

Evaluating Traditional Knowledge on Climate Change (TKCC): A Case Study in the Central Dry Zone of Myanmar

Wai Yar Lin Zin^{1,2}, Piyakarn Teartisup^{1*} and Prapeut Kerdseub¹

¹Faculty of Environment and Resource Studies, Mahidol University, Nakhon Pathom 73170, Thailand

²Governance for Resilience and Sustainability Project (GRSP), United Nations Development Programme, Yangon 11211, Myanmar

ARTICLE INFO

Received: 25 May 2018
Received in revised:
6 Sep 2018
Accepted: 14 Sep 2018
Published online:
25 Oct 2018
DOI: 10.32526/ennrj.17.2.2019.09

Keywords:

Climate change/ Impacts/
Adaptation/ Traditional
knowledge/ Central Dry Zone

* Corresponding author:

E-mail: tpiyakarn@gmail.com

ABSTRACT

Local people in the Central Dry Zone (CDZ) of Myanmar have been facing climatic variability for several decades. They are among the first communities to observe climate and environmental changes first-hand, and are applying traditional knowledge and skills in order to adapt to these changes. We used participatory action research in which a series of group discussions and debates were conducted in community workshops at the village level. Using this input, we analysed the perceptions of the local people about climate variability, impacts, and adaptation practices. The majority of the local people perceived climate change patterns in the CDZ with the increase of temperature and erratic rainfall patterns perceived as the most critical changes. The majority of the people also perceived that the impacts of climate change have already been affecting agriculture and its related sectors, including land and water resources and their livelihood strategies. Most of the local people also perceived that migration of young people away from the communities has gradually increased due to the consequences of climate change impacts. Farmers have already been attempting to cope with those climate change impacts by using locally relevant adaptation measures such as mixed and multiple cropping systems, changing to drought-resistant plant varieties, and using soil conservation measures to cope with water scarcity. In addition, most of the local people perceived that getting information from traditional weather prediction was helpful to cope with drought and erratic rainfall patterns. However, the results suggest the adaptive capacity of the local people in responding to the impacts of climate change can be improved. In this regard, effective adaptation planning relies on the best available knowledge base, and the urgent need to respond to the pressures of climate change has put a premium on the generation, interpretation and use of information to improve adaptive capacity, including improved access to scaling up the traditional best practices of local people.

1. INTRODUCTION

Myanmar is one of the top ten nations prone to climate change and extreme events (Kreft et al., 2016). There is increasing evidence that climate change will strongly affect Myanmar and will be one of the challenging issues for future development, particularly in the drier regions (Horton et al., 2017). Seventy percent of the country's population reside in rural areas and mainly depend on agriculture, livestock and fishery for their livelihoods and thus the economy of the country and the livelihoods of the majority of its people are increasingly at risk due to climate change (Swe et al., 2015). The Central Dry Zone (CDZ) of Myanmar encompasses three regions, namely the lower Sagaing, Mandalay, and Magway Regions, occupying 13% of the country's

total land area with a current population of 9,794,814 (19% of country's total) (MNCR, 2014). The great majority are rural residents (83% of total population) in this area and they have been practicing their farming practices using traditional adaptive ways even though they are facing the impacts of climate change (Vauhgan and Levine, 2015). The climate is semi-arid and records of annual rainfall, as well as the mean rainy days over the CDZ during the last three decades, clearly indicate a declining trend (MOAI, 2015). In the dry zone, the scarcity of water has become a serious issue (NCEA, 2010b) and the traditional farming systems and cultivation practices are not adapted to these new climatic conditions, which have made the area more vulnerable to the impacts of climate change (NCEA, 2010a). A

previous study reported the extent to which uncertain rainfall destabilizes crop production and rural livelihoods in this CDZ region (Matsuda, 2013). Livelihood activities in the CDZ are dominated by agricultural activities and this zone has low rainfall with high variability and uneven distribution and the risks and uncertainties associated with rain-fed agriculture are high (JICA, 2010; Kyi, 2011).

Traditional knowledge of indigenous peoples and local communities for ecosystem management and sustainable use of natural resources is gaining credence as a key weapon in the fight against climate change (Swiderski et al., 2011). There has been a growing awareness that scientific knowledge alone is inadequate for solving the climate-crisis, and the knowledge of local and indigenous peoples is increasingly recognized as an important source of climate knowledge and adaptation strategies (Finucane, 2009; Nakashima et al., 2012). As traditional knowledge can provide efficient, appropriate and time-tested ways of advising and enabling adaptation of communities to climate change, local adapted practices should be regarded as the starting point in developing new strategies for applicable practices in the field (UNFCCC, 2007).

A review of the literature reveals that climate change adaptation is necessary, for both the mitigation and avoiding the unacceptable impacts of climate change. Climate change has been obvious in Myanmar since 1977 and the climate data have indicated a general warming trend and a decreasing precipitation trend with a range of 2-339 mm per year (NCEA, 2010a). Prolonged dry spells, particularly in July, has delayed crop harvesting and decreased crop yield and water shortages are a serious issue in the dry zone of Myanmar (NCEA, 2010b). Due to these serious issues, the traditional farming systems and cultivation practices are not adapted to these new climatic conditions and as a consequence, this region has become more vulnerable to the impacts of climate change (NCEA, 2010a). However, the local people are the first responders confronting climate change and they are also the ones who need to adapt their farming practices to new climatic conditions in which it is necessary to understand their perceptions of climate change and their knowledge coming from their observation and experiences (Chen et al., 2010).

There is a need to evaluate the knowledge of local people that comes from their experiences and

observations, as they attempt to adapt to the impacts of climate change. This is important in the case of the CDZ of Myanmar where there is a lack of information even though this area is highly vulnerable to the impacts of climate change. At the global scale, the responses to climate change are currently occurring (Adger et al., 2005) and traditional knowledge could also provide efficient and time-tested methods for adaptation to climate change (UNFCCC, 2007). Thus the climate change adaptation practices that are suitable to a local area have to be regarded as the starting points for foreseeable climate change adaptation strategies and action plans. This research focused on traditional knowledge on climate change and the objective of this study is to evaluate the climate change adaptation related to traditional knowledge in the CDZ of Myanmar. Thus, in this article, we evaluated the traditional knowledge of local people in terms of climate change factors, impacts and adaptation through their diverse perceptions in the CDZ of Myanmar.

2. METHODOLOGY

2.1 Study area and village profile

The research was conducted in the CDZ of Myanmar. Specifically, the study was carried out in Yathar village in Myingyan Township, Mandalay Region; Than Pin Kan village in Chaung-U Township, Sagaing Region; and Let Pa Kan village in Pakokku Township, Magway Region (Figure 1). The information, including topographic, demographic, and natural resources in Table 1 shows the conditions of the study areas.

Myingyan Township lies at an elevation ranging from 49 m to 529 m above sea level, Chaung-U Township is between 34 m and 2,760 m above sea level, and Pakokku Township ranges from 34 m to 1,472 m above sea level, respectively. The climate is hot and semi-arid with an average annual rainfall between 600 mm and 900 mm and the mean annual temperature between 26°C and 27.5°C (GAD, 2016). According to Myanmar National Census Report (MNCR, 2014), Pakokku Township is more populated than the other two townships. The urban population is less than the rural population in all three townships. Regarding gender ratio, the female population is greater than the male population in all three townships. As for the age groups of people, the most influential age group is between 15 to 64 years

old, comprising more than 65% of the. The literacy level in both urban and rural areas is more than 90%. At the township level, private employees are significant and account for more than 22% of the total urban population. Overall, the rural population is more than the urban population and more than 68% of the population are rural residents. More than 70% of the rural population are farmers and they rely

on agriculture for their major livelihood. Thus, total cropped areas are more than the forested areas in all three townships. Agricultural production systems are mostly based on rain-fed agricultural systems, while some irrigation is also found. While agriculture is their major livelihood, most of the farmers also practice small-scaled livestock.

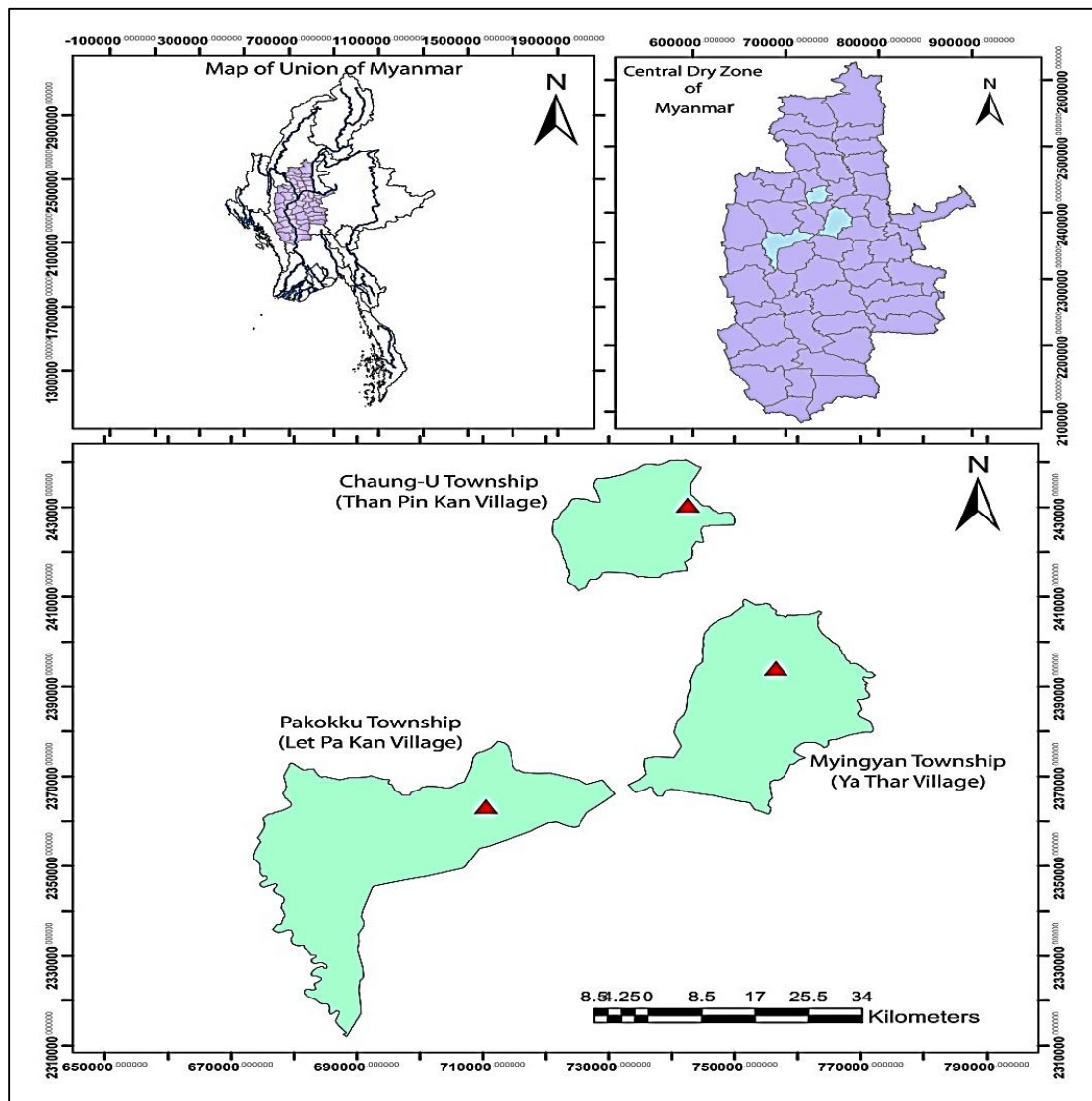


Figure 1. Location of study area; Ya Thar village in Myingyan Township, Than Pin Kan village in Chaung-U Township and Let Pa Kan village in Pakokku Township (MIMU, 2017)

2.2 Methods

Participatory Action Research (PAR) was applied in this research to establish a data set of traditional knowledge on climate change in the CDZ of Myanmar. PAR covers a series of participatory approaches to action-oriented research (Kindon et

al., 2007). Appreciation-Influence-Control (AIC) technique (World Bank, 1996; Ratner and Smith, 2014) was used to explore the traditional knowledge of the local stakeholders about climate change. A qualitative inquiry method was applied to ensure reliable results.

