fertility Management, System of Rice Intensification, Climate-Smart Irrigation, Supplemental Irrigation, Agricultural Extension, Ancestral Agroforestry Systems, Enabling Advisory Services, Gender Responsive Approach, Climate smart Pest management, Index-base Crop Insurance and so on. GACSA and FAO also published Policy Brief Enabling Advisory Services for CSA (http:// www. fao. org/ gacsa/resources/gacsa-csa-documents/en/).

Each compendium provides a comprehensive overview of the challenges and issues for sustainable development, both related and unrelated to climate change. It discusses the options and opportunities for each CSA pillar, identifies potential synergies and trade-offs between the different objectives of CSA, and underscores the importance of inclusive processes engaging stakeholders across different sectors and institutional levels.

2.1 Soil management

Soil

Soil is a dynamic resource that supports plant life. It is made up of different sized mineral particle (sand, silt and clay), organic matter and numerous species of living organisms. Thus, soil has biological, chemical and physical properties, some of which are dynamics and can change in response to how the soil is managed.

The importance of soil

Soil is a critical component to most agricultural and environmental systems- it is not just a medium for plant growth and support. Whether the objective is crop production, urban development, livestock management, turf-grass maintenance or environmental protection, understanding the role of soil in physical, chemical and biological processes cannot be ignored. Soil performs many roles in natural and managed environments, including facilitating plant growth, regulating water supplies, recycling materials, hosting soil organisms and providing physical support. In most, if not all, cases, it is a combination of the physical, chemical and biological properties of soil that determines the soil's ability to properly function for these different roles.

The role of soil

- Soil provides several essential services or functions. Soil supports the growth and diversity of plants and animals by providing a physical, chemical and biological environment for the exchange of water, nutrients, energy and air.
- Soil regulates the distribution of rain or irrigation water between infiltration and runoff and regulates the flow and storage of water and solutes, including nitrogen, phosphorus, pesticides and other nutrients and compounds dissolved in the water.
- Soil stores, moderates the release of and cycles plant nutrients and other elements.
- Soil acts as a filter to protect the quality of water, air and other resources. Soil supports structures and protects archeological treasures.

Soil function

Soil function describes what the soil does. Soil functions are: (1) sustaining biological activity, diversity and productivity; (2) regulating and partitioning water and solute flow; (3) filtering and buffering, degrading, immobilizing and detoxifying organic and inorganic materials, including industrial and municipal by-products and atmospheric deposition; (4) storing and cycling nutrients and other elements within the earth's biosphere and (5) providing support of socioeconomic structures and protection for archeological treasures associated with human habitation.

Soil quality

Soil quality is the capacity of a specific kind of soil to function, within natural or managed ecosystem boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality and support human health and habitation. Changes in the capacity of soil to function are reflected in soil properties that change in response to management or climate.

Mechanisms that concerns related to soil quality

Evaluating soil quality can improve the response to many resource concerns, including those listed below.

- Loss of soil by erosion
- Deposition of sediment by wind or floodwater
- Compaction of layer near the surface
- Degradation of soil aggregates or soil structure
- Reduced infiltration and increased runoff
- Crusting of the soil surface

- Nutrient loss or imbalance
- Pesticide carryover
- Buildup of salts
- An unfavorable change in pH
- Loss of organic matter
- Reduced biological activity
- Poor residue breakdown
- Infestation by weeds or pathogens
- Excessive wetness
- Increased water-repellency of soils due to fire
- Reduced water quality
- Greenhouse gas emissions

Soil Texture, Soil Structure and Macro-pores

Soil phases

From a physical standpoint, soil is a three-phase system: solid, liquid and gas. Each phase is equally essential for growth of plants. The solid phase is made up primarily of minerals along with a small amount of humus in most soils. This phase provides a source of nutrients and anchorage for plants and make up approximately half of the soil volume. The liquid and gaseous phases are in the soil pores and occupy the other half.

The main soil particles

Soil mineral particles can be grouped together into five broad classes. First, particles such as stones, boulders and gravel larger than 2 mm are separated from soil material less than 2 mm using sieves. The soil that passes through the 2 mm sieve is called 'fine earth'. Fine earth is then divided into three particle-size fractions: sand, silt and clay. The proportion of sand, silt and clay in the fine earth is referred to as the soil's 'texture' and is used to classify soils into several textural groups.

Table 2.1 The size range of particles in the UK, US and International System of Classification

Fraction	UK System	US System	International System
Stones/gravel	>2.0 mm	>2.0 mm	>2.0 mm
Coarse sand	2.0 - 0.2 mm	2.0 - 0.2 mm	2.0 - 0.2 mm
Fine sand	0.2 - 0.06 mm	0.2 - 0.05 mm	0.2 - 0.02 mm
Silt	60 – 2 [m	50 – 2 [m	20 – 2 [m
Clay	<2 [m	<2 [m	<2 [m

Soil Texture

Soil texture describes the relative proportions of sand, silt and clay particles in a soil. These amounts, expressed as percentages, are divided into twelve different soil textural classes. The textural classes describe whether the soil properties are dominated by one or more of the three particle size separates (for example, sandy, silty, or clayed-). If the soil is characterized as loam or loamy soil this suggests that it has a mixture of the three separates such that the soil's properties exhibit an equal influence of sand, silt, and clay. The soil textural classes are readily illustrated on a textural triangle (Figure 2.1).

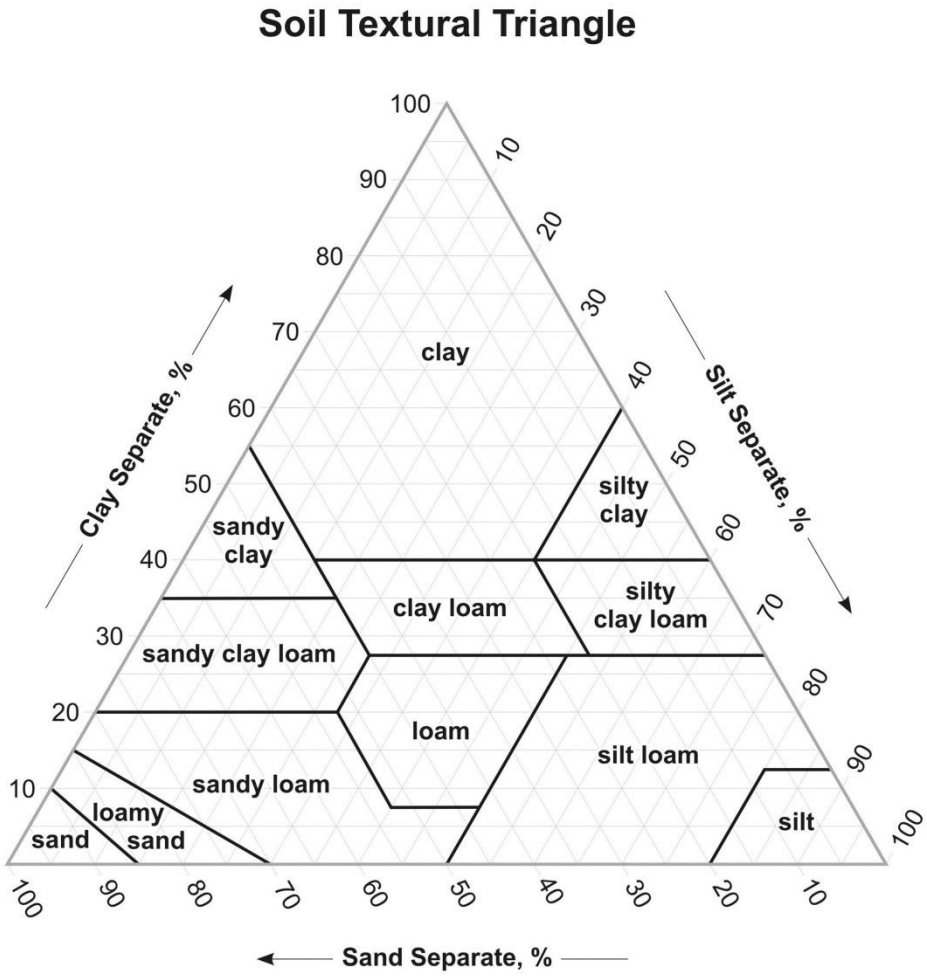


Figure.2.1 Soil Textural Triangle (© Sensors 2013).

Soil Structure

Soil structure describes the combination and arrangement of primary soil particles (sand, silt, and clay) into secondary particles, or units, called aggregates or peds. The spaces between the

peds are the pores that conduct and store water and allow air exchange between the soil and atmosphere. The characteristics of these pores are determined by the size and shape of the peds.

Structural Type (Shape)

Soil scientists recognize six basis types of soil structure; granular, platey, angular blocky, sub-angular blocky, prismatic, and columnar (Figure 2.2).

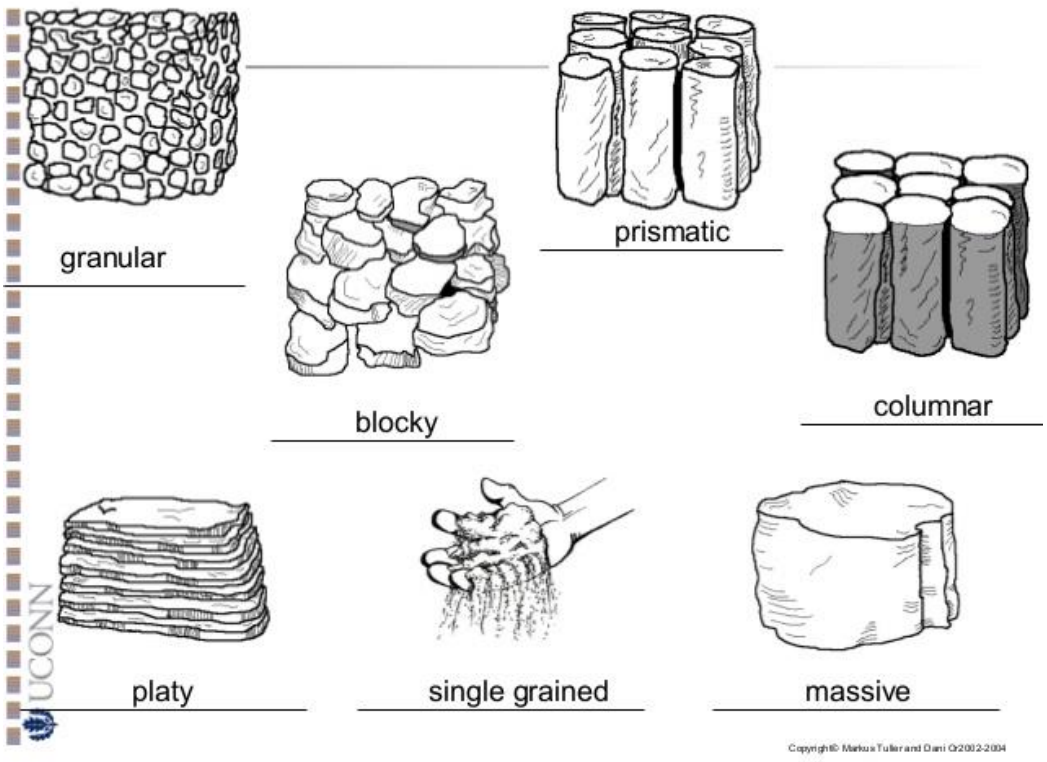


Figure.2.2 Types of Soil Structure (© UCONN).

Soil Porosity

The total amount of pore space, or porosity, can be defined as the percentage of the total soil volume not occupied by solid particles (mineral or organic).

Soil porosity conveys information about ease of root penetration, water-holding capacity and soil strength.

Healthy soil is a combination of minerals, rock, water, air, organic matter (plant and animal residue), microorganisms, including bacteria, fungi and protozoa and a variety of insects and worms. This intricate web carries out a process that continually replenishes the soil and maintains long-term soil fertility.

For sustained growth, plants require macro-nutrients and trace elements. Macro-nutrients include nitrogen (N), phosphorous (P), potassium (K), calcium (Ca), magnesium (Mg) and sulfur (S). Trace elements include, iron (Fe), manganese (Mn), copper (Cu) and zinc (Zn). For optimum plant growth, soil must be capable of storing these nutrients and transferring them to the root surface for uptake by plants.

2.2 Conservation Agriculture (CA)

Conservation Agriculture (CA) is an approach to managing agro-ecosystems for improved and sustained productivity, increased profits and food security while preserving and enhancing the resource base and the environment (*FAO definition:* www.fao.org/ag/ca*)*.

Conservation Agriculture is a concept for resource-saving agricultural crop production that strives to achieve acceptable profits together with high and sustained production levels while concurrently conserving the environment. CA is based on enhancing natural biological processes above and below the ground. Interventions such as mechanical soil tillage are reduced to an absolute minimum, and the use of external inputs such as agrochemicals and nutrients of mineral or organic origin are applied at an optimum level and in a way and quantity that does not interfere with, or disrupt, the biological processes.

CA is characterized by three linked principles (Richards et. al, 2014):

1. **Minimum soil disturbance:** Zero tillage is ideal, but the system may involve controlled tillage in which no more than 20 to 25% of the soil surface is disturbed.

2. **Retention of crop residues or other soil surface cover:** Many definitions of CA use 30% permanent organic soil cover as the minimum, but the ideal level of soil cover is site-specific.

3. **Use of crop rotations:** Crop rotation helps reduce build-up of weeds, pests and diseases. Where farmers do not have enough land to rotate crops, intercropping can be used. Legumes are recommended as rotational crops for their nitrogen-fixing functions.

The world population will reach 9 billion in a few decades; that means demanding more food to feed the exploding population. This is a challenge as the natural resources are dwindling. For the sustainable increase production of food, there is no other option but to link /integrate production with sustainability. One new strategic goal of FAO is sustainable crop production intensification (SCPI). CA is the core strategy of SCPI or in other word, applied sustainable agriculture.

2.2.1 History of conservation agriculture

The idea of minimizing soil disturbance was introduced in the 1930s as a soil conservation system to counter the Dust Bowl by US Conservation Tillage Service in the United States, but the term "conservation agriculture" was not coined until the 1990s. First no-till was

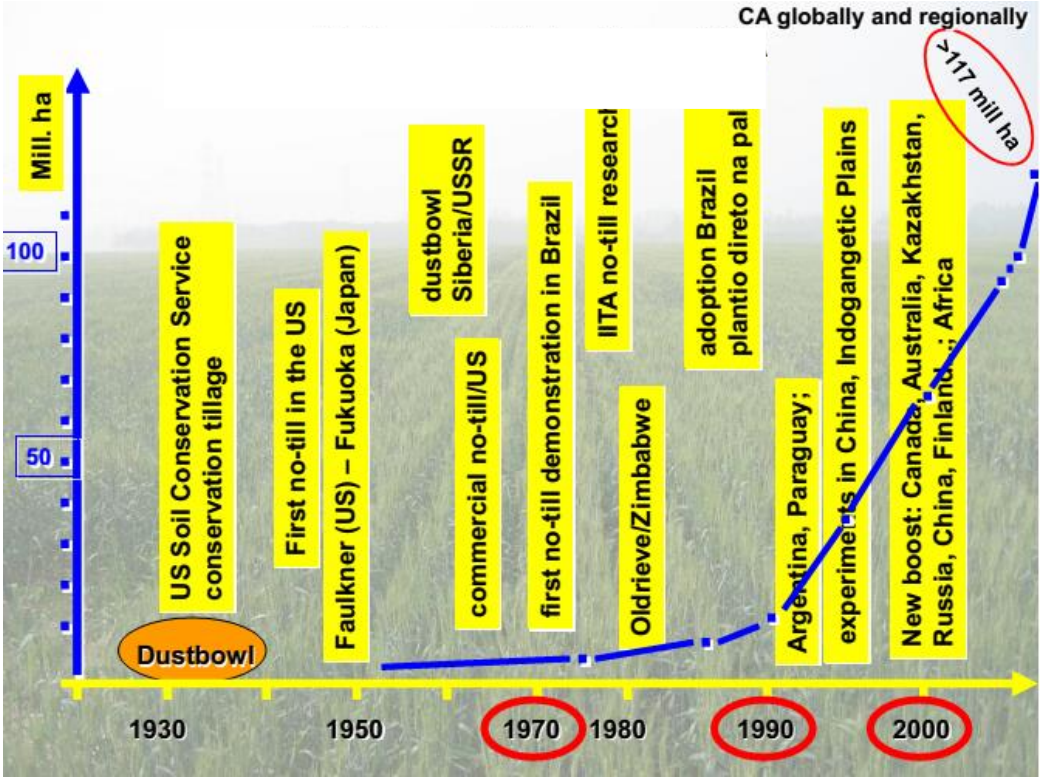


Fig. 2.3 History and adoption of Conservation Agriculture (© Mkomwa, 2015).

practiced in US and followed by Japan in the early 1950s. Some countries practiced no till in 1970s and it popularity increased abruptly after 1990, adopted in many countries reaching over 100 million ha after 2000. Only recently has CA been promoted on the basis of its climate adaptation and mitigation benefits. CA is now widespread in parts of the Americas, as well as Australia. In the tropics, Brazil has the longest experience with CA, where the principles have been practiced since the 1970s and CA now covers over 30 million hectares. CA spread from Brazil to other South American countries, and is widely practiced in Paraguay and Uruguay as well. African farmers have adopted CA in the last 15 years, but at slower rates. Little data is available on adoption in Asian countries.

CA is more than just no-till but aims at “never till” whenever conditions are favorable. By incorporating with other best practices such as integrated pest management (IPM), integrated plant nutrient management (IPNM), integrated crop management and landscape management (IC-LS), agroforestry, etc., it is sustainable agriculture and ecosystem management. CA also includes organic matter and carbon recycling, biodiversity (rotation, soil life), biological processes, and climate change adaptation and mitigation.

Fig. 2.4 Mix cropping of sunflower, sweet corn and maize (Left). Sequential cropping of peanut, upland rice and chickpea (Right), (©FAO/U.Theinsu, 2017, Myanmar).

2.2.2 Benefits of CA

Stable yields: The water- and soil-conserving effects of CA help to stabilize yields against weather extremes. Often, CA increases average yields in the long term. By using CA practices farmers need to use less machinery cost, they can save 70% for the fuel, 50 % of the labour and 20 -50 % of inputs. The job becomes less drudgery and stable yield can be expected for food security, and farmers can enjoy better livelihood and income.

Drought buffering: CA increases soil water content by increasing infiltration and reducing runoff and evaporation. Increased infiltration improves water use efficiency and buffers crops against drought. Mulch cover also buffers the soil against temperature extremes. For example, in rain-fed semi-arid highlands of Mexico, soil water content during dry periods was 10-20 mm higher in maize fields under CA than in those with conventional tillage and residue removal. Infiltration was on average 24-38 mm per ha greater on CA fields in southern Africa as compared to conventionally tilled plots.

Reduced field preparation costs: CA reduces costs associated with tillage, whether manual or by machinery. In mechanized rice-wheat systems in India, field operational costs were 15% lower under CA. In manual maize systems in Malawi, CA fields required 20% less labor than conventional ridge and furrow fields. The reduction in field preparations with CA also allows timelier planting, which supports successful harvests

Reduced soil erosion: Reducing tillage and maintaining soil cover with crop residues can reduce erosion by up to 80%. CA also generally increases soil organic matter in topsoil, as well as soil biological activity and biodiversity.

Climate change mitigation: Under certain conditions, CA may contribute to climate change mitigation through carbon sequestration and reduced GHG emissions, but climate change adaptation rather than mitigation should be the main policy driver for its promotion.

2.2.3 Challenges to CA adoption

Though CA practices can provide multiple benefits, experience shows several common constraints to its adoption.

Appropriate soil type: Wetlands and soils that have poor drainage are generally challenging for CA. Heavy mulch can slow drying and cause disease problems, and increased water infiltration can exacerbate drainage problems.

Sufficient availability of crop residues or other mulch: If crop yields are very low, there may be insufficient quantity of residues to effectively practice CA. The need for crop residues as livestock feed is also a common constraint to CA practice.

Affordable access to fertilizer and herbicides: In some cases, appropriate use of fertilizers as a complement to legume residues is necessary when initiating CA to increase crop yields and available quantity of crop residues.

Weed control: Eliminating tillage sometimes increases weed pressure in the early years of CA adoption, but weeds decrease over time if controlled well. Many adaptations of CA use herbicides to control weeds.

Delayed yield benefits: While CA sometimes increases yields in the long term, farmers may need to wait 3 to 7 years to see yield increases. It takes time for farmers to gain experience with

CA, and the improvement of soil structure and fertility is a slow process. More immediate benefits are likely to be related to savings in labor or other costs.

2.2.4 Implications for climate-smart agriculture initiatives

Mitigation-adaptation synergies are possible: CA has been shown to increase water productivity in dry areas, and can help buffer against the decreasing and more erratic rainfall likely under future climate change. Contributions to climate change mitigation through soil carbon sequestration are also possible, and depend on increasing inputs of organic matter to the soil.

Consider capacities, resources and regional contexts: Targeting CA promotion effectively requires examining factors at multiple scales: farm, village and region. Capacities and resources of farmers, village land tenure patterns and regional infrastructure such as roads and markets can all determine the success of CA.

Be flexible: The particular technologies involved in CA differ markedly between countries, and even regions within a country. Sometimes a particular practice (e.g. crop rotation) may be dropped altogether. Policies to scale up CA should not be overly prescriptive, as local adaptation by farmers is necessary and desired.

Look beyond the crops: Some opportunities—such as associating support for CA with efforts to increase livestock productivity—are not immediately obvious. Adaptation to climate change often requires shifts in entire farming systems, and CA practices may be just one piece of the puzzle.

2.2.5 Policy engagement

For wider adoption of CA, policy support is necessary. In China, for example, CA was mentioned in number 1 party document. CA was promoted to prevent dust storms around Beijing before the Olympic game. Subsidies for mechanization exclude ploughs and priority was given to no-till seeding equipment. DPR Korea is another example where CA was promoted by Ministry of Agriculture and the Academy of Sciences as approach to sustainable and intensive agriculture

2.2.6 Conclusions

CA is universally applicable/location specific. It has been practiced on 8% of farmland and is growing exponentially. It is compatible with MDGs, UN conventions and FAO's strategic objectives. On the other hand, it is productive and sustainable (win-win situation) and responding to climatic challenges. However, supportive policies for accelerated adoption are required.

2.3 Biomass Recycling and Soil Health

A variety of wastes generated through different agricultural and other activities in our day to day life including crop residues in the form of straw, stover, husk, biomass of uncultivated plant species and weeds, forest biomass; animal wastes and by products like dung, urine, bones, fish processing wastes and human habitation wastes like garbage, sewage and sludge etc.. Crop residues are abundantly generated in large quantities during crop cultivation. After harvesting the economic part(s) the plants are considered as wastes and are generally dumped on field side in mound.

2.3.1 Effect of Recycled Organic Wastes on Soil Properties

The positive impact of organic waste application on the improvement of physical properties of the soils such as soil structure, water holding capacity, soil temperature, bulk density, total porosity, pore size distribution, soil resistance to penetration, aggregation, aggregate stability, hydraulic conductivity, base exchange capacity and resistance to soil erosion have been well documented (Aggelides and Londra, 2000; Elsgaard et al., 2001).

Gonzalez et al. (2010) recorded a positive change of soil physical properties after organic amendment application, as soil organic carbon content, fulvic acid fraction, electrical conductivity and soil respiration were found significantly higher whereas bulk density showed lower values at higher doses of vermicompost–compost amended soil.

2.3.2 Carbon pool in the soil

Soil organic carbon (SOC) content decreased rapidly when crop residues from the field were removed regularly coupled with practicing conventional tillage. Increase in soil organic carbon was principally due to the continuous addition of carbon through addition of the roots and crop residues at regular interval. The incorporation of crop residues also increased the crop available phosphorus either directly by the process of decomposition and release of phosphorus from the

biomass or indirectly by increase in the amount of soluble organic matter which are mainly organic acids that increase the rate of desorption of phosphate and, thus, improve the available phosphorus content in the soil.

2.3.3 Benefits of recycling of organic wastes in nutrient management

- Utilization of embedded nutrients of organic wastes
- Conservation of energy
- Complementary source of plant nutrients
- Reduction of import cost of fertilizers
- Maximization of fertilizer use efficiency
- Ecological balancing of soil and land
- Reduce environment pollution
- Sustained agricultural growth

Existing practices

Generally, farmers burn crop residues like stalks of pigeon pea and cotton without recycling them. This is a great loss to the farmer as well to the land, as the land is deprived of biomass, which helps build precious soil organic carbon. This harmful practice is leading to increased CO_2 emissions besides depriving crop residue to the soil. Farmers resort to burning of the crop residue as removing it involves higher costs for labour to uproot, chop and mix in the soil.

Resilience practice/technology

In order to encourage farmers to change this practice, rotavator machine was introduced in the National Initiatives on Climate Resilient Agriculture (NICRA) villages in India. The harvested crop stalks/ stubbles are chopped into small pieces and incorporated in-situ into the soil with varying efficiencies depending upon the left over residue. The cost of implement is USD 2000 to 3000 and field capacity of the rotavator is 5-6 ha/day. Rotavator helps in obtaining of early seedbed preparation soon after harvesting of monsoon crops for sowing of winter crops. This not only requires low energy in tillage operation but also mixes and incorporates the stubbles of previous crop thoroughly in the soil. This improves the soil physical properties and hence, results in increased crop yield. Incorporation of green manuring crops such as *Sesbania aculeata*, mungbean and cowpea in wet conditions can be taken up to improve soil health.

Rotavator for incorporation of cotton stalks Incorporation of green biomass

Figure 2.5 Rotavator for incorporation of cotton stalk (left) and green manure (right) (Source: vikaspedia.in).

2.3.4 Soil organic matter

Soil organic matter is any material produced originally by living organisms (plant or animal) that is returned to the soil and goes through the decomposition process. At any given time, it consists of a range of materials from the intact original tissues of plants and animals to the substantially decomposed mixture of materials known as humus.

Most soil organic matter originates from plant tissue. Plant residues contain 60-90 percent moisture. The remaining dry matter consists of carbon (C), oxygen (O), hydrogen (H) and small amounts of sulphur (S), nitrogen (N), phosphorus (P), potassium (K), calcium (Ca) and magnesium (Mg). Although present in small amounts, these nutrients are very important from the viewpoint of soil fertility management.

Organic matter existing on the soil surface as raw plant residues helps protect the soil from the effect of rainfall, wind and sun. Removal, incorporation or burning of residues exposes the soil to negative climatic impacts, and removal or burning deprives the soil organisms of their primary energy source.

Organic matter within the soil serves several functions. From a practical agricultural standpoint, it is important for two main reasons: (i) as a “revolving nutrient fund”; and (ii) as an agent to improve soil structure, maintain tilth and minimize erosion.

As a revolving nutrient fund, organic matter serves two main functions:

- As soil organic matter is derived mainly from plant residues, it contains all of the essential plant nutrients. Therefore, accumulated organic matter is a storehouse of plant nutrients.
- The stable organic fraction (humus) adsorbs and holds nutrients in a plant-available form.

2.3.5 Microbial activity and microbial biodiversity

Healthy soil supports the functions of ecosystems by enhancing the health of plants and animals. A healthy microbial community is vital to fertility, productivity, and sustainability of an ecosystem.

Soil microorganisms are vital for the continuing cycling of nutrient and for driving above ground ecosystems. It is important to study microbial diversity not only for basic scientific research, but also to understand the link between diversity and community structure and function. Soil bacteria and fungi play pivotal roles in various biogeochemical cycles (BGC). Soil microorganisms also influence above-ground ecosystems by contributing to plant, plant health, soil structure and soil fertility (Meliani et al. 2012). However, activity and species composition of microbes are generally influenced by many factors including physic-chemical properties of the soil, temperature and vegetation. The dynamics of soil microorganisms have important implications for the response of subsurface soil ecosystems to perturbations.

2.4 Integrated Farming and Efficient Use of Fertilizer

2.4.1 What is Integrated Farming System (IFS)?

The Integrated farming system, also known as Integrated Biosystems, is a combination of integrated approaches to farming rather than monoculture approaches. In this system an inter-related set of farming practices are used, in which the waste product from one component becomes an input for the others, thereby reducing the cost and improving the productivity. Integration is the most important aspect of sustainable resource management. The emergence of Integrated Farming Systems (IFS) has led to the development of a framework to improve the feasibility of small-scale farming operations. Since IFS maximizes the utilization of waste materials from one form as resources in another, it not only ensures the increase in overall income for the whole agricultural systems, but it also reduces the environmental impacts caused by waste products of the intensive farming activities.

2.4.2 Scope of IFS

IFS usually refer to agricultural systems that integrate livestock and crop production. IFS can include a wide range of enterprises related to agriculture, such as crop, livestock, poultry, fish, tree crops, plantation crops, and so on. A combination of one or more enterprises will give greater return than a single enterprise, especially for small-scale farmers. To establish inter and intra subsystem closer integration is attempted within each farm/garden/pond etc. at the level of nutrient exchange as well as at the functional level.

2.4.3 Goals of IFS

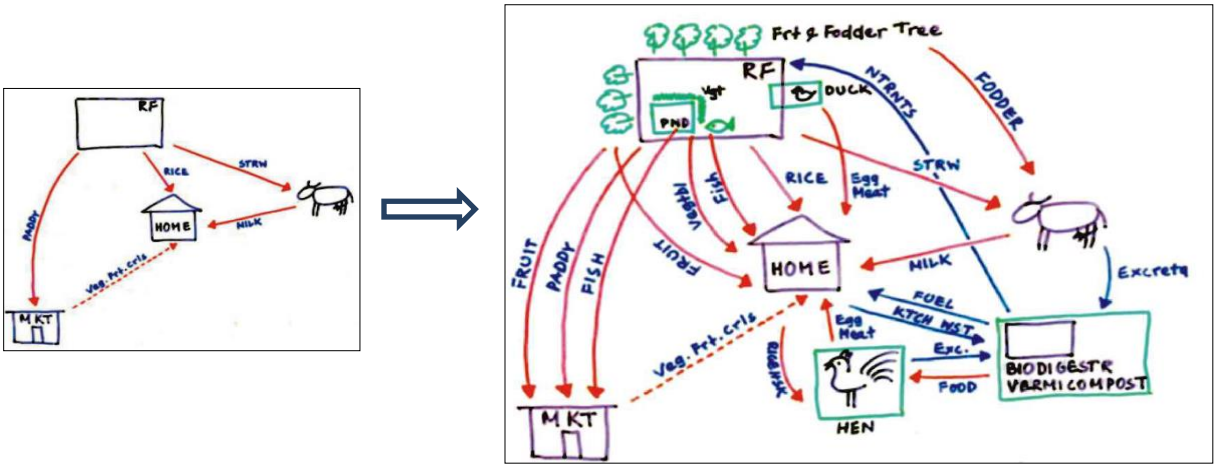
The Goals of the Integrated Farming Systems (IFS) are:

- To provide a steady and stable income amelioration of the system's productivity and
- To achieve agro-ecological equilibrium through the natural cropping system management and reduction in the use of chemicals

2.4.4 Advantages of IFS

- It improves space utilization and increase productivity per unit area
- It provides diversified products
- Improves soil fertility and soil physical structure from appropriate crop rotation
- Reduce weeds, insect pests and diseases from appropriate crop rotation
- Utilization of crop residues and livestock wastes
- Less reliance on outside inputs – fertilizers, agrochemicals, feeds, energy, etc
- Higher net returns to land and labor resources of the farming family

Current traditional farming system adopted by farmer have one rice field (RF) which provide rice for household consumption and getting income by selling some paddy in the market, getting some fodder from straw as well as getting some milk for their children. Introducing IFS by making a small pond for fish and duck culture in the lowland area of rice field, cultivate vegetables on the bund of the pond, growing fruit and fodder tree in the bund of the rice field, making compost by using waste materials. By changing current traditional farming system to IFS, production system is diversified and can support each other, which can reduce cost and increase production and earning (Figure 2.6).



Traditional Farming System

Integrated Farming

Figure 2.6 Advantages gained from integrated farming system (IFS) from simple farming system. (Source: Basu *et al.*, 2013).

The practitioner can use IFS to

- Improve productivity
- Regulate nutrient and material flows
- Increase on-farm biodiversity
- Limit diseases
- Reduce the smell of some livestock operation

2.4.5 The components of IFS

It will include crops, fish farming, poultry, pigs, cattle, sheep and goat, fodder production, kitchen gardening. The crop activities may consist of grain crops (corn, sorghum, rice, beans, soybeans, etc.), vegetable crops, plantation crops (coconut, banana, plantain, etc.), root crops (cassava, cocoyam, sweet potato, etc.), sugarcane, tree crops (moringa, mulberry, nacedero, leucaena, etc.) and fodder crops. The livestock activities may consist of poultry, pigs, cattle and small ruminants and are introduced to obtain waste products as a source of nutrients and other functional inputs. The selection of crops is dependent on family consumption, market, soil type, rainfall and type(s) animals raised, while livestock on family consumption, potential market, and availability of resources. Careful selection of the different components is very important so that they interact positively; e.g. chickens can be destructive in a vegetable garden, but in a fruit orchard they can keep the pests/weeds under control. In a garden some plants/birds/animals etc. are deliberately introduced, while other living things grow by

themselves or come to the garden if a suitable environment is created or food/water/shelter is provided.

