វិទ្យាស្ថានសភាកម្ពុជា

PARLIAMENTARY INSTITUTE OF CAMBODIA

RESEARCH PAPER

Regional fellowship program

The Future Challenges Posed by Climate Change on Water Utilization in the Dry Zone of Myanmar

Researcher:	Ms. Daw Su Thandar Shein, Fellow from Myanmar
Direct Supervisor:	Ms. Ros Bandeth, Senior Instructor
Editor:	Dr. Jan Taylor, Communication Advisor

February 2018

Notice of Disclaimer

Abbreviations

ADRA	: Adventist Development and Relief Agency
CDN	: Construction of Dutch NGOs
DI	: Department of Irrigation
DMH	: Department of Metrology and Hydrology
GCMs	: General Circulation Models
IPCC	: Intergovernmental Panel on Climate Change
IWMI	: International Water Management Institute
NASA NEX-GDDP	: NASA Earth Exchange Global Daily Downscaled Projections
NGOs	: Non-Governmental Organizations
SWC	: Soil and Water Conservation
TDH	: Terre des Hommes
UNDP	: United Nations Developmental Programme
USAID	: United States Agency for International Development
WHH	: Welt Hunger Hilfe
WRUD	: Water Resources Utilization Department

Table of Contents

List of Tables and Figures

1. Introduction

The dry zone of Myanmar covers more than 54,000km, encompassing 54 Townships which span from lower Sagaing Region, to the western and central parts of Mandalay Region and most of Magway Region.[1] It is mostly flat, with the Irrawaddy River (joined by the Chindwin River) flowing through it from north to south. The Bago Hills run parallel to the Irrawaddy River in the southern part of the Dry Zone.[2] It is characterized as densely populated and more rural compared with the national average. The current population of Myanmar's dry zone districts is 9,794,814 (19 percent of the total).[3] Among these people, the great majority are rural residents (83 percent).[3] Approximately 43 percent live in poverty and 40-50 percent of the rural population are landless.[4] Population density is approximately 1.7 times the national average.[3]

Figure 1 Location of the Dry Zone

The dry zone is the most water-stressed region of the country. Around 70 percent of households have access to safe water for domestic use but seasonal water scarcity is very common.[2] A quarter of all households report that they have insufficient water during the dry summer season.[5] Access to water differs greatly between communities. Villagers access water for farming and domestic use from a combination of sources, including rivers and streams, large and small reservoirs, village ponds and groundwater.[2] According to the International Water Management Institute's community-level survey, of the amount of water used in villages (excluding irrigation) about 15-20 percent is used for drinking purposes, about 50 percent for other domestic uses and 30-40 percent for livestock.[2]

The dry zone of Myanmar is currently facing water scarcity for agricultural and domestic use. This challenge has encouraged development partners to implement projects to address water scarcity in the area. The global predictions of the Intergovernmental Panel on Climate Change (IPCC), however, suggest that water challenges will emerge in the dry zone as a result of climate change. This means that, long term, climate change will have a greater impact on agriculture and food security and that there is, therefore, a need for strong adaptation strategies for agricultural systems to be developed. Therefore, this study aims to review current and future water challenges in the dry zone caused by climate change and to identify the lessons learnt from current and past water programs in this area. This review aims to address the following objectives:

1.1 Objectives

- To review the historical and future climate change scenarios in Myanmar and particularly in the dry zone of Myanmar;
- To identify current and future water utilization challenges for domestic use and agriculture in the dry zone of Myanmar;
- To review the current and past water programs and lessons learnt in the dry zone of Myanmar.

1.2 Methods

This paper reviews existing documents from the government, NGOs and development partners who are involved in water issues in the dry zone of Myanmar. The study relies on existing data and statistics from the government of Myanmar and the IPCC. In total, seven research reports, four assessments, one summary report, one thesis, two country profiles and two government strategies and other online datasets have been used for this paper.

2. Historical and Future Climate Change Scenarios in the Dry Zone

In Myanmar, high temperatures, water scarcity, variability of rainfall and droughts take place every year. The most vulnerable communities in Myanmar can be found in all three agro-ecological zones, namely the hilly, dry and coastal zones, and are mainly situated in high risk areas, and they participate in risky livelihood strategies.[6] According to the fact sheet "Climate Change Risk Profile of Burma" by USAID, the historical climate trends since 1980, and future projections up to 2100, can be summarized as follows:[7]

2.1 Historical Climate

Historical climate trends since 1980 include:

- An increase in the temperature of 0.14°C per decade along the coast and 0.35°C per decade in the interior, with the highest temperature increases in the central dry zone;
- An increase in the total annual precipitation of 157 mm per decade along the coast and 37 mm per decade inland;
- Late onset and early termination of the southwest monsoon, the average duration of which has fallen from 144 to 125 days;
- An increase in the frequency and intensity of extreme weather events, such as cyclones, that make landfall every year compared with once every three years during the 20th century.

2.2 Future Climate

Projections indicate that by 2100 there will be:

- A mean annual temperature increase of 0.5°C (low emission scenario) to 5.5°C (high emission scenario), with the highest projected increases in the center and north;
- A weakened monsoon climate and decreased cloud coverage leading to increased drought periods;

- An increase in rainfall variability - during the wettest months (May–October) rainfall ranges from a decrease of 45 mm/month to an increase of 200 mm/month;
- An increase in the frequency and severity of extreme weather events, including cyclones/strong winds, flood/storm surges, intense rains, extreme high temperatures and drought;
- Sea level rise of 0.2–0.6 m or more by 2100.