Table 1. Profile of townships and their respective villages in the study area (MNCR, 2014; GAD, 2016; DMH, 2017; DOA, 2017)

Location	1 st Site		2 nd Site		3 rd Site	
	Myingyan Township	Yather Village	Chaung-U Township	Than Pin Kan Village	Pakokku Township	Let Pa Kan Village
Elevation	Min 49 m Max 529 m	-	Min 46 m Max 2,760 m	-	Min 34 m Max 1,472 m	-
Rainfall (Annual)	Avg annual 682 mm	-	Avg annual 889 mm	-	Avg annual 636 mm	-
Temperature (Annual)	Avg 27.4°C Avg Min 21.6°C Avg Max 33.3°C	-	Avg 26.9°C Avg Min 21.2°C Avg Max 32.7°C	-	Avg 27.2°C Avg Min 21.5°C Avg Max 32.9°C	-
Climate	Hot semi-arid climate	Hot semi-arid	Hot semi-arid climate	Hot semi-arid	Hot semi-arid climate	Hot semi-arid
Population	276,056	2,425	105,958	836	290,139	852
	87,708 (31.8%) (Urban Pop)	-	21,929 (20.7%) (Urban Pop)	-	90,842 (31.3%) (Urban Pop)	-
	188,388 (68.2%) (Rural Pop)	-	84,026 (79.3%) (Rural Pop)	-	199,297 (68.7%) (Rural Pop)	-
Male	124,100 (44.9%)	1,158 (47.8%)	48,456 (45.7%)	416 (49.8%)	130,741 (45.1%)	397 (46.6%)
Female	151,996 (55.1%)	1,267 (52.2%)	57,499 (54.3%)	420 (50.2%)	159,398 (54.9%)	455 (53.4%)
Household (HH)	62,340	522	23,376	261	66,340	198
Age groups						
0-14	24.7%	25.3%	25,640 (24.2%)	23.5%	76,844 (26.5%)	25.7%
15-64	67.5%	67.2%	71,985 (67.9%)	68.4%	191,229 (65.9%)	66.5%
65+	7.8%	7.5%	8,333 (7.9%)	8.1%	22,066 ((7.6%)	7.8%
Education						
Literate (%)	93.0%	92.0%	95.2%	94.0%	90.6%	91.0%
Illiterate (%)	7.0%	10.0%	4.8%	16.0%	9.4%	9.0%
Career	2.3% (Gov't)	72.5%	2.1% (Gov't)	76.6%	5.6% (Gov't)	70%
	22.1% (Private)	(farmers)	23.2% (Private)	(farmers)	20.1% (Private)	(farmers)
	3.4% (Employer)	(Landless)	4.7% (Employer)	(Landless)	2.5% (Employer)	(Landless)
	21.4% (Own account worker)		24.4% (Own account worker)		18.6% (Own account worker)	
Land use						
Cropped area	164,830 acres	3,356 acres	96,258 acres	2,150 acres	135,450 acres	1,850 acres
% of rain-fed	96.60%	100%	98.70%	100%	93.06%	100%
% of irrigated	3.40%	0	1.30%	0	6.94%	0
Forested area	18,777 acres	10%	4,900 acres	5%	27,520 acres	15%

There are 57 townships in the three regions of Mandalay, Sagaing and Magway Regions in the CDZ of Myanmar. The researchers used a random

sampling technique in order to select 3 townships. After the researchers had selected 3 townships, purposive sampling technique was used in order to

select 3 villages (1 village in 1 township). Then, stakeholder analysis was carried out to select the participants from each village. The stakeholders were categorized as 3 groups: Local famers (Group A), Village leaders (Group B), and Respected Elders (Group C). The stakeholders were purposively selected according to the inclusion criteria because this research focused on the climate change related to traditional knowledge in the CDZ of Myanmar. There were 90 (30 x 3 villages) participants involved in the research in which each village occupied 30 participants and each group of participants included 10 people. The stakeholder workshops were conducted in three villages, namely Yathar village (Myingyan Township), Than Pin Kan village (Chaung-U Township), and Let Pa Kan village (Pakokku Township), respectively, to collect the required information for this research.

The study was based on group work and discussions with the key stakeholders analysed by the inclusion criteria by applying AIC technique as the primary data-collection method. Several group discussions were also conducted by using the participatory tool known as “Mind Map.” An analysis was carried out in order to link the relationship between traditional knowledge and climate science. In addition, a validation process was included to check the empirical evidence on the climate change factors (i.e., the climate change factors here occupied the temperature and the rainfall data), impacts, and adaptation. The step of evaluation in participation and perceptions of local people was done to ensure the validity of the research results. Within the above mentioned context, the participants’ opportunity to express their perceptions on climate change was very important in determining the climate change factors, impacts, and adaptation.

3. RESULTS AND DISCUSSION

3.1 Perceptions of local people on climate change factors

Climate change is defined by the United Nations Framework Convention on Climate Change (UNFCCC), in its Article 1, as “a change of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods” (IPCC, 2014). NCEA (2010a) states that the impacts of climate change in Myanmar are inevitable with increasing temperatures and decreasing

precipitation trends, with frequent cyclones devastation almost every year since 2002 (except the year 2005), with the late onset and early withdrawal of the southwest monsoon. People’s observations, experiences, knowledge and perceptions of extreme climatic events and their impacts motivate the people to follow the precautions (Grothmann and Reusswig, 2006; Siegrist and Gutscher, 2006; Thieken et al., 2007; Siegrist and Gutscher, 2008) and influence whether or not to follow the adaptation practices (Berkes and Jolly, 2001; Alessa et al., 2008). Moreover, local observations and perceptions could reflect local concerns (Danielsen et al., 2005) and the actual impacts of climate change (Laidler, 2006). Besides, public experiences and their views on the past climate change events can help predict the possible impacts in the future (Lorenzoni and Pidgeon, 2006). Thus, local experiences, observations, and perceptions should be taken into account in the context of climate change for the successful implementation of climate-change initiatives (Byg and Salick, 2009).

In terms of climate change and variability, particularly for changes of temperature, a study by Swe et al. (2015) stated that 90% of the surveyed population in the country perceived the changing climatic patterns in their environment and there are two major changes that perceived in the dry zone and a study of Win (2010) also stated that 90% of the respondents in the country perceived the changes of climatic patterns in Myanmar. As a result, according to the study, more than 90% of the surveyed local stakeholders observed that the overall trend of the climatic conditions was an increase in temperature in all seasons, as well as the increase in frequency, intensity and duration of drought. The local respondents have a very clear memory dominated by higher variability of climatic conditions, adverse impacts and their effects leading to disturbances of their livelihoods. In terms of temperature trend, the 30 years of temperature data from 1986 to 2016 (DMH, 2017) shows a significant variation of temperature trend in all three study townships (Figure 2). In addition, Myanmar’s Initial National Communication under UNFCCC that temperatures sometimes reach 40°C and over in the CDZ during the hot seasons, for instance the actual mean maximum temperature for 2006 was recorded at Monywa in Sagaing Region (part of CDZ of Myanmar) as 34.6°C, in which the records of the

past few years showed the temperatures ranging between 10.7°C and 34.3°C (INC, 2012). As a result of the participants' response, it was highly confident that the temperature has generally increased over a decade as they felt the effects of the extreme heat.

For example, they changed their working hours in the farms, in particular, they currently stop working in the field before 10 am, while they could have worked until 11:30 am in the past 10 years in the study area.

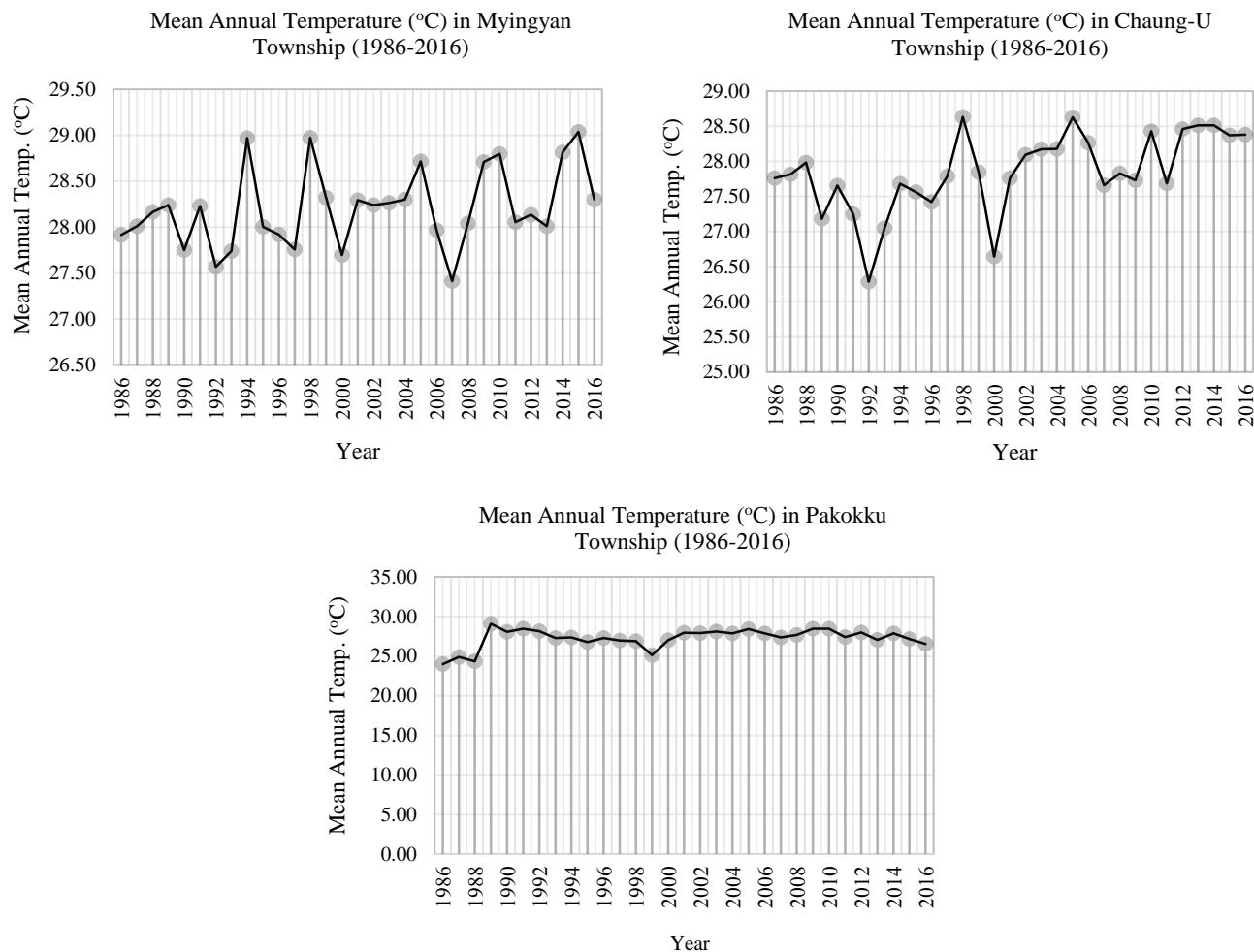


Figure 2. Temperature trend from 1986-2016 in Myingyan, Chaung-U and Pakokku Townships (DMH, 2017)

The majority of the participants (more than 90%) perceived an increasing temperature and increasing number of hot days, particularly in April and May which are the hottest months during the hot season. In this regard, the number of moderate to severe hot days (i.e., maximum temperature greater than 40°C) were higher in the months of April to May. The total number of moderate to severe hot days in Magway (623 days in April, 340 days in May and 228 days in March), Monywa (368 days in April, 275 days in May and 48 days in March) and Mandalay (324 days in April, 171 days in May and 46 days in March) reported by Aung et al., in 2017, support this perception.

Regarding the rainfall variability, more than 90% of the participants perceived that annual rainfall and rainfall intensity have changed over to either an increasing trend or a decreasing trend in the CDZ of Myanmar and most of the participants also perceived the irregular onset and withdrawal of the monsoon in the study area. In addition, other participants perceived climatic changes such as “unseasonal rainfall, shift in rainy season, the late onset of monsoon, early departure of the monsoon” in the study area even though there were many contradictory perceptions concerning “rainfall increase” versus “rainfall decrease” in the different

localities of the villages where the study was carried out.

As of rainfall variability, the 30 years observed Township rainfall data from 1986 to 2016 (DMH, 2017) show a slight increasing trend in all three townships in Figure 3 that shows the erratic behavior of rainfall pattern with overall slight increases is discernible and it coincides with the perceptions of the participants who perceived climatic changes in the past 30 years. A study also stated that the dominant erratic rainfalls in the recent decades might be the major reason for the farmers to perceive the unusual trends of decreasing as well as increasing trend rather than the usual trend in the CDZ of Myanmar (Swe et al., 2015). As a result, most of the local people involved in the study generally agreed that there is a drought and it increases in frequency, intensity and the length of

duration because they felt hotter and they found that there was a prolonged dry spell during the rainy season. For example, there was a lack of rain for a period of 1.5 to 2 months in the study villages, and it adversely affected their major livelihood of agricultural production. Thus, drought can occur in a number of areas in the country and it was significant in the dry zone. The years 1954, 1957, 1961, 1972, 1979 and 1991 were most affected by drought and a significant drought happened in 2009 (INC, 2012). In addition, droughts mostly occurred in the dry zone area during the pre- and peak monsoon period of 2010. A slight drought occurred nationally in Myanmar during 2011, 2012 and 2013, however, severe and moderate droughts occurred in the dry zone area, some regions and states, and mild drought occurred in some regions and states in Myanmar (Yi, 2015).