Table 2.2 Major components of Integrated Farming Systems (Source: Prakash et. al. 2015)

Crop	Livestock and Poultry	Fishery	Secondary Agriculture
Cereals, Pulses Oilseeds Fruits Vegetables Species Plantation crops Flowers Fodder/ forage crops Agro-forestry Sugarcane Fiber crops	Cattle Buffalo Pig Goat Sheep Chicken Duck	Composite fish culture Fingerling production Paddy cum fish culture	Beekeeping Mushroom cultivation Vermicomposting Biogas production Azolla cultivation Sericulture Moriculture

2.4.6 Efficient Use of Fertilizers

Efficient use can be defined as maximizing yield with a minimum amount of fertilizer. The greatest efficiency usually results from the first increment of added fertilizer/nutrients. Additional increments of fertilizer/nutrients usually result in a lower efficiency but may be profitable. A grower who wants to maximize profits will usually sacrifice some fertilizer efficiency. Some useful practices on efficient use of fertilizers are explained below.

Soil Testing: Soil testing is a means of evaluating the soil's ability to supply these nutrients. Some soils are naturally fertile or have been made more fertile by the use of fertilizers or other nutrient sources.

An assessment of what the soil can supply can be related to crop yields and is used extensively for making fertilizer and lime recommendations. Soils that test low in phosphorus (P) or potassium (K) will need larger amounts of fertilizer P and K than soils testing high in these two nutrients. Much fertilizer energy can be saved by soil testing if fertilizers are applied to soils that have the greatest need and by using reduced rates where soil reserves are high.

Liming: Liming soil to the optimal pH for a crop helps makes nutrients more available, thus reducing the need for fertilizers. This will be especially useful for farmers working on soil of low pH as in lower Myanmar where annual rainfall is plenty. Limestone is an important source

of the essential nutrients calcium (Ca) and magnesium (Mg). It is commonly used to raise the soil pH, which is a measure of soil acidity or alkalinity.

Nutrient availability to plants is often affected by soil pH, with the greatest availability generally occurring between pH 6.5 and 7.0. For example, on acid soils (below 5.5), soluble aluminum is toxic to many plants and reduces the availability of P fertilizers. On alkaline soils, P availability is also reduced, resulting in reduced fertilizer efficiency and crop yield.

Liming acid soils will also improve nodulation of legumes and increase fixation of atmospheric nitrogen, thereby reducing added N fertilizer requirements.

Fertilizer Placement: It has long been known that banding (placing fertilizer near the seed at planting) is more efficient at supplying nutrients to the crop than broadcast applications, yet some crop producers have moved away from band applications. One of the reasons for this shift is that many crops no longer respond to P and K fertilizers where soils are already high in these nutrients.

Another reason for the shift from band to broadcast fertilizer is the increased labor cost and time involved in band application. Uniform application of broadcast fertilizer is important in maximizing yields. Deep placement of urea fertilizer becomes a promising technology in Myanmar

Time of Application: Side-dress applications of nitrogen (N) applied after plant emergence - particularly on shallow-rooted crops such as groundnut grown on sandy soils which are subject to leaching, or on crops grown on fine-textured soils where denitrification is a problem – may be used advantageously to increase effectiveness of fertilizers.

Applying N through the irrigation system is another means of improving nitrogen efficiency. Such a procedure requires little additional energy for application and assures that adequate nitrogen is available during the plant's greatest period of use. This practice is well adapted to sandy soils where leaching of N is a problem. In this case, fertigation should be considered for water use efficiency as well where water source is scarce like in dry zone area.

Use of Manure

Manure is an organic nutrient source available on poultry and livestock farms. Often equivalent to a low-analysis fertilizer, it thus requires a great deal of energy for uniform distribution to the

field but should be effectively utilized whenever possible. The nutrient composition of manure varies greatly, depending on the type of livestock and the methods of handling and spreading. Incorporation of manure immediately after application will reduce volatilization losses of ammonia nitrogen and nutrient runoff from manure and result in better nutrient recovery.

Use of Legumes in Rotation: Incorporating a legume crop such as alfalfa in the crop rotation is an excellent way of improving the N status of the soil. Legumes fix atmospheric N by a process called symbiotic N fixation. Therefore, roots and nodules rich in N when plowed under release readily available N for other crops.

Nutrient Carry-Over: Fertilizer residue and manure nutrients often carry over from one year to another. More carry-over can be expected with high application rates and following droughty years. Yield reduction due to drought, poor stand, or insect or disease problems often results in less nutrient uptake and removal, which can significantly influence the carry-over of fertilizer.

Crop Rotation: Crop rotation is also important in using fertilizer efficiently. A low nutrient-requiring crop such as soybeans following a heavily fertilized corn crop may require little or no fertilizer. Such practices are common and helpful in utilizing fertilizer efficiently.

2.5 Crop Production (management)

2.5.1 System of Rice Intensification (SRI)

To maximize agricultural production, mitigate GHG emissions, and enhance food security, fundamental changes are needed in rice production systems. One alternative option is to apply the System of Rice Intensification (SRI) which requires less agricultural inputs (land, seeds, fertilizers, pesticides) and less water compared to conventional rice cultivation (Thakur, 2010; Geethalakshmi *et al.*, 2011; Jain *et al.*, 2013).

The System of Rice Intensification (SRI) as a knowledge-based methodology increases the productivity and resilience of rice, and more recently also of other crops. Its simple changes of agronomic practices were assembled in close collaboration with farmers during the 1970s-80s in Madagascar. Since 2000, SRI has been spreading to other countries, and today we estimate that more than 10 million farmers are benefiting from the application of this methodology in more than 50 countries of Asia, Africa and Latin America (SRI-Rice 2016; FAO 2016; World Bank 2010).

Application of SRI practices can raise household incomes, enhance soil fertility, and protect crops against climatic, pest, and disease stresses. For irrigated rice production, for which SRI was first developed, farmers transplant young and single seedlings, spacing them widely in a grid pattern, keeping soils moist and fertile, but not flooded, enhancing them with compost and other sources of organic nutrients, doing regular and early weeding that aerates the soil, and incorporating weeds into the soil to decompose.

Key components of SRI

SRI involves some combination of the following changes in rice cultivation practices.

- **Land preparation:** Soil should be well worked and well-leveled so that there is good soil structure, and plant roots can grow easily. Correct leveling helps farmers to achieve uniform wetting of their soil through irrigation with a minimum application of water.
- **Varietal selection:** Choose a variety, improved or traditional, that is well-suited to local conditions (soil, climate, drainage, etc.), being resistant to anticipated problems like pests or irregular water supply, and having desired grain characteristics.
- **Seed selection:** Only the best seed, with good density and formation, should be used. Submerging the seed in a pail of water, with enough salt dissolved in it to make a salt solution in which an egg will float, enables farmers to separate and discard any light and inferior seeds as these will float. Just use the good seeds that sink to the pail's bottom.

1. **Raise seedlings in unflooded nurseries (dry nursery bed)**, not planted densely and well-supplied with organic matter.

Fig. 2.7 Nursery raising in foam boxes (left) and nursery raising in plastic trays (right) (©FAO/U.Theinsu, 2018, Myanmar).

2. Land preparation of transplanting rows by row markers

Soil should be well worked and well-leveled so that there is good soil structure, and plant roots can grow easily. Correct leveling helps farmers to achieve uniform wetting of their soil through irrigation with a minimum application of water. Before transplanting, the rows are drawn by row markers to make easy for transplanting. This can be done by rakes of different teeth or by rollers.

Fig. 2.8 Transplanting lines drawn by a simple rake (left) and transplanting lines drawn by a roll marker (right) (©FAO/U.Theinsu, 2018, Myanmar).

3. **Transplant seedlings at a very young age** – 8 to 12 days old, at most 14 days old, instead of the usual age for seedlings of 3-4 weeks or more.

Fig. 2.9 A piece of nursery bed (left) and young seedling with seed sack (right) (©FAO/U.Theinsu, 2018, Myanmar).

4. **Transplant seedlings quickly, carefully and shallow** – taking care to have minimum trauma to roots.

Fig. 2.10 Young seedling with seed sack (left) and one seedling at each point (right), (©FAO/U.Theinsu 2018, Myanmar).

5. Transplant single seedling in one place s at wider distance of 25x25 cm in a square pattern in un-flooded plot.

Fig. 2.11 Paddy fields seen after transplanting in SRI (©FAO/U.Theinsu, 2018, Myanmar).

6. **Do not continuously flood the soil** – soil saturation causes plant roots to degenerate and suppress soil organisms that require oxygen; either apply *small amounts of water* daily, to keep soil moist but not saturated, or *alternately flood and dry* the soil.

Fig. 2.12 Healthy seedling bearing in cracked soil (©FAO/U.Theinsu , 2018, Myanmar).

7. **Weeding and intercultivating - Weed control** is preferably done with a simple mechanical hand weeder (Rotary Weeder). This *aerates the soil* as it eliminates weeds, giving better results than either hand weeding or herbicides.

Fig. 2.13 Weeding by intercultivator (left) (©Myint Thaung) and earththing up of tillage (right) (©FAO/U.Theinsu, 2018, Myanmar).

The water irrigated in the field for weeding and intercultivation will be drained in the soil gradually after weeding operation. No more watering is done till next weeding time. The paddy plants are not kept under submerged condition. Hand weeding is also necessary to keep the paddy field to be free from weeds at all times.

8. Provide as much organic matter as possible to the soil – while chemical fertilizer gives positive results with SRI practices, the best yields will come with organic fertilization. This does more than feed the plant: *it feeds the soil, so that the soil can feed the plant*.

Table 2.3 Comparison of conventional and SRI practices

Conventional Rice Management	SRI – management
•Transplant older seedlings, 20-30 days old, or even 40 days old	•Transplant **young seedlings**, 8 – 12 days old, and certainly less than 15 days old to preserve subsequent growth potential

•Transplant seedlings in clumps of plants and fairly densely, 50 – 150 plants m2	•Transplant **seedlings singly**, one per hill, and in a square pattern 25x25 cm, or wider if or when the soil is more fertile –Transplant quickly (15 – 30 minutes after removal from nursery) –Shallow (1-2 cm deep) and vertical planting
•Maintain paddy soil continuously flooded, with standing water throughout the growth cycle	•Keep **paddy soil moist, but not continuously saturated**, so that mostly aerobic soil conditions prevail
•Use water to control weeds, supplemented by hand weeding or use herbicides	•Control weeds with **frequent weeding** by a mechanical hand weeder (rotating hoe or cono weeder) that also aerates the soil
•Use chemical fertilizers to enhance soil nutrients	•Apply as much **organic matter** to the soil as possible; can use chemical fertilizer, but best results from compost, mulch etc.,

(Source: Selvaraju, 2013).

Benefits of SRI

The benefits of SRI reported by (Uphoff , 2007; Zhao et al. 2009 and Thakur et al. ,2010) are:

1. Increase in yield/ha – **52%** (21 to 105%)
2. Increased net income/ha – **128%** (59 – 412%)
3. Reduction in cost of production – **24%** (7 – 56%)
4. Reduction in water requirement – **44%** (24 – 60%)
5. Shorter time to maturity (1-3 weeks less)
6 Protection against biotic stresses pests/diseases (Sheath blight, leaf folder, brown plant hopper) – **70% reduction** in incidence
7. Tolerant to abiotic stresses - drought, storm damage, extreme temperatures
8. Higher milling outturn (by ~ 15%) – lower chalkiness.

Contribution to Climate-Smart Agriculture

- Reduced water requirements by higher crop water-use efficiency benefits both natural ecosystems and people in competition with agriculture for scarce water supplies.
- Less use of inorganic fertilizer – reactive N is “the third major threat to our planet after biodiversity loss and climate change” - already returns are greatly diminishing.
- Less reliance on agrochemicals for crop protection enhances the quality of both soil and water.

- Buffering against the effects of climate change - drought, storms (resist lodging), cold temperatures.
- SRI causes mitigation of Climate Change as methane emission from rice fields are determined mainly by water regime and organic inputs. Flooding causes methane emission and organic inputs stimulate methane emissions as long as fields remain flooded. However, mid-season drainage and intermittent irrigation can reduce methane emission by 40% (Wassmann *et al.,* 2009).

2.5.2 Challenges for adoption of SRI

Challenges for adoption of SRI are as follow:

Quality of training and technical follow-up: For best results, farmers need to understand the SRI methodology well and gain confidence in it. This is best done over at least three rice cropping seasons. In the first season, farmers witness the crop performance improvements through demonstrations, preferably on their own fields. In the second season they confirm the experience and gain technical proficiency; and in the third season they start expanding surface area and integrating SRI into their broader farming systems and community-based activities, such as irrigation management and mobilization of labour (Styger and Uphoff . 2016).

Importance of rice production to households and their opportunity costs: If rice is farmers' primary crop and already intensively-cultivated, and if getting the greatest returns from their land and other resources is desired, SRI will be very attractive. Where rice is cultivated in a more extensive manner or as a secondary crop with substantial opportunity costs of intensification, SRI will be of less interest to these farmers.

Access to appropriate tools and equipment: Access to suitable weeders, transplanters or direct-seeders for SRI operations is often lacking. Many weeder prototypes have been developed for varying environments, but their distribution remains a challenge within some countries. Mechanical transplanters and direct-seeders that perform well for SRI are still being developed in some places. If implements are not available, this slows SRI adoption for labour-constrained households or for medium- and larger-scale farming operations.

Assuring market access: Increases in overall rice production need to be accompanied by improved market access and appropriate remuneration for the crop produced, even when

farmers are growing rice just as their staple food. If market payoff is not assured, farmers are less likely to be interested in increasing their production and in crop intensification.

Policy support: This is crucial since SRI lik e other agro-ecological approaches works within a longer-term time frame. Government subsidization of agrochemical inputs, for instance, can divert farmers' efforts and interests away from making sustainable intensification efforts.

Social organization of labour and of water management: Farmers do not cultivate in isolation. They are embedded in communities where agricultural operations are to some extent synchronized and cooperative. In order to change rice production practices and go to scale, a social process of embracing this change needs to happen, especially in irrigation schemes where farmers depend on each other for water access and management (Styger et al. 2011).

Learning process involving successful farmers: In most countries, farmers have given leadership in the development and adaptation of SRI practices. Extension services, often oriented toward input-based technologies, need to be well-trained on the SRI principles and practices in order to be effective in their job. At present, most research is undertaken through on-station experiments rather than in farmers' fields.

2.5.3 Contribution to CSA pillars

SRI increases productivity, farm livelihoods and food security

The combined application of the SRI practices results in **improved plant phenotypes and physiological processes**. SRI plants grow taller, have stronger and thicker tillers, thicker leaves, deeper roots, and a much larger root mass in combination with improved photosynthesis efficiency. Also, increases in beneficial microbial activity and processes have been recorded in the SRI plant-soil environment, which are key for improved plant performance and productivity.

Farm livelihood and food security are improved based on significantly higher yields, usually associated with similar or lower cost of production compared to conventional methods. This results in increased income and the availability of more rice at household level. Many SRI farmers in Asia and Africa achieve rice self-sufficiency and even produce a surplus, which allows them to sell some rice and cover household costs such as medical expenses and school fees for their children, among others.

SRI helps farmers adapt to and increase their resilience to the impacts of climate change.

Based on the improved and stronger plant types with larger and deeper root systems that result from applying SRI methods, these plants are more resilient toward climate-change impacts as witnessed every year in the countries where farmers have adopted SRI. Among the most important benefits are:

Reduced water requirements and greater drought resistance:

SRI plants thrive with 30-50% less irrigation water compared to always flooded rice. Reduced competition among plants in combination with aerated and organic matter-enriched soils creates stronger plants above and below ground with larger, deeper, less-senescing root systems, which can resist drought and extreme temperatures better.

Higher pest and disease resistance:

Stronger and healthier rice plants are less susceptible to pest and disease attacks. Given the much lower plant density with SRI, less humidity builds up within the plant canopy as air can circulate more easily among the plants. This provides pest and diseases with a less favorable environment compared to densely planted and continually-flooded conventional rice paddies.

Greater resistance to rain and wind damage from storms. As SRI plants have thicker tillers and deeper roots, and as they are more widely spaced, they have been shown to resist strong rain and winds better than conventional paddy rice. A study in Japan reported that during a storm event, 10% of SRI field lodged compared to 55% of an adjacent conventionally-managed field.

SRI mitigates greenhouse gas emissions

SRI management contributes to mitigation objectives by decreasing the emissions of greenhouse gases (GHG) when continuous flooding of paddy soils is stopped and other rice-growing practices are changed.

- Methane (CH4) is reduced between 22% and 64% as intermittent irrigation (or alternate wetting and drying, AWD) means that soils have more time under aerobic conditions.

- Nitrous oxide (N2O) emissions increase only slightly with SRI or sometimes decrease as the use of N fertilizers is reduced. No studies so far have shown N2O increases offsetting the gains from CH4 reduction.

- Total global warming potential (GWP) from rice paddies was reduced with SRI methods in the above studies by 20-30%, and up to 73% in one of the studies

- Rice production's carbon footprint is reduced to the extent that less fertilizer and fewer agrochemicals are used. GHG emissions from producing, distributing and using these inputs equal about 5-10% of the global warming potential (GWP) from all direct emissions from food production.

GHG emission studies with SRI are still in the early stages, and more detailed studies are needed to better link and understand how individual practices contribute to increasing or reducing GHG emissions. However, the mitigation potential of alternate wetting and drying, a component of SRI, is well established (Richards and Sander 2014).

2.6 Crop Improvement for Climate Change (Breeding Strategies for Climate Change)

2.6.1 Introduction

Climate change is any long-term significant change in the "average weather" of a region or the earth as a whole. Average weather may include average temperature, precipitation and wind patterns. It involves changes in the variability or average state of the atmosphere over durations ranging from decades to millions of years.

2.6.2 Effects of Climate Change

The climate change has two types of effects, viz., direct and indirect effects. The direct effects of climate change include effect on (i) temperature, (ii) rainfall, (iii) sunlight, (iv) CO_2 concentration, etc. As a result of change in these aspects in a region, there are indirect effects or change in the (i) pest scenario, (ii) disease situation, (iii) water availability, (v) day length, (vi) biodiversity and (vii) cropping pattern.

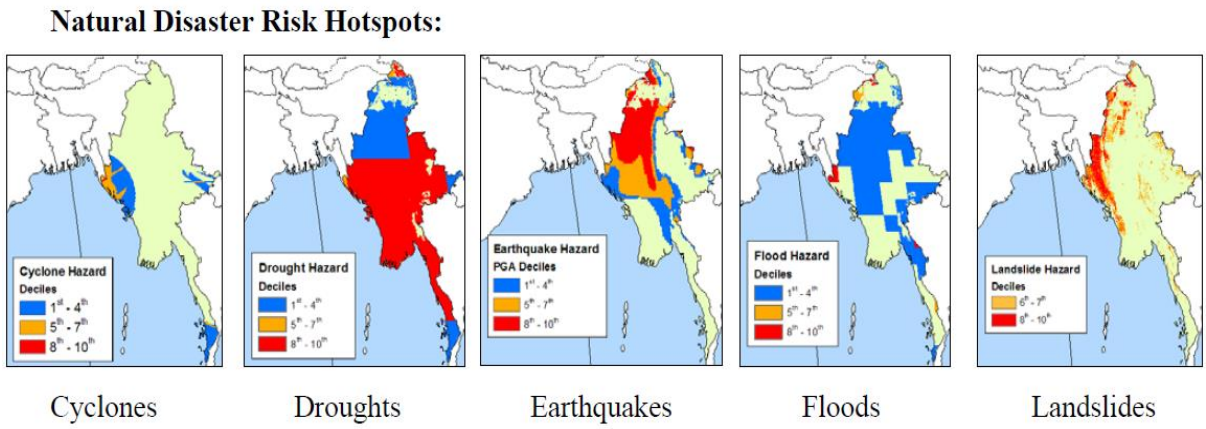


Fig. 2.14 Natural disaster risk hotspots in Myanmar. Source: Burma_profile1 (**https://www.ldeo.columbia.edu/chrr/research/profiles/pdfs/burma_profile1.pdf**).

2.6.3 Climate Change and Breeding

Gradual change in the climate over a long period will lead to several new problems such as appearance of new insects, new weeds, high temperature, drought conditions, change in rainfall etc. As a result of climate change, the following problems emerge.

Fig. 2.15 extreme of climate change: drought (left) and flood (right)

(Source: Vidallo *et al.*, 2015).

(i) Water scarcity or excess depending upon the change in the rainfall pattern,

(ii) Drought if there is low rainfall and increase in temperature,

(iii) Change in response to thermo and photoperiods depending upon the change in sunlight and day length,

(iv) Appearance of new insects, disease, and weeds in the changed climate,

(v) Change in the adaptation of cultivars in the areas of climate change,

(vi) Change in the cropping pattern in the region of climate change.

Table 2.4 Climate change and its effects

S.N.	Climate change	Anticipated Effects
1.	Rise in temperature	Drought, desert expansion, insects, diseases. Crop adaptation, etc.
2.	Rainfall pattern	More Rainfall: Flood situation, water stagnation, cropping pattern. Low Rainfall: Water deficit, drought, etc.
3.	Sunlight	Thermo and photo period requirement.
4.	Wind velocity	Lodging of crop cultivars

Such types of changes will require new set of crop cultivars for successful crop production. To keep pace with the climate change, breeders have to make continuous concerted efforts. The climate change needs to be converted from a difficulty into an opportunity.

2.6.4 Sources of Resistance

In crop plants, there are five important sources which can be used for developing suitable cultivars for cultivation in the region where climate change is taking place. These sources include: (i) germplasm collections, (ii) cultivated varieties, (iii) wild species and relatives, (iv) induced mutations and (v) transgenes.

Table .2.5 Situation of Climate Change and Breeding Strategies

No.	Situation of Climate Change	Breeding Strategies
1.	Low rainfall in paddy growing region	(i) Development of upland paddy cultivars that can be grown with irrigation without standing water (ii) Shifting of paddy with crops with low water requirement
2.	Very high rainfall in paddy growing areas	Development of floating varieties of paddy
3.	Rise in temperature leading to drought situations	Development of drought and heat resistant crop cultivars
4.	Very high rainfall in pulses growing areas	Shifting of pulses crops with paddy and sugarcane
5.	Sudden appearance of new insects and disease due to climate change	Development of crop cultivars resistant to new insects and disease

6.	Moisture deficit in wheat growing areas	Development of drought resistant cultivars of wheat
7.	Low intensity of light and lesser sunlight days	Development of thermo and photo insensitive crop cultivars
8.	Delayed onset of Monsoon	Development of crop varieties suitable for late sowing
9.	Increase in wind velocity	Development of crop cultivars resistant to lodging

(Source: Singh, 2007)

2.6.5 Screening Techniques

The screening of breeding material can be carried out looking to the new problem arising as a result of climate change. The new problems may include heat, drought, excessive moisture, new insects, new diseases and new weeds. The standard procedures available can be adopted for screening of material to tackle these problems. The material can be screened under both natural and controlled conditions to select genotypes suitable for a particular situation. Under artificial conditions the screening of breeding material should be carried out under the controlled conditions representing climate change.

2.6.6 Future Breeding Goals

In view of the climate change, the future plant breeding efforts need to be directed toward the following thrust areas.

1. The new crop varieties should be tolerant to drought and heat that are crossed due to increase in temperature. Crop breeding programs to develop temperature and drought-tolerant high yielding cultivars of the identified crops should be initiated urgently so that the desired kinds of crop cultivars are available when efforts of climate change are noticed.
2. The new varieties, especially grown during winter season should have characteristics of early flowering, photo- and thermo-insensitivity, early maturity and high productivity.
3. The plant genetic resources, especially landraces from those areas that have similarities with climate change can be used to start breeding programs for developing varieties suitable for climate change.
4. The new crop cultivars for climate change can be developed using a combination of conventional breeding approaches, marker assisted selection, induced mutations

and transgenic-breeding. Crop based coordinated programs need to be launched to develop early-maturing, high yielding and temperature and drought tolerant varieties as early as possible.

5. The desirable genotypes for climate change can also be selected in the breeding populations of some ongoing research programs. There will be need for identifications of areas where the climate change conditions already exist or resemble. In such areas, large segregation populations can be screened foe selection of desirable genotypes.

2.6.7 Practical achievements

In the past, several cultivars in different crop species have been developed with resistance to various insects, disease and drought. Conventional breeding approaches along with modern crop improvement techniques will be rewarding to solve various problems that arise in future as a result of climate change.

Adopted crop varieties:

Table 2.6 Adopted crop varieties

Rice

No.	Variety Name	Growth duration	Plant height (cm)	Potential yield (bsk/ac)	Resistance
1	KhoneMyint – 4	115		60-80	Drought resistance
2	Shwe Ma Naw	117	75	80-100	BB resistance
3	Sin Nwe Yin	110	105	90-130	BPH resistance
4	Shwe Myanmar	115	105	90-130	BB resistance
5	EinmaYebaw	115		80-100	BB resistance
6	Yezinlonethwe	125	_	90-130	BPH, Blast and BB resistance
7	Yadana Toe	120 -125	125	100 -140	BPH, Blast and BB resistance
8	ShwePyiHtay	127	99	90-100	BB resistance
9	ShweThwe Yin	115		80-100	BB resistance
10	Sinthukha	140	107	100-120	BB resistance
11	Hninkar	175		50-70	Submergence resistance, BB resistance

12	Sinthwelatt	140	120	100-140	BB resistance
13	Shwe Asian	116	–	100-110	Salinity resistance, Drought resistance
14	Pyi Myanmar Sein	116-120	124	100-110	Alkaline soil and Salinity soil, drought resistance
15	Sar Ngan KharnSinthwelatt	140-145	84	75-100	Resistance to Saline concentration 6 dm/m
16	Ye Myote Khan -1	155	100	80-100	Resistance (10 -14) days submergence, logging
17	Ye Myote Khan -2	143	103	82-135	Resistance (10 -14) days Submergence, Logging resistance
18	Ye Anelo – 6	110	120	90 -140	Drought resistance
19	Ye Anelo – 5	116	126	90 -100	Drought resistance
20	Ye Anelo – 4	117	115-120	90 -100	Drought resistance
21	Ye Anelo – 2	112	106.5	60 -90	Drought tolerance rice leaf roll resistance Yellow draft resistance
22	Ye Anelo – 1	115	120	70 -90	Drought tolerance
23	Myaungmya May	137	127	80 -100	Logging resistance
24	AkariHmwe	125	99	90 -115	Logging resistance
25	Sin Thiri	125	105	80 -100	Bacterial Blight and Rice Blast Resistance
26	Thee Htut Saba - 2	125-130	115	80-100	Rice Blast Resistance
27	Thee Htut Saba - 3	125-130	115	70-90	Rice Blast Resistance
28	YezinYarsaba -5	130-135	130	50-70	drought tolerance
29	Si Lay	125-130	125	60-80	Bacterial leaf streak and rice blast resistance
30	Sin ShweThwe	125-130	125	60-80	Rice Blast Resistance
3 1	ShweThwe Lay	135-140	110	80-100	Bacterial Blight and Rice Blast Resistance

Black Gram

No.	Variety Name	Growth duration	Potential yield (bsk/ac)	Resistance
1	Yezin-7	90-95	28-30	Resistance to Yellow Mosaic Virus

Chickpea

No.	Variety Name	Growth duration	Potential yield (bsk/ac)	Resistance
	Yezin-5	95	29	Moderate resistant to wilt disease
1	Yezin-6	86	25.08	Heat tolerant moderate resistant to wilt disease

2	Yezin-11	80-85	25-30	Moderate resistant to wilt disease

Groundnut

No.	Variety Name	Growth duration	Potential yield (bsk/ac)	Resistance
1	Sinpadathar-5	120	55	Resistant to general diseases
2	Sinpadathar-6	105-115	35	Tolerant to drought
3	Kyaung-gon	140-150	50	Tolerant to drought
4	Magwe Pinpyant-1	150-160	50	Tolerant to drought
5	MagwePinpyant -2	140-150	50	Tolerant to drought

Sesame

No.	Variety Name	Growth duration	Potential yield (bsk/ac)	Resistance
1	Magway – Ni 1/04	85	20	Drought tolerance, Phylody resistance
2	Magway – Ni 2/04	85-90	12-17	Drought tolerance
3	Sin –Yadanar 3	95-100	9-12	Drought tolerance
4	Sin-Yadana 5	90-95	10-15	Disease resistance
5	Hnan-Ni 25/160	90-95	9-15	Drought tolerance, Phylody resistance
6	Magway – 7/9	80-90	9-15	Drought tolerance

Green Gram

No.	Variety Name	Growth duration	Potential yield (bsk/ac)	Resistance
1	Yezin-11	60-65	20.22	Resistance to Yellow mosaic
2	Yezin-14	70-75	17	Resistance to Yellow mosaic

Maize

No.	Variety Name	Growth duration	Potential yield (t/ha)	Resistance
1	Yezin -10	100-110	7.4-7.7	Moderate resistance to Banded leaf and Sheath Blight
2	Yezin-11	105-115	7.1- 7.8	Moderate resistance Leaf Blight

Sunflower

No.	Variety Name	Growth duration	Potential yield (bask/ac)	Resistance
1	Yezin Hybrid (1)	80-85	55-60	Resistant to alternaria leaf blight

2.7 Crop and Livelihood Diversification

2.7.1 Livelihood diversification

Ellis (2000) classifies rural livelihoods into farm and non-farm based on the proportion between landless households and those with access to land for farming. Nevertheless, these two groups are traditionally connected: farmers provide employment for landless laborers in the same village or village tract.

Agriculture remains a mainstay for livelihoods in rural Myanmar, but village populations are increasingly exposed to an array of non-agricultural livelihood options, either locally or distant. These processes of *de-agrarianization* are indicative of a need for close attention to household-scale levels of livelihood diversification (Pritchard et al. 2017). The most common livelihood activity is casual wage labor, followed by farming, small trade and sale of livestock.

The labor requirement for farming activities may depend on the time of crop growth and the cropping pattern: single crop or double crop. As the demand for labor may be more intensive at the time of land preparation, transplanting and harvesting of paddy, farmers will face the problem of labor shortage. Double or triple cropping based on irrigation keep labor requirements high but may lead to a chronic labor force shortage in agriculture over the long run, especially, if they are preferable and competing livelihood activities available, such as in the Delta (fishing, emerging industrialization). Such opportunity to generate income from a diversified livelihood should be encouraged so that to make sure farmers get sustainable income at least for their survival although they faced difficulties and crop failure due to severe weather conditions. To address labor shortage issues, farm mechanization may help the farmers to accomplish the tasks in time.

The causes of livelihood diversifications by the individuals and households can be divided into two: survival and choice or survival and accumulation. There are many factors influencing the

variations of livelihoods for rural people: skills (e.g. trading, vehicle repair, brick making), education (e.g. business job or government job), gender (only male workers are demanded for construction work), and lack of credit access. For example, farmers use cash funds generated from non-farm to purchase agricultural inputs or farm equipment.

In this case, public and private sector can support the rural communities by providing technical and vocational education training (TVET) for capacity building, developing micro-finance systems as well as creating more job opportunities to generate more income. The government of Myanmar is trying its best and private sector is giving assistance to achieve the goal. Currently, the Myanmar Agricultural Development Bank (MADB) is giving loans to farmers although the amount MMK 150,000 (about USD 100) per acre, up to 10 acres per farmer is not enough to cover all the cultivation costs. However, the government interest rate (about 2 percent for one cropping season) is much lower than from the loan from a local money lender (at least 5 to 10 percent per month and also requiring collateral in some cases). Some non-government organizations are also providing cash and kind assistance to farmer and loan with reasonable interest rate.

The extent to which agricultural incomes influence household nutrition and food security out comes depends on a number of factors including the characteristics of food markets, level of empowerment to make decisions on household food purchases, and household nutritional knowledge. Economic research has also shown that income generating activities within various agricultural projects can have a positive, negative, or neutral effect on nutritional outcomes (World Bank, 2007).

2.7.2 Crop diversification

After the success of Asian Green Revolution, crop diversification is strongly regarded as a vital element in raising incomes, improving food security and reducing poverty (Ibrahim et al., 2009). As crop diversification is fundamental for development in agrarian based economies, it has been promoted to enhance household incomes and ensure food and nutrition security. At the household level crop diversification is a major pathway for household food security and nutrition through incomes realized from the sale of agricultural produce. Sometimes, practicing crop diversification may be impractical for a small holder due to the financial and other limitations.

Under the different topography, climate and soil types, more than 61 kinds of crops are usually cultivated in Myanmar. They include cereals (paddy, wheat, maize, sorghum, etc.), oilseeds (groundnut, sesame, sunflower, niger, mustard, etc.), pulses (17 kinds of pulses: black gram, green gram, pigeon pea, soy bean, etc.), industrial crops (cotton, jute, sugarcane, rubber, oil-palm, coffee, etc.), kitchen crops (chilly, onion, garlic, etc.) and fruits and vegetables (mango, banana, cabbage, tomato, etc.) (MOALI, 2016). According to the Global Food Security Index 2014, Myanmar is ranked 86 out of 109 countries (http://foodsecurityindex.eiu.com/Index).

Although the country produces a surplus of food in different items, many households in rural areas are suffering from chronic and acute food insecurity. The Dry Zone is a poverty-stricken area and one of the most food insecure regions of the country comprising Magway, Mandalay and lower Sagaing regions (WFP 2011). It is also characterized by a large crop-diversity with three or more different crop types cultivated. The most common crops grown are pulses (pigeon pea, groundnut, sesame, chickpea, cow pea and green gram), rice and maize (MOALI 2016). Growing cowpea in rotation with rice breaks the pest and disease cycle for both crops because most rice pests and diseases do not transfer to cowpea and most cowpea pests and diseases do not transfer to rice. On the other hand, in the off season after the rice harvest, cowpea cropping can create new jobs.