2.3 Future Climate Change Scenarios in the Dry Zone

In Myanmar, studies that could be downscaled to produce climate change projections in the dry zone are limited. Based on available data that the researcher could find, the future climate change scenarios in the dry zone are as outlined below. The sea level rise parameter is not relevant to the dry zone, so it is not included.

2.3.1 Temperature

The annual range of projections for the central dry zone suggest that the temperature will increase by the end of the 21st century. The average increases in temperature for the central dry zone will span between 0.7 ºC and 1.1 ºC for 2011-2040, and between 1.2 ºC and 2.7 ºC by 2041-2070, according to NASA Earth Exchange Global Daily Downscaled Projections (NASA NEX-GDDP) dataset (Tables 1 and 2). The temperature increases are smaller during the wet season and larger for the remainder of the year.

Table 1 Projected change in mean temperature from 2011-2040 compared with the 1980-2005 average for the nation of Myanmar as a whole and in eight major regions

Region	Annual		Hot Season (MARCH TO MAY)		Wet Season (JUNE TO OCTOBER)		Cool Season (NOVEMBER TO FEBRUARY)	
	Low Estimate	High Estimate	Low Estimate	High Estimate	Low Estimate	High Estimate	Low Estimate	High Estimate
Myanmar (All Regions)	+0.7°C	+1.1°C	+0.8°C	+1.2°C	+0.6°C	+1.1°C	+0.7°C	+1.2°C
Ayeyarwady Delta	+0.5°C	+0.9°C	+0.6°C	+0.9°C	+0.5°C	+0.8°C	+0.5°C	+1.0°C
Central Dry Zone	+0.7°C	+1.1°C	+0.9°C	+1.2°C	+0.6°C	+1.0°C	+0.7°C	+1.2°C
Northern Hilly	+0.7°C	+1.2°C	+0.8°C	+1.3°C	+0.6°C	+1.2°C	+0.7°C	+1.2°C
Rakhine Coastal	+0.7°C	+0.9°C	+0.7°C	+1.0°C	+0.6°C	+0.9°C	+0.7°C	+1.1°C
Eastern Hilly	+0.7°C	+1.2°C	+0.9°C	+1.4°C	+0.6°C	+1.2°C	+0.7°C	+1.3°C
Southern Coastal	+0.6°C	+1.0°C	+0.6°C	+1.1°C	+0.6°C	+0.9°C	+0.6°C	+1.0°C
Yangon Deltaic	+0.6°C	+1.0°C	+0.7°C	+1.1°C	+0.6°C	+1.0°C	+0.6°C	+1.1°C
Southern Interior	+0.7°C	+1.1°C	+0.8°C	+1.2°C	+0.6°C	+1.1°C	+0.7°C	+1.1°C

Source data: NASA Earth Exchange Global Daily Downscaled Projections (NASA NEX-GDDP) (2015)

Note: Low estimate refers to the 25th percentile of model outcomes in greenhouse gas emissions scenario RCP. High estimate refers to the 75th percentile of model outcomes in greenhouse gas emissions scenario RCP 8.5.

Table 2 Projected change in mean temperature from 2041-2070 compared with the 1980-2005 average in eight major regions and for the nation of Myanmar as a whole

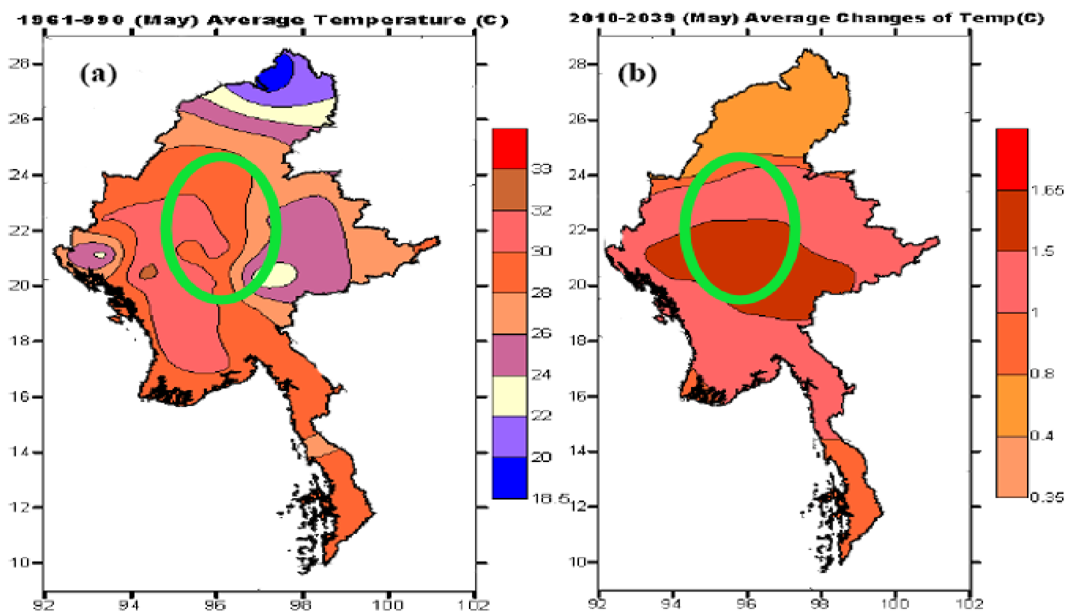
Region	Annual		Hot Season (MARCH TO MAY)		Wet Season (JUNE TO OCTOBER)		Cool Season (NOVEMBER TO FEBRUARY)	
	Low Estimate	High Estimate	Low Estimate	High Estimate	Low Estimate	High Estimate	Low Estimate	High Estimate
Myanmar (All Regions)	+1.3°C	+2.7°C	+1.4°C	+2.9°C	+1.1°C	+2.4°C	+1.3°C	+2.8°C
Ayeyarwaddy Delta	+1.1°C	+2.1°C	+1.2°C	+2.4°C	+1.0°C	+2.0°C	+1.1°C	+2.4°C
Central Dry Zone	+1.2°C	+2.7°C	+1.5°C	+2.9°C	+1.1°C	+2.3°C	+1.3°C	+2.9°C
Northern Hilly	+1.4°C	+2.8°C	+1.5°C	+2.9°C	+1.2°C	+2.7°C	+1.4°C	+2.9°C
Rakhine Coastal	+1.2°C	+2.4°C	+1.3°C	+2.7°C	+1.1°C	+2.1°C	+1.2°C	+2.6°C
Eastern Hilly	+1.4°C	+2.8°C	+1.6°C	+3.1°C	+1.2°C	+2.5°C	+1.5°C	+2.8°C
Southern Coastal	+1.1°C	+2.4°C	+1.2°C	+2.6°C	+1.0°C	+2.2°C	+1.1°C	+2.5°C
Yangon Deltaic	+1.2°C	+2.4°C	+1.2°C	+2.7°C	+1.1°C	+2.2°C	+1.2°C	+2.7°C
Southern Interior	+1.3°C	+2.6°C	+1.4°C	+2.9°C	+1.1°C	+2.3°C	+1.3°C	+2.7°C