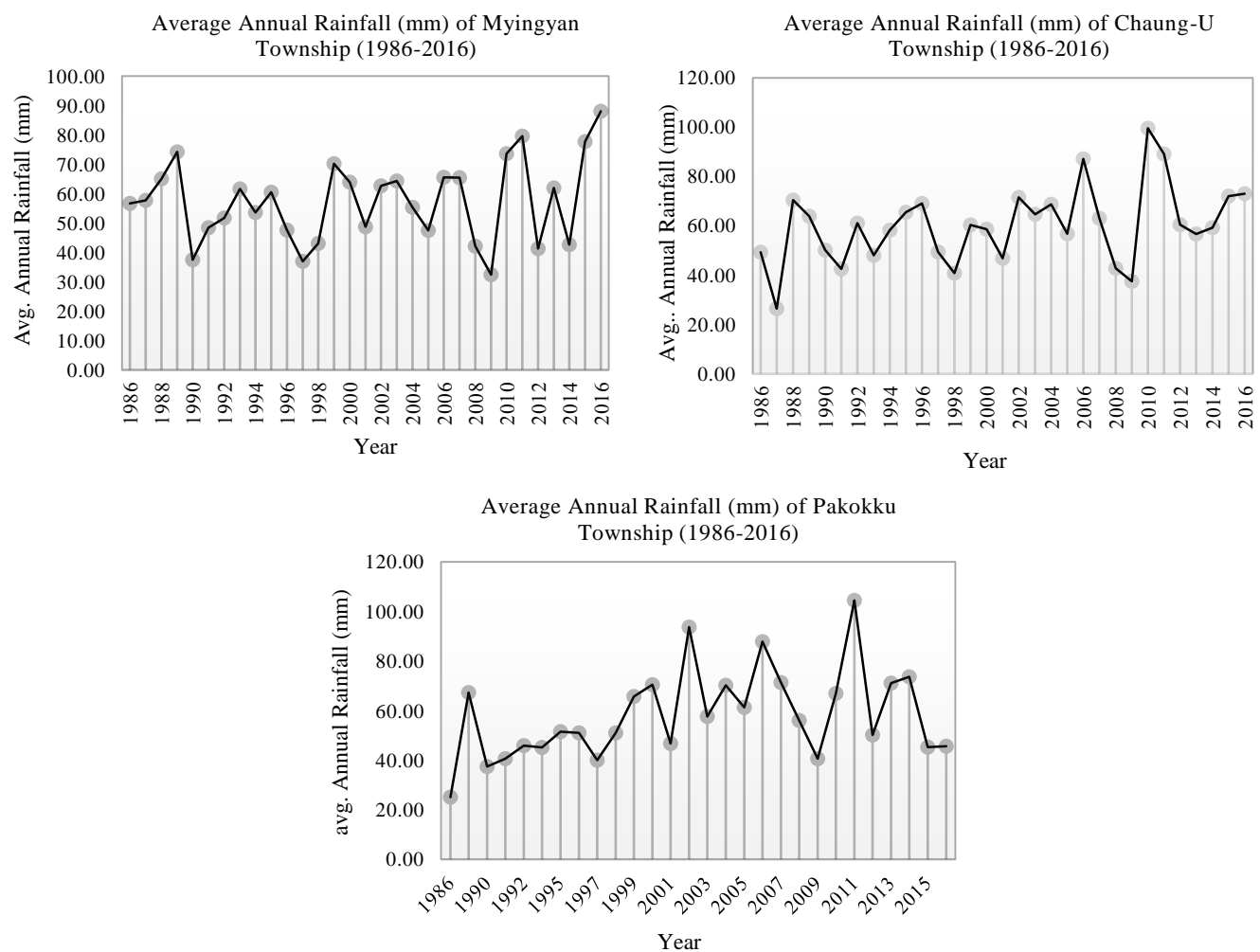


Figure 3. Observed average annual rainfall and its trend from 1986-2016 in Myingyan, Chaung-U and Pakokku Townships (DMH, 2017)

A study reported that 21% of the CDZ Townships were affected by drought every year (1967-1987), meaning that the possibility of drought in any given townships is once every five years (Tin, 1990). Figure 3 shows the erratic behavior of rainfall pattern with the overall slight increases discernible and it coincides with the perceptions of the participants who perceived climatic changes in the past 30 years (DMH, 2017). As a result, the CDZ of Myanmar frequently experienced droughts in which the rainfall level is noticeably lower than normal years. Therefore, the findings of the participants' response also showed that they perceived the occurrence of droughts in any given townships of the CDZ area. This is because they observed that there were significant prolonged dry spells and the rain did not come over long time, particularly a continuous 1.5 to 2 months, such as in 2008.

According to the participants' responses, more than 90% perceived that there was a shift in the rainy season and it was a high confidence with their observations and experiences that there was a late onset and early withdrawal of monsoon season and the precipitation varied significantly. They observed that there was a prolonged dry spell during the rainy season and less rainfall. They observed that the first rain was irregular, sometimes it started early, but sometimes not. For example, the rain came in late April in the year 2017 while the previous year was in May. In addition, they mentioned that the monsoon leaves in September and the rain finishes in October, while July and August are the most intensive and higher precipitation in the CDZ area, meaning that there is an occurrence of rainfall variability and shift in rainy season. The annual rainfall in the dry zone is normally 737.5 mm (475-1,000 mm) and the rainy days ranges from 41-62 days per year between 1967 and 1987 (Tin, 1990; Kyi, 2012). As a result, climatic fluctuations in the CDZ have become more intense, occurring with more frequent droughts and changes of rainfall patterns such as late onset and early withdrawal of monsoon while the rainfall is becoming more intense at the same time (DOA, 2017). As a result, the CDZ experiences frequent changes of the number of rainy days and amount of the rainfall in the last two decades. Therefore, most of the participants (more than 90%) involved in the study villages perceived that the precipitation significantly varies with unstable and erratic rainfall and shift in the rainy season.

The southwest monsoon makes its appearance in lower Myanmar about the third week of May and it gradually extends northwards and is usually established over the whole country by about the first week of June, while the area of CDZ has double maxima rainfall in May, September and October (Aung et al., 2017). The monsoon begins to retreat about the middle of September and the total rainfall of the monsoon is about 635 mm in the CDZ while the coastal region is about 5,080 mm (Aung et al., 2017). Thus, appearance of the early southwest monsoon is closely related to rain in the CDZ (Aung et al., 2017). As a result, most of the participants perceived that CDZ is now receiving lower total rainfall and they also know about the relationship of the southwest monsoon and the start of rain in the CDZ from their experiences and observations. For example, they mentioned that they know when the rain will come because they recognize the significant symbols, such as the appearance of monsoon and storm winds from the Bay of Bengal, meaning that if there is an appearance of storm wind, it is sure that the rain will come soon, whereas if there is a monsoon appearance, the rain is not sure to come and the dry spell period will be long.

3.2 Perceptions of local people on climate change impacts and their effects

IPCC (2014) states the term "impacts" in climate change refers to as "effects on natural and human systems of extreme weather and climate events and of climate change. Impacts, however, generally refer to as effects on lives, livelihoods, health, ecosystems, societies, culture, services, and infrastructure due to the interaction of climate changes or hazardous climate events occurring within a specific time period and the vulnerability of an exposed society or system. Impacts are also referred to as consequences and outcomes. The impacts of climate change on geophysical systems, including floods, droughts, and sea level rise, are a subset of impacts called "physical impacts".

In the dry zone context, the most experienced impacts of climate change are erratic rainfall, reduction in crop yield, prolonged drought and shift in cropping season (Dumenu and Elizabeth, 2016). According to the findings of the participants' responses, most participants perceived that the climatic fluctuations occurring in the CDZ of Myanmar, such as increase in temperature, frequent

severe droughts, rainfall variability and rainfall patterns change, and the shift in rainy season. Drought years have significant adverse effects on the production of crops, leading to food shortages for both people and livestock in the region (Tin, 1990; Kyi, 2012). Also, the results of the Department of Meteorology and Hydrology's climate change scenarios states that the drought hazard in the CDZ area is likely to become more severe in the coming century (INC, 2012) and as a result, the CDZ is at high risks of potential threat of drought.

The average mean temperature in the CDZ is about 27°C and the temperature often rises to about 43°C in the summer period and such a dry environment with its other natural limiting factors has led to conditions of growing food insecurity and severe environmental degradation (Khaing et al., 2016). In addition, a study states that high variability of rainfall is a significant stress to farming in the CDZ which is primarily rain-fed and, as a result, local farmers are highly susceptible to climatic variability, especially the beginning and end of the monsoon season and the duration and timing of the mid-season rain gap (Vaughan and Levine, 2015). In addition, low seasonal rainfall totals limit crop selection, production yields, and quality and this problem is exacerbated by insufficient crop water management (Vaughan and Levine, 2015). According to this study, more than 90% of the respondents perceived that the yield of field crops declined as a consequence of erratic rainfall and prolonged dry spells in the rainy season. For example, the local farmers faced significant prolonged dry spells with no rain for more than 2 months in the year 1998 resulting in a failure of groundnut that could not be harvested as animal fodder. In addition, the year 2002 was also significant in the effect of pest infestation on the field crops (pigeon pea) and the crops could not be harvested in the study villages. Likewise, the year 2016 was also significant in the effect of pest infestation because of prolonged dry spells. As a result, weather uncertainty, particularly rainfall variability and prolonged dry spells, negatively affect the field crops with insufficient availability of rainwater for production and increased pest infestation of field crops. This correlates with a previous study on the agricultural production as a result of climate change in the dry zone of Myanmar which showed that decreasing yield and increasing

pest infestation are the most prominent impacts of climate change in the CDZ (Swe et al., 2015).

Kyi (2012) stated that droughts mostly occur in the early monsoon period causing a shortage of soil moisture that can adversely affect crop productivity, meaning that the agricultural and economic droughts always follow a natural drought in an affected area. It was significant that drought years correlated highly with adverse effects on the production of crops that lead to food shortages for both people and livestock in the CDZ (Tin, 1990; Kyi, 2012). The recent droughts that happened in 2009, 2011, 2012 and 2013 in Myanmar and the dry zone communities caused adverse effects (INC, 2012; Yi, 2015). The dry climate and erratic rainfall resulted in short cropping seasons and low yields. One study in the dry zone reported that the losses of the crops were significant due to the nature of climate change drought hazards during a 10 year period (2001-2011) or example, there were crop losses by 81.43% of farm households in Nyaung-U, Mandalay Region and 94.29% of farm households in Meiktila, Mandalay Region due to low rainfall and thus the crop losses were due to insufficient rain during growing season (Kyi, 2011).

According to the participants' responses, more than 90% of the participants agreed that land, water, and field crops were negatively impacted by rainfall variability, prolonged dry spells, and severe droughts. For example, they responded that it caused a significant yield declination of field crops such as sesame and green gram. For instance, the yield was 10 baskets per acre in the past 10+ years, however, it gradually changed to 6 baskets per acre during existing years 2016 and 2017. The situation has totally changed as this sesame crop could not be cultivated since the previous 7-8 years (since 2010-2011). As a result, the effects of the climate change impacts, particularly drought and rainfall variability, negatively affect the yield of field crops, as well as the second ordered effects such as pest infestation and plant diseases in the CDZ area.

Temperature determines soil moisture loss, decomposition of organic matter, nutrient availability and water holding capacity of soil (McCarl et al., 2001). Precipitation variability could also somewhat alter the availability of water for irrigation, while temperature variations affect evaporation (MaCarl et al., 2001). As a result, more than 90% of respondents perceived that the effects of

climatic variability due to increasing temperature and rainfall variability on the soil and water were significant in the loss of soil moisture content, lack of water holding capacity, and reduced soil fertility. For example, they observed that the years 2009 and 2011 (severe drought years) were the worst. Soils of the dry zone are generally sensitive to degradation due to a combination of low base fertility, high base salinity, low organic content, exposure to brief periods of intense rainfall, and low annual rainfall totals. Soil erosion, in particular, severe in upland areas, is largely as a result of high intensity rainfall and rapid surface runoff. Additional causes of reduced soil productivity include fertilizer and pesticide misuse, and over-cropping (Morris and Waterhouse, 2001; ADB, 2006; FAO, 2005; Vaughan and Levine, 2015).

The longer length of dry spell period causes inadequate food for both people and animals and such a slow onset drought hazard has become the greatest threat to humanity (Blaikie et al., 2004). In terms of livestock affected by the climate change impacts, more than 90% of the respondents perceived that the impacts of climate change particularly drought affects the livestock activities in the study villages in which scarcity of animal fodder and water shortage were significant. As a result, the drought years in the CDZ are under the hardship conditions for both people and domestic animals. The findings from the participants' responses showed that there was a scarcity of animal fodders particularly for the cattle and goats and the worse situation was in the drought years, for example, the year 2009 was the hottest period and the domestic animals such as goats and cattle naturally died. At every drought years, they faced the shortage of fodder and they had to cut and carry the tree leaves such as "the wild cactus" from fence of the farms. For domestic animals such as cows and goats, the shortage of food and water is the overarching problem and the livestock raisers get noticeably adverse effects while the people could survive against these adverse effects by managing their consumption and quality of meals.