There are a number of agricultural practices and technologies which enhance food security, resilience and productivity in a sustainable manner. Some of them are briefly outlined below:

Cropping system adjustment: Adjusting the planting calendar by synchronizing with the occurrence of precipitation will likely help farmers cope with increasing climatic variability and temporal water scarcity.

Stress-tolerant crop varieties: Stress-tolerant crop varieties can help cope with biotic stresses (pest and disease) and abiotic stresses (drought, flood, salinity, heat). In the Ayeyarwaddy Delta, a range of rice varieties have been introduced for cultivation, including salt-tolerant, deep-water, waterlogged, and submerged rice varieties.

Crop diversification and intensification: In the central Dry Zone, a number of crops are cultivated using crop intensification systems. This includes the mixed/multiple cropping systems and the sequence cropping systems.

In the past, farmer has no liberty to grow any crop they like if they are living in a project area or under a certain irrigation system where growing paddy is a must. A variety of high value crops: some legume, vegetable and cut-flower, can be grown in these areas. Whilst the potential for diversification is considerable it is unlikely to happen to any degree until the policy environment is liberalized to allow freedom of farmer choice within a market-oriented system. Recently, farmers are reluctant to grow legumes due to the falling prices as a consequence of the policy change from Indian side which is a huge market for Myanmar. This situation demands for finding alternative crops with promising market. The capacity of domestic infrastructure to handle high quality perishable crops for export and lack of incentives to attract foreign investment are major constraints to diversification for the perishable products such as vegetable, fruit and cut-flower.

2.7.3 Contribution to CSA

There is good potential to mitigate the risks of the ongoing poverty trap related to the continuous reliance on the cultivation of rice through crop diversification by improving R&D and extension delivery of improved cropping systems, and the scope for this urgently needed change (see NAPA Working paper 5, 2016).

QSEM (2016) reported that improvements in rural agriculture-based livelihoods have varied significantly by region and improvements have been most noticeable in Shan, Chin, and Ayeyarwady whereas agricultural livelihoods in Magway, Mandalay and Rakhine are constrained by frequent weather-related shocks. It has been recommended that livelihood interventions need to take into account how different socioeconomic groups within villages balance a range of livelihood opportunities. Understanding these variations will enable livelihood-interventions to build on opportunities and maximize development outcomes.

Fig. 2.16 Crop diversification helps increase farm profits in Myanmar (© DOA).

Fig. 2.17 Crop diversification (left), prepared land for legume (front), paddy (middle) and maize (back); mung bean (right). (©Myint Thaung).

2.8 Organic Farming for Sustainable Agriculture

2.8.1 What is organic farming?

According to the Codex Alimentarius Commission, 'organic agriculture is a holistic production management system that avoids use of synthetic fertilizers, pesticides and genetically modified organisms, minimizes pollution of air, soil and water, and optimizes the health and productivity of interdependent communities of plants, animals and people' (Codex Alimentarius Commission. 2001).

It relies on fertilizers of organic origin such as compost manure, green manure, and bone meal, with the objectives of environmental, social, and economic sustainability. Organic farming can provide quality food without adversely affecting the soil's health and the environment.

There were 57.8 million hectares of organic agricultural land in 2016, including in-conversion areas. The regions with the largest areas of organic agricultural land are Oceania (27.3 million hectares, which is almost half world's organic agricultural land) and Europe (13.5 million hectares, 23 percent). Latin America has 7.1 million hectares (12 percent) followed by Asia (4.9 million hectares, 9 percent), North America countries (3.1 million hectares, 6 percent), and Africa (1.8 million hectares, 3 percent). The countries with the most organic agricultural land are Australia (27.1 million hectares), Argentina (3 million hectares), and China (2.3 million hectares) (Willer and Lernoud 2018).

Organic farming has beneficial effects on sustainable agriculture, especially where there is evident degradation of resources, such as soil erosion, due to conventional farming system. Today, use chemicals and fertilizers are rapidly increasing to maximize the farm productivity to meet the ever-increasing food requirements due to population explosion. The prolonged and over usage of chemicals has inevitably led to human and soil health hazards along with environmental pollution. Farmers in the developed countries are therefore encouraged to convert their existing farms into organic farming. In general, organic standards are designed to allow the use of naturally occurring substances while prohibiting or strictly limiting synthetic substances.

The key characteristics of organic farming include careful mechanical intervention based on organic materials, such as protecting the long-term fertility of soils by maintaining organic matter levels, fostering soil biological activity, nitrogen self-sufficiency through the use of

legumes and biological nitrogen fixation, effective recycling of organic materials including crop residues and livestock wastes and weed, and diseases and pest control relying primarily on crop rotations, organic manure, and resistant varieties. A great emphasis is placed to maintain the soil fertility by returning all the wastes to it chiefly through compost to minimize the gap between NPK addition and removal from the soil.

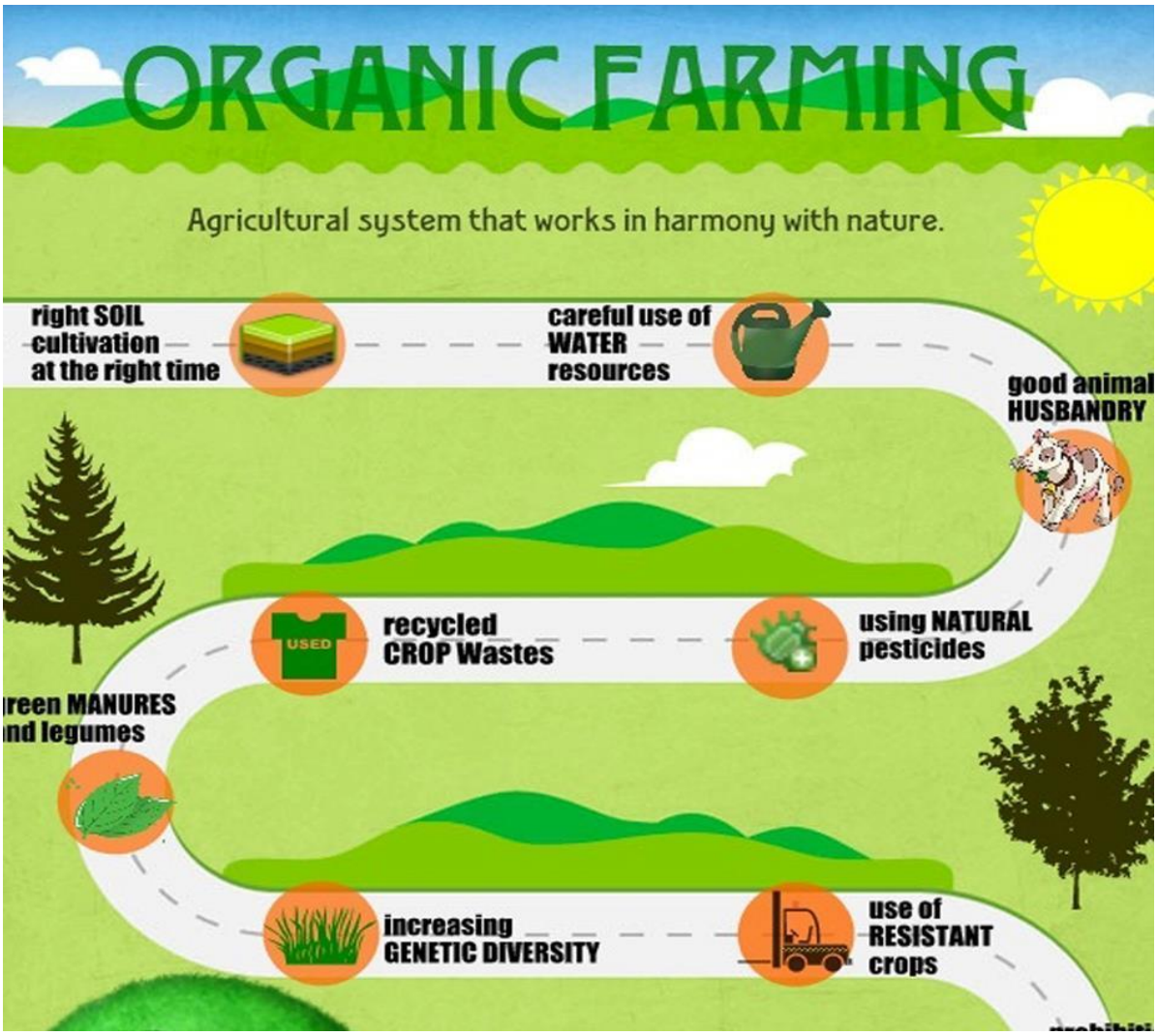


Fig. 2.18 The activities involved in organic farming (© Ghimire, 2014).

2.8.2 Conventional, conservation and organic farming

Agriculture production has to increase by 70% within 2050 in order to keep pace with population growth and changing diets. However, this production increase will have to be achieved in a way that preserves the environment and reduces the vulnerability of agriculture to climate change. Agriculture will furthermore need to minimize the emissions of greenhouse gases, pesticides and plant nutrients like nitrogen and phosphorous to the environment. Organic

agriculture, conventional agriculture and conservation agriculture can be considered as different approaches for dealing with these production and environmental challenges.

Fig. 2.19 Some green manure crops (© TNAU, 2016).

Table 2.7 Key differences between the different forms of agriculture

	Conventional agriculture	Organic agriculture	Conservation agriculture
Ploughing	Yes	Yes	No
Residues retained	No	Limited	Yes
Crop rotations	Limited	Yes	Yes
Use of mineral fertilizer	Yes	No	Yes
Use of pesticides	Yes	No	Yes

2.8.3 Organic Sources of Plant Nutrients

Application of organic sources encouraged the growth and activity of mycorrhizae and other beneficial organisms in the soil and is also helpful in alleviating the increasing incidence or deficiency of secondary and micronutrients and is capable of sustaining high crop productivity

and soil health. Farmers generally use straw of the harvested crop as animal feed or bedding. In most cases, straw is used as bedding to trap urine to increase N cycling. Wet straw and manures from the animal sheds are collected every day and stored or composted on the farmer's premises. The composted manure is applied either immediately or stored until the next crop season depending upon farmer's socioeconomic conditions. In particular, soil, water, and nutrient management strategies, such as reduced tillage and use of raised beds, that avoid the deleterious effects of puddling on soil structure and fertility, improve water- and nutrient-use efficiencies, and increase crop productivity, may be appropriate.

Fig. 2.20 A piece of land with organic farming (Source: solutionsandco.org).

2.8.4 Effect of Organic Nutrition on Crop Productivity

Addition of organic matter in the soil is a well-known practice to increase crop yields. The application of organic materials can increase grain and straw yield of rice. The application of spent mushroom and rice straw compost though comparable with FYM increased rice grain yields by 20 per cent over NPK fertilizer (Stockdale et al., 2001). An organically managed field activity of earth worm is higher than in inorganic agriculture. In low-input agriculture, the crop productivity under organic farming is comparable to that under conventional farming, and the growth of rice was better under continuous organic farming than with conventional farming (Chhonkar 2002). Under biogas slurry with panchagavya (cow dung, urine, milk, curd and ghee are mixed in proper ratio and then allowed to ferment), increased nitrogen accumulation at all growth stages on maize, sunflower, and green gram, as well as higher yield of maize and sunflower was observed in India (Sofia *et al.*, 2006). The organic matter incorporation increased soil water retention in soil and hence enhanced root growth, culminating in high

yields of maize. The impact was greater in maize than in cowpea, especially with gliricidia leaves (Chandra and Chauhan 2004).

2.8.5 Effect of Organic Nutrition on Soil Fertility

Organic farming can sustain higher crop productivity and improving soil quality and productivity by manipulating the soil properties on long term basis. Clark et *al.*, (1998) reported that organic and low-input farming practices after 4 years led to an increase in the organic carbon, soluble phosphorus, exchangeable potassium, and pH. Organic farming improved organic matter content and labile status of nutrients and also soil physicochemical properties. Addition of carbonaceous materials such as straw, wood, bark, sawdust, or corn cobs helped the composting characteristics of manure. These materials reduced water content and raised the C: N ratio (Yadav et al., 2000).

2.8.6 Principles of organic agriculture

The main principles of organic farming are as follows (Chandrashekar, 2010):

- To work within a closed system and draw upon local resources as much as possible
- To maintain long-term fertility of soils
- To avoid all forms of pollution that may result from agricultural techniques
- To produce foodstuffs in sufficient quantity and having high nutritional quality
- To minimize the use of fossil energy in agricultural practices
- To give livestock conditions of life that confirm to their physiological needs and
- To make it possible for agricultural producers to earn a living through their work and develop their potentialities as human being

The principles of organic agriculture are concerned with how agriculture and food production ought to be done and should be ethical principles with sufficient generality and guiding force. The cyclical principle is a principle that linked our abilities to act in relation to nature. It concerns certain aspects of our lives and actions, focusing on our relation to natures systems and cycles in food production. The precautionary principle arose in such a broader environmentalist setting, and the nearness principle is closely related to even broader democratic principles. As ethical principles they are of a general nature.

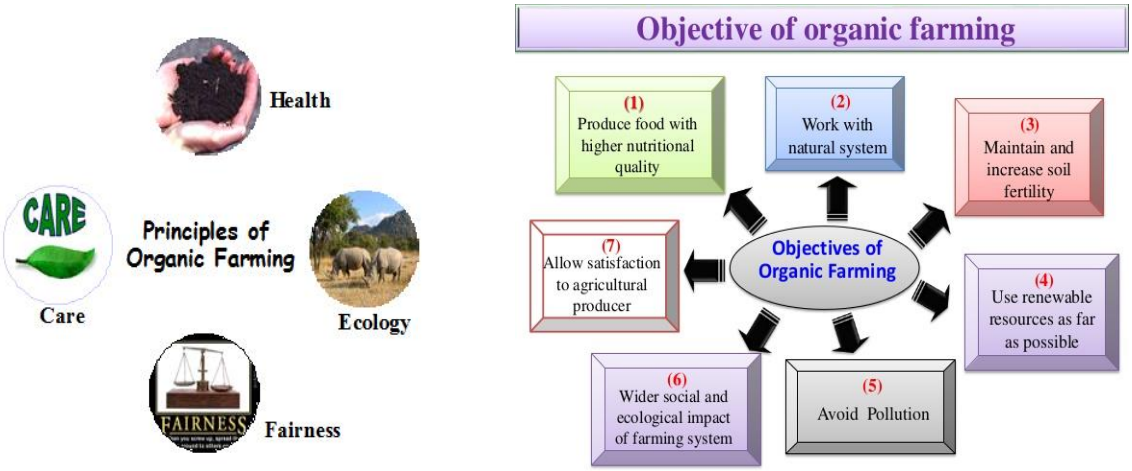


Fig. 2.21 Principles and objectives of organic farming (© TNAU, 2016).

1. The cyclical principle

It is a principle for how to interact with nature. It says that organic food systems should emulate and benefit from nature's systems and cycles, fit into them, and help sustain them. This is the oldest and most established organic principle. Kindred concepts are the ecological principle and the idea of naturalness.

2. The precautionary principle

It is a principle for how to make decisions on changes in technology and practice. It says that action should be taken to prevent harm, even if there is no conclusive scientific evidence that this harm will occur. The principle also calls for the active promotion of cleaner, safer technologies and comprehensive research to detect and reduce risks.

3. The nearness principle

It is a principle for how to learn and communicate in food systems. It says that possibilities for personal experience and close contact between consumers, producers, researchers and other organic actors should be created and maintained. All relevant actors should be encouraged to take part in the development of organic agriculture. This participation should be facilitated by promoting transparency and cooperation in the production and communication processes in the organic food systems.

2.8.7 Contribution to CSA

Organic agriculture mitigates climate change because it:

- Reduces greenhouse gases, especially nitrous oxide, as no chemical nitrogen fertilizers are used and nutrient losses are minimized.
- Stores carbon in soil and plant biomass by building organic matter, encouraging agro-forestry and forbidding the clearance of primary ecosystems.
- Minimizes energy consumption by 30-70% per unit of land by eliminating the energy required to manufacture synthetic fertilizers, and by using internal farm inputs, thus reducing fuel used for transportation.

Organic agriculture helps farmers adapt to climate change because it:

- Prevents nutrient and water loss through high organic matter content and soil covers, thus making soils more resilient to floods, droughts and land degradation processes.
- Preserves seed and crop diversity, which increases crop resistance to pests and disease. Maintenance of diversity also helps farmers evolve new cropping systems to adapt to climatic changes.
- Minimizes risk as a result of stable agro-ecosystems and yields, and lower production costs.

2.8.8 Consideration for scaling up

In the case of crops like rice, organic cultivation appears to be less economical as compared to other crops. However there is more scope for minimizing the economic cost and environmental loss, under organic farming system in the long-run (Rajendran, 2002). Besides these, environmental balance is maintained such that crops, trees, animals and man can live more harmoniously. Reducing the use of pesticide can provide the growers with direct economic benefits by decreasing the cost of inputs, thereby increasing net returns (Brenner, 1991).

Organic agricultural systems have an inherent potential to both reduce GHG emissions and to enhance carbon sequestration in the soil. An important potential contribution of organically managed systems is the careful management of nutrients, and hence the reduction of N_2O emissions from soils, which are the most relevant single source of direct GHG emissions from agriculture. More research is needed to quantify and improve the effects of organic paddy rice production and to develop strategies to reduce methane emissions from enteric fermentation (e.g., by promoting double-use breeds). Indirect GHG emissions are reduced in organic systems by avoidance of mineral fertilizers.

2.9 Participatory Seed Production and Seed Saving

2.9.1 Seed sector analysis

Seed is the most important input to harvest a good crop. The potential yield of crop depends on the quality of the seed used for cultivation of crop. Use of quality seeds alone can enhance the crop productivity by 15-25%. One of the main reasons for low productivity of crops is not availability of reliable quality seeds in the local markets. To enhance productivity, seed should be of high quality, which will express full potential yield of the genotype under favourable cultivation environments. Therefore seed sector improvement was carried out with the assistance of Japan International Cooperation Agency (JICA).

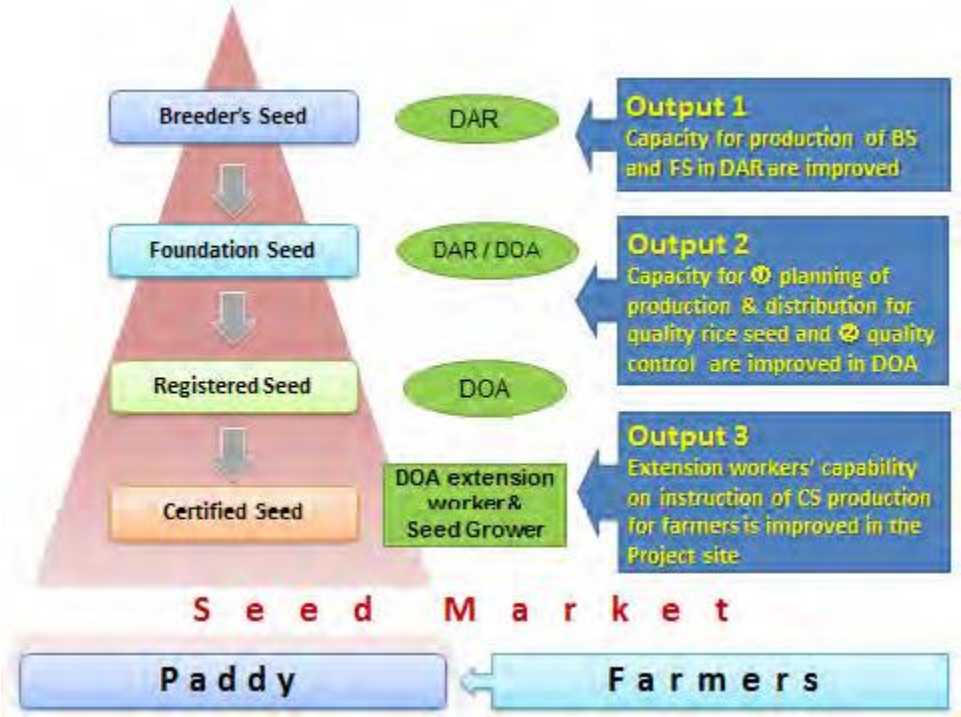


Fig.2.22 The outline and seed flow of a JICA project on development of participatory Multiplication and distribution system of Quality Rice Seed (© JICA).

The seed sector of Myanmar can be characterized by three major clusters of seed systems i.e.: a) the informal seed system b) the intermediate seed system, and c) the formal seed system . These seed systems are specific in the crops they target, types of varieties, quality of seed and ways of seed marketing and dissemination. Overall, the different types of seed systems fulfill the specific seed demand of farmers.

Table.2.8 Various seed systems within national seed sector of Myanmar

Characteristics	Informal seed system	Intermediary	Formal seed system		
	Farmer saved seed	Community based seed production	Public seed system	Public-private seed system	Private seed system
Key actors	Framers, local traders	NGOs	Government	Government and national private seed companies	International private seed companies
Types of crops	Food crops, some cash crops	Food crops	Food crops, cash crops	Food crops, cash crops	Cash crops, food crops, feed crops
Key crops	Rice, wheat, maize, food legumes, local vegetables, potato	Rice, legumes	Rice & maize (OPV, hybrid), sunflower (hybrid)	Rice, potato, maize	Vegetables (exotic, improved), maize & rice (hybrid)
Types of Varieties	Landraces, recycled improved varieties	Improved varieties, local varieties	Improved varieties (OPV, hybrid)	Improved varieties	Improved (hybrid)
Types of seed Quality	Informal seed	Certified or quality seed,	Certified or quality seed	Certified or quality seed	Certified
Dissemination /Marketing	Gift, barter, exchange, local traders, sale in village market	Exchange	Sale through contact farmers, agro-dealer shops	Sale through contact farmers, traders and agro-dealer shops	Agro-dealer shops, seed imports

(Source: Van den Broek *et al.*, (2015).

The overall performance of the present system is not in line with the objectives of the overall agricultural policy. More than 90% of the seed planted of most crops is farm saved seed, while many improved varieties have been developed by research for a large number of crops (Van den Broek *et al.*, (2015). In addition, only for vegetables and hybrid maize a more advanced private production and marketing system has been developed while for most other crops the performance of the seed value-chain is rather limited.

The overview of support programmes shows that most of the Development Partners, (I) NGOs and government projects concentrate on the formal, public seed system. The public-private seed system is much less developed in Myanmar. In addition, there are limited interventions in improving the informal and intermediary seed systems which still provide around 95% of seed to farmers for most crops, and are crucially important for conservation and use of plant genetic

resources and climate adaptation strategies. Also, very few projects focus on new variety development.

2.9.2 Changing infrastructure for seed sector improvement

Van den Broek *et al.,* (2015) pointed out a number of issues in the enabling environment that are hampering the growth and/or transformation of the different seed systems. The first is the relative dominance of the public sector in the production and marketing of seed. The second major challenge is the quality assurance system. Major limitations were observed in the system of field inspections and seed testing at all levels, placing great emphasis on quantity rather than quality, from the Department of Agriculture Research (DAR) Seed Farms to the Department of Agriculture (DoA) Seed Farms and from Seed Villages to the Inspection Lab. The third one is limited communication and collaboration between DAR, the Seed Division and Extension Division of DoA leading to inefficiencies in the performance of the seed chain, reducing the number of in-demand varieties reaching farmers and reducing the overall seed quality.

Table 2.9 Overview on formal seed production in 2013-2014 seasons in Myanmar

Crop	Types of seed	Area (ha)	Seed production (ton)
Rice	Breeder's seed (BS)	_	2.96
Rice	Foundation seed (FS)	102	3.80
Rice	Registered seed (RS)	798	197.49
Rice	Certified seed (CS)	Not available	Not available
Maize	Certified seed (CS)	100	35.15
Green gram	Certified seed (CS)	34	9.70
Pigeon pea	Certified seed (CS)	279	82.63
Groundnut	Certified seed (CS)	4	2.45
Sesame	Certified seed (CS)	408	14.55
Sunflower	–	36	16.61

(Source: MoAI, 2014, * 2013-2014 rainy season data).

The DAR is responsible for breeder's seed production. DAR and DoA are both involved in foundation seed and registered seed production at the 43 government farms established across the different agro-ecological production zones of Myanmar. These government farms provide foundation and registered seed to seed village schemes, contact farmers, national private seed companies, NGO programs and millers who multiply to certified or quality seed. It is obvious

to see the public sector stakeholders playing key role and dominating the seed multiplication chain.

2.9.3 Informal seed system

The informal seed system will remain playing a dominant role in Myanmar's seed sector. It is estimated that currently the informal system contributes more than 95% of all rice seed planted in Myanmar, and for most other crops this percentage is higher (except for vegetable and maize seeds).

Since the sales of quality seeds were sluggish and advantages of using CS were not well recognized among stakeholders such as paddy production farmers, traders and rice millers, one JICA project was conducted milling demonstration for the stakeholders. The test showed that red rice ratio of CS origin paddy was significantly lower than that of none CS paddy collected from Labutta, Myaungmya and Hinthada townships. Similarly the head rice ratio of CS origin paddy was significantly higher than that of none CS paddy (JICA 2017).

2.9.4 Strengthening local rice seed production of premium varieties

Specific aromatic rice varieties (often combined under the name Pawsanhmwe) have a high demand in Myanmar's food market. Superior varieties travel long distances from their place of origin (e.g. Shwebo) to the farmer's field. Especially, in the Southern delta areas these varieties are popular while the availability of good quality seed is low. Some activities in the LIFT program are supporting farmers to better select new varieties (e.g. through Participatory Variety Selection) and support livelihoods in better seed management practices and developing local seed markets.

In addition, these activities can also contribute to conserving and using the agro-biodiversity, which will be necessary for the continuous adaptation to climate change. Myanmar's current diversity in rice varieties (including land-races) includes traits that are less susceptible to droughts, floods and salinity (Van den Broek et al. (2015).

Fig. 2.23 (a) Mass activity for seed selection at vegetative growth stage (left) and (b) before harvest in Myingyan (right), (© DOA).

Fig. 2.23 (c) Mass activity for eating quality test on breeding lines of paddy in Myingyan (© DOA).

2.9.5 Community seed banks

Community seed banks are mostly informal collections of seeds maintained by local communities and managed with their traditional knowledge, whose primary function is to conserve seeds for local use. Seeds are obtained from the farmers in the community and are selected and stored depending on the agreed storage system. Community seed banks can take different forms, for example, seeds can be stored in pots in a shed or community buildings, or in clay pots on the floor, in a family granary or on the kitchen shelf.

Once the seeds are collected from the farmers, they are stored in a community seed bank until they are needed. One of the purposes of a community seed bank is to serve as an emergency seed supply when farmers experience a shortage of seeds, due to failure or destruction of crops as a result of floods, droughts, pests and diseases.

As climate change has a significant impact on agricultural production, growing local varieties, which have a high degree of genetic diversity, is highly important because these varieties have the ability to better withstand and adapt to environmental stresses and changes. Setting up community seed banks may help farmers to acquire varieties that are adapted to local conditions; these varieties may not be accessible through formal seed systems, may be costly or may suffer from erratic supplies. If farmers, in particular small holder farmers with poor resources, can access these locally adapted varieties, it can help them to get access to seeds for the next planting season as well as provide them with an emergency seed supply in times of crisis, thus making them less dependent on the formal seed systems.

Fig. 2.24 Some village seed banks. © Green Foundation
Source: http://www.greenfoundation.in/ community-seed-banks-nba/ (Left) and Source: http://ubinig.org/index.php/home/ printAerticle/51/english (Right).

Revolving Seed Bank system

Some organizations like Community Agency for Rural Development set up village based seed banks to help rural community with the aim of improving household food security and food sovereignty. Their main objectives were to help local farmers access (1) to modern farming technology, (2) to better and productive seed for higher farm production and (3) to market oriented seed for their higher income and food security.

Fig 2.25 Seeds ready to distribute to the farmers (left); farmers to receive delivery in Chauk (right) (© DOA).

Local farmers can loan seeds from the bank which is managed by village selected committee and farmers are obliged to replace one fold of the seed in line with agreement between farmers and the committee. Profits are meant to use for farmers' better living standard among the members. These sorts of activity should be encouraged to strengthen participatory seed production system in Myanmar.

Under the Fostering Agricultural Revitalization in Myanmar (FARM) project, some common interest groups (CIG) were supported and encouraged to produce quality seeds for the local community. There were some other groups producing quality seeds for local farmers in some regions. These groups should be given financial as well technical assistance. Local farmers should be organized to participate in the community seed producing system.

2.10 Water Management

2.10.1 Alternate Wetting and Drying (AWD) Techniques for Rice Cultivation

What is Alternate Wetting and Drying?

Alternate wetting and drying (AWD) is also known as intermittent flooding. AWD is the practice of flood initiation and recession. It was first developed at the International Rice Research Institute (IRRI). As a rice flood management practice, AWD is used to maximize rainfall capture and reduce irrigation pumping while maintaining grain quality and yield.

Alternate wetting and drying consists of flooding a field to a reasonable depth and allowing the flood to naturally subside to the soil surface via infiltration and evapotranspiration. This

subsidence can be a mud (or drier) consistency at the soil surface before re-flooding depending on field specifics including soil texture and irrigation capacity.

The timing, frequency, and extent of the wetting and drying cycles depend on rice growth stage, prevailing weather and field conditions, and grower comfort level with the practice. After holding the initial flood for 3 weeks, it is common to refrain from applying a flood for five or more days between wet-dry cycles when using AWD. A full flood is maintained at panicle initiation (green ring) and at flowering, when rice is most sensitive to water stress.

Alternate Wetting and Drying (AWD) is a water-saving technology that farmers can apply to reduce their irrigation water consumption in rice fields without decreasing its yield. In AWD, irrigation water is applied a few days after the disappearance of the ponded water. Hence, the field gets alternately flooded and non-flooded. The number of days of non-flooded soil between irrigations can vary from 1 to more than 10 days depending on the number of factors such as soil type, weather, and crop growth stage.

How to implement AWD?

A practical way to implement AWD is to monitor the depth of ponded water on the field using a 'field water tube'. After irrigation, the depth of ponded water will gradually decrease. When the ponded water has dropped to 15 cm below the surface of the soil, irrigation should be applied to re-flood the field with 5 cm of ponded water. From one week before to one week after flowering, ponded water should always be kept at 5 cm depth. After flowering, during grain filling and ripening, the water level can drop again to 15 cm below the surface before re-irrigation. Alternate wetting and drying can be started a few days after transplanting (or with a 10-cm tall crop in direct seeding). When many weeds are present, AWD can be postponed for 2-3 weeks until weeds have been suppressed by the ponded water. Local fertilizer recommendations as for flooded rice can be used. Apply fertilizer N preferably on the dry soil just before irrigation.

Fig.2.26 Water at 15 cm depth: Time to irrigate and flood the field again (Source: IRRI 2009).

Safe AWD?

The threshold of 15 cm water depth (below the surface) before irrigation is called 'Safe AWD" as this will not cause any yield decline. In Safe AWD, water savings are in the order of 15-30%. After creating confidence that Safe AWD does not reduce yield, farmers may experiment by lowering the threshold level for irrigation to 20, 25, 30 cm depth, or even deeper. Lowering the threshold level for irrigation will increase the water savings, but some yield penalty may occur. Such a yield penalty may be acceptable when the price of water is high or when water is very scarce.

The Field Water Tube

A tube can be made of 40-cm long plastic pipe or bamboo, and have a diameter of 15 cm or more so that the water table is easily visible. Perforate the tube with holes on all sides. Dig the tube in the soil so that 20 cm protrudes above the soil surface. Take care not to penetrate through the bottom of the plow pan. Remove the soil from the inside so that the bottom of the tube is visible. Check that the water table inside the tube is the same as outside the tube. The tube can be placed in a flat part of the field close to a bund, so it is easy to monitor the ponded water depth.

Fig. 2.27 Field water tube from PVC and a field tube under flooded conditions Note the holes on all sides (Source: IRRI 2009).

How does AWD reduce greenhouse gas emissions?

Methane (CH_4) in wet or "paddy" rice soil is produced by the anaerobic decomposition of organic material after the flooding of rice fields. Allowing the field to drain removes the anaerobic condition for a time and halts the production of CH_4, thus reducing the total quantity of CH_4 released during the growing season. The production of nitrous oxide (N_2O) is also regulated by the presence of oxygen. In contrast to CH_4 however, the recurring shift between aerobic and anaerobic conditions favors bacterial conversion of other nitrogen compounds to N_2O and its release from the soil. The production of N_2O is also strongly influenced by the availability of nitrogen in the soil. Thus, N_2O emissions increase with the amount of nitrogen fertilizer applied to rice paddies.

Where can AWD be practiced?

In general, lowland rice-growing areas where soils can be drained in 5-day intervals are suitable for AWD. High rainfall may impede AWD. If rainfall exceeds water lost to evapotranspiration and seepage, the field will be unable to dry during the rice-growing period. Farmers must have control over irrigation of their fields and know that they will have access to water once fields have drained. AWD in rain-fed rice is not recommended due to uncertain water availability when fields have to be reflooded.