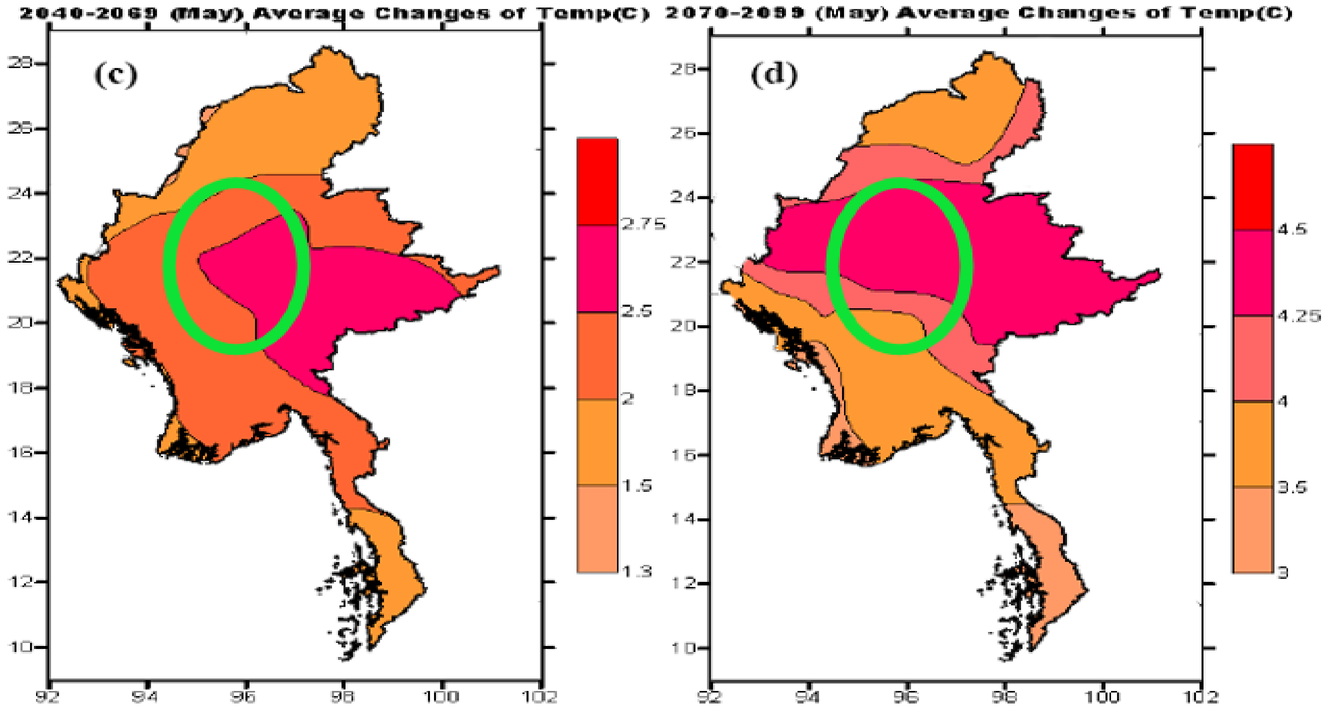
Source data: NASA Earth Exchange Global Daily Downscaled Projections (NASA NEX-GDDP) (2015)

Note: Low estimate refers to the 25th percentile of model outcomes in greenhouse gas emissions scenario RCP. High estimate refers to the 75th percentile of model outcomes in greenhouse gas emissions scenario RCP 8.5.

In the same vein, according to the DMH-computed ECHAM5 model simulation, that uses the scenarios for Average Surface Air Temperature for analysis, the average rise in the surface air temperature for the 21st Century in the dry zone in May will be between 0.8˚C and 1.6˚C during the first 30-year projection period (2010s-2039s), 1.6˚C and 2.6˚C in the middle phase 30-year period (2040s-2069s), and 3.29˚C and 4.23˚C for the last 30 years of the century (2070s-2099s) (Figure 2). This model is similar to the first that predicted a rising temperature for the dry zone within the 21st century.