Regarding the impact on human capacity, according to the findings from the participants' responses, the local people have reduced their working hours in the farms due to the heat stress. For example they can work their agricultural activities in the morning time from 6 to 10 am, but they could

have worked until 11:30 am in the last two decades. In addition, a study by Vaughan and Levine (2015) stated that inhibited and irregular farm incomes limit the purchase and effective use of quality inputs comprised of seed, fertilizer, pesticide, and labor in which shortage of the labor is a significant issue in the farm particularly during the peak season, which is exacerbated by regionalization, urbanization and low crop profitability in the CDZ. In the context of low profitability, undiversified production, and repeated exposure to environmental and market shocks, many households in the CDZ are experiencing a deepening cycle of debt, which acts to further reduce their ability to cope and adapt in which the current data indicates that 79% of CDZ households are in debt that is large in absolute and relative terms (Vaughan and Levine, 2015). More than 90% of the participants perceived that the dry zone farmers face the debt cycle forced by the environmental shocks and stresses such as land degradation, rainfall variability, severe drought, and poor access to quality farm inputs comprised of labor shortage, increase of farm wages, etc. and low profitability. These issues make the dry zone farmers stresses due to debt burden increase. For example, according to findings from participants' responses, dry zone farmers are concerned that they cannot use many inputs to agriculture and they use only family labors particularly for smallholder farmers because the cost and benefit are unpredictable due to weather uncertainty. On the other hand, labor costs have gradually increased and its associated issues are the shortage of labors because the causal labors migrate to urban areas and abroad for seeking employment opportunity. As a result, the dry zone farmers do not dare to invest as much as they can in the agricultural production because they are struggling in the vicious cycle of debt, for example, when they face crop failure in a year, they cannot recover these losses within two or three years.

Migration issues are also critical in the study villages and the number is gradually increasing. For example, 50 people found to have emigrated away from one of the study villages (Than Pin Kan village in Chaung-U Township, Sagaing Region). A study in rural Sahal in South Africa stated that migration by young people was identified as "both an impact and adaptation measure: the absence of young people is by older people remaining in the household felt as an indirect impact of climate, which is considered to be

partly responsible for declining yields and few opportunities within in agriculture thus causing people to leave; but it is, of course, also an adaptation measure by the family to secure income from remittances and thereby economic difficulties that may be directly or indirectly caused by climate factors” (Ole et al., 2009). According to the findings, more than 90% of the participants generally agreed that migration is an issue in the CDZ as young people leave their farms, moving to the urban areas and abroad to find an alternative opportunity. As a result, it is a negative impact of climate change. As a consequence of migration by young people, more than 90% of participants perceived that they face a shortage of labor in the agricultural farms and increase of wages. As a result, most of the participants perceived that the migration of young people to leave their agricultural farms is a negative impact of climate change in the CDZ.

Negative impacts to public health include vector, food, and water borne illnesses. These illnesses are a severe issue for the people of Myanmar as it is calculated to have a “very high”

risk for major infectious diseases, and with warming temperatures, the problem will only get worse (Slagle, 2014). Myanmar National Adaptation Programme of Action to Climate Change states that “increasing temperatures and erratic precipitation patterns will create favorable conditions for the spread of infectious disease” (NAPA, 2012). According to the findings, the majority of the participants (more than 90%) generally agreed that they experienced the dengue fever due to the effect of mosquitos. Other health issues related to adverse climatic effects, such as heat stresses, are the feeling of headache and loss of death particularly for vulnerable groups such as older people and children in the study villages.

As discussed above is the significant findings resulted from the participants’ responses from the following Table 2 in terms of climate change factors, impacts and their effects on climate sensitive sectors. Table 3 shows the participants’ response to validate the facts that they perceived the climate change factors, climate change impacts and their effects on climate sensitive sectors in the study villages.

Table 2. Perceptions of local people on climate change factors, climate change impacts and the effects of climate change impacts in Yathar village in Myingyan Township, Than Pin Kan village in Chaung-U Township and Let Pa Kan village in Pakokku Township in CDZ of Myanmar

Area characteristics	Traditional Knowledge (TK) on Climate change factors, climate change impacts and their effects on climate sensitive sectors						
	Land	Water	Field crops	Livestock activities	Livelihood strategies	Human body (Social aspect)	Tools and techniques
Rainfall (Precipitation) changes	Soil degradation, erratic rainfall and prolonged dry spells affect soil fertility loss and loss of soil moisture contents	Shortage of rainfall, Water scarcity, Water unavailability	Shortage of rainfall and erratic rainfall made crop failures, decline crop yields for rain-fed agriculture. Shift in rainy season affects field crops to be failed.	Water scarcity affects poor animal health, prolonged dry spells affects scarcity of fodders	Erratic rainfall and prolonged dry spells affect major livelihoods particularly agriculture and water resources	Poor human health due to water quality and scarcity of water	Use of thinking map, Group Discussion, Content analysis
Temperature changes	Increased temperature affects water holding capacity in the soil, reduce soil moisture content.	Increased evaporation of surface water, early dryer of village water ponds, inadequate water availability	Increased temperature is confident that determines soil moisture loss and reduced water holding capacity of soil that link to agricultural production (McCarl et al., 2001).	Increased mortality of livestock death due to extreme heat	Increased temperature affects major livelihoods activities	Poor human health due to extreme heat such as headache, human death particularly vulnerable groups (children and older people)	Use of thinking map, Group Discussion, Content analysis

Table 2. Perceptions of local people on climate change factors, climate change impacts and the effects of climate change impacts in Yathar village in Myingyan Township, Than Pin Kan village in Chaung-U Township and Let Pa Kan village in Pakokku Township in CDZ of Myanmar (cont.)

Area characteristics	Traditional Knowledge (TK) on Climate change factors, climate change impacts and their effects on climate sensitive sectors						
	Land	Water	Field crops	Livestock activities	Livelihood strategies	Human body (Social aspect)	Tools and techniques
Shift in rainy season	Soil moisture loss, reduce soil moisture content	Rainfall variability, Water unavailability due to prolonged dry spells	Late onset and early withdrawal of monsoon affect seasonal cropping patterns	Inadequate water availability for animal uses, scarcity of fodders	Increased vulnerability to livelihoods	Shortage of water, inadequate water availability for drinking	Use of thinking map, Group Discussion, Content analysis
Climate change impacts	Drought, Erratic rainfall affect land degradation	Drought, Erratic rainfall affect water resources	Drought, Erratic rainfall affect field crops Pest infestation, Plant diseases	Drought, Erratic rainfall affect livestock activities	Drought, Erratic rainfall affect livelihoods activities	Extreme heat made increased vulnerability to human health	Use of thinking map, Group Discussion, Content analysis
Primary effects of climate change impacts	Land degradation Loss of productive land due to extreme weather events (drought)	Loss of water resources and reduced water availability, increased surface water evaporation	Loss of field crops due to soil degradation and water unavailability under changing climate	Loss of livestock activities related to fodders, water availability, and mortality due to extreme climatic event (drought)	Loss of livelihoods activities due to increased vulnerability to climate change (drought and erratic rainfall)	Increased vulnerability to human health, living conditions for survival due to extreme heat	Use of thinking map, Group Discussion, Content analysis
Second-ordered effects of climate change impacts	Reduced soil fertility, decreased maintenance of soil moisture content	Water scarcity, inadequate water availability for agriculture, Shorter period of water availability due to drought	Declined crop yields, Crop failures due to drought and erratic rainfall, effect of seasonal cropping patterns due to shift in rainy season, Loss of productive land due to extensive rainfall (not frequent) or drought, Pest infestation to field crops, Diseases to field crops	Poor animal health, Mortality of animal due to extreme heat, Scarcity of livestock fodders, inadequate reliable water	Losses of income per year from agriculture due to drought, indebtedness due to loss of livelihoods activities, Increased migration due to drought to seek new career opportunities, shortage of labor in agriculture	Loss of productive capacity due to heat stress, Increased vulnerability to human health, Reduced working hours due to extreme heat	Use of thinking map, Group Discussion, Content analysis

3.3 Perceptions of local people on adaptation to impacts of climate change

IPCC (2014) states the term “adaptation” that refers to as: “the process of adjustment to actual or expected climate and its effects. In human systems,

adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate and its effects”. Societies can respond to climate change by adapting to its impacts

and by reducing greenhouse gases emissions (mitigation), thereby reducing the rate and magnitude of the change (UNFCCC, 2007). Adaptation can be distinguished into two types: indigenous adaptation and system or introduced adaptation (START, 2012). Adaptation covers both “hard” and “soft” technologies and not only new technologies or locally developed technologies (Glatzel et al., 2012). At the local level, adaptation comprises of two stages such as perceiving the change in climate and deciding whether to adapt and deciding which climate adaptation measures to choose (Madison, 2007).

Adaptation measures resulted from the study were the existing adaptation practices to respond to the impacts of climate change in the context of dry zone region. In terms of most affected sectors by the impacts of climate change such as land, water, field crops, livestock activities, livelihood strategies and social/economic condition, the perception of the local people were assessed to identify the adaptation measures to climate change impacts. Most significant

adaptive measures/adaptation practices were identified in accordance with the perceptions of the local people. Most of the participants were the local farmers who mainly rely on agriculture as their major livelihoods. Table 3 suggests the adaptation practices resulted from the perceptions of the local participants involved in the research in order to respond to the impacts of climate change in each climate sensitive sector that the local people perceived. In this, the participants stated how they have observed and attempted to apply their traditional knowledge in order to adapt to the impacts of climate change. However, they mentioned the most common adaptation practices related to traditional knowledge that they have been attempting to adapt to climate change impacts, including agricultural practices, soil degradation and water scarcity, livestock activities, livelihood strategies. However, as the major livelihoods of the dry zone people are agriculture, they mostly focused on the agricultural adaptation practices and its related adaptation measures.

Table 3. Checklist on factors related to perceptions of local people on climate change in Ya Thar Village in Myingyan Township, Than Pin Kan Village in Chaung-U Township and Let Pa Kan Village in Pakokku Township

Factors related to climate change	Perceptions of local people		
	1 st Site	2 nd Site	3 rd Site
1. Climate change factors			
1.1 Increased in temperature in all seasons, highly confidence in summer	×	×	×
1.2 Decreased in intensity and annual rainfall	×	×	×
1.3 Increased in frequency, intensity, and duration of drought	×	×	×
1.4 Shift in rainy season	×	×	×
2. Climate change impacts			
2.1 Drought	×	×	×
2.2 Erratic rainfall	×	×	×
3. Effects of climate change impacts			
3.1 Water scarcity and shortage of water availability	×	×	×
3.2 Effects on seasonal cropping patterns	×	×	×
3.3 Reduced yield of field crops	×	×	×
3.4 Reduced soil fertility due to drought	×	×	×
3.5 Decreased soil moisture content (lack of water holding capacity in soil)	×	×	×
3.6 Pest infestation to field crops due to drought and rainfall variability	×	×	×
3.7 Plant diseases due to drought			×
3.8 Scarcity of livestock fodder and loss of pastures due to drought	×	×	×
3.9 Reduced working hours due to heat stress	×	×	×
3.10 Increased migration to other areas for alternative career opportunity	×	×	×
3.11 Effects on health of children and older people due to extreme heat	×	×	×

1st Site=Ya Thar Village (Myingyan Township), 2nd Site=Than Pin Kan Village (Chaung-U Township), and 3rd Site=Let Pa Kan Village (Pakokku Township)

The acceptance of climate change adaptation strategies is determined by numerous demographic, socioeconomic and organization or institutional characteristics (Deressa et al., 2009; Hassan and Nhemachena, 2008; Yusuf et al., 2008; Shongwe et al., 2014). Adaptation involves harms and opportunities, as well as failures and successes, as the effect of climate occurs over a span of time (WICCI, 2011). Thus, adaptation to climate change is important for two main reasons: it can decrease exposure and vulnerability (Howden et al., 2007; Schmidhuber and Tubiello, 2007; Falco et al., 2011; Oo et al., 2017). Even though human and natural systems have a certain capacity to cope with adverse circumstances, adaptation will be needed to maintain this capacity with continuing climate change (IPCC, 2012). In this regard, the choice of local farmers in climate change adaptation strategies is determined by demographic characteristics, socio-economic characteristics at the household level, organizational or institutional characteristics and by the agro-ecological contexts (Hassan and Nhemachena, 2008; Yusuf et al., 2008; Deressa et al., 2009; Shongwe et al., 2014; Tessema et al., 2013; Oo et al., 2017). Therefore, in this study, the local participants perceived the adaptation measures at the household level in the context of localized agro-ecological settings as the study was conducted in the dry zone area.