Advantages

1. Large reductions in methane emissions are possible compared to continuous flooding.
2. It will help the economic use of water during rice cultivation.
3. The drying phase of rhizosphere will help root growth and its sustainability for water transport to rice plants even under low soil moisture conditions.
4. Farmers will be able to know the status of water of their rice growing fields and would be able to balance irrigation with achieving minimum methane emissions.
5. The savings of irrigation water will have impact on environment because of reduced withdrawal of ground water and a reduction in consumption of diesel for water pumps.
6. Protection of water levels of ground water may also reduce arsenic contamination in rice grain and straw.

Disadvantages

1. Occasionally, rice productivity is reduced using AWD technology if moisture stress condition is induced. However, the reduction of yield was less compared to the yield reduction due to the direct moisture stress effect.
2. N_2O emissions are increased.

Fertility Management

Properly managed AWD should not influence nutrient management in terms of rates and timings of fertilizer application. No changes are needed to nitrogen (N) fertility management. A single preflood N fertilizer application simplifies water management through the season. A continuous flood should maintain well saturated soils for a full three weeks following pre-flood N application to ensure efficient N uptake by rice plants. If a two-way split N management plan is used for conventional cultivars the midseason N application should be applied into the floodwater which is maintained for at least 5 days following application.

2.10.2 Water Harvesting and Saving Techniques

Water harvesting in dry zone area

The dry zone area includes 51 townships of 11 districts within Magway, Mandalay and Sagaing regions. Although the land in these areas may be fertile and productive in the past, now it becomes dry land and the annual rainfall is about 25 inches. On the other hand, heavy rainfall

within a short duration enhanced soil erosion in this area. The soil fertility is poor and crop production is no longer profitable due to the land degradation. The main causes of land degradation are:

(a) soil erosion by water / wind erosion
(b) human activities (deforestation, insufficient reforestation, the wrong cultural practices, etc,).

Soil erosion can be caused by leaving the land without soil cover or no crop, the land is sloping to one side and run- off water resulted from poor absorption due to compact soil.

Figure 2.28 The causes of soil erosion, burning (left) and harrowing along the sloping line (right) (© Yar Zar Naing Win, TAF).

Land degradation

It has been found out that the current rate of soil erosion ranged from 0 to 114 t ha^{-1} yr^{-1}, and that the average rate of soil erosion increased from 14.2 to 54.6 t ha^{-1} yr^{-1} over a period from 2000 to 2012. The major types of land degradation were physical and chemical soil degradation such as salinization and solidification due to the impact of climate change. Farmers identified topographic condition, soil types, improper crop management practices and climatic factors as the main causes of soil erosion. The observed crop yields of monsoon rice, groundnut, sesame and cotton in the highly degraded area were 3–12 times lower compared with the yields of these crops grown in less degraded area (Kyawt K.K. Tun et al.2015).

Figure 2.29 Soil erosion in dry zone area, rill erosion (left) and eroded poor soil (right) (© Yar Zar Naing Win, TAF).

This means immediate remedial measures are urgently need to prevent further degradation of the soil in these areas. A number of things can be done to prevent soil erosion and also to conserve moisture for crop production. The first thing is growing wind break trees to prevent wind erosion.

Wind break trees

Wind breaks mean growing certain type of trees or tall crops in the field together with the crop or in the periphery of the filed so that to reduce the velocity of the wind. Fast growing perennials, for example, the lead tree, *Leucaena glauca* and *Gliricidia sepium*, suitable for the region can be selected as wind break tree (Figure 3). The benefits of wind break are:

1. to reduce yield losses due to strong wind
2. to prevent wind erosion
3. to reduce moisture loss due to wind
4. to supplement animal feed and food for human
5. to get firewood for the rural community and
6. to enrich organic matter in the soil from the residues of wind break trees.

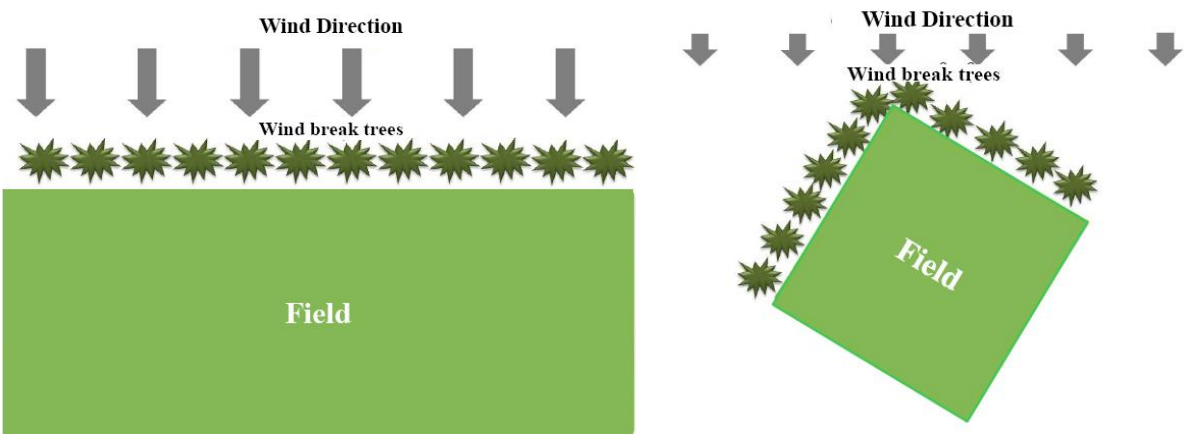


Fig. 2.30 Planting wind break trees.

Figure 2.31 Pigeon pea as Wind Break (Inter-cropping with pigeon pea and groundnut) (© Yar Zar Naing Win, TAF).

Moisture conservation

In dry zone area, the annual rainfall is very limited and the distribution is not even occurring intensively in short duration leading to soil erosion. The wrong harrowing method enhanced the soil erosion. On the other hand, it is very important to prepare the land in time to catch up the remaining moisture in the soil.

To conserve moisture in the soil, fast growing crops from leguminous family can be grown as green manure before the main crop, for example, groundnut in dry zone area. It is a great way to add nutrients to the soil. Green manure involves planting a crop that is meant to be incorporated into the soil to increase its fertility. In agriculture, green manure is created by leaving uprooted or sown crop parts to wither on a field so that they serve as a mulch and soil amendment. The green manure crop must be ploughed under at the time of flowering. Green manures usually perform multiple functions that include soil improvement and soil protection.

Leguminous green manures contain nitrogen-fixing symbiotic bacteria in root nodules that fix atmospheric nitrogen in a form that plants can use. This performs the vital function of fertilization. If desired, animal manures may also be added. Depending on the species of cover crop grown, the amount of nitrogen released into the soil lies between 40 and 200 pounds per acre. With green manure use, the amount of nitrogen that is available to the succeeding crop is usually in the range of 40-60% of the total amount of nitrogen that is contained within the green manure crop.

Incorporation of cover crops into the soil allows the nutrients held within the green manure to be released and made available to the succeeding crops. This additional decomposition also allows for the re-incorporation of nutrients that are found in the soil in a particular form such as nitrogen (N), potassium (K), phosphorus (P), calcium (Ca), magnesium (Mg), and sulfur (S).

Microbial activity from incorporation of cover crops into the soil leads to the formation of mycelium and viscous materials which benefit the health of the soil by increasing its soil structure (i.e. by aggregation). The advantages of green manure are: prevent soil erosion as a soil cover, improve soil structure after decomposition, retain soil moisture and temperature, reduce weed problem and improve soil fertility.

Fig.2.32 Green manure (green gram) before and after ploughing (© Yar Zar Naing Win, TAF).

Fig. 2.33 Eroded soil (left) and *Sesabania cannabina* as in flowers before ploughing for green manure (right) (© Yar Zar Naing Win, TAF).

2.10.3 Water harvesting

For the successful crop production, water is essential. In some cases, water shortage especially in the later part of crop growth after flowering can cause reduction in the yield or total failure of the crop. As the rainfall is scarce, the rain water must be conserved at the time of raining for later use. A small pond measuring 14 m x 6 m x 2 m can be constructed and covered with 500 mesh vinyl sheet. From this pond, 2 acres of land can be irrigated twice. That can be of great benefit to the farmer at the time of water scarcity especially in post rainy season. On the other hand, this is a low cost technology.

Figure 2.34 Small pond coverved with vinyl sheet for water storage, 500 mesh poly vinyl sheet at YAU (left) and aother type of vinyl sheet used by some famrers (right) (© Myint Thaung).

2.10.4 Supplemental irrigation

Supplemental irrigation – the addition of limited amounts if water to essentially rainfed crops to improve and stabilize yields when rainfall fails to provide sufficient moisture for normal plant growth – is an effective response to alleviate the adverse effects soil moisture stress on the yield of rainfed crops during dry spells. Supplemental irrigation, especially during critical crop growth stages, can improve crop yield and water productivity (Nangia et al. 2018).

Benefits of supplemental irrigation:

- Supplemental irrigation is a simple but highly effective technology that allows farmers to plant and manage crops at the optimal time, without being at the mercy of unpredictable rainfall.
- Field trials in several countries showed massive increases in wheat and barley yields with small quantities of supplemental irrigation.
- Supplemental irrigation allows farmers to plant their crops early, increasing yields and preventing exposure to terminal heat and drought stress in hot areas, and frost in cold areas.

Challenges to adoption of supplemental irrigation practice

Biophysical, economic, capacity/knowledge challenges to adoption:

i. **Soil texture** is a major deciding factor when introducing SI. Sandy soils have low water holding capacity and high rates of water infiltration compared to soils with higher levels of clay content.

ii. The **crop** is another important factor in deciding irrigation depth. Some crops are more water-requiring than others.

iii. **Landscape of the irrigation site** is another important criterion. If the land is uneven, water cannot flow at a constant rate and cannot reach every corner of the field. In such situations, sprinklers or drips are recommended.

iv. **Capacity of the reservoir** should be such that it can meet the demand of the crop. It is very expensive to excavate, especially in remote locations. When deciding on the capacity, it should be sufficient to meet crop water demands and, in the case of water harvesting, the runoff generated from the upstream catchment area. If the

catchment area is insufficient, the reservoir will not get filled and will be unable to meet the crop water demand.

v. **Supplemental irrigation depth and timing** is an important decision. SI is not intended to meet the full crop water demand. It is a critical dose which can increase yields significantly as well as save the crop from failure during a dry year. The depth of SI needs to be fixed when designing the water storage better to apply small doses of SI rather than all in 1–2 operations.

Contribution to CSA pillars

Supplemental irrigation practices increase productivity, farm livelihoods and food security and helps adapt to and increase resilience to climate change impacts

Climate change adaptation strategies can only be effective if done in an integrated manner. For rainfed agriculture, the strategies may need to encompass water management, crop improvement, cultural practices, policies, and socioeconomic and other issues. Less and more erratic precipitation is expected in the dry areas as a result of global warming. Lower precipitation will cause a further moisture stress on already stressed rainfed crops and some areas on the peripheries of the rainfed zones may drop out of dryland agriculture as a result. It is also expected that rainfall will be more erratic and intensive, and the season will have prolonged drought spells. Crop yields and WP losses are mainly associated with soil moisture stress during such drought spells. Prolonged drought spells during the rainy seasons resulting from global warming will make the crop situation even worse and further drops in yields are expected as a result. Supplemental irrigation, by definition, deals with two situations. It adds some water to compensate for lower rainfall and less moisture storage and it alleviates soil water stress during dry spells. It is however, important to quantify the changes in rainfall characteristics and the durations of potential drought spells in order to design SI schedules to adapt the system to climate change.

Supplemental irrigation mitigate GHG emission

Supplemental irrigation can help mitigate greenhouse gas (GHG) emissions in two ways: (1) Increased yields achieved with SI (compared to rainfed production) result in higher carbon sequestration rates in plant biomass and for the build-up of soil organic carbon (SOC), especially if crop residues are returned to the soil or if cover cropping practices keep the soil

protected as much as possible (Lal, 2004). This increase in SOC, in turn, has a synergistic effect on adaptation through improved soil fertility as well as reduced nutrient leaching and soil erosion. If this soil fertility improvement results in a decrease of mineral fertilizer use, additional mitigation benefits can be obtained through a reduction of GHG emissions linked to fertilizer manufacturing and use.

(2) When substantial yield gains are achieved through SI compared to a relatively low increase in farming inputs, the GHG emission intensity per unit of produce decreases (for more detail see Nangia et al. 2018).

2.11 Improved Micro Irrigation for Vegetables

Water is quite essential for the successful production of crops. Crop failure due to scarcity of rain is not uncommon in dry zone area. Selection of appropriate irrigation system for horticultural crops is very important. The most commonly used irrigation systems are furrow irrigation, sprinkler irrigation and drip irrigation. In some cases, sub-irrigation may be used.

2.11.1 Water saving technology/Drip irrigation

Drip irrigation/Micro-irrigation (MI) is the most efficient method of irrigating. While sprinkler systems are around 75-85% efficient, drip systems typically are 90% or higher. Imported drip systems are still relatively expensive in Myanmar and it is primarily wealthier farmers who currently enjoy these benefits. There are also perceptual barriers to adoption as many farmers are accustomed to applying copious amounts of water to vegetable crops and are unfamiliar with drip or their crops‟ actual water requirements. Approximately 5000 small farm drip systems have been installed in Myanmar since 2008 and the number of users is increasing at an accelerating pace (Rowell et al. 2015).

Micro-irrigation (MI) comprises a family of irrigation systems that emit water through small devices. The devices usually deliver water onto the surface of the soil very close to the plant, or below the surface of soil directly to the root. MI systems predominate in arid and semi-arid regions where problems of water scarcity are extensive. In irrigated agriculture, they are used mostly for row crops, mulched crops, orchards, gardens, greenhouses, and nurseries.

Figure 2.35 Sprinkler is mostly used for irrigation in Myanmar

(Source: journals.ashs.org and sandeepdripirrigation.com).

The Basic Parts of a Drip System

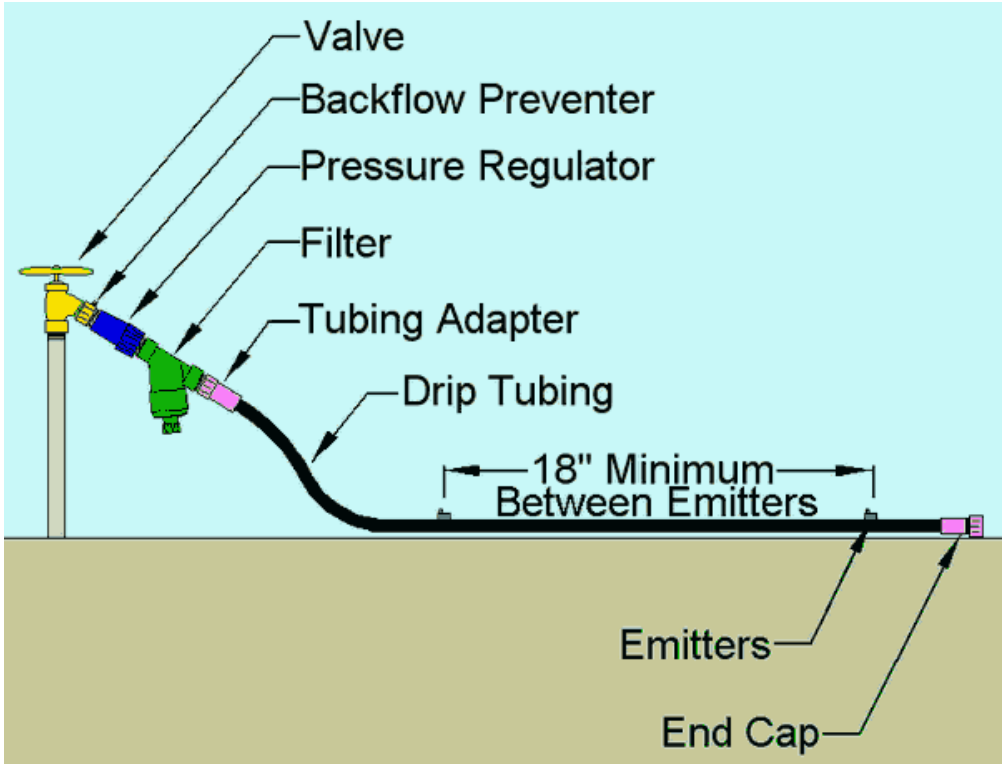


Figure 2.36 Basic parts of drip irrigation

(Source: https://www.amazevegegarden.com/458/modern-drip-irrigation-systems-set-you-free/).

Emission devices deliver water in three different modes: drip, bubbler, or micro-sprinkler. In drip mode, water is emitted in droplets and trickles. In bubbler mode, the water bubbles out from the device. In the case of the micro-sprinkler, the water is sprinkled, sprayed, or misted.

The water-saving potential of the MI technologies can be acquired in two ways. This concept can be explained as ‘dry’ water saving and ‘wet’ water saving. Dry water saving refers to reducing the water consumption for a particular crop. Wet water saving is achieved when the yield of a crop is enhanced without changing the amount of water consumed (Kumar et al., 2008).

MI technologies typically reduce the risk of water supply shortages during drought or in semi-arid or arid areas because of their high efficiency (less non-beneficial soil–water evaporation, wind draft, evaporation of canopy-intercepted water). This technology was used in Yezin Agricultural University to irrigate paddy field as well as corn field in 2008 Monsoon season. However, its efficiency could not be evaluated due to the heavy rain in this season.

Fig. 2.37 Drip irrigation in a paddy field at Yezin Agricultural University (© Myint Thaung).

Figure 2.38 Drip irrigation to a corn field and a close view of a drip pipe (Source: irrigationaustralia.com.au).

2.11.2 Fertigation: Fertilizing with Drip Irrigation

Fertilizer is often over-applied or insufficiently distributed in conventional methods of fertilizing. But fertilizing more precisely can trigger optimal conditions for plants during different life phases. Fertigation is a method of fertilizing that achieves a more precise application. Fertigation is quite simply, adding water-soluble fertilizer to an irrigation system in order to apply exact amounts directly to the root system. While fertigation can be implemented in less effective methods of irrigation, like a sprinkler system, a fertigation system using drip tape is much more efficient.

Increased efficiency

Drip irrigation provides a direct source of hydration to the root zone. The root system of the plant is therefore able to absorb higher amounts of nutrients. This method is used to keep a strict application regiment and to correct any nutrient deficiencies that can be analyzed through plant tissue. Another benefit of drip tape fertigation is that sometimes fertilizers can contaminate the soil, increasing the risk of soil borne disease. Directing fertilizers and amendments to the root system minimizes the levels of contamination in soil. Drip tape irrigation reduces the contact between water and leaves, stems and fruit, minimizing the development of diseases. Furthermore, because drip tape is directed towards the crop's roots and eliminates flooding, weed control is a lot easier.

Many growers using a soil medium and drip tape will bury it slightly below the ground and call it subsurface drip irrigation (SDI). SDI should help protect drip tape from sun exposure and damage done by cultivation or weeding. In dry climates, SDI helps to reduce water evaporation and waste by creating an even more direct path to the root system.

Efficiency is a major reason to use drip irrigation systems. Both water application and fertilizer application is much more precise than in traditional overhead watering. Precision creates a more unified and productive crop that performs exceptionally well. On the contrary, traditional watering, like overhead watering or flooding, methods of farming in general are failing in the area of sustainability.

These benefits of drip irrigation include higher yields, improved product quality, earlier maturity, and reduced risk of foliar (and some soil borne) diseases. Other advantages over conventional irrigation include higher water use efficiency and application uniformity that is unaffected by wind and causes less soil crusting. In some cases weed pressures are reduced and farmers can perform weeding and other field operations while irrigating. Less energy and labor

are generally required for drip irrigation. Application of plant nutrients through drip systems (fertigation) enables precise fertilizer placement and timing, resulting in better nutrient use efficiency. Drip has also been used successfully on saline soils and with saline water where other irrigation methods failed. Lastly, drip irrigation has synergistic interactions with plastic mulches which further boost yields and product quality.

Fig 2.39 The gravity-fed system irrigates leafy vegetables in discarded water bottles while leftover water collected at the bottom is recycled (left) and Screening of drip laterals (right) (Source: lifegate.com and journals.ashs.org).

Although drip irrigation system is efficient to save water use, there is one big issue still remains. Drip irrigation has significant barriers to adoption by small farmers in developing countries. These include high initial system costs (especially if most components are imported), the need for relatively clean water, and the tendency for emitters to clog with contaminants such as dissolved iron.

2.12 Agroforestry

2.12.1 Introduction

Agroforestry has the potential to contribute to both climate change mitigation and adaptation by sequestering carbon and enhancing resilience. To provide the services needed to combat weather extremes and other climate change associated impacts, agroforestry ought to be practiced proactively.

Agroforestry can also be defined as a dynamic, ecologically based natural resource management system that, through the integration of trees on farms and in agricultural landscapes or through the production of agricultural products in forests, diversifies and sustains production for increased economic, social and environmental benefits for land users (FAO, 2016).

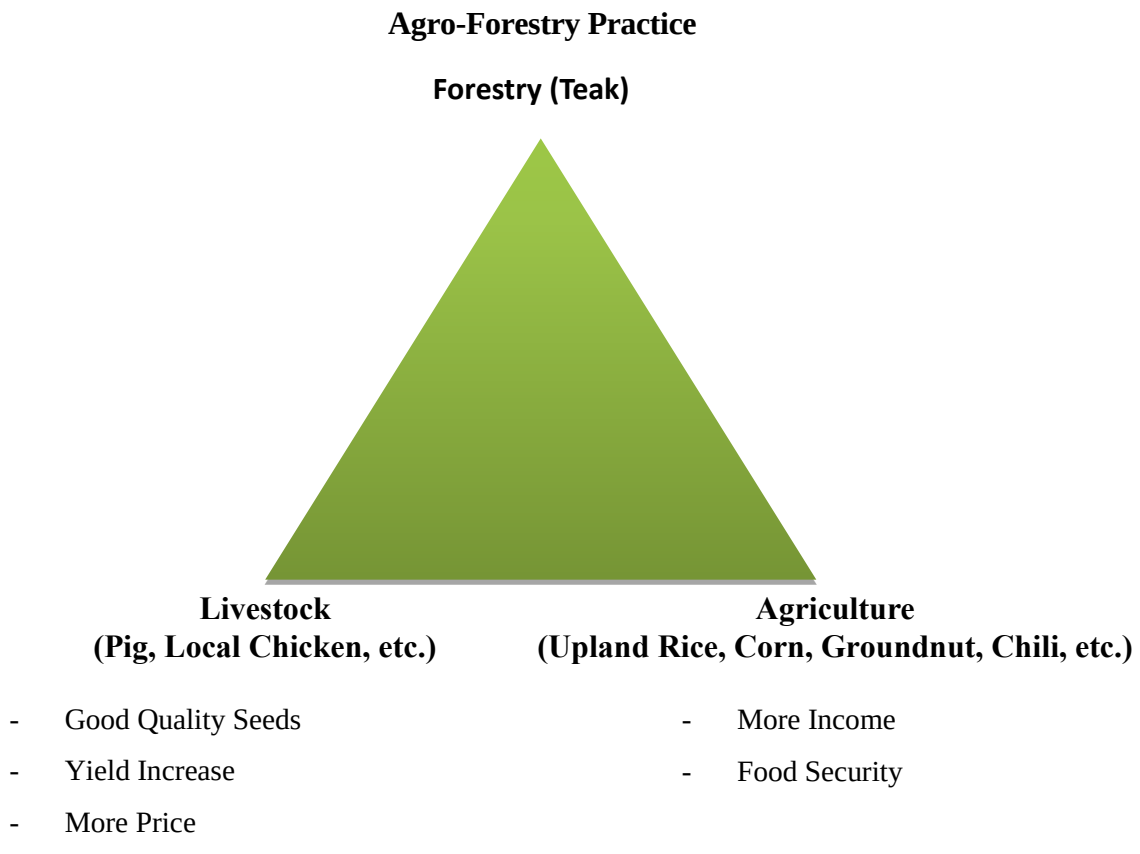


Fig. 2.40 A simple model of agroforestry.

2.12.2 History of agroforestry in Myanmar

Agroforestry has existed in Myanmar over centuries. The first advent was seen with the "Taungya" system of shifting cultivation, a forerunner to agroforestry. The word is reported to have originated in Myanmar and means hill (Taung) cultivation (ya). It was subsequently used to describe the afforestation method in Myanmar.

In 1856, when Dietrich Brandis was in Myanmar, he realized the detrimental effect of shifting cultivation on the management of timber resources and encouraged the practice of "Regeneration of Teak" (*Tectona grandis*) with the assistance of "Taungya", which involved the cultivation of agricultural crops in forests. Two decades later, the system proved to be so efficient that teak plantations were established at very low costs. In 1890s, the concept was then introduced from Myanmar to Chittagong and Bengal areas in colonial India. The "Taungya" system is often cited as a popular and mostly successful agroforestry approach to establishing forest plantations in Myanmar.

There are various kinds of agroforestry practices: agro-silvicultural, silvopastoral and agro-silvopastural commonly practiced. The country also features diverse ecological zones where agroforestry can certain play a vital role, from the dry central area through the extremely long (and vulnerable) coastline to high mountain ranges.

2.12.3 Concepts and principles of agroforestry

Agroforestry is distinguished from traditional forestry by having the additional aspect of a closely associated agricultural or forage crop. Agroforestry systems and practices vary with the needs of different farmers, and outcomes may also differ considerably, depending on the conditions under which agroforestry is practiced.

To be called agroforestry, a land-use practice must satisfy four key criteria—the 4 I's (Gold, et al., 2013):

- **Intentional**. Combinations of trees, crops and/or animals are intentionally designed and managed as a whole unit rather than as individual elements in order to yield multiple products and benefits;
- **Intensive**. Agroforestry practices are intensively managed to maintain their productive and protective functions. These practices often involve annual operations such as weeding, cultivation, pruning, pollarding and fertilization;

- **Interactive**. The biological and physical interactions between the tree, crop and animal components are actively manipulated to yield multiple products and benefits; and
- **Integrated**. The tree, crop and/or animal components are structurally and functionally combined into a single integrated management unit. Integration may be horizontal or vertical, and above or below ground, either sequentially or simultaneously.

The economic benefits include the reduction of agricultural inputs, especially when using leguminous species which fix nitrogen to improve soil fertility. At the same time, this maintains or increases production and may diversify production in farming systems, for example, food, fodder, lumber, building materials and wood fuel.

The social benefits include improvements to the health and nutrition of the rural poor. The on-farm production of several products, often collected from off-farm sources, can reduce the time and effort needed to obtain them, often lessening the burden on women or generating money if the products can be sold.

The environmental benefits may include a range of environmental services such as improving soil fertility, minimizing soil erosion, giving crops and livestock protection from the wind, restoring degraded lands, and water conservation. If properly designed and managed, agroforestry systems can also contribute to biodiversity conservation and climate change adaptation and mitigation. However, if not done properly, agroforestry can cause decreases in production because of competition among trees and crops.

2.12.4 Different types of agroforestry

The practice of agroforestry can be divided as different systems based on their nature as follows:

1. **Hillside systems** - This is more or less similar to slash and burn subsistence agriculture. Due to heavy seasonal floods, the exposed soil is washed away, leaving the now infertile barren soil exposed to the arid drought season. Farmed hillside sites had to be abandoned after several years and new forest was burned.
2. **Parkland** - Parklands are visually defined by the presence of trees widely scattered over a large agricultural plot or pasture. The trees are usually of a single species with clear regional favorites. Among the beaks and benefits, the trees offer shade to grazing

animals, protect crops against strong wind bursts, provide tree pruning for firewood, and are a roost for insect or rodent-eating birds.

3. **Shade systems** - With shade applications, crops are purposely raised under tree canopies and within the resulting shady environment. For most uses, the understory crops are shade tolerant or the over-story trees have fairly open canopies. A conspicuous example is shade-grown coffee.
4. **Alley cropping or Strip cropping** - With alley cropping, crop strips alternate with rows of closely spaced tree or hedge species. Normally, the trees are pruned before planting the crop. The cut leafy material is spread over the crop area to provide nutrients for the crop. In addition to nutrients, the hedges serve as windbreaks and eliminate soil erosion.
5. **Taungya** - It is a vastly used system originating in Myanmar. In the initial stages of an orchard or tree plantation, the trees are small and widely spaced. The free space between the newly planted trees can accommodate a seasonal crop. Instead of costly weeding, the underutilized area provides an additional output and income. In more complex taungya system, a series of crops are planted between-tree space. The crops become more shade resistant as the tree canopies grow and the amount of sunlight reaching the ground declines. If a plantation is thinned in the latter stages, more space will be available for growing crops.

Fig. 2. 41 Some types of agroforestry: parkland (left) (Source: lift.fund.org) and shade system (right) (© Myint Thaung).

2.12.5 Agroforestry and ecosystems

It also enhances ecosystems storing carbon, preventing deforestation, increasing biodiversity, protecting water and reducing erosion. In addition, when applied strategically on a large scale, enables agricultural lands to withstand weather events, such as floods and climate change.

For agroforestry to succeed it must make economic sense – a business model that works for all stakeholders. Shifting cultivation is a practice of clearing forests for the cultivation of crops. After harvesting the crop, the land is left fallow for over 10 years, allowing the forest to re-grow. Declining land sizes has however made the practice unsustainable. Villagers now clear forests permanently to establish sugarcane or rubber plantations. Agroforestry, which is an integration of livestock and crop farming, is seen as a better more sustainable alternative.

Agroforestry – the integration of trees and shrubs with crops and livestock systems – have a strong potential in addressing the problems of food insecurity in developing countries. Done well, it allows producers to make the best use of their land, can boost field crop yields, diversify income and increase resilience to climate change.
A National Agroforestry Strategy and Action Plan is urgently needed for landscape restoration and livelihood development from mountains to the coast in Myanmar.

2.12.6 Agroforestry contributions to CSA

Agroforestry increases productivity, farm livelihoods and food security

Agroforestry enhances the nutrient retention and cycling in the agroecosystem through the practice of mulching, in particular with N-fixing tree species. While under slash-and-burn cultivation soils are exhausted after three to four harvests and plots return to fallow, the increase in soil fertility under agroforestry allows each plot to be cultivated for a period of more than ten years, if properly managed, while delivering increased yields at the plot level.

At the level of the entire farm, agroforestry increases land productivity due to the extended cultivation period of single plots and the reduced area of fallows. This increased land productivity enhances the provision of basic grains for smallholder households, reduces the production risk and improves their food security. Potential yield surplus can be sold on the market to generate income as well as tree products from the agroforestry plots, such as fruit and timber. In order to capitalize on the increased yields, it is important to ensure that

appropriate grain storage facilities are in place that allow farmers to sell surplus when prices are favourable. The trees can also provide forage for livestock and firewood for household consumption. Despite the relatively high labour requirement for the establishment of plots, agroforestry also requires less labour on average **(**Schnetzer, 2018).

Agroforestry helps adapt to and increase resilience to climate change impacts

Tree canopies have the direct benefits of reducing soil temperature for crops planted underneath and reducing runoff velocities caused by heavy rainfall. Healthy and diverse ecosystems are more resilient to most natural hazards. Trees on farms can be used as shelterbelts or windbreaks and play an important role in protecting against landslides and floods. Agroforestry also helps restore and protect ecosystem services related to soils and watersheds due to improved management systems and better management of biomass, including crop residues (FAO, 2010).

The permanent soil cover results in increased water infiltration into the soils and provides protection of the soil surface, thereby reducing the generation of surface runoff and the erosion of soil. The improvements of soil quality under agroforestry in terms of organic matter content and porosity lead to a higher water retention capacity. This in combination with higher infiltration rates allows to reach higher soil moisture levels which increases the resilience to prolonged dry spells and drought. In both extreme climatic events agroforestry proved its worth allowing farmers to harvest surpluses by mitigating impacts and increasing crop resilience.

Forests facilitate primary production, nutrient cycling, soil formation and the provision of ecosystem goods, such as non-timber forest products, food and fuel. Therefore, for forest activities to support CSA, adaptation actions targeted particularly at the most vulnerable communities and sectors of the population (e.g., women, children, the elderly, indigenous populations) and forested ecosystems (e.g., woodlands, mountains, wetlands) are required to focus on the most efficient and cost-effective adaptation options, in addition to capitalising on adaptation-mitigation synergies. These options should focus on sustainable forest management and/or agroforestry.

Agroforestry mitigates greenhouse gas emissions and capture carbon

By abandoning the practice of clearing land of vegetation by fire, considerable amounts of GHG emissions can be avoided. The total global warming potential for agroforestry, including abandoning burning, GHG fluxes between soil and atmosphere, and changes of carbon stocks in soil and vegetation, was estimated to be four times lower than for slash-and-burn.

Table. 2.10 Forest-related adaptation strategies for selected climate change impacts

Climate change impact	Adaptation strategy
Increased risk of fire due to higher frequency of heat waves and expansion of areas affected by drought.	Forest fire protection: fire guards, fire awareness etc.; Reduce deforestation and degradation which open up the forest, decreasing shade and humidity, exacerbating local climate variation, and increasing drought, land degradation and susceptibility to fires.
Erratic rainfall.	Protection of land from flooding and erosion; Rainwater harvesting techniques; Use of hydrogel during tree planting in dry season.
Extreme weather events, e.g., droughts and floods.	Tree planting/agroforestry, watershed management, risk management plans.
Regulation of water flow and water quality.	Protection of stream banks and catchment areas to improve water quality and quantity. Forest ecosystems store water, regulate base flows, mitigate floods and reduce runoff, erosion and sedimentation.
Reduced agricultural yields.	Sustainable forest management, as the rural poor increase their collection of wild foods and other products from the forest. Agroforestry.
Outbreaks of pests and diseases.	Selection of resistant tree and crop species.