Figure 2: IPCC Special Report Emissions Scenarios (SRES A2)
(a)- 1961-1990 average temperature in May; (b) average changes of temperature for 2010-2039; (c) average changes of temperature for 2040-2069; (d)average changes of temperature for *2070-2099.*
The Dry Zone Project Area is encircled in green (Department of Meteorology and Hydrology, 2010)





2.3.2 Precipitation

For the central dry zone, the annual projected change in mean precipitation (as a percentage) is from 2 percent to 11 percent from 2011-2040 and from 9 percent to 26 percent in 2041-2070, according to NASA Earth Exchange Global Daily Downscaled Projections (NASA NEX-GDDP) dataset. However, this varies by season. Increased precipitation is mainly expected during the wet season, but it then significantly drops during the hot season (from March to May) and the cool season (from November to February) between 2041 and 2070. (Tables 3 and 4)

Table 3 Projected change in mean precipitation (%) in the 2011-2040 period compared with the 1980-2005 average in eight major regions and for the nation of Myanmar as a whole

Town/citiy	Annual		Hot Season (MARCH TO MAY)		Wet Season (JUNE TO OCTOBER)		Cool Season (NOVEMBER TO FEBRUARY)	
	Low Estimate	High Estimate	Low Estimate	High Estimate	Low Estimate	High Estimate	Low Estimate	High Estimate
Myanmar (All Regions)	+1%	+11%	-11%	+12%	+2%	+12%	-23%	+11%
Ayeyarwady Delta	-1%	+11%	-13%	+18%	0%	+10%	-27%	+13%
Central Dry Zone	+2%	+11%	-14%	+13%	+3%	+12%	-32%	+9%
Northern Hilly	+2%	+13%	-10%	+14%	+3%	+16%	-19%	+8%
Rakhine Coastal	0%	+9%	-17%	+14%	+2%	+10%	-30%	+8%
Eastern Hilly	0%	+10%	-11%	+11%	+2%	+12%	-25%	+9%
Southern Coastal	-1%	+8%	-10%	+8%	-2%	+9%	-11%	+18%
Yangon Deltaic	0%	+12%	-12%	+19%	+1%	+11%	-29%	+14%
Southern Interior	+1%	+11%	-11%	+11%	+1%	+13%	-28%	+14%

Source data: NASA Earth Exchange Global Daily Downscaled Projections (NASA NEX-GDDP) (2015)

Table 4 Projected change in mean precipitation (%) in the 2041-2070 period compared with the 1980-2005 average in eight major regions and for the nation of Myanmar as a whole

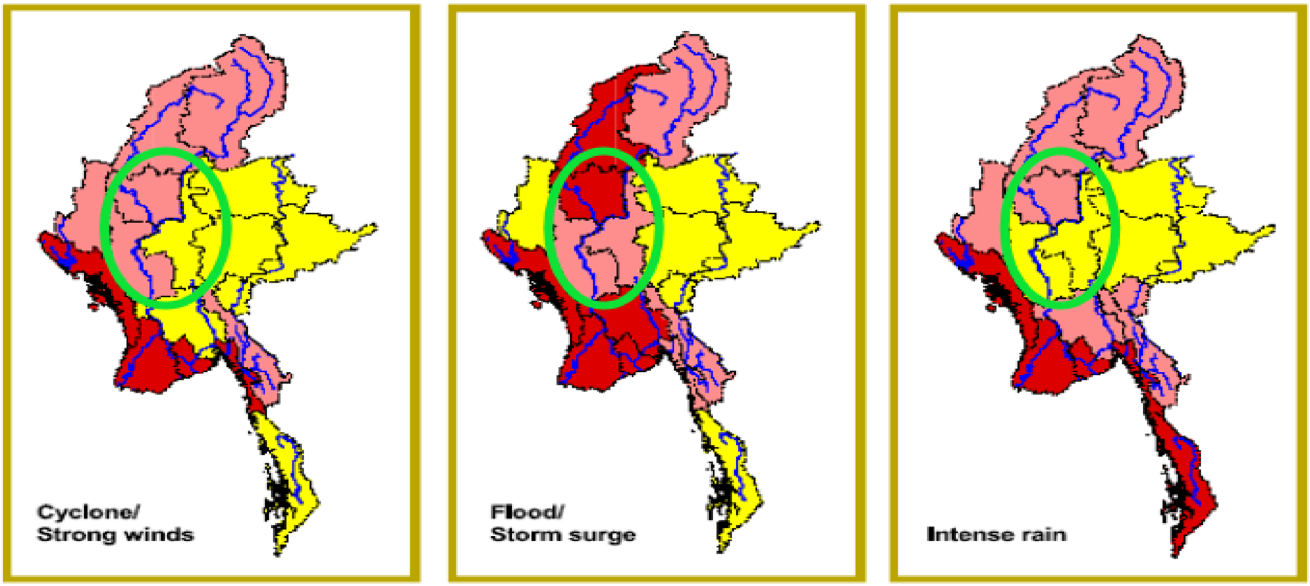
Town/citiy	Annual		Hot Season (MARCH TO MAY)		Wet Season (JUNE TO OCTOBER)		Cool Season (NOVEMBER TO FEBRUARY)	
	Low Estimate1	High Estimate2	Low Estimate	High Estimate	Low Estimate	High Estimate	Low Estimate	High Estimate
Myanmar (All Regions)	+6%	+23%	-7%	+19%	+6%	+27%	-12%	+11%
Ayeyarwady Delta	+3%	+23%	-7%	+19%	+3%	+25%	-9%	+15%
Central Dry Zone	+8%	+22%	-12%	+14%	+9%	+26%	-19%	+6%
Northern Hilly	+7%	+27%	-4%	+33%	+7%	+30%	-14%	+10%
Rakhine Coastal	+5%	+20%	-17%	+12%	+6%	+23%	-20%	+2%
Eastern Hilly	+7%	+24%	-8%	+14%	+7%	+30%	-15%	+7%
Southern Coastal	+3%	+16%	-2%	+13%	+1%	+18%	-1%	+29%
Yangon Deltaic	+5%	+24%	-4%	+17%	+5%	+26%	-5%	+15%
Southern Interior	+7%	+25%	-5%	+11%	+7%	+29%	-6%	+15%