Adaptation of agriculture to climate change is urgent as its impact on agriculture is already evident and the trends will continue even if greenhouse gases emissions are stabilized at current levels (World Bank, 2006). Adaptation to climate change is critical and could reduce the adverse impacts of climate change on crop production and farmers in most affected areas have already stated to adapt by changing crop mixes, using water conservation measures, and adopting risk management techniques to lessen the consequence of the increased drought frequency (IPCC, 2007; Norton et al., 2010; World Bank, 2012). In this regard, according to the findings from the participants' responses, the majority of the participants perceived that the most common agricultural practices are use of mixed and multiple cropping systems, change of cropping practices (change of type of crops and selection of the field crops, variety change, local variety change, and the use of local variety or use of drought resistant variety).

Mixed cropping system and multiple cropping system are most common and significant practices in the study villages, for example, dry zone farmers use to cultivate by mixing two or more crops such as cotton in the early rainy season together with pigeon pea as a mixed crop, pigeon pea together with maize, groundnut together with maize, groundnut together with pigeon pea and groundnut together with pigeon pea and cotton in all study villages. The reason why they use this mixed and multiple cropping system is that the main purpose is to cover the cost of their inputs because even if one crop will be lost by the weather uncertainty, the cost can be covered by other crops. Further purpose of using these cropping systems is to improve the soil fertility, minimize the evaporation from the soil and reduce the weedy because there is no space in the farm by cultivating two or more crops. Thus, mixed cropping practice is more effective rather than using the single or monocropping practice under changing climate in the dry land. In addition, the reason why the Dry Zone farmers use the change of cropping practices, and shift in cropping calendar was that they could have clearly observed the benefits - the field crops could resist to respond to the effects of climate variability and betterment of crop yields. However, it depends on the type of farmland (type of soil). For example, they cultivated tobacco for more than 10 years from the year 2006 to 2011, and currently they cannot cultivate the tobacco and they replaced tobacco with climate resistant crops (cotton) since 2012 in Ya Thar village in Myingyan Township. Likewise, there was a similar case in other study villages such as Than Pin Kan village in Chaung-U Township (i.e., farmers replaced cotton and pigeon instead of growing sesame) and Let Pa Kan village in Pakokku Township (i.e., currently they replaced groundnut instead of growing sesame). As a result, the change of type of crops is effective and getting positive benefit for the dry zone farmers as one of the most prominent adaptation practices.

The other significant practices to adaptation are use of soil conservation measures such as use of soil preparation techniques before planting season and use of tractors to make soil grooves to harvest the rainwater, use of organic manure such as cow dung to improve soil fertility, and improvement of water holding capacity to increase maintenance of soil moisture content and minimizing the surface runoff. Use of soil preparation techniques are water

saving technology that is more relevant to the dry regions particularly where there is shortage of rainfall and prolonged dry spells. A study reported that dry zone farmers are using chemical fertilizer as well as animal manure as the most common strategies to maintain soil productivity and other good agricultural practices such as proper land preparation, application of decomposed organic matter and crop rotation are also applied in order to cope with soil fertility degradation (Swe et al., 2015; Oo et al., 2017). As a result, even though there are diverse practices currently being adopted, the dry zone local farmers prefer to use organic manure such as cow dung to improve soil fertility and traditional land preparation techniques in order to save water efficiently, improve soil fertility, increase the water holding capacity in the soil and minimize the soil erosion. More than 90% of the participants perceived that traditional soil preparation technique is effective for not only water use efficiency but also improvement of soil fertility that bring benefits for the local farmers in responding to climate change impacts in dry zone area. One study reported that soil and water conservation techniques were used to avoid the risk of flooding as well as improve soil moisture and organic matter retention (Belay et al., 2017).

In addition, use of local weather prediction for agricultural adaptation is also significant to improve agricultural adaptation. A study states that dry zone farmers use the traditional techniques to predict weather particularly rainfall, based on the wild plants, the wild animals and the special natural phenomenon, rather than the weather information from the Departments concerned (Kyi, 2012; Swe et al., 2015). In this context, as the dry zone farmers rely on the rainwater, traditional weather prediction technique used by the local farmers is useful for them and it is based on the common understanding that comes from generations to generations. The local farmers use the observed symbols in predicting the weather by applying the characteristics of the nature that they observed nearby and the overarching way of prediction is “Sayings” that had been traditionally noted. According to their observations, there are two types of weather prediction such as short-term and long-term predictions. For example, rain is quite close to coming soon when “black ants” are seen moving their eggs to another place. Another significant symbol is the “Voice of Tokay Gecko

(Gekko gekko)” that is one species of the reptile and it is locally called as “Tauk Tae” in Myanmar. In this regard, in Myanmar tradition, there is a “saying” in terms of “Tokay Gecko” as “Weather fortuneteller” and it is still believed particularly in the countryside. Another significant example that is commonly used in the CDZ of Myanmar as “Symbol of flowering of Cactus (*Cereus repandus*)” which is locally called “Ta Zaung” in the CDZ and this plant is characterized by the dry zone. The common understanding of this plant in terms of traditional weather prediction is that when this plant blooms in the late summer and the flower become wilt, the rain will come within a week and when this plant blooms in the late rainy season, the rain will withdraw soon. Further customized example is that there is a saying “When the Htaung tree (*Acacia lucophloea*) blooms the flowers in July (Wa Khaung month of Myanmar Calendar Year), there is no rain or a few rain even if the rain comes.” Like this year, the local farmers faced prolonged dry spells without rain for a long period or a few rain in the rainy season.

Getting the adequate information about weather forecasts is very important to ensure that local farmers receive up to date weather forecasts in which it is critical for decision making to either use early and late planting as an agricultural adaptation strategy by the local farmers (Belay et al., 2017). Thus, weather information is very important for those dry zone farmers and they mainly rely on the weather information for their rain-fed agriculture by using traditional weather prediction technique and their knowledge on astrology (i.e., the astrological knowledge is belonged to the elder people in the village and they use to share to the farmers in which they can predict the weather for both short-term and long-term prediction based on the Myanmar Calendar Year), for example, there are two heavy raining days every single year in CDZ of Myanmar and these are called “Kyi Lwe Rain” or “Phyauk Seik Rain” and “Kan Sin Rain. This common sense is recognized by the local people, and the rain comes during a week before and after 145 days counting from the first day of Myanmar New Year (17th April or 6th day of Tagu month of Myanmar Calendar year and it is called as “Kyi Lwe Rain” or “Phyauk Seik Rain”. It was also found that the rain surely comes on 138th and 152nd days from the first day of Myanmar New Year and it is called as “Kan Sin Rain”. It is still true for the local farmers and these

rain benefits for the farmers and they cultivate the late-rained crops. Unless the rain comes on 15th or 16th September, the farmers face the crop failures in this year. Local farmers follow this seasonal calendar that comes from their traditional knowledge on weather prediction for agricultural adaptation. Thus, access to weather information is very important for the rain-fed farmers particularly in dry zone in order to adapt to their agricultural practices. As a result, traditional knowledge on weather prediction of the local farmers is highly significant in agricultural adaptation to climate change because they use to prepare to cultivate the field crops based on the weather information that they traditionally predicted. Thus, traditional knowledge can help forecast local weather, predict extreme events and provide accessible information to farmers at a local scale as well as they can monitor climate change in specific locations and fill the resolution gap of scientific models (Swiderski et al., 2011).

Regarding the adaptation measures on scarcity of water, most common adaptation practices that majority of the participants perceived are construction of rainwater collection tanks for safe and reliable water, renovation of the ponds to extend the period of water availability and improve water storage capacity, and digging deep tube wells to improve water supply throughout the year. Collecting rainwater, digging tube wells and getting water from the common-used wells are the topmost individual adaptation strategies in order to cope with water scarcity in the dry zone and those strategies are only useful for household water consumption (Swe et al., 2015; Oo et al., 2017). For agricultural adaptation to cope with the water scarcity, the local farmers in the study villages use soil preparation technique to save water efficiently and improve the water holding capacity in the soil in that soil preparation technique is effective for not only water use efficiency but also improvement of soil fertility and increase in the length of maintaining the period of soil moisture content. In this context, for example, the local farmers use to carry out the soil preparation on their farms for four times before the planting season because what they understand is “the more the plowing until the soil particles are tiny, the better the soil for water holding capacity and maintenance of soil moisture content”. Thus, a study stated that the dry zone farmers use potential adaptation practices such as pursuing water-harvesting

techniques, changing growing season, application of gypsum, growing drought-resistant plant varieties and other traditional practices based on traditional knowledge such as pre-monsoon growing of the crops in the dry land that helps the farmers to cope with the water scarcity, especially in sesame cultivation (Swe et al., 2015; Oo et al., 2017).

Dry zone local farmers raise livestock by integrating with agriculture and it is a small scale and domestic production. Major domestic livestock are cattle and goats. The most common adaptation actions in the study villages are improved storage of fodders from agricultural residues such as plant body of groundnut and dried grasses for off-farm season, access to water availability for animals, and access to animal health care due to extreme heat. Even though the local farmers do not raise the livestock as a major livelihood, they are attempting to initiate raising cattle not only for their farms but also for breeding. This is because when the field crops are lost by weather uncertainty, the income from livestock breeding covers the proper income amount. For example, “one farmer said that he raised female cattle for reproductive purpose, he got a profit from this cattle breeding approximately three or four million Myanmar Kyat equivalent to 2,500-3,000 US\$ during 10 years period. What he suggested was that “if the farmers will do domestic livestock breeding together with agriculture, it is sure to get benefits and it might recover for some amount of the cost of crop failure due to the effects of climate change impacts in dry zone.”

For the livelihood strategies, they attempt to adapt to have improved agricultural practices, improved access to water resources to respond to water scarcity and shortage of water, and improved domestic livestock breeding for additional income beyond agricultural production. In the dry zone, 83% of the population is rural (MNCP, 2014) and the primary livelihood strategies are related to agricultural crop production in which farm labors are 25%, crop sales are 58% and other are 17% respectively in CDZ (JICA, 2010). Agriculture is the most effected sectors by the impacts of climate change, particularly rainfall variability and severe drought. As a result, the farmers face hardships to their livelihoods. Therefore, the local farmers try to find the ways of adaptation to cope with the impacts of climate change by attempting to adapt to agricultural practices. However, a small percentage

of farmers left their farms and migrated to urban areas and abroad in order to seek employment opportunity for alternative livelihoods and they remit the cast to their family. Most of the farmers have been trying to adapt to their livelihoods by applying traditional knowledge to be able to improve their livelihood activities. A few percent of farmers have tried to improve domestic livestock breeding in order to cover their income from livestock activities beyond the agricultural practices. In addition, farmers attempt to invest in education for their generation because they understand that they cannot stop and control the natural events and seeking alternative way of livelihoods opportunity through investment in education is better for their future generation. Furthermore, most of the participants in the study villages generally agreed that currently improved income from alternative livelihood opportunity such as getting remittance from migration (in both urban area and abroad) is one of the adaptation measures in the study villages. Thus, migration was acknowledged as the positive aspect of income to support as one of the significant adaptation measures even though migration was mainly perceived in a negative sense because more work was left for the older people and the agriculture farms due to the effects of climate change impacts (Ole et al., 2009).

As the dry zone area is economically hardship and the incidence of extreme climate related event particularly for drought, the local people are hard to survive for their livelihoods with low adaptive capacity (Vaughan and Levine, 2015). Extreme heat related effects also affect human health and the local people try to cope with these effects with their adaptive capacity as much as they can, for example, they attempted to access to information by the government programme of early warning systems in terms of extreme heat and heat waves in order to avoid these extreme events. In addition, access to safe and reliable water for drinking water is also important for human health, so the local people adapted to get access to this from rainwater collection tank and deep tube wells and they filtered those water and used it. In addition, due to the extreme heat, shift in working time is also effective to avoid the higher temperature in the agricultural farms because the farmers go to their farms in the early morning starting at 6 am and return home at 10 am in the study villages. In addition, they use

mosquito net to avoid the dengue particularly for the children as there are many mosquitos because of favorable weather condition in the dry zone area. Thus, the majority of the participants (more than 90%) perceived that the most common ways that the local people adapt to the human health by the effects of climate change impacts are - uptake of early warning systems (access to information about the extreme heat, heat waves, etc), use of mosquito net to protect the effects of dengue, and improved access to safe and reliable water. As discussed above, the significant findings resulted from the participants' responses from the following Table 4 in terms of climate change adaptation practices how they have attempted and been attempting to cope with the adverse impacts of climate change. Table 5 shows the participants' response to validate the facts that they perceived the climate change adaptation measures in the study villages.