(Source: CSA Manual, 2017).

2.13 Sloping Agricultural land Technology (SALT)

2.13.1 Introduction

Much of the land now under cultivation in Asia has been classified as degraded or as having undergone moderate-to-severe erosion. According to FAO, many Asian countries now have 20% or more of their lands considered degraded," with some countries approaching 50%

(MBRLC, 2012). In the early 1970s, in response to poor yields caused by severe soil erosion on hillside farms in the Philippines, 'Sloping Agricultural Land Technology' (SALT) was developed.

SALT is a system in which dense hedgerows of fast growing perennial nitrogen-fixing tree or shrub species are planted along contour lines thus creating a living barrier that traps sediments and gradually transforms the sloping land to terraced land. Farmers can use any leguminous trees and shrubs found on their farms. When a hedge is 1.5 to 2 m tall, it is cut back to a height of 40cm and the cut branches are placed in the alleys between the hedgerows to serve as mulch for conserving moisture and as organic fertilizer (green manure). The hedgerows markedly reduce soil erosion and contribute to improving and/or maintaining soil fertility by acting as a source of organic matter.

Rows of permanent crops such as coffee, cacao, citrus and banana can be dispersed throughout the farm plot. The alleys not occupied by permanent crops are planted on a rotating basis with cereals or other crops and legumes (e.g. mung bean, soybean, peanut, etc.). This cyclical cropping helps maintain soil fertility and provides the farmer with several harvests throughout the year.

There are several forms of SALT and various forms of SALT farming systems are briefly outlined below (see MBRLC for more information).

SALT 2 (Simple Agro-Livestock Land Technology) is a small, livestock-based agroforestry system (preferably with dairy goats) and has a land use of 40% for agriculture, 20% for forestry and 40% for livestock. Hedgerows of different nitrogen fixing trees and shrubs are established on the contour lines. The manure from the animals is utilized as fertilizer both for food and forage crops.

SALT 3 (Sustainable Agroforest Land Technology) is a cropping system in which a farmer can incorporate food production, fruit production and forest trees that can be marketed.

SALT 4 (Small Agrofruit Livelihood Technology) is based on a half-hectare piece of sloping land with two-thirds of it developed in fruit trees and one-third intended for food crops. Hedgerows of different nitrogen-fiing trees and shrubs are planted along the contours of the farm.

The underlying objectives of the system are to:

- control soil erosion;
- help restore soil structure and fertility;
- be efficient in food crop production;
- be easily duplicated by upland farmers using local resources and without the need for external loans;
- be culturally acceptable;
- be fully productive in as short a time as possible;
- require minimal labour;
- be economically feasible and ecologically sound.

2.13.2 The ten steps of SALT

Step 1: Make an A-frame

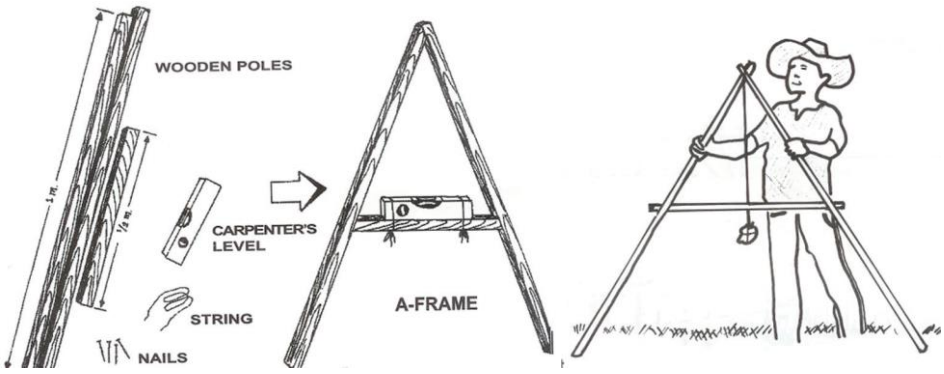


Figure 2.42: Assembly and use of an A-frame (left). The rock-and-string variation (right).

Step 2: Locate and mark the contour lines

Step 3: Prepare the contour lines

Step 4: Plant seeds of nitrogen-fixing trees and shrubs (NFTS)

Step 5: Cultivate alternate strips

Step 6: Plant permanent crops

Step 7: Plant short- and medium-term crops

Step 8: Regularly trim the NFTS

Step 9: Practice crop rotation

Step 10: Build and maintain green terraces

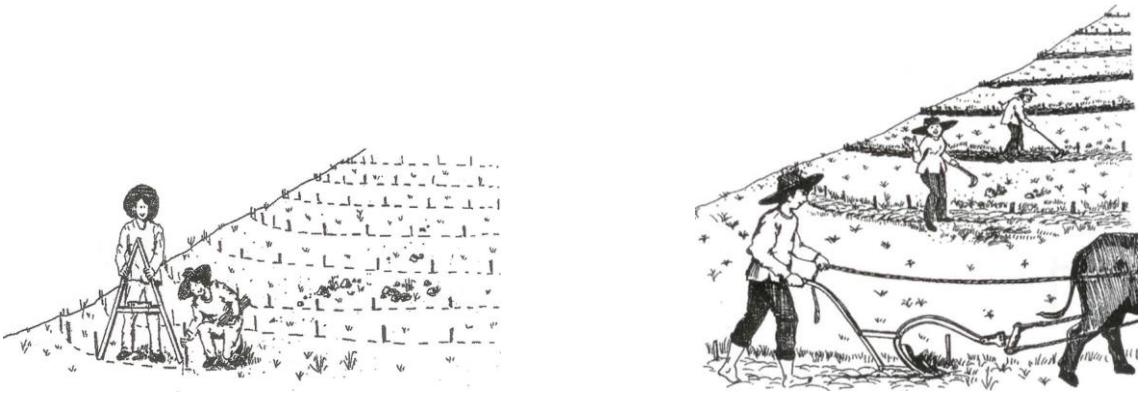


Fig. 2.43: Laying out a contour line. (left) Plowing contour lines on a hillside (right)

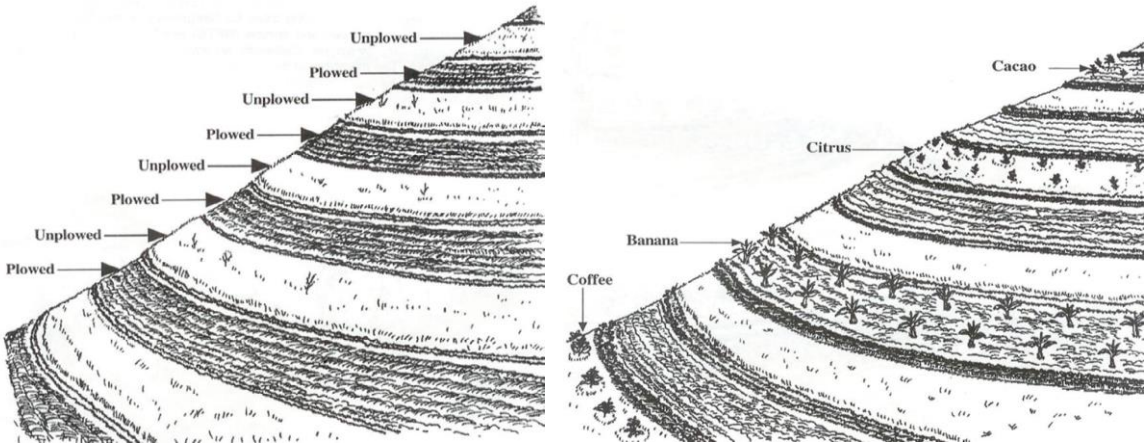


Fig. 2.44: Alternating plowed and unplowed strips (left); Permanent crops planted in every third strip (right).

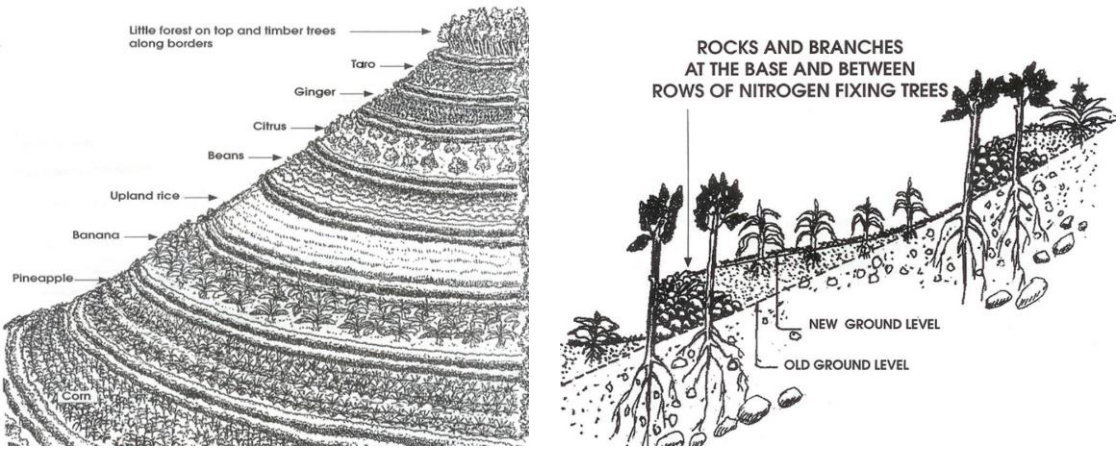


Fig. 2.45 Strips of short- and medium-term plants, in between strips of long-term crops in SALT (left). Build-up of terraces over time with the SALT system (right).

(*Source: ECHO's technical Note # 72: Sloping Land Agricultural Technology- How to Farm Hilly Land without Losing Soil).

Conclusion

SALT is not a miracle farming system or a panacea for all the upland problems. To establish a 1 ha SALT farm requires much hard work and discipline–there is no easy way. It takes 3-10 years to deplete the soil of nutrients and to lose the topsoil; no system can bring depleted, eroded soil back into production in a few short years. Soil loss leads to low yields and poverty, but land can be restored to a reasonable level of productivity by using SALT.

2.14 Community forest in Myanmar

Of Myanmar's 67.6 m ha land area, forests currently cover around 48%, although there has been a declining trend for the last century (they covered over 65% early in the 20th Century). The declining trend is particularly dramatic for dense forests, which have more than halved in the last 20 years, from covering 45.6% of land in 1990, the single largest land use, to now just 19.9%. Between 1990 and 2010, Myanmar lost an average of 372,250 ha or 0.95% per year. In total, between 1990 and 2010, Myanmar lost 19.0% of its forest cover, or around 7,445,000 ha. (Kyaw Tint et al., 2011).

The long -term decline in forests, is due to a combination of factors: change of land use (especially land hunger from the growing population), commercial timber harvesting (and the indirect effect of increasing accessibility through road construction), and also intensifying pressure on remaining forests for livelihood needs especially, fuel wood.

Returning control of the management rights and responsibilities for village forests to the villages is seen by policy makers as critically important in the 1990s both to mobilise communities to protect and regenerate adjacent forests, and also to ensure that they fulfill their forest product needs locally. Hence, the Community Forestry Instruction (CFI) was issued in 1995, and initiated the promotion of Community Forestry in Myanmar in collaboration with UNDP, JICA, and DFID projects. Implementation received a major boost through the Forestry Master Plan (2001) which mandated that 2.27 mil. acres (1.36% of the country) be handed over to FUGs by 2030-31.

Aims of CF were: (1) to regain environmental stability, (2) to address basic needs for the local communities, (3) to acquire the active participation of rural population in forest restoration and conservation, and (4) to support the economic development of the country.

Community Forests gives the basic need of the community and contributes to the protection of soil, water catchments, ecosystem and biodiversity. Global climate changes affect the livelihood of local community but wild food remains of great importance for food security not only for indigenous peoples but also for all communities. Communities perceive that the resources and availability of wild food became increasing and also availability of wild food products.

Fig 2.46 Community forest of Wine Maw Township (© Forest Department).

Annual progress of Community Forest establishment since 1995 had averaged 6,943 acres (2,810 ha), and there are now 572 Forest Users Groups with certificates, managing 104,146 acres of forest, (with more awaiting their certificate). Implementation progress has been highest in Shan, Rakhine, Magway and Mandalay, most of which have been under UNDP project support.

Fig 2. 47 Kahnyin Chaung Villagers and Forest Department officials with the notice for the 508-acre community forest (left) (© Nyi Tu, Global New light of Myanmar) and growing trees for community forest in dry zone (right) (©Forest Department).

Community forest in dry zone

Total area under the community forest in dry zone is presented in table 2.11 below. Tree species planted in community forest for fuel-wood plantation are catechu (Sha) - *Acacia catechu*, rain tree (Kokko) - *Albizia lebbek*, neem (Tamar) - *Azadirachta indica* , lead tree (Bawzakaing) - *Leucaena leucocephala* and j*ujube tree (*Zi) - *Ziziphus jujuba* **.** All of these tree species are providing fire wood for the rural community.

Table 2.11 Community forest establishment in Dry Zone.

Sr.	Region	CF Area (Ac)	No. of User Group	No. of User Group Member
1	Sagaing	6093.87	95	5,410
2	Magway	6404.83	63	280
3	Mandalay	3934.76	24	572
	Total	**16433.46**	**182**	**6,262**

Source: Department of Forestry (Dec, 2013)

Fig 2.48 Community forests are useful as a source of firewood for the rural community (Source: thecvf.org).

Across almost all CF sites, improvement of "ecosystem services" has been observed e.g. water supply, soil condition and biodiversity habitat. One of the most dramatic ecosystem services has been storm protection in the delta region: in one site the regeneration of the community forest seems to have been the decisive factor in protecting the lives of villagers when cyclone Nargis hit in 2008. Communities are thus significantly contributing to the national re-greening objectives enshrined in the CF Instructions.

3. SYSTEM APPROACHES

3.1 Landscape management

3.1. 1 Introduction

Climate-smart agriculture interventions must address more than a few technologies, farming techniques, or social issues. To achieve good outcomes, practitioners must take a "systems approach" to CSA that looks at development through economic, environmental and social lenses. Climate-smart agriculture (CSA) goes beyond new technologies and practices like drought resistant varieties or precision farming. To achieve the multiple objectives of productivity and food security, enhanced farmer resilience and reduced greenhouse gas emissions, CSA must adopt various systems perspectives. These include landscapes and ecosystems, as well as value chains. From the systems perspective, it is important to pursue synergies between the different elements of the system, analyze and address trade-offs, and perform cost and benefits analysis.

Landscapes include forests, valleys, mountains, rivers, the sea, agricultural land, human settlements, and so on. It is a place-based system that resulted from interactions between people, land, laws, rules, regulations, and values. A common definition by the Food and Agriculture Organization of the United Nations (FAO) states that landscapes are “an area large enough to produce vital ecosystem services, but small enough to be managed by the people using the land which produces those services. Landscapes should not be confused with ecosystems, as a landscape can contain various ecosystems, and human activities and institutions are viewed as an integral part of landscapes and not as external agents.

Landscape approaches integrate sustainable management of ecosystems and natural resources with livelihood considerations. In other words, landscapes are multifunctional system approaches, providing benefits and services for a wide range of ecosystem processes, species and social actors. Landscape approaches seek to understand the different elements and related interests in the landscape (e.g. water resources, agricultural production, biodiversity conservation and forest management) and their interdependencies. The main reason for applying landscape approaches is to move away from narrow sectoral approaches with uncoordinated and competing land uses, to integrated planning and management where the multiple interests of stakeholders are considered, synergies identified and trade-off among

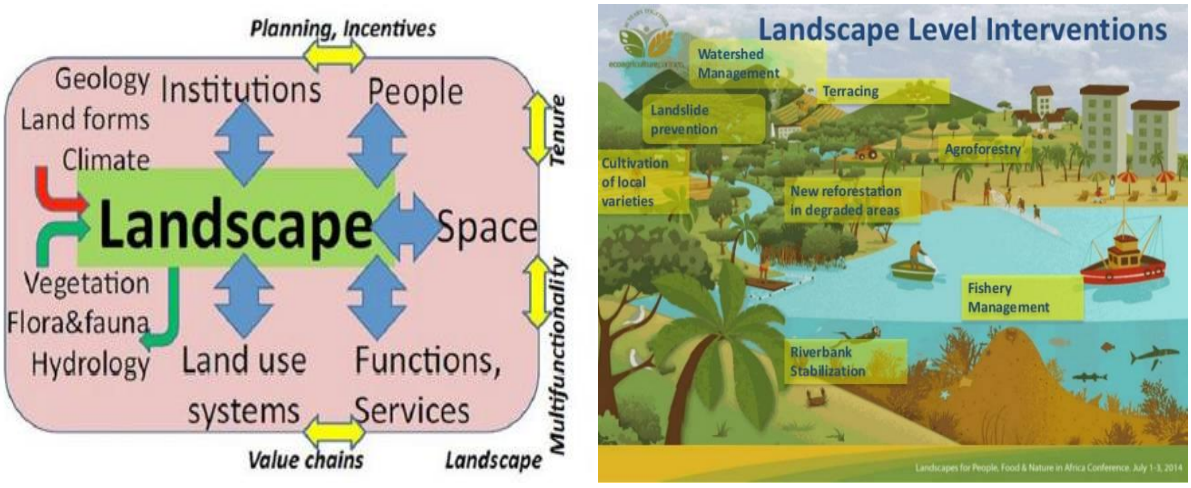


Fig.3.1 Landscape as interaction between human actions, ecosystems and the abiotic factors that shape the physical environment (Minang *et al.*, 2015; Scherr, 2013).

different uses negotiated. Landscape approaches include integrated watershed and river basin management, sustainable landscape approaches, ecosystem approaches, integrated crop-livestock management, agroforestry, sustainable fisheries management, sustainable forest management, and improved rangeland management.

3.1.2 Managing landscape for climate smart agriculture system

Different landscapes require different approaches, depending on the state and nature of the resources, land use dynamics, and social and economic contexts.

- Managing agriculture, forestry and fisheries at a landscape scale is key to achieving sustainable development.
- Appropriate land-use planning and decision making at the landscape level should be based on a participatory, consensus-based and people-centred approach.
- Production sectors are often managed in isolation from each other and this can be counterproductive. Coordination at the landscape level facilitates the integrated management of production systems and the natural resources that underpin ecosystem services needed for all sectors. Climate-smart agriculture (CSA), which follows a landscape approach, can address the challenges involved in inter-sectoral natural resources management.
- Measuring and monitoring the multiple benefits of climate-smart landscapes is essential for tracking the impact of inter-sectoral efforts.

- Scaling up CSA and moving from pilot projects to large-scale programme and policies by applying a landscape approach requires a diverse range of strategies and practices. It is important to create awareness and partnerships between sectors, mainstream CSA into policies and build capacities at all levels. These activities must be supported by an enabling policy and market environment.

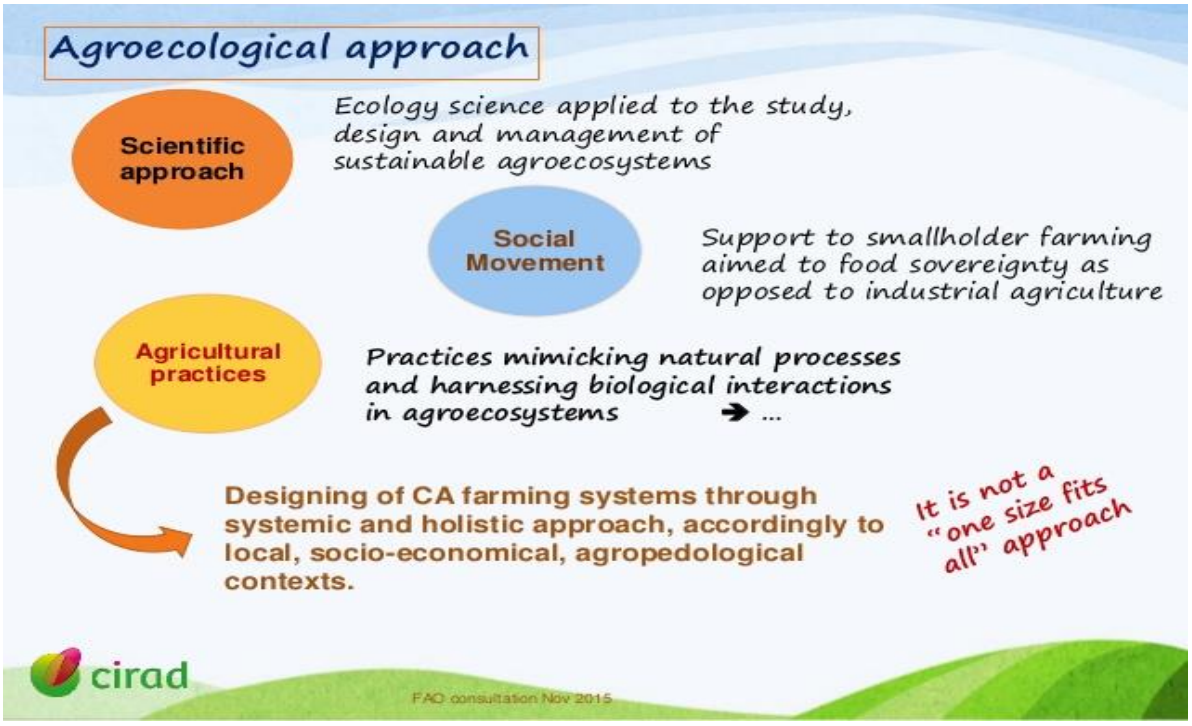


Fig. 3.2 A conceptual framework of an agroecological approach (©Enjalric and Hainzelin, 2014).

3.1.3 Contribution to CSA

From a climate-smart agriculture (CSA) perspective, the main objective of a landscape approach is to enhance the synergies between CSA and the ecosystem services, by sustaining the environment, including the air, water, food and materials. The diversity and outcome of desirable landscape interventions are likely to be related to all three pillars of CSA: productivity, adaptation, and mitigation.

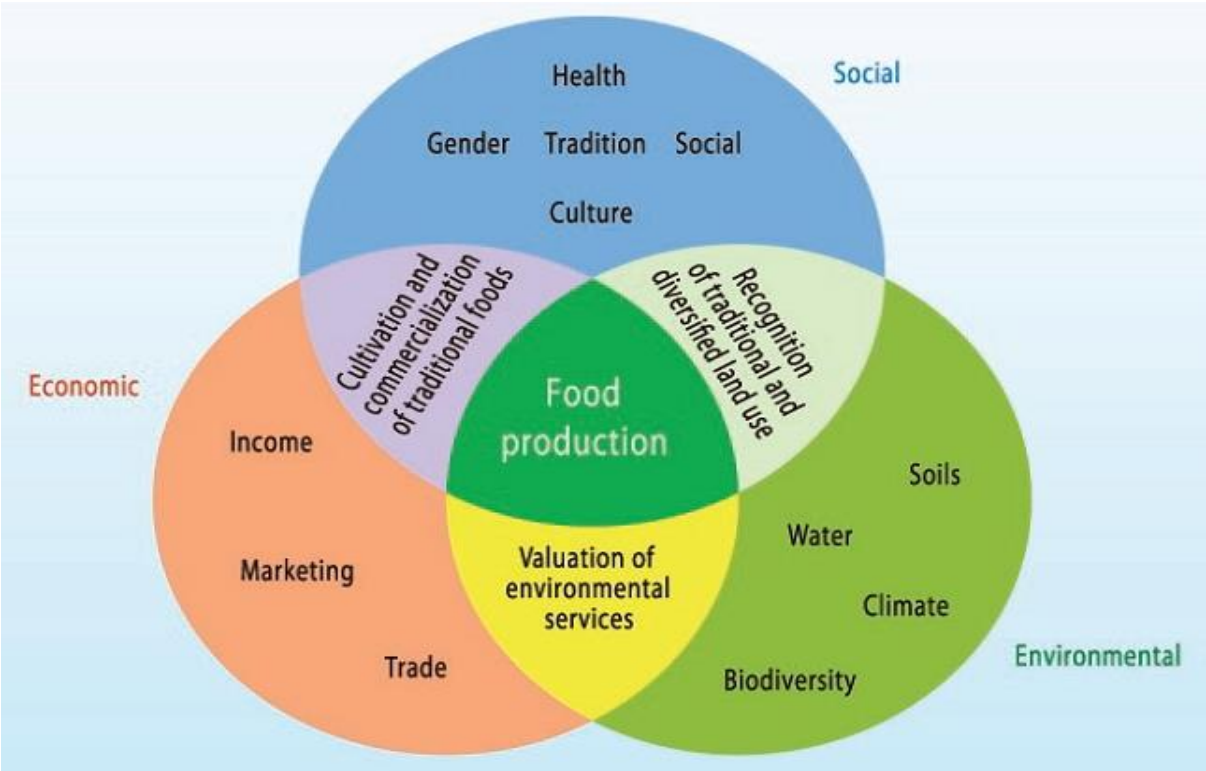


Figure 3.3 The framework of agroecosystem approach

(Source URL:https://www.groundswellinternational.org/approach/agroecological-farming/).

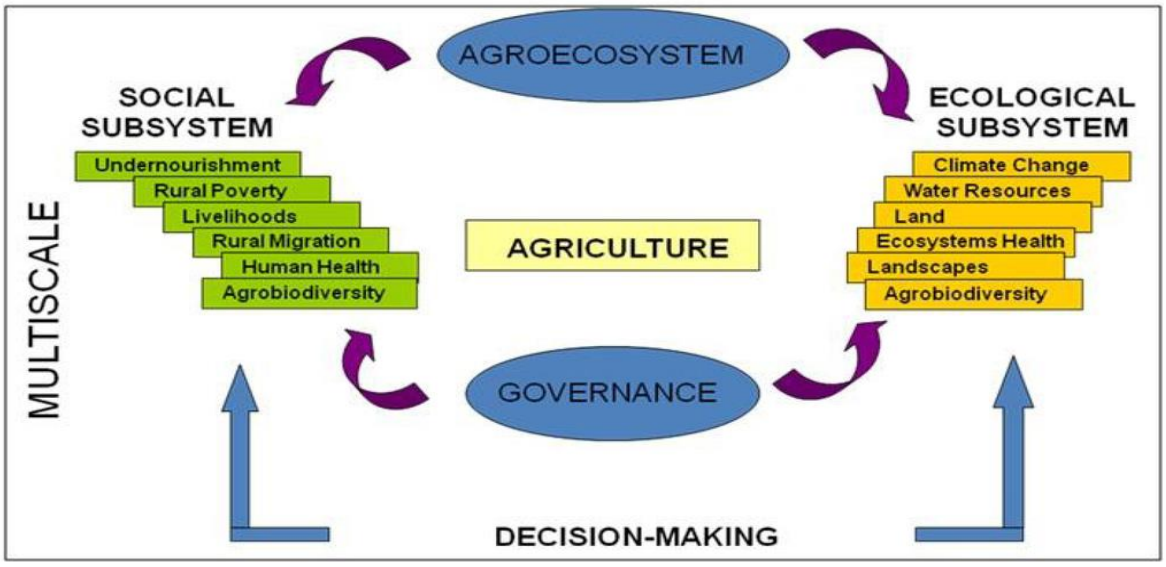


Figure 3.4 The relationship in system (landscape) management (Rivera-Ferre *et al.*, 2013).

Productivity

A landscape level approach enhances field level productivity because it maintains ecosystems service and creates synergies between differed production systems. For example, landscapes may harbor pest predators or beneficial insects, increase or stabilize pollination services or help to improve the timing and flow of water. At the same time, mixed crop, livestock and agroforestry systems can be complementary and mutual beneficial.

Adaptation

A diversity of land uses and species as well as genetic diversity across the landscape can reduce risks (pests, diseases and climate events). Moreover, a more diversified portfolio of food and income sources can act as a buffer against climatic (and other) shocks.

Mitigation

More diversified systems embedded in a broader landscape approach with increased focus on perennial crops, grasslands, woodland, forest and wetland is an effective way to reduce greenhouse gas (GHG) emission and promote carbon sequestration.

Conclusion

A systems approach is needed to understand and manage a 'farm'. This defines the concepts of farm systems, their structure, operation and management, the relationships among internal and external factors, response to changing circumstances, and modifications to deal with change. Study of a system requires definition of goals and objectives, boundaries and the structure and function of its components. Feedback mechanisms and interactions are important features of farm system structure and operation. Farm systems can often be better understood through analysis and the study of their sub-systems; and circle or problem-cause diagrams can assist this. Farmers design their systems to make best use of the prevailing climate and soil, but a wide range of technological, commercial, social, political and personal factors determine farmers' goals and management. Important characteristics of systems include productivity, profitability, efficiency, stability, sustainability, equity, flexibility, adaptability and resilience. Efficiency of resource use should be optimized. In addition, efficient use of energy and water are necessary for profitable production.

3.2 Value Chains

The conceptual framework of agricultural value chains includes a sequence of value adding activities, from production to consumption, through processing and marketing. Each segment of a chain has one or more backward and forward linkages. A value chain in agriculture identifies the set of actors and activities that bring a basic agricultural product from production in the field to final consumption, where at each stage value is added to the product.

Growth and development of agricultural value chains for local and external markets can be considered as a powerful tool for poverty reduction and to fight against the challenge of food-security in developing countries. Myanmar relies on agriculture as the backbone of its economy and the sector brings around one-third of country's gross domestic product (GDP) annually. The agriculture sector employs 70 per cent of the labour force in the country (MOALI, 2016). Therefore, promoting agriculture value chains is an important part of the agenda in Myanmar's agriculture development.

3.2.1 Rice Value Chain

The rice ecosystems of Myanmar include irrigated lowland, rain fed lowland, deep-water, and upland. The rain fed lowland area is the largest of total rice land. Rain fed lowland and deep-water rice cultivation is seen in the delta region and coastal strip of Rakhine State. Irrigated lowlands are mainly in Mandalay, Sagaing, and Bago divisions. The upland area is mostly in Mandalay, Sagaing, and Shan states. Planting season starts in June-August for the monsoon paddy which is harvested in November-January while the summer paddy is from November-December to April-May.

Export price of Myanmar rice is now much lower than in other export countries such as Thailand and Vietnam because of poor quality. Infestation of storage pests such as rice weevils, color and deteriorations due to improper post-harvest practices caused rejection to import by some countries from Europe and Middle East.

3.2.2 Actors along the Value Chain

Rice Value Chain Map

In the rice value chain, there are a number of actors involved such as input suppliers, local farmers, paddy brokers/traders (millers), millers, rice wholesalers and retailers. The structure of the rice value chain map is shown in figure 3.5.

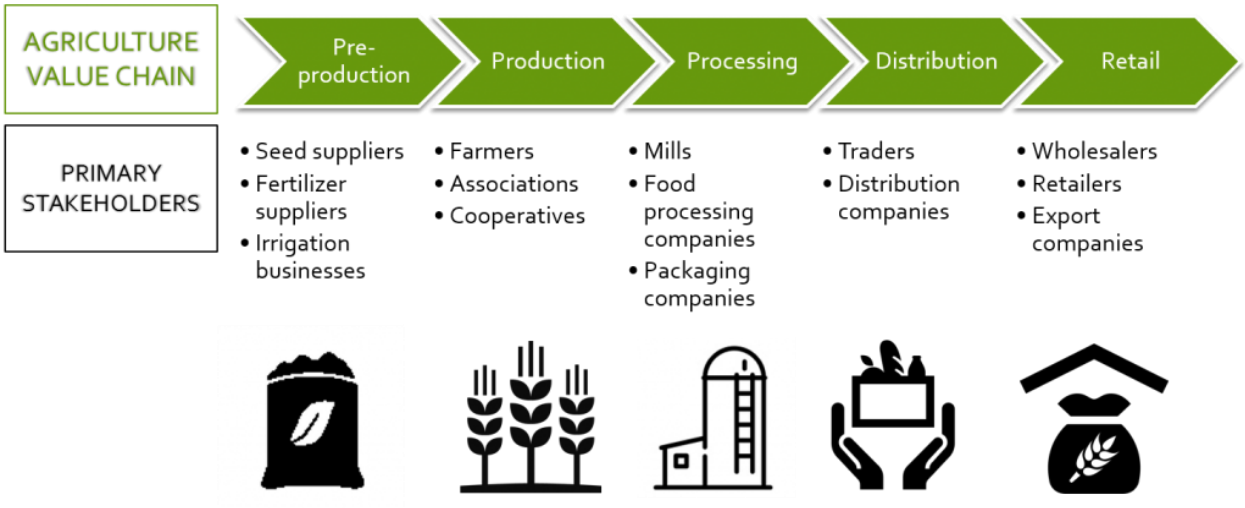


Fig. 3.5 Stakeholders involved in rice value chain.

Input Suppliers

The major agro inputs used in rice production are chemical fertilizers, bio-fertilizers, pesticides, tractors, threshing machines and fuel oil for machines. There are many agrochemical companies and distributors across the country. Farmers use the fertilizers about 15% of the total production cost.

Farmers

Farming Practices: According to the growing pattern, farmers mainly grow in monsoon season as rain fed crop and summer rice where irrigation water is available. The averaged farm size is about 2 hectare for the majority of farmers. Transplanting method is mostly practiced by many farmers but direct seeding may be done to overcome labour shortage. Some farmers use the pre-owned seed, while others procure from nearby villages and Department of Agriculture. Most of the farmers store the seeds in regular bags, granaries and round bamboo baskets. They use to determine the quality seeds for the main characters as the same size of seeds; free from off type; good germination percentage; and free from seed borne diseases.