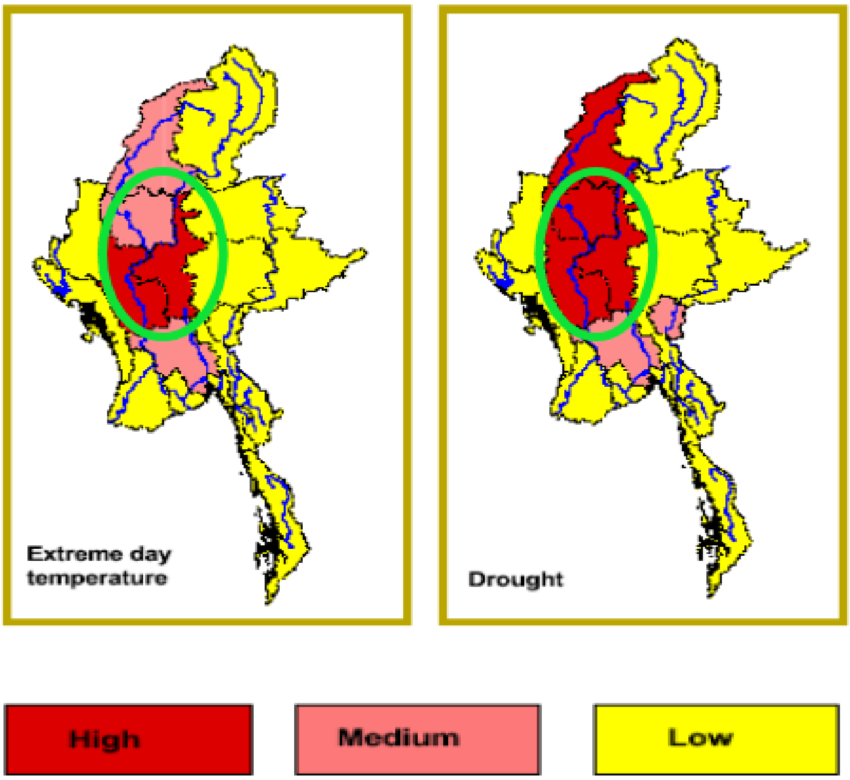
Source data: NASA Earth Exchange Global Daily Downscaled Projections (NASA NEX-GDDP) (2015)

2.4 Exposure to future risk levels in the dry zone

It is estimated that, in the future, the risks encountered in the dry zone in terms of extreme day temperatures and drought will be higher than other risks, such as cyclones, strong winds, floods and intense rain, according to the General Circulation Models (GCMs). This means that the most vulnerable sectors in the dry zone in the future will be agriculture and water resources (Figure 3). [8]

Figure 3 Risk levels for different climate-related hazards in Myanmar, based on the extrapolation of observational time-series data and confirmed by General Circulation Models (GCMs). The project area (dry zone) is encircled in green





Source: Department of Meteorology and Hydrology (DMH), November 2009

3. The Current Challenges in respect of Water for Domestic and Agricultural Use in the Dry Zone of Myanmar

3.1 Water scarcity

Water scarcity is not only a problem for agriculture but also for domestic use, and has been widely acknowledged to be a key constraint to development, a hindrance to livelihoods and to people's wellbeing in the dry zone.[9] According to data from the Water Resource Utilization Department, in Magwe, Mandalay and Sagaing, 6.65 million people access domestic water from more than 13,700 wells, two thirds of which are deep. Drinking water is mainly accessed from wells, while water for livestock and washing is drawn from open ponds in the wet season or shallow wells in the dry season.[10]

However, it has been found that village ponds often dry up in the early stages of the dry season and villagers then revert to subsurface supplies that are more annual in nature but are situated quite remotely.[11] Water scarcity for domestic use also takes place during the monsoon when there are dry spells. If the dry spells last for prolonged periods (more than two or three weeks), this can cause problems for local people. During such times, water resources are limited to rainwater or shallow wells.[2]

With regard to water for agriculture, water scarcity mostly occurs in the early monsoon period and is due to droughts. Normally, annual rainfall is 29.5 inches (the average of the extremes of 40 inches to 19 inches) and the number of rainy days range from 41 to 62 days per year (1967-1978): Around 21 percent of the dry zone Townships are affected by drought every year.[12] Thus, the probability of drought occurring in any given Township is once in every five years.[13] According to the characteristics of identified droughts using rainfall series, the first serious drought to hit the area took place during 1979 and 1980.[14] The second hit lower Sagaing and Mandalay, and took place during 1982 and 1983. The third - during 1993 and 1994 - hit the whole dry zone area.[14] According to the Drought Annual Report (2010-2013) of the Department of Metrology and

Hydrology (DMH), drought also occurred in the dry zone area during the pre- and peak monsoon period of 2010. The droughts have mainly affected agricultural fields, farmer activity and the availability of drinking water. [15]