3.4 Evaluation of knowledge gaps towards implementation of adaptation measures

Toward implementation of the execution of activities on climate change adaptation practices, it was analyzed to identify the gaps between the traditional knowledge and climate science in order to bridge these gaps in implementation of the adaptation actions. In this regard, change impact analysis (Wiegers, 2017) was used to identify these gaps based on traceability of data from the results. There are three aspects in terms of change impact analysis procedure comprised of (1) it is required to understand the possible implications of making the change in which change produces a large ripple effect; (2) it is required to identify all the files and documents that might have to be modified once the team incorporates the required change; and (3) it also needs to identify the tasks required to implement the change, estimate the effort needed to complete those tasks (Wiegers, 2017).

In addition, the framework identifying the gaps on climate change factors, impacts and adaptations by analyzing the overall programme of the research study included five steps: (1) identification of the stakeholders, (2) stakeholder analysis, (3) change impact analysis, (4) execution of activities, and (5) monitoring the executive activities (stakeholder management). In this context, the study was carried out by identifying the stakeholders and the location of the study in which three groups of stakeholders were

Table 4. Perceptions of local people on climate change adaptation in Yathar village in Myingyan Township, Than Pin Kan village in Chaung-U Township and Let Pa Kan village in Pakokku Township in CDZ of Myanmar

Perceptions of local people on climate change adaptation practices in CDZ of Myanmar						
Area characteristics	Land	Water	Field crops	Livestock activities	Livelihood strategies	Human body (Social aspect)
Climate change adaptations	Uptake of soil conservation measures such as use of soil preparation techniques before planting season and use of tractors with a proper deep to make soil grooves (Oo et al., 2017; Swe et al., 2015)	Improved rainwater harvesting by land management practices to increase maintenance of soil moisture content and minimizing the surface runoff (Swe et al., 2015)	Use of mixed and multiple cropping systems (Matsuda, 2013; Swe et al., 2015; Oo et al., 2017)	Improved storage of fodders from plant body of groundnut and dry grasses for off-farm season (Ky, 2012)	Improved agricultural practices to enhance livelihoods	Improved access to information by Government programme of early warning systems about extreme heat and heat waves
	Making soil grooves in the farms to catch up the rainwater (Swe et al., 2015)		Use of change of cropping practices (use of change of type of crops and selection of the field crops; use of variety change, use of local variety (drought resistant variety) (Matsuda, 2013; Swe et al., 2015)	Improved access to water availability for animals	Improved access to water (Swe et al., 2015)	Improved access to safe and reliable water for drinking
	Use of organic manure such as cow dung to improve soil fertility (Swe et al., 2015)	Use of mixed crops with minimized space in the farms for improving maintenance of soil moisture content and rainwater (Matsuda, 2013)	Use of shift in cropping calendar to respond to rainfall variability and shift in rainy season (Oo et al., 2017)	Access to animal health care due to extreme heat;	Attempted to improve domestic livestock raising for additional income together with agriculture (Belay et al., 2017)	Shift in working time (change of working hours) to avoid heat stress
	Improvement of water holding capacity in the soil for agriculture (Ky, 2012; Oo et al., 2017)	Construction of rainwater collection tanks for safe and reliable water	Use of soil conservation measures and rainwater harvesting (Swe et al., 2015; Oo et al., 2017)	Improved livestock raising for additional income beside agriculture (Belay et al., 2017)	Improved income from alternative livelihood careers (getting remittance) from migrations (Ole et al., 2009)	Improved access to health care (use of mosquito net to protect the effects of dengue)
	Use of chemical fertilizers to improve soil fertility to improve crop yields (Maung et al., 2016, Swe et al., 2015)	Renovated the ponds to extend the period of water availability and improve water storage capacity	Use of pesticide and fungicide to respond pest infestation and diseases (Swe et al., 2015; Oo et al., 2017)		Attempted to invest in education for future generation	
		Digging deep tube wells to improve water supply	Use of local weather prediction for agricultural adaptation (short- and long-duration) (Swe et al., 2015)		Improved access to human health care	

identified such as local farmer groups, village leaders group, and elders group who are paid respect by the local communities and the study area was also identified. The second step is the stakeholder analysis and it was carried out by setting the inclusion criteria in order to select the individual stakeholder to involve in the study based on the criteria accordingly. The third step is the analysis of the change impacts in terms of climate change impacts and best practices adaptation to climate change impacts in the dry zone area. In this step, the perceptions of the identified stakeholders in the previous steps were assessed in terms of climate change impacts and adaptation practices based on their experiences and observations relevant to the local context. The fourth step is the identification and analysis of the adaptation practices responding to the impacts of climate change and implementation stages of the best practices of adaptation measures resulted from the perceptions of the involved stakeholders. The last step is the management of the stakeholders as well as the monitoring of the execution of adaptation practices in

which it is important to identify the gaps the traditional knowledge and climate science at the implementation stage.

The purpose of using change impact analysis is to analyze the changes in terms of climate change impacts and adaptation practices for the dry zone communities and it is essential to plan and implement the relevant change management activities (proper best practices) for those communities. For this process, the inputs are the setting of programme objectives, identification and analysis of stakeholders, and their participation and dialogues to identify the climate data, climate change impacts, and adaptation practices within the context of the CDZ of Myanmar. Upon the outcomes of the participation and dialogues of the local stakeholders, the gaps were found by the change impact analysis. The following chart is the framework of change impact analysis in order to identify the gaps toward the implementation of the executive activities for creating a proper strategy and action plan (Wiegers, 2017).

Table 5. Checklist on perceptions of local people on climate change adaptation practices in Ya Thar Village in Myingyan Township, Than Pin Kan Village in Chaung-U Township, and Let Pa kan Village in Pakokku Township

Factors related to climate change adaptations, resulted from the stakeholder workshop	Condition: (Use of traditional knowledge to adapt to climate variability, climate related extreme event (drought), and seasonal climate patterns)		
	1 st Site	2 nd Site	3 rd Site
1. Adaptation to agricultural practices			
1.1 Uptake of soil conservation measures for agriculture	×	×	×
1.2 Water use efficiency under rain-fed agriculture	×	×	×
1.3 Change of cropping practices	×	×	×
1.4 Use of variety change	×	×	×
1.5 Use of local variety (drought resistant plant variety)	×	×	×
1.6 Shift in cropping growing season	×	×	×
1.7 Use of land/soil preparation in pre-monsoon period (before the planting season)	×	×	×
1.8 Use of cropping pattern change such as mixed cropping system and multiple cropping system	×	×	×
1.9 Use of local weather prediction for agriculture adaptation	×	×	×
2. Adaptation to land and water resources			
2.1 Using traditional soil preparation practice for growing crops to maintain soil moisture content	×	×	×
2.2 Watershed management for soil conservation and improved water holding capacity in the soil for agriculture and improvement of existing forest		×	

Table 5. Checklist on perceptions of local people on climate change adaptation practices in Ya Thar Village in Myingyan Township, Than Pin Kan Village in Chaung-U Township, and Let Pa kan Village in Pakokku Township (cont.)

Factors related to climate change adaptations, resulted from the stakeholder workshop	Condition: (Use of traditional knowledge to adapt to climate variability, climate related extreme event (drought), and seasonal climate patterns)		
	1 st Site	2 nd Site	3 rd Site
2.3 Use of land/soil preparation in advance before the planting season (off-farm season)	×	×	×
2.4 Construction of rain water collection tanks for safe and reliable water	×	×	×
2.5 Renovation of ponds to improve water storage capacity and extend the period of water availability	×	×	×
2.6 Use of deep tube wells to improve water supply	×	×	×
3. Adaptation to livestock activities			
3.1 Storage of animal fodders from agricultural residues for off-farm season	×	×	×
3.2 Initiatives for planting grasses for animal fodders particularly for cattle	×		
3.3 Access to water availability for animals	×	×	×
4. Adaptation to livelihood strategies			
4.1 Improved adaptation practices on agriculture, livestock, land and water resources	×	×	×
4.2 Efforts to extend livestock raising to recover the crop failure due to weather uncertainty	×		
4.3 Change of working hours for agriculture due to extreme heat and higher temperature	×	×	×
4.4 Efforts to invest in education for alternative livelihoods for the future generation	×	×	×
4.5 Migration to seek employment opportunity for alternative livelihoods and remittance	×	×	×
5. Adaptation to human health			
5.1 Uptake of early warning systems (access to information about the extreme heat, heat waves, etc)	×	×	×
5.2 Access to safe and reliable water for drinking	×	×	×
5.3 Changes of working hours (working time – shift in working time) due to extreme heat	×	×	×
5.4 Use of mosquito net to protect the effects of dengue	×	×	×
6. Adaptation of improved access to information and communication			
6.1 Improved access to early warning information in terms of climate related extreme events such as drought, extreme heat and higher temperature	×	×	×
6.2 Uptake of traditional way of weather prediction for agriculture	×	×	×

1st Site=Ya Thar Village (Myingyan Township), 2nd Site=Than Pin Kan Village (Chaung-U Township), and 3rd Site=Let Pa Kan Village (Pakokku Township)

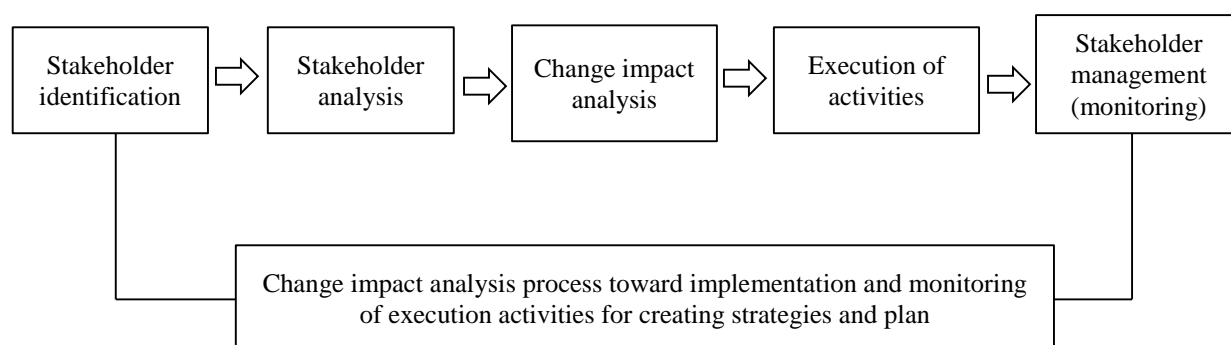


Figure 4. A framework for change impact analysis to identify the gaps on the change management activities for implementation

As a result, the gaps and tendency in the programme were found by monitoring the stakeholder management upon the results such as climate change factors (temperature change, precipitation change and high variability of rainfall, prolonged dry spells, and shift in rainy season), climate change impacts, and adaptation practices. Significantly, the tendency is the low adaptive capacity of the local stakeholders in responding the impacts of climate change, in particular, this is the need of technology and financial support to their traditional knowledge and a further need is to improve adaptive capacity including improved access to scaling up the traditional best practices. Being weak in regards of knowledge and adaptive capacity, the dry land people are thus helpless in the face of climate variability and its impacts (Mortimore, 2009). Therefore, the knowledge gap identified by the change impact analysis in terms of climate change impacts and adaptation practices to cope with these impacts in the dry zone is an opportunity in order to enhance these gaps in developing a strategy and action plan for effective implementation to cope with new climatic conditions. The following chart (Figure 5) shows the process of the implementation of change impact analysis programme that has been carried out and is the overall implementation process of the change impact analysis based on the results from the perceptions of the identified stakeholders involved in the study villages. In addition, it has identified the knowledge gaps in the implementation of adaptation practices and these gaps will be the opportunities in developing a new adaptation strategies based on the traditional knowledge.

3.5 Implementation strategies of the climate change adaptation practices linking with traditional knowledge and climate science

As per the change impact analysis (Wiegers, 2017) identified the gaps and execution of activities on climate change factors, impacts and adaptations, it was found the findings of the change impact analysis over a programme, including inputs and outputs toward addressing the implementation of the adaptation practices. According to the framework analysis, it includes three steps such as (1) review and re-use the existing results as inputs to the programme setting, (2) change impact analysis that emphasizes the change impact assessment activities and outputs in order to make a strategy and action plan, and (3) implementation of execution of activities. In this context, each step in the following chart (Figure 6) was carried out according to the existing results from the diverse perceptions of the identified stakeholders in this research to be able to do a strategy and plan until the implementation of the change management activities.

The first step addresses the inputs that focus the programme location, the stakeholders involved in this research, results from the field data analysis, and the identified change drivers in which existing results were reviewed and re-used as the inputs to the programme setting. In this regard, this step is important to review the existing results to be able to draw the gaps in order to go the next step for planning the programme activities to re-use as the programme inputs. According to the existing results analysed from the study, the review was included the study area - Ya Thar village in Myingyan Township, Than Pin Kan village in Chaung-U Township, and Let Pa Kan village in Pakokku Township.