Most of the farmers sometimes change the seeds due to seeds renewal and better variety. They understood well the results of use of poor quality seeds due to the conditions of off type occur, poor germination rate, and reduce the yield. Depending on the use of inputs, cost of cultivation ranged between 200,000 and 350, 000 Kyats per acre.

Yield: Paddy yield may differ (40 to >100 baskets per acre) depending on soil types and availability of using fertilizers (Chemical and FYM). Drying after harvest to reduce to the required moisture content may be sometimes problem as the rain occurs by that time. That may affect the quality of rice.

Farmers' Marketing: According to the producers' level interviews, the quality of rice is low to medium due to rain during harvesting period and lack of investment for paddy drying facilities. This is leading to low to medium price range. Currently, rice production is enough for the local consumption and willing to demand high quality of rice. It must try to get good quality paddy and produce high quality rice to increase locally exported rice in the future.

Paddy Traders

Millers mainly serve as paddy traders to get good quality paddy by checking themselves because of the small scale miller type and using small scale capacity. They mostly buy paddy from within village and nearby villages. Traders give current market price after checking good quality output rice. Quality specification in buying paddy is generally defined by low moisture content (well dried), low impurity, low inert materials, low grain color distortion, etc. Price difference between good and poor quality is quite low, less than 25% (1000-1200 kyat/basket) and thus farmers have low incentive to keep their products' quality. Traders give the transportation cost from farm gate to miller.

Millers

There are two type of millers based on their size of business as small mills and commercial (large) mills. In the villages, there are some small mills with milling capacities from 10 to 20 baskets per hour and thus it can be run by family labour and about 1-2 hired labour. Whereas, there are some private commercial mills with high capacity situated at some strategic places and use rice-husk and electricity as the power source. The owners of rice mills collect the required amount of quality paddy themselves. Negotiation on the price is made according to the quality, and quantity. Payment methods may vary such as by means of advanced payment system, cash down payment system or 50% cash down and giving back after selling.

Milling out-turn (recovery) varies according to the difference in varieties, unfilled grain percent, etc. Regarding to the quality of rice, it is classified as special, average quality and low quality rice according to the market demand. Millers sell milled rice mostly to village retailers and wholesalers with cash down payment system or 50% cash down and giving back after selling.

Township Wholesalers: Rice millers send the processing rice to the end markets for wholesalers and/or retailers in township market who are always contacted for their business in long term. The end market price of domestic rice depends on the price of millers selling price, quality differences and quantity bought by the consumers. Farmers who are insufficient for their home consumptions and non-farmers households from rural areas buy from these shops. Cash down payment system is used for wholesalers. Depending on the market demand, the wholesalers order by phone to the village millers. They always contact for market information.

When the better rice quality is demanded, the wholesalers contact with other wholesalers from regional market. So the wholesalers would import by car and cash down payment system is used.

Township Retailers: Retailers contact with village millers or township wholesalers. They take the required amount of rice from them and mainly used 50% cash down and giving back after selling payment system. They also have the connection with wholesalers from regional markets.

3.2.3 Value Chain Analysis of Rice

Price Changes along the Chain

The most considerable factor to study a value chain is price changes in each tier. Agricultural products' marketing is "risky" not only for traders and millers but also for farmers due to the price changes that governed by so many factors such as demanded quality and supply volume in local market, surplus of regional market, and price changes of the related commodities, policy issue and expected price of the future, etc.

Linking the Rice Value Chain

Linking the actors between the different channels is a very important issue to reach end market opportunity, either by the vertical linkages (coordination between different functional actors) or the horizontal linkages (relationships between actors within the same function).

Vertical Linkages

The relationships among the actors from input supply and distribution to the final market levels of the value chain are vertical linkages. It is critical for moving a product from inception to the market and for transferring benefits, learning and embedded technical, financial and business services. Among the vertically related firms, the mutually beneficial relationships can be improved by accessing to new markets, new skills and a wide range of services. This can reduce market risk by securing future sales and create incentives for the adoption of more value-added functions or activities. Vertical linkages of rice value chain were mainly observed within the local market and less related with regional and export market channels, but it still has limited coordination between actors at different levels.

Farmers (producers) get the price set by the owners of mill (traders) for paddy selling. Farmers have no connection with rice wholesalers and retailers in the villages and township levels. However, rice millers have connection with village retailers and/or township wholesalers who distribute the rice to township retailers. .

Due to the higher rice quality demand, township wholesalers contact with other regional wholesalers from rice surplus regions. Village rice millers and township wholesalers are well known about update market information from related wholesale markets and they have authorized to decide paddy buying price based on market information. Therefore, paddy farmers are governed by village rice millers or township wholesalers.

The main challenge for the farmers is to sell paddy of poor quality for which traders buy at discount prices based on claims of lower quality. When paddy quality is high, traders agree to give higher price without the claims. Therefore, these relationships show that village millers are the key actors in local market channel.

Due to the nature of paddy market flow and rice market flow, it is impossible for the farmers to meet with end buyers along the chain and no chance to know the requirement of market demand. The chains occur separately in paddy market flow, rice market flow in local market

channel and rice market flow from regional market to local market channel. It is still needed to recognize and work together to define common objectivities, share risks and benefits in the development of actors along the value chain.

Horizontal Linkages

The connection between the same levels is called horizontal linkages. In the producers' level, they known each other well but it is very rare to share their production and financial aspects. It is better to organize and develop Farmers Extension Group (FEG) and share the technologies via FFS approach.

Factors and Supporting Services

Extension and Training: Regarding paddy production development, Department of Agriculture (DoA) is pushing for education and extension services in Myanmar. But township team of DoA conducts only for the targeted zones and does not cover all villages to provide several extension activities in the study areas. It is very important to develop the basic knowledge of cultural practices, advanced production practices, pest and disease management, post-harvest technologies, etc.

Financial Services: Myanmar Agricultural Development Bank (MADB) is the only financial service supporting the paddy farmers from Government sector. Although farmers can get loan about 150.000 Kyats per acre up to 10 acres, it will not cover for the whole cost of cultivation. So they have to rely on money lender with high interest rate for the mortgage service and putting the gold as the collateral. A few farmers get loan from their traders without interest rates. Saving and micro-credit systems are not developed well in the area.

Transportation: The transportation system within local villages, from local villages to wholesale market is road transport or through the water way. The transportation cost may be higher due to the fuel price.

End Markets Opportunities

Currently there is not a potential for export market because the farmers put not much emphasis on the paddy quality due to the lack of harvesting and threshing facilities and driers for paddy.

If the farmers cannot produce demanded quality of paddy, it will consequently affect quality rice production and lead to locally import rice from regional channels. If the farmers could produce quality demanded paddy, benefits would be expected for all the actors from producers up to final consumers.

3.2.4 Major Constraints and Bottleneck along the Value Chain

Constraints in Production: Growers have the agricultural constraints from the production to the market. The growers are meeting the scarcity of labor in the study areas and other ones explained about unfavorable weather condition that could reflect to get higher quality products. However, some of the growers have the difficulties for the lack of capital for farm investment. Some farmers are meeting lack of the technology for planting systems and post-harvest technology. Some face pests and diseases problems and want to get more information about pests and diseases control methods. Some growers have no chance to access high yielding varieties for their farms, face lack of market access and receive lower market price for their products. Additionally, some farmers are facing soil and water related problems.

Constraints in Processing: It is still needed to develop processing system to produce the quality rice. In the village level, some small rice mills (Hula or Ngar Pon) are used to process the local paddy consumption. Village small millers have worst technology than commercial large millers and sometimes they have difficulties in getting maintenance services. They produce poor quality of rice and lower milling return and lower profits to the farmers.

Constraints in Marketing: Constraints for rice millers are difficulties in getting good quality and sufficient quantity of rice given the current poor quality of paddy. Large scale marketers would like to upgrade or use commercial large mills. Some growers have lack of market access and lower market price for their products.

Farmers know the price mainly from their neighbour or from the traders as the main source. However, the daily changes of the price are not available. Therefore, market information system and marketing knowledge will need to be developed among the paddy growers.

Constraints in Working Group Actions: The actors along the value chain face difficulties in organizing themselves in group. Some INGOs should organize community strengthening and capacity development and should establish FFS to share their knowledge and develop team building skill.

Lack of Transparency in the Chain: Growers generally feel that they are being exploited by the paddy traders because they cannot sell the rice to the wholesale market. This may be due to a lack of price transparency on the part of the paddy traders.

Constraints for Financial Service Providers: The limited supply of financial service providers relevant to farmers is a major constraint not only in the local area but also in the whole country.

Bottleneck along the Value Chain of Rice: According to the major constraints along the value chain and outlook of the rice industry, the bottleneck to develop the value chain is in "**production of high quality rice**". For this bottleneck, there is a need to provide the good quality seed, share seed multiplication training and demonstration plots via FFS approach, guide for effective fertilizer application methods, support harvesting and threshing related machines, small scale driers for paddy when the late monsoon rain occurs during harvesting period, post-harvest handling practices and apply contract farming system to sure market demand for quality products, provide suitable amount of loans and practice saving and credit system among the farmers, etc.

3.2.5 Recommendations

Recommendation for short term solutions include the distribution of suitable registered paddy seed, giving relevant trainings for rice production and processing and post-harvest handling, to create a farmer-center or FFS, to provide market information and financial support, etc.

Long-term solutions include developing commercial large mills, increased mechanization and mechanization services, setting small-scaled paddy driers in each cluster, to facilitate paddy growers to become members in MRIA, and strategic end-uses and by products (as championed by MAPCO or MRIA) to generate more value adding and facilitate transmission of better paddy prices back to farmers.

3.3 Harvesting & post-harvest management

3.3.1 Introduction

In some areas of Myanmar where the remaining soil moisture is high enough after harvesting monsoon paddy, farmers used to grow green gram or black gram which can fetch good prices. To catch up the remaining moisture, farmers leave sheaf of paddy on the bunds surrounding

the paddy field until the cultivation process of legume is finished. When untimely rain occurs by that time, the sheaf are soaked with rain water and consequently the quality of paddy and rice after threshing substantially deteriorates, the rice become discolored and stingy smell is detected and sometimes no longer suitable for human consumption. The price becomes drastically lower. As a result, the income of farmers suffers with great economic loss. In this case, the introduction of combine harvester or some other small farm machinery will help farmers to prepare the land for legumes and timely harvest and threshing of rice to get quality product. In some cases, farmers are using zero tillage, i.e. just cutting the stubble without plowing the field. In upper Myanmar, chick pea seeds are broadcasted in the paddy field before it is harvested. At the time of paddy harvest, the chick pea plants reach to a height of about six inches. Farmers are adopting climate smart agriculture without realizing that they are doing this. These practices can also solve the problem of labor shortage that farmers are facing across the country currently.

3.3.2 Small farm implements for moisture saving

Soil moisture is very important for crop cultivation starting from the land preparation to the final harvest of a crop to get a good growth and a better yield. It is more obvious for rain-fed crops especially in dry zone area where the rainfall is scarce. Drip irrigation and drip pipe, sprinkler irrigation and sprinkler nozzle, PVC buried water diffuser, plastic mulches, portable hand-hold tensiometer, etc. are commonly used to save water.

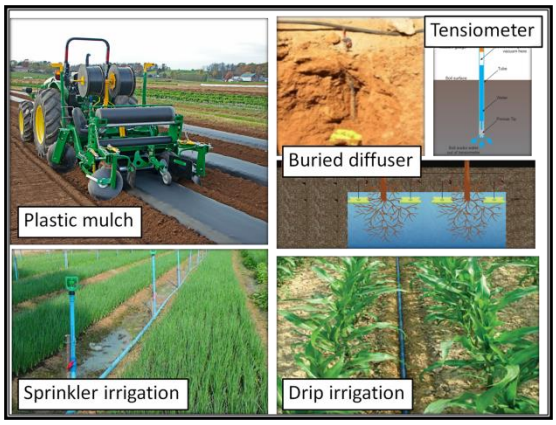


Fig. 3.6 Mulching and drip irrigation for water and moisture saving.

3.3.3 Mechanization for timely harvest

Timely harvesting is very crucial in determining the quality of the produce and for avoiding undesirable quantitative and qualitative postharvest losses. It can be achieved efficiently by the use of mechanical harvesters for commercial scale crop production. Harvest mechanization offers farmers at least three ways to maintain profitability: (1) reduced costs per unit; (2) contributes to the ability to expend total production volume and (3) provides a more reliable, cost-effective replacement for the diminishing labor pool.

Fig. 3.7 Combine harvester at YAU.

3.3.4 Drying for quality improvement

Drying is one of the essential factors affecting grain quality and its storability. Any delay in the drying process, incomplete drying or ineffective drying will reduce the grain quality and result in postharvest losses. The only practical means of preventing grain quality deterioration is immediate drying of high moisture paddy as sun drying, the conventional method or mechanical drying facilities.

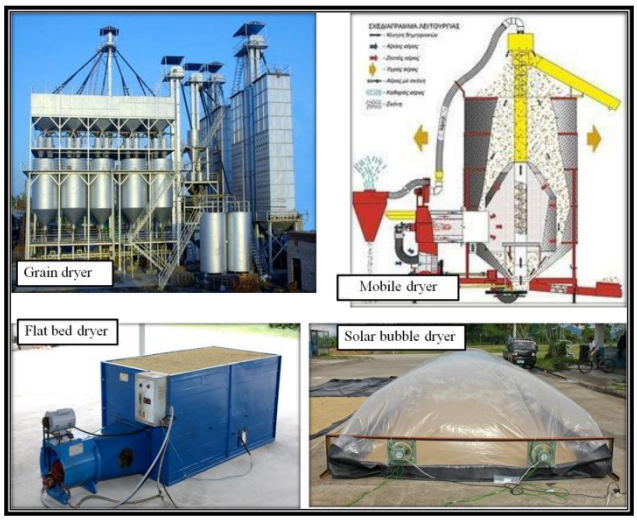


Fig. 3.8 Different types of grain dryers.

3.3.5 Grain/seed storage

The primary objective of storage is to maintain the quality of the commodity from the time of loading for as long as is required. The storage building should be clean and easily accessible.

Fig. 3.9 Different types of grain storage in bulk, bags and silos.

3.3.6 Postharvest Systems

Postharvest technologies are needed to reduce or eliminate postharvest losses. The reduction of postharvest losses of agricultural produce is a major strategy to augment food supply, attain food security and ensure economic stability. A crop saved is a crop produced.

Postharvest handling is “a set of operations undertaken from the time of harvest up to the time just before consumption or discard (fresh-market produce) or just before processing when most or all the enzymes have been inactivated, frequently by blanching (processed products)”. For cereal grains and seeds, the unit operations include harvesting, threshing, drying, storage and milling.

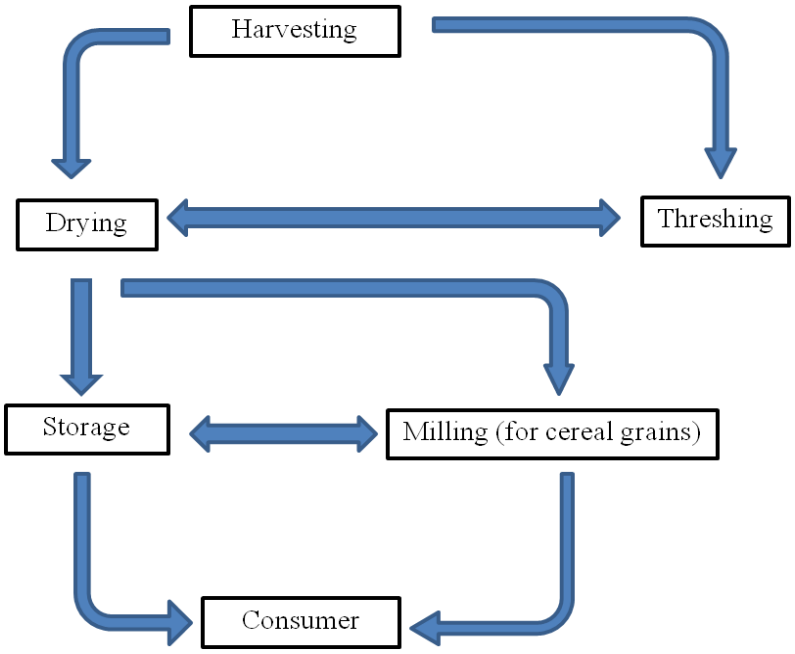


Fig. 3.10 General stages in the postharvest handling system for durable crops (Cereal grains and food legumes.

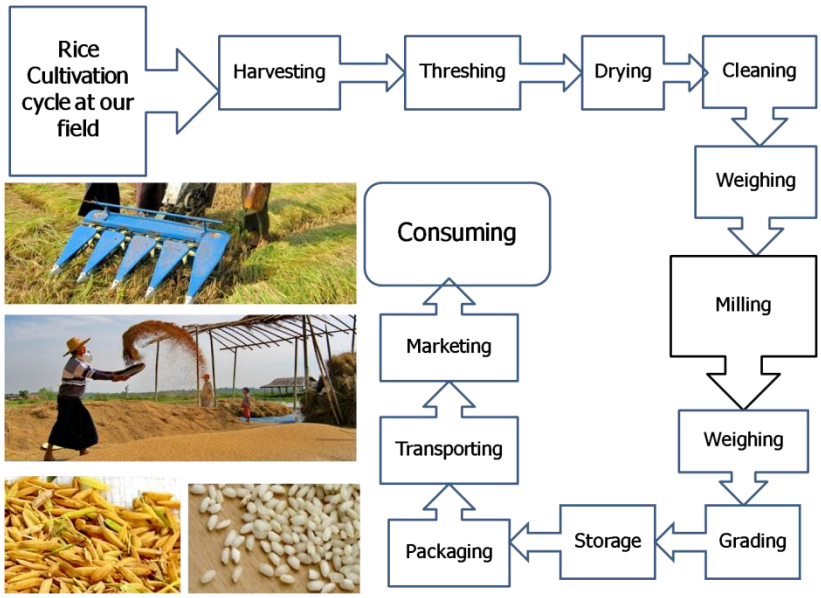


Fig. 3.11 Different stages of rice postharvest handling.

4. ENABLING ENVIRONMENTS

4.1 Crop insurance to protect farmers in Myanmar

Farmers are facing the problems of climate change such as flood or drought for the last few years in Myanmar. In 2015-2016, the submerged area was 1,520,226 acres and the damage was 763445 acres. Due to natural disasters that happened in 2016-2017 fiscal year, more than 438,828 acres of crop plantations in ten states and regions, including the Union Territory, were destroyed. Therefore, MMK 4,664.8311 million from the president's special fund was provided for re-cultivation and growing alternative crops. The problems aggravated due to heavy rain within a short duration in early part of the rainy season in 2018 where the submerged area was 1,233,557 acres until August and the damaged area was 563,527 acres across the country. The spillway of some dam collapsed and crops were flooded.

According to statistics, in 2012, about 400,000 acres of farmlands in Ayeyawady Region were damaged by flooding. Farmers are going into debt due to floods that come about every three years and there is no system for them to recover their losses as there is no crop insurance system. Currently, farmers rely on agricultural loans. But a loan system coupled with crop insurance would provide more benefits to farmers. It is difficult for farmers to pay full premiums for crop insurance. The solution is probably some kind of government subsidy for crop insurance. It is also necessary to raise public awareness about insurance in areas at higher risk for natural disasters.

Fig. 4.1. Farmers trying to move buffalos away from flooded area (left) (Source: cnn.com) and damaged paddy field at harvest (right) (© Yan Linn, GKC).

Myanma Insurance was founded in 1952, providing 27 types of insurance. There is no insurance to cover the agricultural sector or crops. This will be a new challenge for the

insurance industry. Crop insurance will pay for any loss depending on the yield, according to the agreement made by both the parties. This means insurance will cover the loss if the yield is lower than the expected volume owing to erratic weather.

4.1.1 Crop insurance systems in some neighboring countries

In India, the "Weather Based Crop Insurance Scheme – WBCIS" intends to provide insurance protection to the cultivator against adverse weather incidence, such as deficit and excess rainfall, frost, heat (temperature), relative humidity, etc., which are deemed to adversely impact the crop during its cultivation period. Rate of interest and collateral requirement on crop loans depends on the amount being disbursed. The interest rate is 7% p.a. Government of India also provides interest subvention of 3% p.a. to prompt repaying farmers, thus making available the crop loans to them at 4% p.a.

In Thailand, farmers who join the crop insurance scheme are required to pay an insurance premium of 60 – 100 baht (USD1.5 to 2.5) per rai (ca.0.4 ac), depending on the degree of risk in the location of their farmland while the government will contribute between 64 (USD 1.5) and 383 baht (USD 9.5) per rai. Farmers who are customers of the state-owned Bank for Agriculture and Agricultural Cooperatives will receive a discount of 10 baht per rai. The insurance coverage is 555 baht (USD 13.9) and 1,111 baht (USD 278) per rai, offering protection mainly from floods, drought, storms, cold weather, fire and disease.

As a partner, GIZ's ASEAN Sustainable Agrifood Systems project (www.asean-agrifood.org) provides technical advisory support to Thailand's Bank of Agriculture and Agricultural Cooperatives through Remote Sensing-Based Information and the Insurance for Crops in Emerging Economies (RIICE) project, also a GIZ partner.

RIICE is a public-private partnership aimed at reducing the vulnerability of smallholder rice farmers through the use of remote sensing technologies to map and observe rice growth. Such information can help stakeholders involved in rice production to better manage the risks involved (www.riice.org).

4.1.2 Myanmar situation

So far there is no crop insurance policy in Myanmar. Although some companies claimed that they have been practicing crop insurance, it rather protects their own interest to make sure getting the sale of agrochemicals in case of the crop failure due to certain problem such as flood, drought, pests and diseases.

Premium rates

One of the challenges to implementing crop insurance is setting a suitable premium rate. This is because there is no prior benchmark in Myanmar and no qualified actuary to measure risk levels in the country's insurance sector. The premium rate may vary depending on crop varieties, growing season and regions. To achieve success in the crop insurance sector, multi-stakeholders, including officials, the insurer, the insurance buyer and related organisations, must make concerted efforts to achieve success in implementing the crops insurance system.

As such, the pilot project is being carried out to gauge and set a suitable crop insurance premium rate. Global World Insurance will calculate the premium rate, based on the market price of paddy across one acre of farmland. Should compensation payouts be required in the event of bad weather, this will be calculated based on the market price per acre of paddy harvested in each region.

The implementation of a recently approved crop insurance scheme to protect farmers in Myanmar, while urgently needed, will face challenges as stakeholders grapple with the risks and complexities. In January 2018, the Ministry of Planning and Finance approved a two-year pilot crop insurance project aiming to cover damages to crops as a result of erratic weather conditions in Myanmar.

The project, which will first be carried out on an experimental basis, is being offered by Global World Insurance, and will cover only paddy for now. It commenced in 2018 monsoon paddy season and cover the Yangon, Ayeyawady, Magwe and Mandalay regions. Currently, the company was piloting crop insurance for 100 acres of paddy farms in Labutta and 200 acres in Kangyidaunt and Pathein. The premium was about 5000 Kyats per acre (2% of the paddy price). The insurance covers only for severe weather such as storm, flood and drought.

Myanmar Agribusiness Public Company (MAPCO) is thinking about Inventory Credit System to help farmers with storage facilities. Under this scheme, farmers can store their farm product (paddy) after harvest like depositing some money at the bank. They have to pay certain amount of interest, probably 1.5 to 2.0 percent with the temporary agreement. Farmers can borrow some money from the company without selling paddy at the time of harvest where the lowest price is offered by the brokers. They can sell it when the price increases after some time. However, there are many things to be considered from both sides. Sincerity, positive attitude and mutual respect may be quite essential for the success of the system. Even, the contract farming was facing certain problems right now.

In 2017, MAPCO pledged to pay MMK 500, 000 per 100 baskets (about 2 tonnes) of paddy. The minimum price should be above the production rate topped up with a benefit margin for the farmers. Farmers need to provide quality product without any adulteration. This must be clear whether the price is farm gate price or at the rice mill and who will pay for the transportation, loading and unloading.

It is also for the first time a crop insurance scheme is being implemented in the country. In Myanmar, insurance is mainly offered by state-owned provider Myanma Insurance and a smattering of private insurance companies. However, the existing portfolio of products and services does not include crop insurance.

This is the case even though agriculture accounts for one third of Myanmar's GDP, provides jobs for half the population and represents one fifth of the country's exports. Meanwhile, the production cost of paddy is also higher in Myanmar compared to neighboring countries due to poor infrastructure and technology. Farmers are at the mercy of unpredictable weather conditions and crop damage due to pests and disease.

But while countries such as India and Thailand have provided a crop insurance system for farmers since 1970, there is no such system to protect Myanmar farmers against losses if crop yields are lower than the expected volume. As such, crop insurance is urgently needed in the country.

A couple of years back, Myanmar's close neighbor India announced to deploy satellites to digitally map each farmland in the country using GPS technology to offer yield-based crop insurance to farmers. Thailand also provides crop insurance to protect its farmers from agricultural damages. The new crop insurance programme follows Myanmar's Development Assistance Policy (DAP), which aims to effectively channel aid funds, provided by international agencies, to develop the country's various sectors including agriculture.

Policy holders are entitled to a one-time insurance payout if their crops are damaged as a result of bad weather within the one year-insurance period, which includes the summer and rainy seasons. Compensation amounts will be verified by Global World Insurance and a farmland management committee.

Lack of support

The other challenge is a lack of government and private sector support. In this case, the government and private sector should work together to make crop insurance a success in

Myanmar and help farmers reduce crop losses. It is also suggested to include crop insurance premiums as part of their loans to farmers from Myanmar Agricultural Development Bank (MADB).

Meanwhile, the Ministry of Agriculture, Livestock and Irrigation is also talking to several insurance companies from Japan about options to offer similar crop insurance policies to Myanmar farmers. Sompo Japan Insurance and government-run Myanmar Insurance are working to adopt a crop insurance system based on climatic conditions. It has also been suggested "crop insurance" as a necessity to make sure the implementation of a functioning system to protect farmers in Myanmar.

Fig. 4.2 Agriculture investments have been rare because they are usually seen as long-term investments. Myanmar also has onerous requirements for foreign investment (© MOALI).

4.2 Integrated Pest Management

4.2.1 Introduction

The most effective, long-term way to manage pests is by using a combination of methods that work better together than separately. Approaches for managing pests are often grouped in the following categories.

Biological control: Biological control is the use of natural enemies—predators, parasites, pathogens, and competitors—to control pests and their damage. Invertebrates, plant pathogens, nematodes, weeds, and vertebrates have many natural enemies.

Cultural controls: Cultural controls are practices that reduce pest establishment, reproduction, dispersal, and survival. For example, changing irrigation practices can reduce pest problems, since too much water can increase root disease and weeds.

Mechanical and physical controls: Mechanical and physical controls kill a pest directly, block pests out, or make the environment unsuitable for it. Traps for rodents are examples of mechanical control. Physical controls include mulches for weed management, steam sterilization of the soil for disease management, or barriers such as screens to keep birds or insects out.

Chemical control: Chemical control is the use of pesticides. In IPM, pesticides are used only when needed and in combination with other approaches for more effective, long-term control. Pesticides are selected and applied in a way that minimizes their possible harm to people, non-target organisms, and the environment. With IPM you'll use the most selective pesticide that will do the job and be the safest for other organisms and for air, soil, and water quality; use pesticides in bait stations rather than sprays; or spot-spray a few weeds instead of an entire area.

There are many definitions of Integrated Pest management (see Bajwa and Kogan, 2002).

Initially, it was referred as Integrated Control and defined by FAO in 1967 as:

> “Integrated control is a pest management system that in the context of the associated environment and the population dynamics of the pest species, utilizes all suitable techniques and methods in as compatible a manner as possible and maintains the pest populations at levels below those causing economic injury” (FAO. 1967).

However, it was modified as follows:

> "Integrated pest management (IPM) is an interdisciplinary approach incorporating the judicious application of the most efficient methods of maintaining pest populations at tolerable. Recognition of the problems associated with widespread pesticide application has encouraged the development and utilization of alternative pest control techniques. Rather than employing a single control tactic, attention is being directed to the coordinated use of multiple tactics, an approach known as integrated pest management” (FAO 1980).

IPM is an ecosystem-based strategy that focuses on long-term prevention of pests or their damage through a combination of techniques such as biological control, habitat manipulation, modification of cultural practices, and use of resistant varieties. Pesticides are used only after

monitoring indicates they are needed according to established guidelines, and treatments are made with the goal of removing only the target organism. Pest control materials are selected and applied in a manner that minimizes risks to human health, beneficial and non-target organisms, and the environment.

These IPM principles and practices are combined to create *IPM programs*. While each situation is different, five major components (Stein 2006) are common to all IPM programs:

1. Identify the pest
2. Monitor pest activities
3. Determine action thresholds
4. Explore treatment options and make treatments
5. Evaluate results

An integrated pest management approach should be ecologically sound, economically profitable and socially acceptable.

4.2.2 Climate Change Impacts on Crop Pests

Climate change will have both direct as well as indirect effects on insect populations. Temperature is the major factor in global climate change that directly affects insect development, reproduction, and survival. Although the insect responses to global climate change vary, the effect of global warming in general has been predicted to increase intensity of herbivore pressure on plants. Climate change will also affect insects indirectly through their host plants (Chander, Husain and Pal 2016)

Effect of climate change on expression of resistance to insect pests

Host plant resistance to insects is one of the most environmental friendly components of pest management. However, climate change may alter the interactions between the insect pests and their host plants (Bale et al. 2002; Sharma et al. 2010). Insect - host plant interactions will change in response to the effects of CO_2 on nutritional quality and secondary metabolites of the host plants. Increased levels of CO_2 will enhance plant growth, but may also increase the damage caused by some phytophagous insects (Gregory et al. 2009). Lower foliar nitrogen

content due to CO_2 causes an increase in food consumption by the herbivores up to 40% (Sharma et al. 2002).

Effect of global warming on the activity and abundance of natural enemies

Relationships between insect pests and their natural enemies will change as a result of global warming, resulting in both increases and decreases in the status of individual pest species. Changes in cropping patterns as a result of climate change will drastically affect the balance between insect pests and their natural enemies. Quantifying the effect of climate change on the activity and effectiveness of natural enemies for pest management will be a major concern in future pest management programs. The population of Oriental armyworm, *Mythimna separata* (Walk.) increase during extended periods of drought (which is detrimental to the natural enemies), followed by heavy rainfall because of the adverse effects of drought on the activity and abundance of the natural enemies of this pest (Sharma et al. 2002). Similar trend was found in August, 2018 at Shan State in Myanmar. According to the report of Plant Protection Division (PPD) in Myanmar, serious infestation of *M. separata , Spodoptera litura, Spodoptera exempta* was found in the corn fields and some adjacent rice fields when heavy rain occurred after dry period at four townships in northern Shan State and two townships in southern Shan State, and among these three species of armyworms, Oriental armyworm, *M. separata* was more abundant. Moreover, as Jiang et al. (2011) stated that each year the *M. separata*, undertakes a seasonal, long-distance, multigenerational roundtrip migration between southern and northern China, abundance of *M. separata* may be due to its migration behavior.

Effect of climate change on the effectiveness of biopesticides and synthetic insecticides

Natural plant products, entomopathogenic viruses, fungi, bacteria, and nematodes, and synthetic pesticides are highly sensitive to the environment. Increase in temperatures and UV radiation, and a decrease in relative humidity may render many of these control tactics to be less effective, and such an effect will be more pronounced on natural plant products and the biopesticides (Isman 1997). Rapid dissipation of insecticide residues due to increases in temperature and precipitation will require more frequent application of insecticides.

Fig. 4.3 Damage symptoms of armyworms at Shan State of Myanmar in 2018 (© PPD, DOA).

4.2.3 Climate-smart pest management

Climate-smart pest management (CSPM) is a cross-sectoral approach that aims to reduce pest-induced crop losses, enhance ecosystem services, reduce greenhouse gas emissions and strengthen the resilience of agricultural systems in the face of climate change. Through the implementation of CSPM, farmers, extension workers, researchers, and public and private sector stakeholders will act in coordination to manage changing pest threats more effectively, and achieve more efficient and resilient food production systems (Heeb and Jenner 2017). The concept of CSPM (figure 4.4) is new and covers a number of interdisciplinary approaches and strategies that can be implemented immediately to begin the process of adapting crop production, strengthening the supporting functions (through extension and research) and creating the enabling environment (via the public and private sector).