3.2 High Cost of Water Access

Surface water (from rivers and storage) is more easily accessible than water from other sources that can incur the costs of pumping, and the construction of infrastructure in areas that are remote from the major rivers. Insufficient storage capacity, and the lack of irrigation infrastructure situated in appropriate locations, constrain access to the water.[10] Electric pumps, while more reliable, have higher fixed costs: the cost of installing a well and electric pump for a village system can be as high as USD 40,000.[4] Shallow tube wells are cheaper to dig than deeper ones, but are also more likely to suffer from water quality issues. The cost of building a pond differs depending on its size and type, while the cost for a small irrigation dam serving 10ha in the dry zone is estimated to be around USD 6,000.[2]

3.3 Pressure on Groundwater

The dry zone has moderate levels of groundwater with annual local recharge estimated at 4,777 Mm^{3}y^{-}1. This is equivalent to about half of the current surface water storage and less than 2 percent of total surface water resources in the dry zone. Although this is sufficient to irrigate a further 11,000 to 330,000 ha by estimating, its use has tended to increase in recent times. [2]
In the dry zone, smallholder farmers access groundwater in several ways, using different types of wells and methods for lifting water, in accordance with the differing depths of the groundwater. There are four main ways of accessing groundwater for agricultural use, including deep tube wells, shallow tube wells and permanent dug wells, shallow dug wells and indirect pumping (Table 5). [2]

Table 5 Accessing groundwater for irrigation in Magwe, Mandalay and Sagaing-MMS

Division	Deep Tube Wells	Shallow Tube Wells	Irrigable Area(ha)
Magwe	1298	-	4271
Mandalay	1346	675	7696
Sagaing	880	1968	20999
Total	6167		

Source: (WRUD http://wrdu.moai.gov.mm)[16]

Generally, groundwater in the dry zone flows from elevated areas to discharge directly or indirectly (through tributaries) to the major rivers. If the water for use through the large number of artesian and sub-artesian tube wells and dug wells and from pumped wells is over-extracted, this situation can be said as a discharge. [17]

3.4 Underperforming Irrigation

Farming in the dry zone is made possible with irrigation that responds to the highly variable rainfall, but the current irrigation systems are often underperforming. It has been found that the actual area irrigated is often much smaller than is indicated as desirable in the plan. This is attributed to a mix of issues, including inadequate funding, the limited technical capacity of communities for operating and maintaining facilities, the availability and cost of energy for pumped systems, and the lack of flexibility in water delivery and scheduling.[2] For the dry season of 2011, the International Water Management Institute (IWMI) estimated that the total irrigated area (using both formal and informal irrigation methods) was 0.27m ha. In all irrigation schemes, the effective irrigated area was considerably smaller than the command areas; for example, the Water Resources Utilization Department (WRUD) reported that in 2012-2013 only 26 percent in the wet season and 15 percent in the dry season of the command area was actually irrigated in Naung-U town. A government report released by the Auditor General's Office in 2012, found that nationally: "Sixty-seven river water pumping stations have achieved 16.3 percent of their target, providing water for 48,833 acres out of the 299,895 acres originally planned"[1], and that some reservoirs and diversion dams could not supply water at all. The report recommended that inefficient schemes be abandoned rather than rehabilitated.[10]

4. The Future Challenges of Water Utilization for Domestic Use and Agriculture in the Dry Zone of Myanmar

Based on the climate projection data above, it is likely that the dry zone will encounter various climate stressors in the future due to the rise in temperature, less rainfall, increased tropical cyclone activity and droughts. From previous studies, this paper found that, in the future, water utilization in the dry zone might encounter water stresses that are more severe than has recently been the case relating to water availability, quality, accessibility and groundwater use. There appears, therefore, to be a pressing need to undertake more appropriate water planning and management.

4.1 Water Availability

As discussed above, the temperature in the dry zone could rise by up to 4.23˚C by the end of 21st century and reduced precipitation is predicted during the hot and cool seasons. The rise in temperature and lower precipitation in the dry zone means that the water available in this area - both surface water and groundwater - will be reduced, and this suggests that safe access to drinking water will also be difficult.[2] According to Labat *et al.* (2004), international projections show that for each temperature rise of 1 ºC, there is a 4 percent increase in global total water run-off, [18] and the groundwater recharge rate and depths will also be affected.[19] However, the severity of drought and the impact of temperature on groundwater availability could also depend on: [19]

- The duration of the drought episodes;
- The type, design and siting of groundwater supplies (shallow dug wells are likely to be more sensitive and interfluve sites are likely to be more affected than those in valleys);
- The demand on sources; and
- The characteristics of the aquifer, in particular its storage (the crystalline basement and volcanic aquifers are likely to be more sensitive than large alluvial formations).