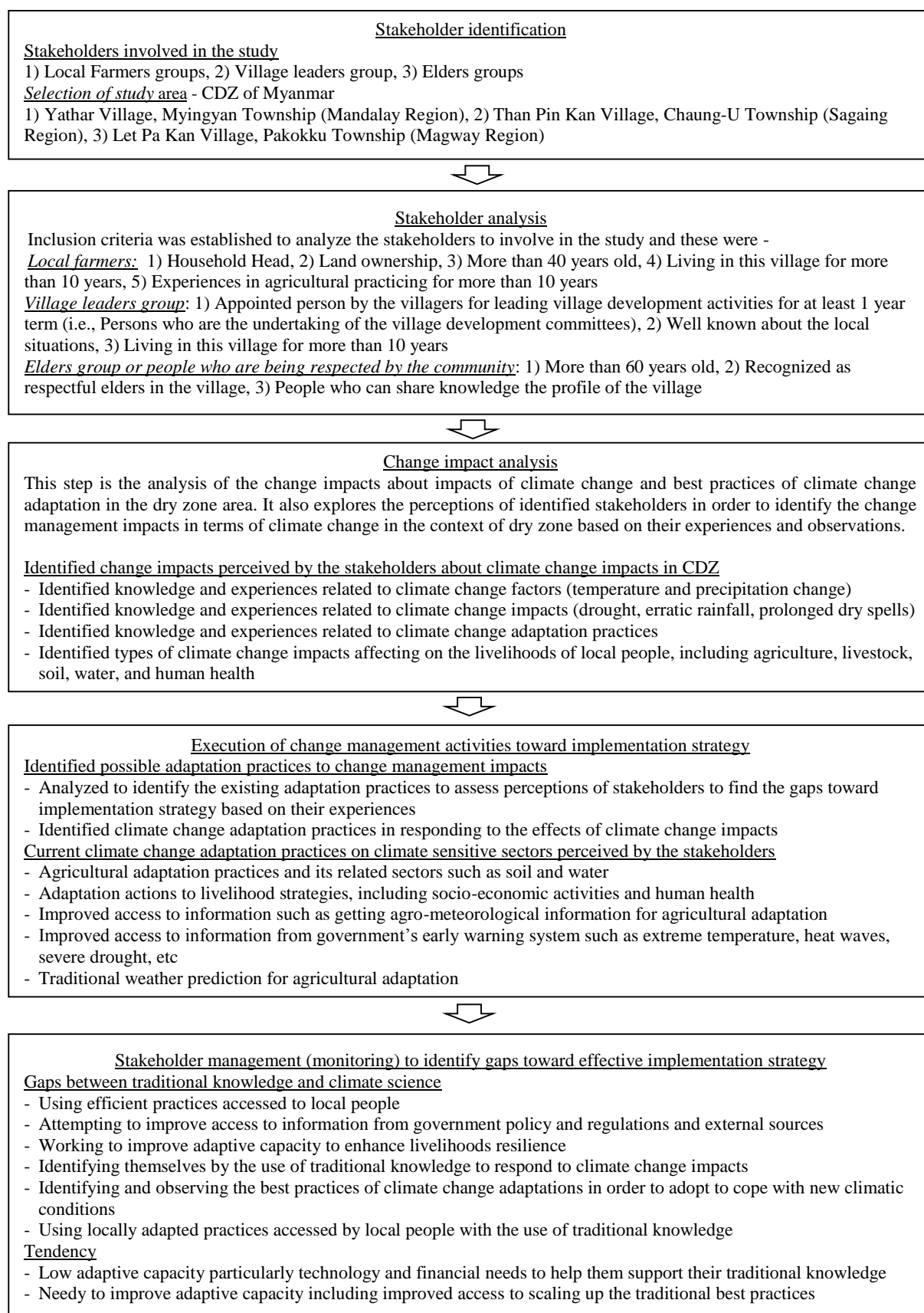


Figure 5. Change impact analysis on implementation of climate change adaptation actions in Ya Thar village in Myingyan, Than Pin Kan village in Chaung-U, and Let Pa Kan village in Pakokku Township

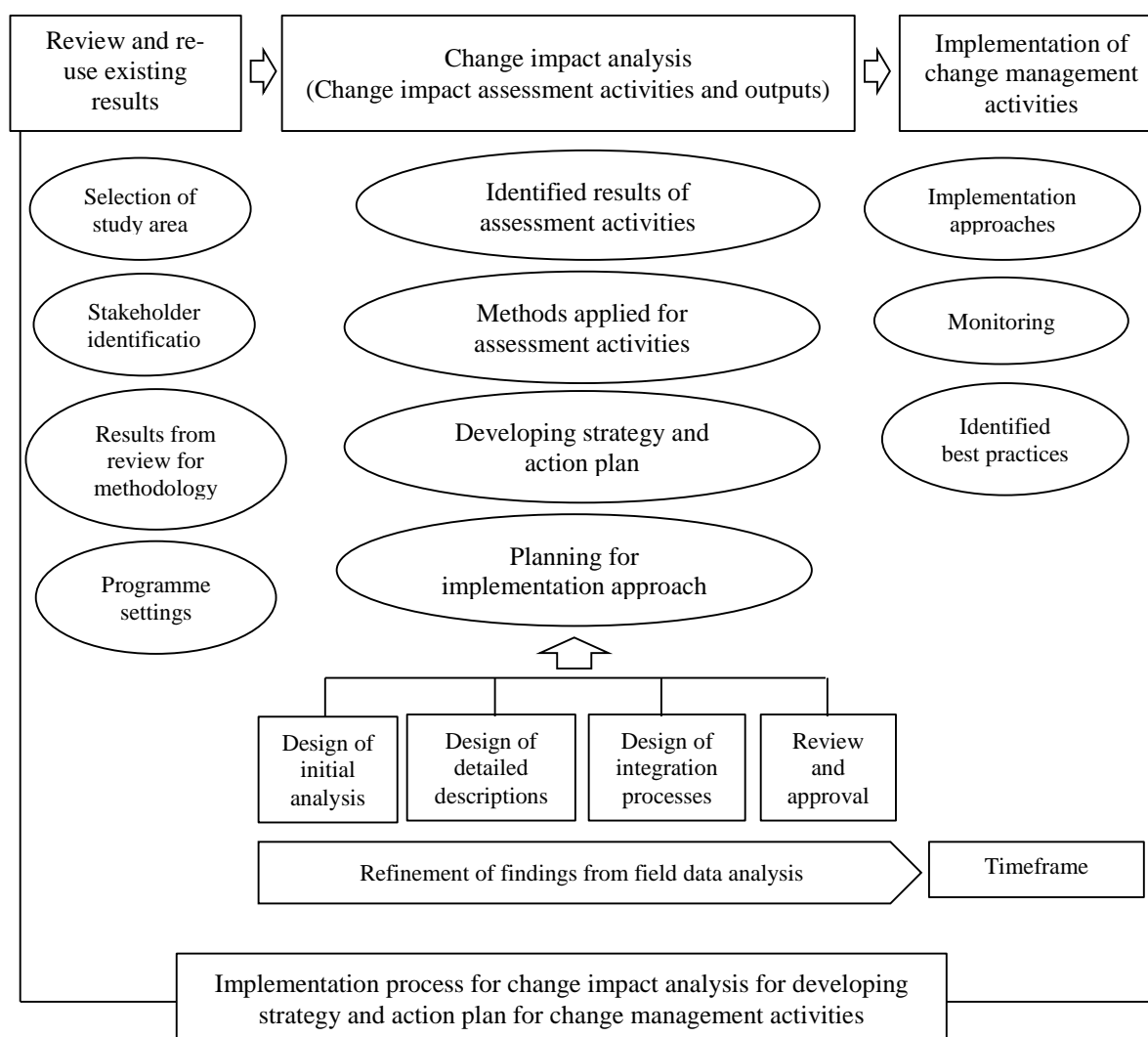


Figure 6. A framework of implementation process for change impact analysis in developing strategy and action plan for best practices of change management activities

Then, the stakeholders were identified and analysed and there were three groups of stakeholders such as farmer groups, village leaders group, and elders according to the inclusion criteria. The study was done by identifying the climate change factors, climate change impacts and adaptation practices related to traditional knowledge based on the perceptions of the dry zone local people. The major findings from review were climate change data, impacts and adaptation practices on climate sensitive sectors particularly for agriculture and its related sectors as the majority of the dry zone local people mainly rely on agriculture as their major livelihoods.

The second step addresses the change impacts analysis upon the change impact assessment activities and these are the output section of the programme. In this, it was identified the climate change impacts and

the effects of climate change impacts that affect the local people in dry zone. In addition, it was also included the stakeholder analysis used to identify the inclusion criteria of the involved stakeholders and the participatory process to further identify the change impacts by the participation of the identified stakeholders. The outputs of this section are the execution activities about climate change adaptation practices to be able to set up the strategy for climate change adaptation related to traditional knowledge of the local people. Obviously, this section was analysed by the four steps such as 1) initial analysis design, 2) detailed design, 3) integrated process design, and 4) review and approval upon the existing results from the field data analysis. As a result, this study found the basement of the research programme addressing the climate change impacts, the effects of climate change

impacts, inclusion criteria of the identified stakeholders to be able to set up the strategy for climate change adaptation actions through participation process. This is the basic outputs toward the implementation of the programme to evaluate the climate change adaptation practices related to traditional knowledge in CDZ of Myanmar.

The third step addresses climate change adaptation practices currently being practiced by the dry zone local people. These are the results in order to make strategy for adaptation practices related to traditional knowledge of local people. Identified locally relevant adaptation practices to climate change impacts are the findings from the change impact analysis toward implementation with a proper timeframe. As a result, change impact analysis upon climate change related to traditional knowledge is the key analysis tool in order to identify the change impact activities by reviewing and re-using the existing results analysed using the field data. Finally, traceability is a key tool to manage the complexity of change and it is essential to use because once it is correctly carried out, the impacts of change can be accurately assessed, the full history of the programme can also be tracked, the involvement of the individual stakeholders can be kept and synced and the quality of the programme can also be improved (Wiegers, 2017). As a result, traceability reflects the complexity of programme data and simplifies the process of addressing a high-quality programme implementation as per the change impact analysis. Therefore, using the change impact analysis in developing the a new strategy and action plan by adopting the locally-driven best practices of climate change adaptation was helpful to local people to cope with the impacts of changing climate. Thus, Figure 7 shows the framework assessment by using existing results of this study and identified the best practices of adaptation to climate change impacts in the study villages.

4. CONCLUSION

In the CDZ of Myanmar, the majority of local people perceived the increasing temperature and erratic nature of rainfall patterns as the most noticeable climatic changes. Most of the participants perceived that there have already been a variety of climate change impacts particularly agriculture and its related sectors such as land and water as well as the livelihood strategies. Specifically, the majority of

the people mentioned that yield declination and pest infestation due to water scarcity as a consequence of rainfall variability and prolonged dry spells were the most prominent impacts of climate change in the CDZ of Myanmar's agricultural production. Currently, migration to urban regions and abroad has been the most implicating factor in the CDZ that the majority of the participants agreed upon. In addition, most of the local participants perceived that the negative impacts to public health that they experienced including dengue fever due to mosquitos and other health issues related to adverse climatic effects such as heat stress causing headache and death, particularly for vulnerable groups, especially older people and children.

The majority of the dry zone local farmers used to apply traditional adaptation practices to counter the impacts of changing climate on agriculture, however, they mentioned that the impact of climate change on regional and individual crop production became larger and started to adopt introduced adaptation practices. In the study, the local participants perceived that growing mixed and multiple cropping systems is helpful to cope with water scarcity and can recover the cost from losses due to climatic variability. In addition, changing the growing season is sometimes the best solution to adapt to scarcity of water that supplements the climate change. In addition, the local people realize that changing to drought-resistant plant varieties is also helpful to cope with the scarcity of water under high variability of rainfall in the dry zone and thus adopting the practice of using drought-resistant plant varieties is better to adapt to water scarcity. Moreover, use of soil preparation for climate-change-driven agricultural production is also a prominent factor to cope with the water scarcity by improving the maintenance of soil moisture content and water holding capacity in the soil that the local people perceived. Another prominent solution to cope with the climate change is the migration to urban and abroad by seeking alternative opportunities in that migration was acknowledged as the positive aspect of income to support as one of the significant adaptation measures despite the migration was mainly perceived in a negative sense. Another prominent adaptation measure is getting information from local weather forecasts by the farmers for climate-driven agricultural production in dry zone.