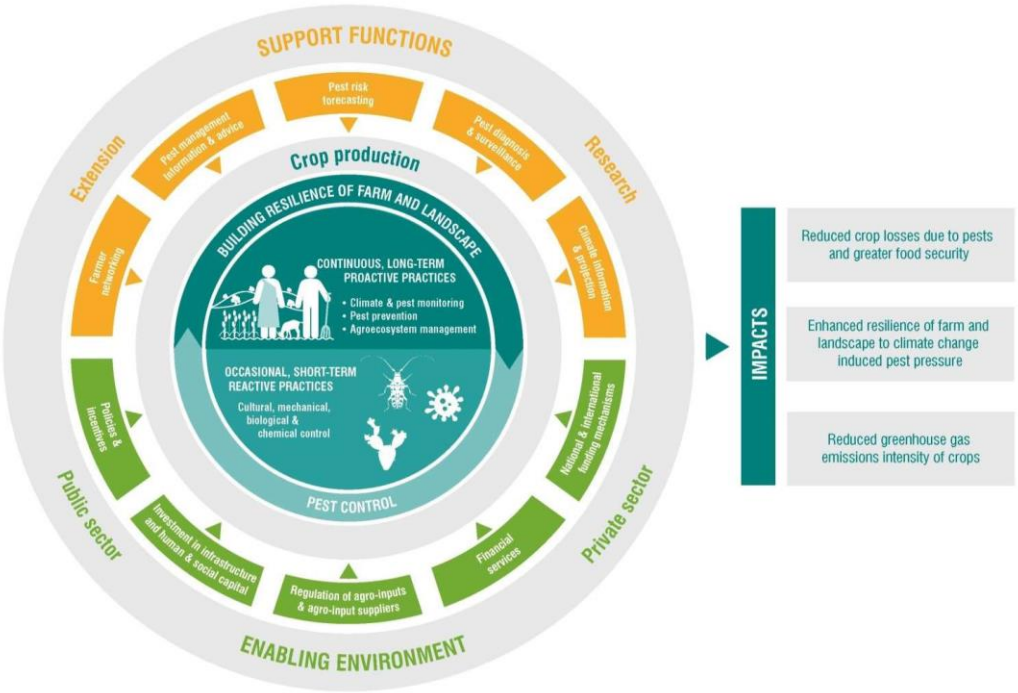


Figure 4.4 The concept of Climate-Smart Pest Management (CSPM) (© Heeb and Jenna 2017).

As figures show, through CSPM, farmers will have the information and tools in hand to immediately and proactively put into action practices (e.g. crop diversification, establishment of natural habitats, careful water management, etc.) that will enhance the health of his/her farm and surrounding landscape, and reduce its susceptibility to pest-induced disturbance. Moreover, through climate and pest monitoring, in combination with climate and pest risk forecasting information, farmers will be able to proactively implement pest prevention practices (e.g. use of pest resistant varieties, careful selection of planting, pruning and harvesting times, push-pull techniques, etc.) in order to prevent the occurrence and/or build-up of expected pest problems. In cases where pest populations do reach economic injury levels, then CSPM enables farmers to make rapid, informed decisions regarding the most appropriate reactive pest control strategy. CSPM fosters the coordinated support from extension and research, and suggests approaches and practices to ensure that the services they provide are relevant, locally-adapted and accessible to all farmers. For example, conducting on the ground research to determine the likely impacts of climate change on crop/pest/natural enemy dynamics, and quantifying the consequences of these impacts, will facilitate the development of targeted adaptive responses that are currently lacking. In addition, the analysis of historical weather and climate data will allow pest risk forecasting to become a viable tool to guide proactive pest prevention strategies. Public and private sector investment is also a very

significant prerequisite to enable supporting institutions to carry out their mandate (especially in developing countries), as well as to enhance the infrastructure required for effective exchange of information and knowledge between stakeholder levels.

How is CSPM implemented?

The first step of any CSPM programme is to conduct a thorough appraisal of the local environment and perspectives. The implications for other farm management decisions should also be considered. For example, changing to a pest-tolerant crop variety may require only minimal investment and knowledge, whereas changing crops because of a new pest invasion may involve investing in new seeding and harvesting equipment, implementing new crop rotation practices and sourcing new buyers and markets for the produce (Macfadyen et al. 2016).

Since CSPM activities involve different stakeholders and institutions, and take place at a range of scales (Chakraborty et al. 2011), interlinking CSPM activities and stakeholders is crucial to overcome barriers that hinder its implementation. For example, enhanced linkages between extension, research and the public/private sector can help to provide the data and resources required to improve diagnosis of pests, inform strategy and research, and reduce response time to these pest threats. In the case of armyworms outbreak in the corn and rice fields at Shan state in Myanmar, PPD was diagnosed three species of armyworms and advised control measures. Then the integrated armyworms management was done in time. Integrated pest management urgently carried out in armyworm infested corn and rice fields at Shan state are as follow:

- Doing continuous scouting to corn and rice fields to monitor the pest status (especially more inside and weedy places in the corn fields than the border)
- Destruction of grasses inside and surrounding fields
- The collection and destruction of egg masses and larvae by hand picking as mechanical control
- Conservation of natural enemies such as lady bird beetles, rove beetles, dragonflies, damsel flies, spiders, ants and parasitoids found in corn and rice fields
- Using B.t (*Bacillus thuringiensis*) and neem insecticide to the undersurface of the leaves in the fields
- Spraying the chemical insecticides such as (Indoxacarb 17 + Lambda-Cyhalothrin 3% EC – 20-100cc/acre), (Chlorpyrifos 50% + Cypermethrin 5% EC – 200-400 cc/acre),

Chlorantraniliprole 51.5% SC – 240cc/acre, Indoxacarb 15 SC – 80-120cc/acre and Flubendiamide 24% WDG – 200-300 gm/acre having contact and stomach action on the whorl of corn plants and putting Carbofuran on the surface of the soil in the fields with heavy infestation and the surrounding grass fields

- Collecting and destroying the pupae in the soil at the base of the plants by mass people (fig 4.5) or deep plowing the grasses along the border and destruction the exposed pupae
- Putting any one insecticide used in the soil (e.g Chlorpyrifos 15g) before planting the next crop
- Using light traps for the control of adult moths
- Avoiding continuous planting of only corn and rotation with cassava
- Avoiding late planting and simultaneous planting with the same maturing corn or rice varieties

Fig. 4.5 Scouting in the rice fields (left) and collecting and destroying the pupae in the soil at the base of the plants by mass people (right) (© PPD, DOA).

As another case study, the tomato leaf miner, *Tuta absoluta*, is a devastating pest of tomato. Its primary host is tomato, but it also affects potato, aubergine, beans and others. In Myanmar, the tomato leaf miner, *Tuta absoluta*, is a serious pest of tomato growing fields of Inlay lake in Shan State (fig 4.5). Many farmers in developing countries including Myanmar, who rely on tomatoes for food security and income generation, are exposed to *T. absoluta* with very little or no support from the public sector. CSPM aims to address this by fostering a coordinated and multi-stakeholder action to create a favorable enabling environment, develop the necessary supporting functions, and contribute to a crop production system that is more resilient to such

pest disturbances, so that farmers' vulnerabilities to climate change induced pest pressures are decreased.

Fig. 4.6 The adult of *Tutal absoluta* (left) and damage tomato (right)
(Source : https://en.wikipedia.org/wiki/Tuta_absoluta **).**

A number of IPM-practices that can be considered under CSPM have been shown to increase crop yields, including selecting pest resistant crop varieties, intercropping, cover crops, climate-adapted push-pull techniques, mulching, and minimum tillage systems.

Finally, CSPM is a dynamic and evolving approach and so continual monitoring and evaluation is also required to assess the implementation and short-term outcomes/impacts of CSPM interventions, and to allow continual re-evaluation of tools and approaches.

4.2.4 Climate change impacts on plant disease development and management practices

Environmental effects on the development of infectious plant disease

Plant diseases occur in all parts of the world where plants grow. They are more common and more severe, however, in humid to wet areas with cool, warm, or tropical temperatures. Although all pathogens, all perennial plants, and, in warmer climates, many annual plants are present in the field throughout the year, almost all diseases, in all but a few very hot, dry areas, occur only, or develop best, during the warmer part of the year. Also, it is common knowledge that most diseases appear and develop best during wet, warm days and nights and that plants fertilized heavily with nitrogen are attacked much more severely by some pathogens than less fertilized plants. These general examples clearly indicate that the environmental conditions prevailing in both air and soil, after contact of a pathogen with its host, may affect the development of the disease greatly (Agrios, 2005).

Actually, environmental conditions frequently determine whether a disease will occur. The environmental factors that affect the initiation and development of infectious plant diseases most seriously are temperature and moisture on the plant surface. Soil nutrients also play an important role in some diseases and, to a lesser extent, light and soil pH. These factors affect disease development through their influence on the growth and susceptibility of the host, on the multiplication and activity of the pathogen, or on the interaction of host and pathogen as it relates to the severity of symptom development (Agrios, 2005).

For a disease to occur and to develop optimally, a combination of three factors must be present: susceptible plant, infective pathogen, and favorable environment. However, although plant susceptibility and pathogen infectivity remain essentially unchanged in the same plant for at least several days, and sometimes for weeks or months, the environmental conditions may change more or less suddenly and to various degrees. Such changes may drastically influence the development of diseases in progress or the initiation of new diseases. Of course, a change in any environmental factor may favor the host, the pathogen, or both or it may be more favorable to one than it is to the other. As a result, the expression of disease will be affected accordingly. Plant diseases generally occur over a fairly wide range of the various environmental conditions. Nevertheless, the extent and frequency of disease occurrence, as well as the severity of the disease on individual plants, are influenced by the degree of deviation of each environmental condition from the point at which disease development is optimal.

Climate change and its effects on crop diseases

Climate change is affecting our agriculture due to 0.74°C average global increase in temperature in the last 100 years. In Myanmar, an increase in temperatures across the whole country is around 0.08°C per decade according to data of last six decades (Maw, 2017). Such changes will have a drastic effect on the growth and cultivation of the different crops. Simultaneously, these changes will also affect the reproduction, spread and severity of many plant pathogens.

Impact of climate change on crop disease has been observed in the disease occurrence of rice, pulses, vegetables and other cultivated crops. According to survey result of Rice disease survey in 2001 and 2001, sheath blight, bacterial leaf blight (BLB) and sheath rot were the most commonly found diseases in the surveyed areas of upper and lower Myanmar, lesser so false smut and ufra disease (Naing et al., 2008). However, diverse range of rice diseases was found to be prevalent in the recent survey, from 2015 to 2017 compared to the previous survey data

of 2001 and 2001. In the recent survey, occurrence of bacterial blight, bacterial leaf streak and rice blast were recorded as the most destructive diseases. Sheath blight, false smut and sheath rot diseases were also found as the second line up diseases. In addition, damage threat 100% loss of rice due to rice blast disease in some of the rice fields in Nay Pyi Taw Council area. Disease management system should be initiated with any major disease of a crop in an area.

Management of Crop Diseases

The convention approach to disease control has not stimulated an active holistic approach to disease management. Disease control has historically depended upon diverse methods ranging from plant resistance and sanitation to intense fungicide application. Research emphasis on disease forecasting, and integrations of management methods are increasing so that disease management technology will be efficient.

Since IDM has to be a part of the agroecosystem, it has to manage a system rather than a single crop or a single disease. It has to provide bases for ensuring crop health of the entire programme in the agroecosystem. In IDM there are two options. The first is to integrate the available methods and resources to suppress a highly destructive disease of a host or secondly, to integrate the methods for managing all the economically important diseases of a crop. Depending upon the importance, both the options require serious considerations. Several plant diseases especially soil-borne diseases are mostly localized and highly destructive in certain places. Unfortunately, no single method has so far given adequate protection against such diseases. In such situations, integration of available methods for controlling of the disease will be both desirable and successful. Attempts to control the major diseases of a crop will be a positive step. It is simple because that all recorded disease of a crop become serious only occasionally as ever varying environments influence the development of a disease. For example, rice is attacked by at least 15 virus and virus-like diseases, 45 fungal pathogens, 10 plant parasitic bacteria, and 6 species of nematodes. All these diseases do not occur in every places and intensity and their attack also varies in different regions. In such condition, only a few of them assume serious problems and IDM could and should be tried (Agrios, 2005).

Integrated management of rice blast disease (an example)

Strategies for adapting to climate change must be developed to limit the development of economic and social problems. Disease-resistant and stress-tolerant rice varieties, for example,

can be grown to prevent reduced crop productivity associated with diseases, and with heat and drought stress. Breeding new rice cultivars adapted to the new climate demands is necessary. Vulnerability mapping, early warning systems and coordination across sectors can prevent losses, and join efforts among investigators from a variety of fields will enable the development of successful and sustainable adaptation strategies (Bevitori1and Ghini 2014.).

Disease forecasting

Blast-forecasting systems have been successfully developed in Japan and Korea based on meteorological data. Various methods of forecasting blast disease have been made based upon information on the fungus, the host plant and the environment. For example, the number of blast lesions was estimated by the numbers of trapped spores and the wetting period of leaves. Besides information on inoculum and climate, the predisposition of the rice plant has also been used for blast forecasting. Often one method works well for one region but does not function at another place.

Control measures

Control of rice blast is usually necessary to prevent crop losses. In order to manage the diseases effectively, it is essential to have knowledge on the crop and also the pathogen. Control measures such as using resistant cultivars, chemicals and cultural methods are available to manage disease.

(a) Resistant crop cultivars

Resistant cultivar against leaf and panicle blast has been the most widely used method of disease control. Control of rice blast in areas of low blast pressure is based primarily on planting resistant cultivars. Where blast epidemics are common and severe, in addition to planting resistant cultivars, which must be changed frequently, control is aided by other cultural practices and using fungicides.

(b) Chemical control

Fungicidal control is largely practiced in temperate or subtropical rice cultivation and little is used in other areas either because of cost limitations, or because of lower or inconsistent disease pressures.

Many fungicides are routinely used to control rice blast. These include benomyl, fthalide, edifenphos, iprofenphos, tricyclazole, isoprothiolane, probenazole, pyroquilon, meferimzone,

diclocymet, carpropamid, fenoxanil, and metominostrobin along with antibiotics such as blasticidin and kasugamycin. Current major products are mainly systemics with a residual activity of at least 15 days. Such chemicals are applied as foliar sprays, as granules into water or seed-box treatments (irrigated lowland rice), or as seed dressings for upland rice.

First applications of most products are recommended as protective applications before or shortly after the onset of leaf blast. Panicle blast treatment should be preventative rather than curative. A total of five foliar applications may be necessary to manage disease.

(c) Cultural control

Besides the use of chemicals and resistant cultivars, adjusting cultural practices are employed in an integrated control programme.

Time of planting has been demonstrated to be an important factor in blast development. Early plantings reduce disease level than later plantings. In early plantings the air temperature is too low at the tillering stage and too high at the heading stage for vigorous disease development.

Seedlings raised in upland nurseries are more susceptible to blast even after they are transplanted. This is explained by the lower silicon content of the epidermal cells. Silicon soil amendments are known to increase host resistance to attack. Various kinds and amount of nitrogen fertilizers affect disease development. Restricted nitrogen fertilizer applications are needed to avoid serious outbreaks of blast. Control of irrigation water has also been used to reduce blast damage. The temperature of the irrigation water is 20°C or below increase blast incidence. Deep transplanting of seedlings has been found to retard growth, delay maturation and reduce yield, as well as causing more blast infection. Close spacing also often increases the severity of the disease. Field sanitation and synchronized planting reduce carryover and/or spread of disease.

4.2.5 Climate change impacts on rodent outbreaks

In May 2008, Cyclone Nargis killed 140, 000 people and destroyed 450,000 houses in Ayeyarwady delta. Fifteen months after cyclone, rodent outbreaks happened in July 2009 in Ayeyarwaddy delta. Among five townships, Bogale and Laputta townships were the most serious. Majority of farmers lost 100% of their rice crop. A campaign based on the collection

of rat tails was organized by government and NGOs and 2.6 million rats were collected within 3 months (Source Nyo Mee Htwe, 2008).

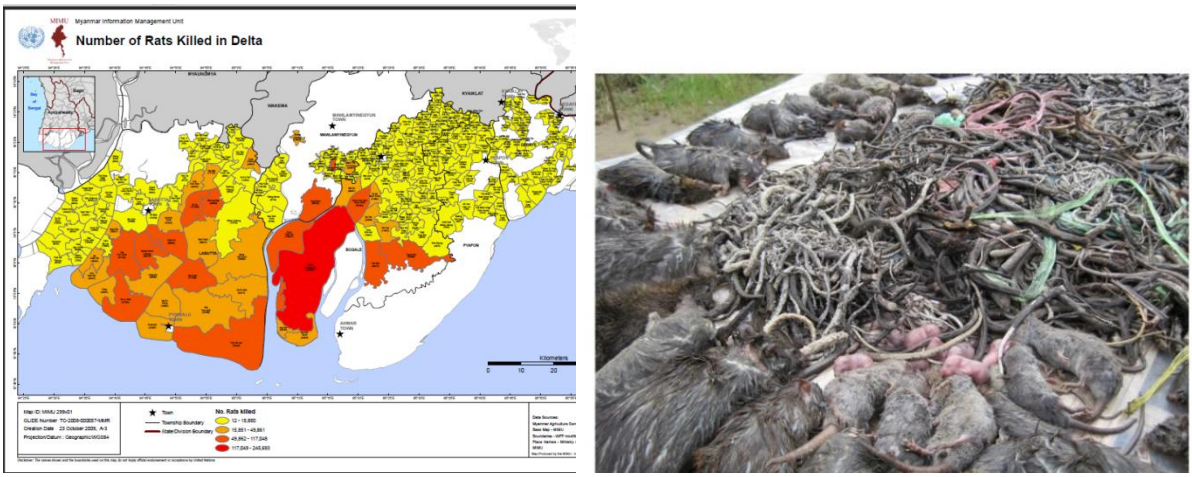


Fig. 4.7 Map of delta region where rodent outbreak occurred (left) and rodents collected through the campaign (right) (© PPD, DOA).

Reasons which caused the rodent outbreaks were asynchronous planting of the monsoon rice crop and temporary abandonment of more than 1/3 of agricultural land which provided food availability & cover. Outbreak 15 months after cyclone is consistent with the biological response time of rodent populations to increase from a low base. Rodent outbreaks following uneven weather changes (flooding & drought) is becoming more common and document rodent outbreak events were in Hinthada Township (2014; 2017) and Gyoepinkauk Township (2017).

Recommended Ecologically-based Rodent Management System (EBRM) to reduce the impact of rodent outbreaks are:

Preventative measures

(1) A synchronous planting (and/or) harvesting of the crops

(2) Well sanitation in and around the crops field and

(3) Monitoring for rats activities.

Protective measures

1. At high rat population, 'Rat tail counting campaign' should be done as community activity.
2. Other rats management activity such as trappings, digging burrows, encouraging predators, using different barriers should be done based on the target rat species.

3. All rodenticides are identified as ‘restricted used’ chemicals and should be used after the consultation with well-trained plant protection staff.

4.3 Climate Information Services

4.3.1 Weather Forecast in Myanmar

Brief history

An independent Burma Meteorological Department (BMD) was established on 1 April 1937. Similarly, an International Meteorological Organization (IMO) was established in 1873. Union of Myanmar became member of IMO in January 1938. BMD was re-organized on 23 October 1972 and renamed as Department of Meteorology and Hydrology (DMH) in the year 1974. Myanmar Daily Weather Report was issued since 1 June 1947. At that time, DMH was under the administration of the Ministry of Transport and Communication. DMH transferred to Ministry of Communications, Posts and Telegraphs from the Ministry of Transport and Communication on 3 February 1992. On 20 August 1999, DMH transferred to the Ministry of Transport.

Role and responsibility

The Department of Meteorology and Hydrology operated a manual controlled daily river forecasting and flood warning system to reduce flood danger as well as to make the precaution of flood since January 1, 1966. The Department started a mini computer based river forecasting and flood warning system during the year 1978 and upgraded to present system during 1987 with UNDP/WMO project. Hydrological Division of DMH is responsible for issuing daily river forecast and flood forecast along 11 major rivers: Ayeyarwady, Chindwin, Sittaung, Thanlwin, Dokehtawady, Bago Shwegyin, Ngawun, Toe, Kalaten and Lay Myo. Whenever warnings are issued from River Forecasting Section (RFS) of DMH, the message is sent to the respective stations by telephone or Single Side Band (SSB) transceiver. As soon as head of the station receive the message of warning, he immediately inform the local authorities and other related departments in order to carry out the necessary action. At the same time the warnings are disseminated through the radio and television as well as through the Newspaper for general public.

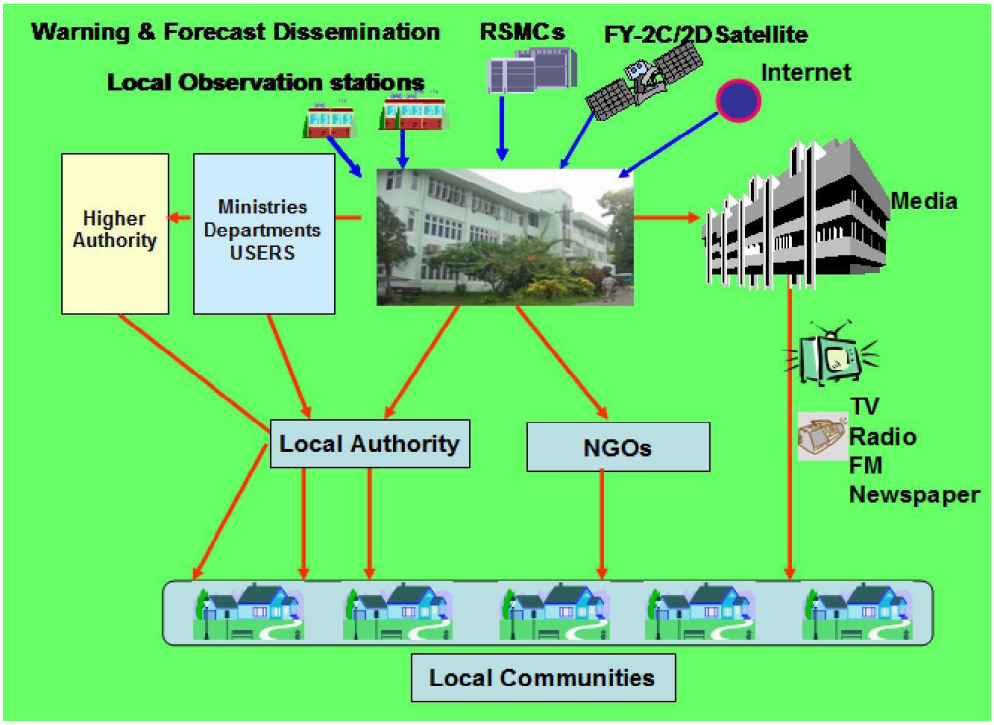


Fig. 4.8 Roles and responsibilities of DMH (© Kyu Kyu Sein, 2014).

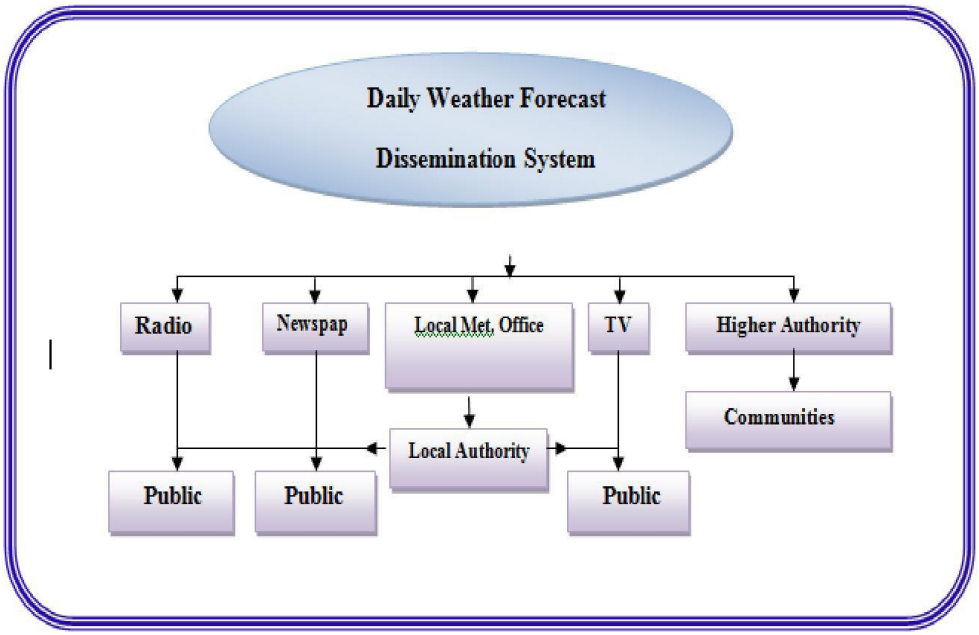


Fig. 4.9 Roles and responsibilities of DMH.

RFS of DMH is using both simple and advanced techniques for issuing flood warning and bulletin to the users and public, and is also applying empirical models based on single and multiple regression analysis for forecasting peak flood level along Ayeyarwady and Chindwin

rivers. The lead time for issuing flood warning is about one to two days for short range forecast and about seven to ten days for long range forecast, especially for deltaic area of Ayeyarwady.

In order to provide runoff data, discharge and sediment discharge measurements are carried out every year at three sites in the selected three rivers by Hydrological Division, Upper Myanmar Division and Lower Myanmar Division.

The department also carries out some other activities such as **discharge measurement, acid deposition monitoring and GIS application in hydrology. There are (22)** Hydrological Stations and (48) Meteorological and Hydrological Stations across the country.

Hydrological Observations - Water Level three times a day, Evaporation once a day, Water Temperature three times a day and Water Velocity Selected Site at every year.

The activities for Hydrological Forecast/Warning/Bulletin include Daily water level forecast, Dekad Forecast, Monthly Forecast, Seasonal water level forecast, Flood Forecast for early, mid, late monsoon period, Flood warning, Minimum Alert Water Level, Significant Water level Bulletin, Flood Bulletin and Minimum Water Level Bulletin.

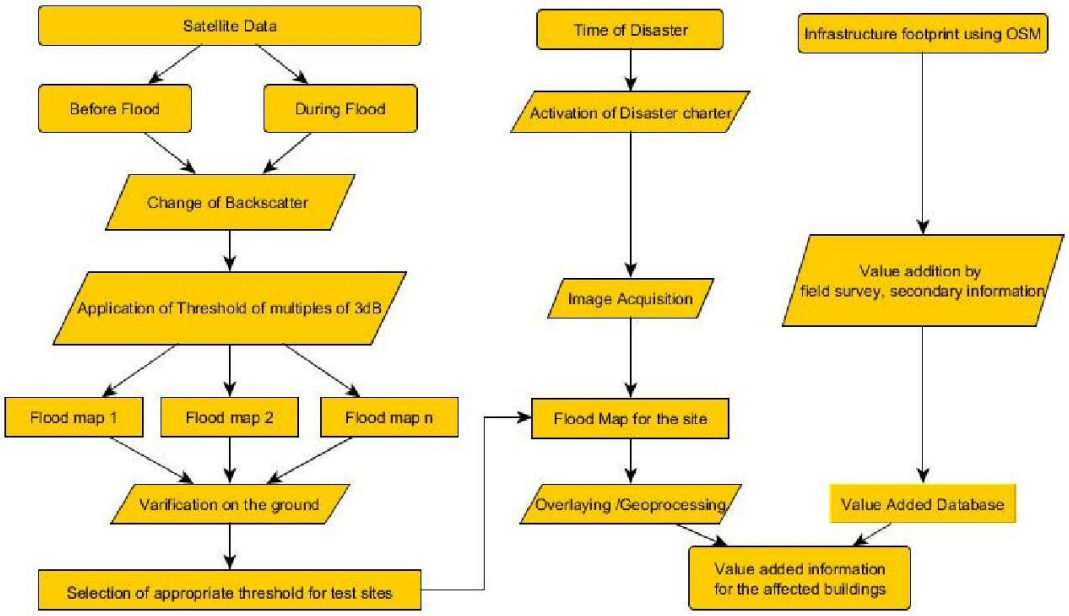


Fig. 4.10 Methodology for flood weather risk management (© Kyu Kyu Sein, 2014).

4.3.2 Weather forecast in traditional ways

In a case study on traditional knowledge for weather prediction in Mizoram, North-eastern India, Chinlampianga (2011) found that bioindicators pertaining to distinctive features of birds, insects, fish, plants, and clouds, relating to weather, drought, and natural calamities were generally valid. Some examples were as follows:

1. Bamboo Partridge, (*Bambusicola fytchii*)**:** If male bamboo partridges roar frequently during spring and summer in the morning after sunrise, rain is expected in the immediate future. Similarly, when it rains in the morning, the roaring of the bamboo partridge at this time indicates that the rain will soon stop for that day in that location.

2. Field cricket, (*Gryllus pensylvanicus*); If a cricket brings new soil particles out of its hole during the dry season, it is thought that rain is coming soon. If the same activity occurs during the rainy season, a heavy rain is expected during the season.

3. Winged termite, *Reticulitermes* sp.)**:** When these insects come out of the soil in a group after a rainfall occurs, it is believed that rain will not come again for some time. If there was no rain in the previous day or week but the insects are coming out of the soil, rain is expected to come soon.

4. Corn field ant, **(***Lasius alienus*)**:** When there are a number of ants moving along a path carrying their food items with them, a heavy rain is expected on the same day, or within one or two days.

5. Common Frog, (*Rana temporaria*)**:** If the frogs croak in a water body in the afternoon until sunset, rain will be coming soon, even during winter and spring season.

6. Bird/Hen and cock, If local domestic chickens search for food even during the rain, it is commonly thought that the rain will last for the whole day. But if the birds stop searching for food when it is raining and take shelter (in the morning or afternoon), the rain is expected to cease soon and to be minimal.

Myanmar also has similar system of weather forecast based on the behaviour of animals. They are as follows:

1. Rain will be scarce or there will be drought if the ants come and stay under a water pot in rainy season.
2. If bird nests are seen close to the ground, there will be drought.

3. If fig trees are fruiting on the upper part, rain will be plenty in early monsoon. Plenty of rain can be expected in mid-monsoon if fruiting in the middle part. Similarly, fruiting in the lower part means plenty of rain in late monsoon.
4. If the tail of a chameleon is green, there will be adequate rain in early monsoon. If the body is green, there will be adequate rain in mid-monsoon and if the head is green, there will be adequate rain in late monsoon.
5. If the dark spots are seen at the base of a monitor lizard's tail, there will be plenty of rain in early monsoon. At the middle, plenty of rain in mid-monsoon and at the tip, plenty of rain in late monsoon.
6. If birds make nest in upper part of the tree, there will be less rain. If it is in the lower part, there will be strong wind.

In a book entitled" the art of Meteorology" by U Thu Ta (1969), the weather conditions and about the clouds described in detail. Extension workers as well as farmer should read the book to get general idea about the climate and weather.

4.4 Infrastructure

4.4.1 Climate Smart Villages

Climate change has a variety of impact on agriculture, farmers and their environment. They include loss of agro-biodiversity and ecosystem services, yield reduction in the crops leading to loss of agricultural and non-agricultural incomes and many other consequences as shown in figure 1.

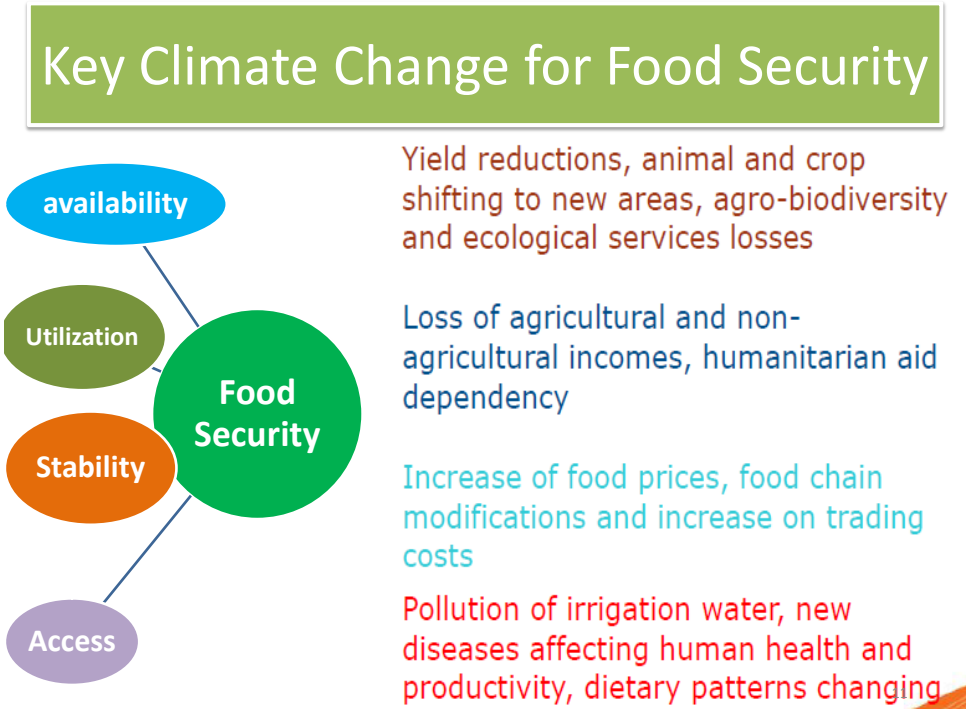


Fig. 4.11 Impact of climate change on food security (Hodges *et al.*, 2011).

The climate-smart village approach (CSV)

The climate-smart village (CSV) approach is an agriculture research-for-development (AR4D) approach to test, through participatory methods, technological and institutional options for dealing with climate change in agriculture. It aims to generate evidence at local scales of what climate-smart agricultural options work best, where, why, and how, and use this evidence to draw out lessons for policy makers, agricultural development practitioners, and investors from local to global levels. The testing is done through a multi-stakeholder collaborative platform at CSV sites. The sites are a cluster of villages, small landscapes, or 10 km² grids. Every CSV site has its own theory of change (To- C: a narrative description of the logical causal chain from research activities to impact) linked to national priorities to ensure that it is consistent

with initiatives and actions across different scales. The process builds on Lipper et al.'s (2014) theory of climate smart agriculture (CSA).