4.2 Water Quality

No specific study has yet been undertaken to predict the impact of future climate change on water quality in the dry zone of Myanmar. However, Bates *et al.* (2008), who synthesized findings on water quality in relation to climate change across the globe, found that higher temperatures in conjunction with increased intensity of precipitation and longer period of low flow could cause water pollution for two major reasons. First, algal bloom and bacterial and fungal content could grow and damage water quality. Second, higher temperatures could raise the level of thermal

[1] https://www.mmtimes.com/national-news/1055-committee-urges-action-on-failing-irrigation-projects.html

stability of lakes and streams which would then reduce oxygen concentrations, thus affecting ecosystems and water quality for drinking.[19]

4.3 Accessibility

Limited accessibility to water will be another issue in the dry zone as a result of climate change. A rise in temperature will lead to an increase in the use of groundwater for domestic and agricultural purposes in this area. People will install irrigation systems to draw water from groundwater supplies more than from other sources because surface water (from rivers and storage) is more readily available. The resulting cost for electric pumping and infrastructure in areas remote from the major rivers would be significant. As a result, it is clear that poor people would have limited options as they cannot afford the cost of pumping systems. Diesel pumps have lower fixed costs, but when the price of diesel is rising, the variable costs will be high.[10] Another challenge is that, given the level of demand in the dry zone for water from irrigation, the water supply might not be sufficient in the future if the current issues relating to underperforming irrigation systems are not addressed effectively. Within the dry zone, the extent of irrigation is not well established.[2] Untimely or inadequate levels of rainfall leave farmers particularly vulnerable to the vagaries of the weather, with some farmers experiencing low crop yields.[10]

4.4 Excessive Groundwater Use and Side Effects

It is clear that increases in the frequency and duration of droughts will increase pressure on groundwater needed for expanding irrigated agriculture.[6] This issue could be another future challenge in the dry zone given the current extraction level of groundwater in the area. According to international data, groundwater levels of many aquifers around the world have been decreasing during the last few decades, but this is generally due to groundwater pumping surpassing groundwater recharge rates, and not to a climate-related decrease in groundwater recharge. There may, however, be regions, such as south-western Australia, where increased groundwater withdrawals have been caused not only by increased water demand but also because of a climate-related decrease in recharge from surface water supplies.[19] [20]

In reality, there is a wide range of exploitation-related effects and it is not always appreciated that differing hydrological environments show varying susceptibility to the side effects of excessive abstraction. Such side effects will, in many instances, be difficult to predict with precision until some systematic monitoring of aquifer response to abstraction has been undertaken. [21]

5. Current and Past Water Programs and Lessons Learnt in the Dry Zone

5.1 Current and Past Water Programs in the Dry Zone

Over the last 20 years, substantial efforts have been made by development partners and NGOs relating to the provision of water for rural communities, with most programs targeting either the domestic water supply, or agricultural water/ irrigation in the dry zone. Around eight major agencies have implemented water programs in the dry zone so far. The five main mechanisms that had been used by those agencies to address water scarcity are:

1. An improvement in formal irrigation infrastructure;
2. Groundwater interventions for domestic and agricultural supply;
3. Rainwater harvesting and storage;
4. Soil and water conservation (SWC) approaches/ watershed management; and
5. Water resources planning and information.

Besides these mechanisms, some NGOs have also sought to address water scarcity through building the capacity of local people to manage water and to integrate water management into people's livelihoods. For example, the programs of Action Aid and ADRA have focused on capacity development, women’s leadership, youth leadership and community participation and training to manage water in the community. ADRA has also implemented a cash-for-work project to mobilize people to participate in building water infrastructure (Table-6). [10]

The United Nations Development Programme is currently supporting the provision of water supplies to more than 1,700 villages in the Dry Zone under the UNDP Human Development Initiative Integrated Community Development Programme and the UN Human Settlements Programme ”Shae Tot”. [10]

Table 5 Water-related interventions currently in use or under consideration in programs in the Dry Zone. [10]

Agency	Technology/Approach	Purpose
WRUD	Spate irrigation	Water supply – irrigation Schemes (infrastructure)
DI	Gravity-fed irrigation schemes	
WRUD	Pump irrigation schemes	
	River diversion	
	Canal irrigation	
Action Aid	Irrigation system improvement	
	Optimizing reservoir operations	
CDN	Sluice gates	
Action Aid	Tube wells (deep)	Water supply -groundwater (infrastructure)
Action Aid	Artesian wells	
ADRA	Tube wells (shallow)	
ADRA	Groundwater recharge	
	Storage tank with deep well	
Action Aid	Wells (hand dug)	
Action Aid	Dike/Road	Drainage (infrastructure)
	Drainage improvement	
	Culvert	
Proximity	Drip irrigation kits	Irrigation-Water application (infrastructure)
	Micro-gardens, hydroponic greenhouses	
TDH	Hydroponics / drip irrigation / RWH	
	Dams / ponds	Surface storage (infrastructure)
	Household water container	
Action Aid	Sand dike /sand dam	
	Turkey nest dams (pumped from rivers)	
Action Aid	Dams and weirs	
ADRA	Rainwater tanks from roof (schools)	
Action Aid	Mini Earth Dam (with government machines)	
	Pond fencing	
Action Aid	Pond renovation	
	Hand pumps	Water lifting Technologies (infrastructure)
	Small pumps	
	Solar pumping from tube wells	
Proximity	Treadle pumps	
	Piped water supply by gravity flow (PSGF)	Water access (infrastructure)
	Household water container	
	Water fetching points (i.e. decreasing work in accessing water)	
CDN	Reclaiming degraded land	Watershed management
	Removal of thorn bushes	
	Re-vegetation	
WHH	Erosion control	
WHH	Removal of sand from canals	
WHH	Bank stabilization in rivers	
	Soil water conservation (mulching etc)	
Action Aid	Community forestry	
ADRA	Woody weed removal	
	Reforming cultivable land (levelling, adding topsoil)	
	Community forestry	
Action Aid	Women Leadership – advisory mother groups	Water planning, capacity development, and integration of water into livelihoods
Action Aid	Youth (Fellows) leadership	
Action Aid	Community Action plan (Approach)	
Action Aid	Collaboration with local government	
ADRA	Cash for work – as livelihood improvement as well as labor	
ADRA	Integration of water supply into livelihoods	
ADRA	Community participation	
ADRA	Training	
TDH	Sustainable agricultural techniques tailored to local environment	
TDH, CDN	Farmer field schools, technical assistance	
	Market value chains	