The strategy of the CSV approach is to:

1. Understand the effectiveness of a variety of CSA options (practices, technologies, services, programs, and policies) not only to enhance productivity and raise incomes, but also to build climate resilience, increase adaptive capacity, and wherever possible, reduce GHG emissions;

2. Develop (no regrets) solutions in anticipation of future climate change impacts;

3. Understand the socioeconomic, gender, and biophysical constraints and enablers for adoption; and

4. Test and identify successful adoption incentives, finance opportunities, institutional arrangements, and scaling out/ up mechanisms while ensuring alignment with local and national knowledge, institutions, and development plans.

Figure 4.12 illustrates the major components of a typical CSV approach. Climate-smart agriculture interventions are considered in a broad sense by including practices, technologies, climate information services, insurance, institutions, policies, and finance. There is no fixed package of interventions or a one-size-fits-all approach. Options differ based on the CSV site, its agroecological characteristics, level of development, and capacity and interest of the farmers and of the local government. The results of the CSV approach are usually a portfolio of CSA options and institutional and financial mechanisms that enable their successful adoption. Promising innovations are then available to be scaled out by the national/subnational governments, nongovernmental organizations (NGOs), and private-sector actors in regions with similar agroecological conditions.

Climate-Smart Villages are sites where researchers, farmers' cooperatives, government officials and private sector partners come together to identify the most appropriate climate-smart interventions in agriculture based on its agro-ecological, climate risk profi le and socio-economic conditions. These interventions include water smart practices (rainwater harvesting, laser levelling), weather smart activities (ICT-based agromet services, index-based insurance), nitrogen and carbon smart practices (precision fertilizers, catch-cropping), energy smart (zero tillage, residue management) and knowledge smart activities (farmer-farmer learning, seed

banks and cooperatives). These interventions work together increase an agriculture community's resilience to climatic stresses.

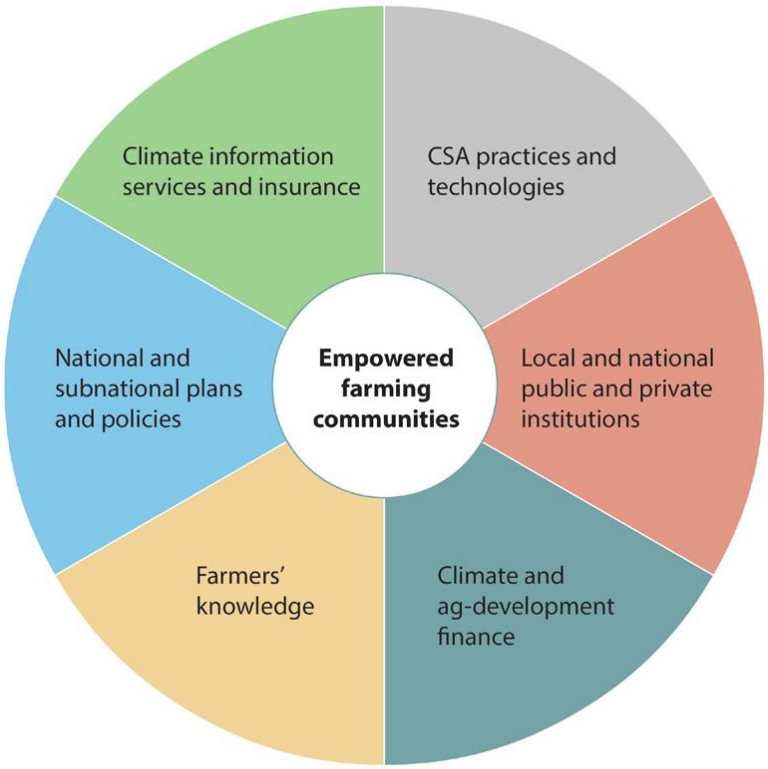


Fig. 4.12 Key components of a CSV AR4D approach (Aggarwal *et al.*, 2018).

4.4.2 Step for setting CSVs

- **Selecting the site:** The location of the Climate-Smart Village is selected based on its climate risk profile, alternate land use options, and on the willingness of farmers and local government to participate in the project.
- **Working with communities:** Community involvement is integral to the success of Climate-Smart Villages. Climate change agriculture and food security (CCAFS) works with existing community groups of farmers, researchers, rural agro-advisory service providers and village officials.
- **Conducting the baseline survey:** Researchers conduct a baseline survey to capture the current socioeconomic situation, resource availability, average production and income and risk management approaches of village households. This enables an assessment of the impact of the interventions after a certain period of time.

- **Prioritizing interventions:** Stakeholders convene to prioritize and test which climate smart technologies and approaches are best suited to their local conditions. Focus group discussions involve farmers in a choice experiment using dummy money to indicate which actions they would most willingly carry out.
- **Building capacity:** Regular training exercises are organised for farmers on good agriculture practices. At some sites, a small farm is used for demonstration on the complete portfolio of interventions.
- **Monitoring and evaluating and progress:** A site coordinator provides technical inputs and liaises with CCAFS resource persons. Participating farmers document their activities and work with the coordinator to evaluate progress.

ICRISAT (2016) has highlighted five approaches for building climate smart villages as follows:

1. The **watershed management approach** focuses on rehabilitating agroecosystems and deploys a pool of climate-smart agricultural practices developed by ICRISAT which have resulted in increasing crop yields and incomes of farmers. This approach which is gaining momentum in India
2. The **futuristic multi-model approach** uses computer simulated scenarios to give policy makers in Zimbabwe the climate scenario up to the year 2050. The result was renewed support for promoting dryland cereals – sorghum and millet and greater support for groundnut value chains.
3. The **digital technologies approach** has helped farmers to adopt climate-smart agricultural practices and take up agroforestry in a big way. In Ghana, farmers who had never used a phone are now using mobiles for climate information to make cropping decisions. About 90% of the farmers find the weather alerts useful and 64% of them also make use of the helpline when needed.
4. The **metrological advisory and farm systems approach** used in Mali, demonstrated that climate change adaptation is achievable by using eco-friendly methods and climate information. Close to 76,000 women and 94,000 men representing all stakeholders in the value chain reported using climate information in their decision making.
5. The **climate and crop modeling approach** helped farmers who followed crop advisories in the drought-prone district of Kurnool in Andhra Pradesh, India, to earn

20% more than those who did not. The success of this pilot project has led to its expansion in other villages of Andhra Pradesh and the neighboring state of Karnataka.

Among the above mentioned approaches, Watershed Management approach can be applied in rain-fed area. Two other approaches, Agricultural and Digital Technologies approaches may also have a good potential and very useful for the famers as well as extension workers as mobile industry is booming in Myanmar. DoA Extension has already set up a section for on call services to solve problems encountered by the farmers. PPD launched PP Mobile Application version 1 in 2017. In this version, 187 insect pests, 137 diseases, 30 weeds, 12 rats and golden apple snail on 25 crops are described with appropriate control measures. Integrated pest management and information on pesticides are also included. Met Advisory and Farm System approach may also be used in Myanmar.

CSVs in Myanmar should be considered focal points for incubating, testing, refining, and improving socio-technical processes for local adaptation. These interventions recognize the context-specific nature of current and anticipated climate change manifestations. CSVs generate locally-relevant, culturally-relevant, ecosystem -based adaptation options. CSVs are also focal points for generating the site-specific evidence of scalable CSA options, and such CSVs will be the basis for generating case studies, impact stories, and advocacy materials. CSVs are expected to serve as models for R&D agencies seeking ways to support local adaptation programs as part of the commitment under the Myanmar NAPA. This involves generation of cost effective and scalable models for fostering CSA adaptation, and adoption on a scale that makes a notable difference to peoples' lives and livelihoods (Barbon, 2018).

In April 2018 in Yangon, the International Institute of Rural Reconstruction (IIRR) launched the four CSVs in Myanmar, namely: Ma Sein village in Bogale (delta), Htee Pu village in Nyaung-Oo (dry zone), Kyaung Taung village in Nyaung Shwe (uplands), and Sakthal village in Hakha (hilly). The CSVs will serve as learning platforms for scaling-out CSA through CBA at the township level.

4.5 Policy engagement

4.5.1 Myanmar Climate-Smart Agriculture Strategy

Agriculture is the most important economic sector in Myanmar as it is essential for national food security and a major source of livelihood for its people. The country's wide agro-ecological diversity enables farmers to grow more than 60 different crops which include tropical and temperate varieties. The predominant food crop is rice which is cultivated in approximately 50% of Myanmar's agricultural land. The agriculture sector contributes 30 % of GDP, 16% of total export earnings and employs 61% of the labor force (MOAI, 2014).

During the 24th ASEAN Summit in May 2014, Myanmar committed to apply CSA to contribute to regional food security and environmental protection. CSA focuses on three pillars in tackling climate change: food security, adaptation, and mitigation.

The Climate-Smart Agriculture Strategy (CSA) has been elaborated in response to the adverse effects of climate change that Myanmar suffers from, such as "scarcity of rainfall, irregular rainfall, heat stress, drought, flooding, seawater intrusion, land degradation, desertification, deforestation and other natural disasters".

The Myanmar Climate Smart Agriculture Strategy aligns with the country's National Adaptation and Plan of Action (NAPA) for climate change, which prioritizes agriculture, early warning systems and forest in its plans and development initiatives.

Adopting agricultural practices that are able to withstand changes in climate and contribute to the reduction of GHG emissions require the application of new technologies, modification of existing ones, and revision of relevant laws and policies.

It seeks to "optimize the benefits and minimize the negative trade-offs across food security, agricultural development and climate change adaptation and mitigation. The key elements of CSA include food security by increasing agricultural productivity, resilience of agricultural systems through adaptation, and mitigation by reducing GHG emission or enhancing carbon sequestration and managing interfaces with other land use management" .

Myanmar's Agenda 21 (MA21) was promulgated in 1997 which set the guidelines in promoting and achieving sustainable development in the country. For the agricultural sector, MA21 has identified two priority areas namely, 1) to promote sustainable agriculture, livestock and fisheries development; and (2) to enhance food security.

To formulate the first two agriculture policies identified in MA21, three key strategies were formulated in 1997, namely:

1) improve paddy rice planting patterns and water management,
2) promote organic farming, and
3) conduct research and development on crop varieties adaptable to climate change.

The MOALI shall be the main implementing agency of Myanmar's climate-smart agriculture strategy in collaboration with other government agencies and local and international partners within Myanmar and in other ASEAN countries. Another strategic area for collaboration is the implementation of Climate-Smart Villages (CSVs) where YAU will serve as the focal point.

The strategy institutionalizes CSVs in Myanmar as a community-based approach to a climate-resilient and sustainable agricultural development. CSVs are benchmark villages that are vulnerable to climate change impacts and where CSA interventions will be tested, prioritized and implemented in close cooperation with the village, government units, and other stakeholders. The CSV approach is a core program that CCAFS is promoting.

The CSA strategy in the Central Dry Zone and other areas will be pursued through adaptation and mitigation programs.

(1) Adaptation Programs - For adaptation, three important initiatives will be prioritized and carried out immediately in the region.

(i) Adapting crop varieties and corresponding farming practices - To increase tolerance and resilience to climate change, a diversity of climate-smart crop varieties will be developed in vulnerable areas like those that are flood or drought prone. For instance, developing new crop varieties including hybrids for commercial production area and open-pollinated varieties for remote areas is required through a climate-adapted crop development program.

The coordinated efforts of DOA, DAR and the community, building village seed banks and promoting them locally will enhance and help farmers diversify crops.

(ii) Disaster risk management in agriculture, the adverse impacts of climate-induced disasters is crop failure and income loss. In reducing the vulnerability to droughts and floods, the use of more water-efficient and/or drought-tolerant crop varieties have a significant role in disaster risk management.

(iii) Crop and income loss risk management currently, there is no insurance program and policy for agriculture in Myanmar. Therefore, risk financing instruments and insurance schemes such as Remote Sensing Index based, Weather-based Insurance System and Crop Insurance System will be formulated in Myanmar to reduce climate-related risks in agriculture. In this regard, the Myanmar Agricultural Development Bank (MADB) will work with the DMH and DOA to establish a steering committee, including other appropriate institutions.

(2) Mitigation Programs: As a mitigation measure, reducing methane from rice fields is an essential program for irrigated rice growing countries like Myanmar.

To reduce methane from rice fields, the following initiatives will be pursued:

- Periodic draining of fields
- Off-season application of rice crop waste
- Discouraging straw burning
- Modified water management strategies coupled with efficient application of fertilizer
- Promoting water harvesting technologies like AWD

4.5.2 Target outcomes

Adaptation targets

(1) New varieties and improved farming systems resilient to drought and water stress
(2) Diversified rural income and improved household economic resilience
(3) Increased prevention and protection against disasters

Mitigation targets:

(1) Reduced CH4 emissions
(2) Reduced land degradation and soil erosion

Double-action targets:

(1) New farming systems and techniques

Climate-Smart Village targets:

1. Improved farmers' livelihoods and income
2. Climatic risks resilience of farming
3. Enhanced farmers' adaptive ability to climate change

Formulating coherent policies and building strong national and local institutions

(a) Formulating coherent policies
(b) Strengthening Myanmar's National Agricultural Research and Extension System for CSA
(c) Rapid Rural Appraisal or Participatory Rural Appraisal in formulating CSA strategies
(d) Gender perspective on CSA
(e) Institutional perspective on CSA
(f) Establishment/strengthening of local agro-meteorology stations
(g) Trade Facilitation and CSA

4.5.3 Implementation in three steps

The implementation of CSA strategies in Myanmar has three steps as follows:

Short-term Steps:

1. Resource and social mobilization
2. Rapid Rural Appraisal (RRA) or Participatory Rural Appraisal (PRA) in benchmarking climate change challenges in the various ecological regions
3. Institutional analysis
4. Establishment or strengthening of local agro-meteorology stations
5. Strengthening communication and public awareness on climate change
6. Evaluation and promoting cultivation of special traditional rice varieties with natural tolerance for deep-water, prolonged flooding, or drought
7. Reducing methane from rice fields and livestock farming
8. Information and knowledge sharing with national, regional and international agencies
9. Promoting adaptive crop – livestock development and farming practices
10. Strengthening climate change research and extension services
11. Practice of conservation agriculture including water, pest and disease management

Medium-term Steps:

1. Developing new high-yielding varieties and livestock breeds, climate smart management options for stress-prone environment
2. Establishment of an adaptation/mitigation information and advisory services

3. Establishment of CSVs in strategic areas
4. Strengthening the NARES

Long-term Steps:

1. Disaster risk management program in farming
2. Crop and income loss risk management program
3. Climate-resilient investment program
4. The Myanmar Climate-Smart Agriculture coordinating body under the Ministry of Agriculture and Irrigation is responsible for monitoring and guiding the government in prioritizing investments in CSA.

4.6 Extension approach

Agricultural extension towards Climate-Smart Agriculture

4.6.1 Challenging and Perspective

Despite the recognized importance of Climate-Smart Agriculture (CSA), the dissemination and uptake of climate smart technologies, tools and practices is still largely an ongoing, challenging process. Barriers at different levels must be overcome and solutions to these challenges must respond to specific local needs.

The development and dissemination of CSA technologies and practices is challenging for several reasons. Firstly, CSA is not a simple ensemble of actions. Crop surfaces are complex systems that must be understood in connection with their climate, weather and atmospheric drivers. This means a strong interdisciplinary vision. Secondly, there must be adequate capacity at different levels to perform the actions and changes needed, and political will to support the implementation of climate-smart actions. This implies engaging multi-actors' interest and, above all, promoting their active involvement. As broadly recognized, all stakeholders – including governments, producers and buyers – should act as one to address the increasingly negative impact of climate change by securing adequate policies, technical and financial conditions for increased productivity, building resilience and the capacity to adapt, and seeking opportunities to mitigate emissions of greenhouse gasses.

The adaption of climate related knowledge, technologies and practices to local conditions, promoting joint learning by farmers, researchers, rural advisor and widely disseminating CSA practices, is critical.

Climate-Smart Agriculture (CSA) has been rapidly taken up by the international community because of its potential to address the urgent needs of climate mitigation, adaptation and resilience, and food security. While lack of location-specific tools, long-term experiences and a favourable enabling environment are barriers to CSA implementation, there are a number of climate-smart technologies and practices that are known and available. Unfortunately, few have shown widespread uptake. One reason for limited uptake and implementation is the difficulty of sharing information and knowledge on effective CSA practices emerging from research. The advisory services suffer in many developing countries from chronic understaffing, limited operational funds and weak linkages to other players, such as research. This situation leads to underperformance of extension systems, limited reach and impact and presents the main challenge for CSA implementation. These systemic constraints can lead to an inability to respond quickly to changing climatic environments with adaptation strategies and are thus a threat for agriculture-based economies.

Extension approaches

Achieving these objectives of CSA requires changes in the behaviour, strategies and agricultural practices of farming households by: improving their access to climate-resilient technologies and practices, knowledge and information for increasing productivity, inputs and market information, information and assistance with income diversification as well as organizing themselves better for collective action. Extension providers can play a major role in supporting these objectives through the following: technology development and information dissemination, strengthening farmers' capacity, facilitation and brokering, and advocacy and policy support. Extension providers in many countries have proven highly successful in using participatory methods and approaches such as participatory technology development, enabling rural innovation and innovation platforms to develop and disseminate technologies and encourage innovation through multiple stakeholder engagement. Extension services also have a wealth of experience in disseminating technologies, information and practices with a range of approaches including traditional extension modes (e.g. interpersonal interaction, demonstrations, field days, printed materials, etc.), ICTs (radio, mobile phones, video, social

media), rural resource centres, farmer-to-farmer extension and farmer field schools, among others.

The new extensionist has therefore mutated from a production centred role to an integrated, cross-sectorial function of the extension ecosystem. Today, extension comes “in many sizes and shapes” and a distinction between the extension approaches as such (e.g. participatory training approach, training and visit approach) or the main underlying principles of the advice (e.g. organic production, integrated production) is not absolute. However, all extension systems share the common challenge of how to best respond to climate change. This is amplified by the fact that CSA considerations in extension strategies can still be considered as new. The need for a shift from a food security focus to an integrated view taking into account both synergies and trade-offs between the three components of CSA is, and will be, a major barrier to CSA implementation and will require considerable investments to develop knowledge and capacities both at extension and farmer level.

Therefore, a functional, climate-smart, sensitive and responsive extension system can be considered as an efficient and cost-effective tool that can play an important role in addressing climate change.

To manage the uncertainties and risks associated with climate change, diversify their agricultural and income options and become more resilient, farmers need to draw on local and scientific knowledge, sharpen their observational and experimental skills and improve their critical thinking and problem solving abilities to be able to make their own decisions about appropriate practices and diversified and resilient income opportunities from a menu of options. RAS have a wealth of experience with non-formal education and experiential learning approaches (e.g. farmer field schools and farmer.

Particularly, bulletins, internet based communication, radio and broadcast, face to face and group meetings and dialogues, seminars and technical meetings are among the main tools used to disseminate agrometeorological information. These tools can provide final users (farmers, actor of the value chain, technical and support services) with proper weather and climate information that is tailored to specific needs, as well as supporting the implementation of activities under the various CSA pillars.

4.6.2 Complementary extension approaches for climate-smart agriculture

There are several ways that extension systems can contribute to CSA. However, the philosophy used (e.g. demand vs. supply led, one-to-one interaction vs. mass extension) and specific approaches suit different types of messages to farmers and provide different possibilities to collect information from farmers' fields. In addition, reach and impact potential, two negatively correlated indicators, are of primary importance and differ between extension approaches: i.e. generally the higher the reach, the smaller the impact and vice-versa (figure 1). Mass media often suits simpler messages while intensive interactions through farmer field schools can be more effective for complex knowledge. Choice of approach combinations can influence the ability of extension services to contribute to food security and income, adaptation and resilience, and climate change mitigation.

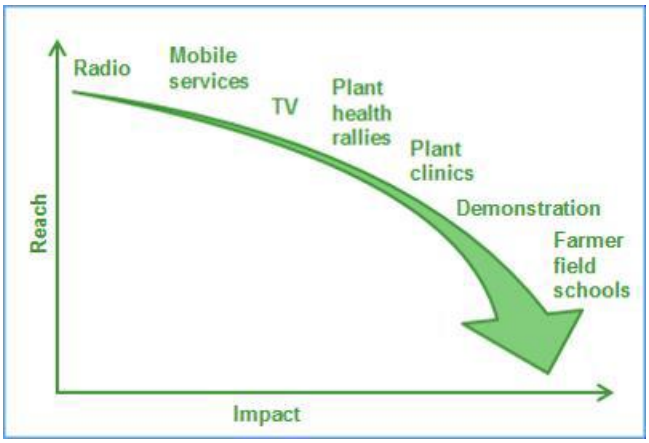


Fig. 4.13 Complementary extension approaches (Raghuvanshi *et al.*, 2018).

Different ways of extension approaches are as follows:

(a)The plant clinic approach to extension works in a similar way to human health clinics; they are the frontline contact point of the national extension system and allow direct information exchange between extension workers and farmers on "any problem and any crop". Plant clinics are a channel for facilitating face-to-face exchange and two-way-flow of knowledge and information between extension workers and farmers and link to other components of a plant health system. They respond to the immediate needs of farmers, offering advice on demand, and are owned by national and local bodies and run on a regular basis in public places that are best suited to meeting farmers.

(b)The plant health rally approach is an extension method for quickly raising awareness about major agricultural risk or threats on important crops, to promote the use of improved agricultural practices, and to collect feedback from farmers on major issues which affect production.

The mass extension campaign approach, in contrast to plant health rallies and plant clinics, delivers targeted messages to thousands of farmers through relevant media such as radio, television, mobile phones and print media, including newspapers and youth targeted publications. Major constraints of national extension systems are shortage of field extension personnel and limited resources to reach large numbers of farmers if spread widely across geographical areas. To tackle these constraints, extension can be more efficiently performed using mass media; for example, in Myanmar the Ministry of Agriculture, Livestock and Irrigation runs a farmer channel aimed at informing and educating the farming community. Extension with mass media can also be run by non-extension players (e.g. radio or television) with technical inputs on messaging from extension workers, for awareness creation or simple information delivery.

Extension services are, and will be key players because of their key role in knowledge transfer and their vicinity to farmers' fields. The correct mix of different extension approaches will largely depend on factors such as: the complexity of the extension messages, the target population and its geographical spread, the available technology, the type and variety of data to be collected from farmers, and lastly on the financial means available for extension as such. On-the-ground implementation of extension also needs to go hand in hand with advocacy and awareness raising of decision makers on the imminent threat of climate change for agriculture in order to make extension more responsive to climate change and contribute to address the triple challenge of food security, adaptation and mitigation.

(c)The Farmer Field School (FFS) is a participatory, non-formal extension approach based on experiential learning that puts farmers and their demands at the centre (FAO, 2002).). FFS is a platform for holistic learning, and should address issues and aspects that directly or indirectly contribute to the performance of the local farming system, even if these issues are not agriculture-based as such. It provides farmers with a low-risk setting to experiment with new agricultural management practices, discuss and learn from their observations, which allows them to develop new practical knowledge and skills, and improve their individual and

collective decision-making (Settle et al., 2014). Climate Field Schools in Indonesia raised awareness of climate change and promoted solutions to cope with changing rainfall patterns, such as recording and interpretation of on-farm rainfall measurements and in-field water harvesting (Winarto et al., 2008).

(d)Farmer-to-farmer extension (F2FE) offers great promise for effectively scaling up climate smart agriculture (CSA). F2FE is "the provision of training by farmers to farmers, often through the creation of a structure of farmer promoters and farmer-trainers" (Scarborough et al., 1997). The objectives of F2FE programs are to increase coverage of large areas and numbers of farmers reached and to enhance sustainability of extension efforts. F2FE programs are common throughout the tropics and are used by many different types of extension providers, including government, NGOs, producer organizations and private companies. F2FE programs contribute to all three pillars of CSA, that is, they help improve productivity, build resilience and reduce greenhouse gas emissions.

4.6.3 Improve training tools for extension agents

Education/training of intermediaries for extension has been proposed to be in two steps for two kinds of intermediaries. The first kind of such extension intermediaries would be working and trained within the centres where the knowledge useful for decision-makers in agricultural production is generated. The second kind of extension intermediaries should be closest to the farmers and operate exclusively at the extension agro meteorology. They should learn to articulate the needs of farmer communities better and seek for (agrometeorological) components that need attention. They should match this with what is or should become available as (agrometeorological) services, in strong contact with the product intermediaries.

Figure 4.14 Extension services- public education (left) and demonstration (right) (Source: Extension Division, DOA).

4.7 Climate change impact and gender

"Gender" refers not to male and female, but to masculine and feminine –that is, to qualities or characteristics that society ascribes to each sex. People are born female or male, but learn to be women and men. Perceptions of gender are deeply rooted, vary widely both within and between cultures, and change over time. But in all cultures, gender determines power and resources for females and males (FAO, 2009).

The gender gap in agriculture is a pattern, documented worldwide, in which women in agriculture have less access to productive resources, financial capital and to advisory services compared to men (FAO, 2011). In the context of Climate-Smart Agriculture (CSA), this gap means that men and women are not starting off on a level playing field. Taking a gender responsive approach to CSA means that the particular needs, priorities, and realities of men and women are recognized and adequately addressed in the design and application of CSA so that both men and women can equally benefit (Nelson and Huyer, 2016).

The impacts of climate change affect everyone. However, not everyone is equally vulnerable, and not everyone has the same capacity to adapt to these impacts. It is clear that climate change will be felt by different groups of people in different ways. Due to differences in socially constructed gender roles and social status, women and men experience the impacts of climate change differently.

Agriculture is central to women's livelihoods, especially rural women. Climatic stresses on agricultural production will make women particularly vulnerable to food insecurity. Rural women are a crucial to agricultural production. In developing countries, on average, women

make up 43 percent of the agricultural labour force, ranging from about 20 percent in Latin America to often over 50 percent in Eastern and Southeastern Asia and sub-Saharan Africa. They also comprise 2/3 of the world's small livestock managers. Between 1980 and 2010, the share of women employed in agriculture increased from about 30 percent to 43 percent in North Africa, and from 35 percent to 48 percent in the Near East (FAO, 2011).

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).

In severe case of food insecurity, women have to sacrifice for other family members by skipping meals or taking less food. Women always get lower wage than men for the same job. Work opportunities (e.g., weeding, harvesting, threshing, and winnowing of paddy) are reduced because of poor crop establishment and poor yields.

It is also vital to note that gender equality and gender equity are different concepts. Gender equality is equal participation of women and men in decision making, equal ability to exercise their human rights, equal access to and control of resources and the benefits of development, and equal opportunities in employment and in all other aspects of their livelihoods (FAO 2013). Gender equity is fairness of treatment for women and men, according to their respective needs (IFAD 2015). Equity and equality both need to be considered in designing CSA interventions.

Empowering women is not just necessary for their well-being, but also a means to broader agricultural development and food security. Women play a vital role in food production, food distribution and food utilization – the three components of food security; they also undertake a range of community-level activities that support agricultural development, such as soil and water conservation, afforestation and crop domestication.

All the CSA interventions need to integrate programming on gender equality and nutrition concerns. Gender norms, roles and customs are very relevant for programme implementation such as assessment and targeting of the specific needs of male and female farmers, selection and gender awareness of the programme implementers, and composition of groups (with

adequate representation of women and girls) and targeting the specific needs and priorities of men and women.

The tools, methods, and indicators/questions used for data/information collection should be gender-sensitive, i.e. they should not exclude women from being able to give their opinions, and by including questions that directly address gender inequalities in the context of implementation. Gender-disaggregated data/information should be collected and gender-sensitive indicators should be created accounting for the diversity of ethnicity, gender, age, class, religion, and culture in the impact assessment. Specific indicators should be developed that are able to measure the achievement of gender equality among programme participants. This may require disaggregation of data by sex and their analysis to identify functional relations and effects.

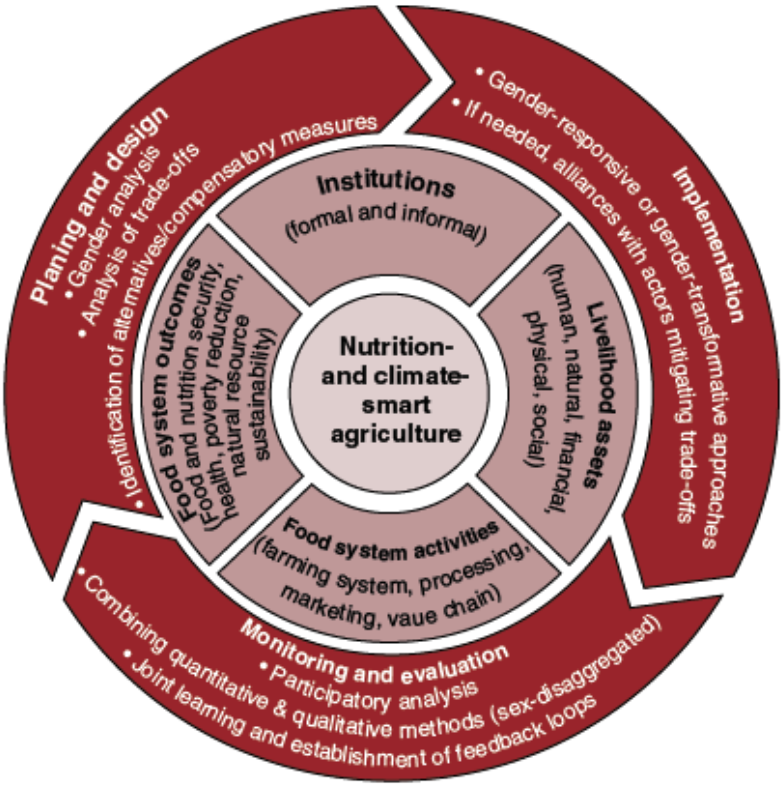


Fig. 4.15 Conceptual Framework for Enhancing Gender and Social Equity in nutrition and Climate-Smart agriculture (© Beuchelt and Badstue, 2013).

4.7.1 The R4 Rural Resilience Initiative

The R4 Rural Resilience Initiative (R4) launched by Oxfam America (OA) and the World Food Programme (WFP) is a comprehensive risk management approach to help communities become more resilient to climate variability and shocks in developing countries. R4 benefits women farmers by contributing to their access to productive assets, as well as by supporting women's savings groups through the Saving for Change program, a cornerstone of the R4 initiative.

Women claimed that they felt empowered: Study in Ethiopia, Kenya and Malawi showed that in addition to having increased access to land, seed, and water for irrigation and drinking, women benefited from training in numeracy, literacy, and business. Having more food and water available also meant that they no longer had to travel far from home to fetch water, with consequent gains in terms of time dedicated to their children or small businesses.

Fig. 4.16 Women participate in an embankment repair cash for work program following Cyclone Giri in Myanmar. (© IRC Myanmar/Burma / CC BY-ND).

Some of the best practices developed through the R4 initiative include the following:

- Equal participation of men and women in Community-based Participatory Planning and management committees at the village level, leading to better targeting and more accurate identification of needs.

- Inclusion of activities that explicitly target women and improve their economic opportunities, such as the development of vegetable gardens, the expansion and improvement of rice cultivation, and the creation of savings groups.
- Inclusion of men in activities traditionally reserved for women, such as the savings groups, which can increase and stabilize a household's resources.
- Reflect socioecological intersections (taking into account both biophysical and human aspects, including gender relations).
- Identify cross-linkages and encourage convergence and coherence across policies.

4.7.2 Gender-sensitive social protection

Social protection programs are critical elements of poverty alleviation strategies. They include social assistance (for example, in the form of cash transfers, school feeding, food-for-work) and social insurance (such as old age and disability pensions and unemployment insurance).

The design of social protection policies and programs with links to CSA creates opportunities to have greater impact, including the following:

- Reaching out to rural women to enhance their role as natural resource managers and as mothers and caretakers.
- Enhancing financial and human capacity to invest in adaptation measures and more effective natural resource management.
- Multidimensional targeting to include economic, social, and environmental risks and vulnerabilities as criteria, such as overlapping income poverty, food security, and climate-risk maps.
- Linking social protection management and information systems with climate-related early warning systems, to promote timely and flexible responses when severe weather events strike.
- Designing public works programs aimed at increasing incomes, while generating "green jobs" in waste management, reforestation, and soil erosion prevention
- Linking social protection to key financial services such as credit and weather insurance to reduce uncertainty and impacts related to climate variability.

4.7.3 Contribution to CSA

Women make active and important contributions to climate adaptation based on their local knowledge, skills and social capital; viewing women as passive victims of climate change is limiting and simplistic. If women had access to resources, on-farm yield could increase by 20-30% reducing the number of hungry people in the world by 12-17% (FAO 2011).

Research on women's adoption of agricultural technologies, including CSA technologies, shows that if constraints in access to finances, information and workload are addressed, women can design and adopt innovative tools and techniques.

Conclusion

Women farmers do adopt CSA practices when they have the information, resources and capacity to implement them. However, serious gender gaps in accessing credit, technology and agricultural inputs, capacity-building and household decision-making hinder their adoption. These key constraints are linked to the assets women possess and their levels of access to income and common property resources. Incorporating a gender equality perspective into policy-making and implementation is necessary to ensure that the vulnerabilities of women and other disadvantaged groups are identified and addressed.

Suggested Topics for Case Studies (Postgraduate Level)

1. Soil Conservation as a measure to increase yield and sequester carbon
2. Disease resistant and early maturing chickpea to boost production / SRI / AWD / Urea Deep Placement
3. Moisture harvesting for groundnut with windbreak trees in dry zone area
4. Biogas to replace firewood in rural area
5. The role of SALT for soil conservation and crop production
6. The role of mechanization to offset climate change
7. Strengthening institutional capacity to adapt to CC

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