5.2 Lessons Learnt

There are important lessons that can be extracted from the experience of NGOs in implementing water programs in the dry zone:

- Future water programs in the dry zone need to keep investing in building irrigation infrastructure in the relevant areas. Irrigation systems have been viewed in relation to their role in providing farmers with access to water to improve their livelihoods, increase their living standards and reduce poverty in the dry zone;
- However, as irrigation needs to be further developed, it is important that, as a necessary precursor to any large-scale irrigation programs, an appraisal of recharge, sustainable yield of aquifers and water quality, relative to current and planned use of groundwater, is undertaken;
- It is worth noting that involving village communities and district/local government agencies in planning, construction and management of village reservoirs, is important. Action Aid and ADRA have successfully expanded participatory methods for working with communities to ensure that water interventions are closely linked to village development plans;
- Experience has shown that village reservoirs can provide livelihood opportunities for the landless, for example, through payments for construction, management and maintenance or establishment of community forests around ponds as part of watershed management (Action Aid). Therefore, these mechanisms still need to be considered for future water programs;
- It is important to ensure long-term maintenance of reservoirs through technical and social approaches;
- Better hydrogeological information could improve targeting and reduce the costs of drilling, so there is a need for hydrogeological research in the dry zone.

6. Conclusion

The effects of climate change in Myanmar are already being felt and will increase in the coming decades: this is proving particularly challenging in terms of water utilization for people in the dry zone. This paper has aimed to review the current water challenges for domestic and agricultural purposes in the dry zone and has identified the future challenges of water utilization caused by climate change. The findings of this paper have revealed that, in the dry zone, both surface and groundwater are equally important for local people's livelihoods. However, currently there are various constraints faced by people in respect of water in the dry zone, such as water scarcity, the high costs of water access, pressure on groundwater and underperforming irrigation.

The projections in respect of climate change in Myanmar show that, overall, the temperature will increase and precipitation patterns will also change over the coming century across the country. Especially, in the dry zone, the temperature is increasing, and changes in the variability, duration and intensity of drought during the hot and cool seasons can be expected by the end of 21st century. This means that the current water availability and accessibility in the dry zone will be worsened in the future. As this paper has shown, water quality and the side-effects of the over-extraction of groundwater, represent other water challenges to be considered by stakeholders in this area.

Several key measures had been used by development partners to address water challenges in the dry zone and several lessons have been identified. However, it is important to note that the main challenge still revolves around the sustainability of those project activities. This paper, therefore, strongly suggests that to improve future water utilization in the dry zone, all the government and non-government agencies involved need to reflect on the current and future water challenges and take into account the lessons learnt in order to design effective water-related interventions in the future in response to climate change in the dry zone.

References

1. Myanmar Information Management Unit, Dry Zone.
2. International Water Management Institute (2015). Improving water management in Myanmar's Dry Zone for food security, livelihoods and health.
3. Myanmar (2014). Population and Housing Census of Myanmar, Provisional Results.
4. JICA (2010). The development study on sustainable agricultural and rural development for poverty reduction programme in the central dry zone of the Union of Myanmar. Report No. RDJR10-502.
5. WFP & FAO (2011). Food Security Assessment in the Dry Zone Myanmar.
6. National Environmental Conservation Committee & (2012). Myanmar's National Adaptation Programme of Action (NAPA) to Climate Change. Ministry of Environmental Conservation and Forestry.
7. USAID (2017). Climate Change Risk Profile: Burma.
8. Khaing (2010). Climate Change Human Security(including food, nutrition and energy security)and Human Rights.
9. International Water Management Instutution (2017). IWMI Recommendations for Priority Action in the Dry Zone of Myanmar.
10. Robyn, J., Rajah, A., Soumya, B., Somphasith, D., Guillaume, L., Matthew, M., Paul, P., Senaratna, S. S., Touleelor, S., Diana, S. & Olivier, J. Identifying priority investments in water in Myanmar's Dry Zone,Final Report for Component 3.
11. McCartney, M., Pavelic, P., Lacombe, G., Khin Latt, Aung Kyaw Zan, Kyaw Thein, Balasubramanya, S., Rajah, A., Aye Myint, Cho Cho, Robyn, J. & Sotoukee, T. (2013). Water resource assessment of the dry zone of Myanmar.
12. Tin Myint Saw. (1990). *Master Thesis: Climtate of the dry zone of Myanmar, .*
13. Kyi Moe Khin. (2012). *Farmer Vulnerability Amidst Climate Variablitlity: A case study of Dry Zone of Myanmar* [Online].
14. Boori, M. S., Choudhary, K., Evers, M. & Paringer, R. (2017). A review of food security and flood risk dynamics in central dry

zone area of Myanmar.

15. Tin Yi. *Drought Conditions and Management in Myanmar* [Online].
16. WRUD Report 3: Appendicies.
17. Drury, L. (2017). Hydrogeology of the Dry Zone – Central Myanmar A summary.
18. Labat, D. (2004). Evidence for global runoff increase related to climate warming.
19. Bates, B. C., Z.W. Kundzewicz, S. Wu and J.P. Palutikof, Eds., (2008). Climate Change and Water: Technical Paper of the Intergovernmental Panel on Climate Change, IPCC Geneva.
20. Austraila, G. (2003).
21. World Bank (2000). Groundwater in Rural Development Facing the Challenges of Supply and Resource Sustainability.