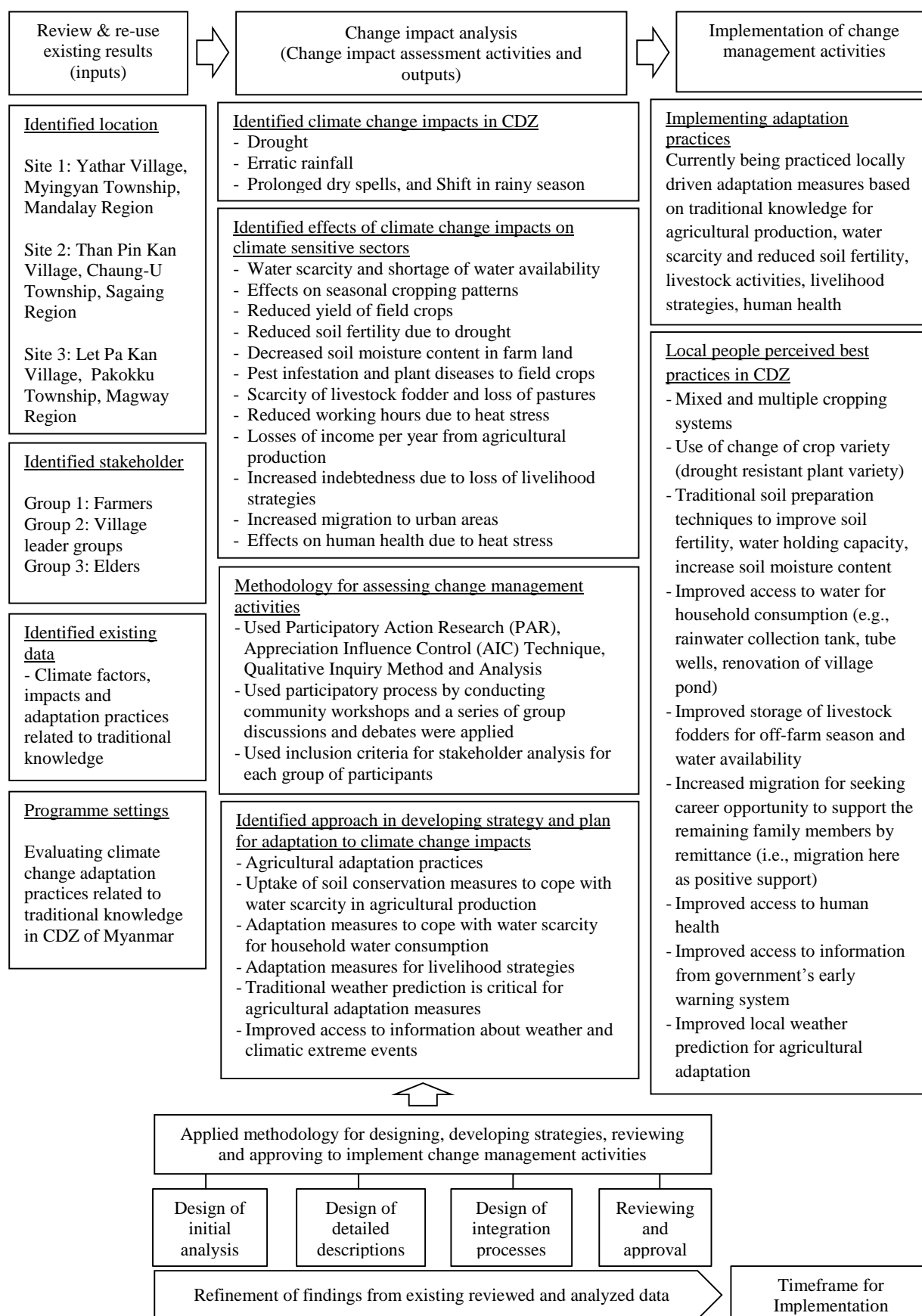


Figure 7. Framework assessment of change management activities of locally relevant adaptation practices in Ya Thar village, Myingyan Township, Than Pin Kan village in Chaung-U Township, and Let Pa Kan village in Pakokku Township

In the study, most of the people perceived and acknowledged that locally-driven adaptation practices for their livelihoods to cope with the impacts of climate change particularly for drought and erratic nature of rainfall were mixed and multiple cropping systems, use of crop variety change (drought resistant plant variety), land and soil preparation technique for climate change driven agricultural production, use of traditional weather prediction for agricultural adaptation, and migration to seek alternative career opportunities as the positive aspect of income to support. It was found that there was a limitation of people perceptions to have coverage the whole concept of the subject matter that the researcher expected. For example, based on the findings, the local people could not discuss the biodiversity and ecosystems in terms of climate change impacts and they just mainly focused on the themes that were very close to their daily life activities, particularly for agriculture and its associated sectors such as land, water resources and livestock integrating with agriculture as the major livelihood of the local people is agriculture. Thus, the implication is that in order to minimize the impacts of climate change and their effects on the livelihoods of the local people, the best local practices still need to be identified and adopted in a manner consistent with the local context in order to enhance local people's adaptive capacity.

ACKNOWLEDGEMENTS

This research was conducted with the financial support provided the scholarship of "Mahidol University-Norway Capacity Building Initiative for ASEAN". The authors would like to thank the reviewers for their constructive comments on the earlier version of the paper. Local stakeholders, facilitators and assistances offered by the local administration in Myingyan, Chaung-U and Pakokku Townships in CDZ of Myanmar are also highly acknowledged for their cooperation and contribution along the field data collection.

REFERENCES

- Adger WN, Arnell NW, Tompkins EL. Successful adaptation to climate change across scales. *Global Environmental Change* 2005;15:77-86.
- Asian Development Bank (ADB). Myanmar National Environmental Performance Assessment Report. National Commission for Environmental Affairs, Ministry of Forestry, Myanmar, UNEP (RRC.AP), and Asian Development Bank; 2006.
- Alessa L, Kliskey A, Williams P, Barton M. Perception of change in fresher in remote resource-dependent Arctic communities. *Global Environmental Change* 2008; 18:153-64.
- Aung LL, Zin EE, Theingi P, Elevera N, Aung PP, Han TT, Skaland GR. Myanmar Climate Report. Department of Meteorology and Hydrology, Ministry of Transport and Communications, Government of Myanmar; 2017.
- Belay A, Recha JW, Woldeamanuel T, Morton JF. Smallholder farmers' adaptation to climate change and determinants of their adaptation decisions in the Central Rift Valley of Ethiopia. *Agriculture and Food Security* 2017;6:24.
- Berkes F, Jolly D. Adapting to climate change: social ecological resilience in a Canadian western Arctic community. *Conservation Ecology* 2001;5(2):18.
- Blaikie P, Wisner B, Cannon T, Davis I. *At Risk: Natural Hazards, People's Vulnerability and Disasters*. 2nd ed. USA and Candana: The Cromwell press; 2004.
- Byg A, Salick J. Local perspectives on a global phenomenon-climate change in Eastern Tibetan villages. *Global Environmental Change* 2009;19(2): 156-66.
- Chen L, Zuo T, Rabina GR. Farmers' adaptation to climate risk in the context of China: a research on Jiangnan Plain of Yangtze River Basin. *Agriculture and Agricultural Science Procedia* 2010;1:116-25.
- Danielsen F, Burgess ND, Balmford A. Monitoring matters: examining the potential of locally-based approaches. *Biodiversity and Conservation* 2005;14: 2507-42.
- Department of Agriculture (DOA). Township agricultural and meteorological information, Myingyan Township, Chaung-U Township, and Pakokku Township, Myanmar; 2017.
- Department of Meteorology and Hydrology (DMH). Myanmar Climate Data. Department of Meteorology and Hydrology: Yangon, Myanmar; 2017.
- Deressa TT, Hassan RM, Ringler C, Alemu T, Yesuf M. Determinants of farmers' choice of adaptation methods to climate change in the Nile Basin of Ethiopia. *Global Environmental Change* 2009;19:248-55.
- Dumenu WK, Elizabeth AO. Climate change and rural communities in Ghana: social vulnerability, impacts, adaptations and policy implications. *Journal of Environmental Science and Policy* 2016;55:208-17.
- Food and Agriculture Organization (FAO). *Agricultural Sector Review Investment Strategy, Volume 1: Sector Review*. Food and Agriculture Organization of United Nations: 2005.

- Finucane M. Why science alone won't solve the climate crisis: managing the climate risks in the Pacific. *Asia Pacific Issues* 2009;89:1-8.
- General Administration Department (GAD). Township profile and general information, Myingyan, Chaung-U, and Pakokku Townships. Myanmar: 2016.
- Glatzel K, Wright H, Makuch Z. Technology innovation and the law - the example of climate adaptation technologies. *Environmental and Energy Law* 2012;92:116.
- Grothmann T, Reusswig F. People at risk of flooding: why some residents take precautionary action while others do not. *Natural Hazards* 2006;38:101-20.
- Hassan R, Nhemachena C. Determinants of African farmers' strategies for adapting to climate change: multinomial choice analysis. *The African Journal of Agricultural and Resource Economics* 2008;2(1):83-104.
- Horton R, De Mel M, Peters D, Lesk C, Bartlett R, Helsing H, Bader D, Capizzi P, Martin S, Rosenzweig C. Assessing Climate Risk in Myanmar. New York, USA: Center for Climate Systems Research at Columbia University, WWF-US and WWF-Myanmar; 2017.
- Initial National Communication (INC). Myanmar's Initial National Communication under United Nations Convention on Climate Change. Ministry of Natural Resources and Environmental Conservation, Republic of Union of Myanmar; 2012.
- Intergovernmental Panel on Climate Change (IPCC). Summary for Policy Makers. *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the IPCC*. Cambridge, United Kingdom: Cambridge University Press; 2014. p. 1-32.
- Intergovernmental Panel on Climate Change (IPCC). Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change. Cambridge, United Kingdom: Cambridge University Press; 2012. p. 582.
- Intergovernmental Panel on Climate Change (IPCC). Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change: Impacts, Adaptation and Vulnerability, *Climate change 2007*. Cambridge, United Kingdom: Cambridge University Press; 2007.
- Japan International Cooperation Agency (JICA). The Development Study on Sustainable Agricultural and Rural Development for Poverty Reduction Programme in the Central Dry Zone of the Union of Myanmar. Tokyo, Japan: Sanyu Consultants Inc; 2010.
- Khaing MA, Zin WW, Kyi TC. Climate change effect in Central Dry Zone, Myanmar. *International Journal for Innovative Research in Multidisciplinary Field* 2016;2:267-73.
- Kindon S, Pain R, Kesby M. Participatory Action Research Approaches and Methods: Connecting People, Participation and Place. London: Routledge. 2007.
- Kreft S, Eckstein D, Melchior I. Global climate risk index 2017: who suffers most from extreme weather events? Weather-related loss events in 2015 and 1996 to 2015. 2016.
- Kyi KM. Farmer Vulnerability Amidst Climate Variability: A case study of Dry Zone of Myanmar. ICIRD; 2012.
- Kyi T. Assessment on Vulnerability and Risk for Climate Change Adaptation of Rural Farmers in Central Dry Zone of Myanmar: Farm Level Case Study, Department of Agricultural Planning. Ministry of Agriculture, Livestock and Irrigation, Government of Myanmar; 2011.
- Laidler G. Inuit and scientific perspectives on the relationship between sea ice and climate change: The ideal complement? *Climatic Change* 2006;78:407-44.
- Lorenzoni I, Pidgeon NF. Public views on climate change: European and USA Perspectives. *Climate Change* 2006;77:73-95.
- MaCarl BA, Adams RM, Hurd BH. Global climate change and its impacts on agriculture [Internet]. 2001. Available from: gecon2.tamu.edu/people/faculty/mccarlbruce/papers/879.pdf.
- Madison D. The perception of and adaptation to climate change in Africa. Policy Research Working Paper 4308. The World Bank Development Research Group: Sustainable Rural and Urban Development Team; 2007.
- Matsuda M. Upland farming systems coping with uncertain rainfall in the Central Dry Zone of Myanmar: how stable is indigenous multiple cropping under Semi-Arid conditions? *Human Ecology* 2013;41:927-36.
- Maung MW, Pulhin JM, Espaldon MVO, Lalican NM. Climate change awareness and farm level adaptation of farmers (Central Dry Zone) in Monywa Township, Sagaing Region, Myanmar. *Journal of Environmental Science and Management* 2016;19(1):46-57.
- Ministry of Agriculture and Irrigation (MOAI). Myanmar Climate-Smart Agriculture Strategy. Ministry of Agriculture and Irrigation, Government of Myanmar; 2015.
- Morris H, Waterhouse DF. The distribution and importance of arthropod pests and weeds of agriculture in Myanmar. *ACIAR Monograph* 2001;67:73.

- Mortimore M. Drylands in a changing world: a new paradigm for people ecosystems and development. Gland Switzerland: IUCN; 2009.
- Myanmar Information Management Unit (MIMU). GIS Resources and Agency Maps [Internet]. 2017. Available from: <http://themimu.info/gis-resources>.
- Myanmar National Census Report (MNCP). The 2014 Myanmar Population and Housing Census: Mandalay Region, Sagaing Region and Magway Region. Nay Pyi Taw, Myanmar: Department of Population, Ministry of Immigration and Population; 2014.
- Nakashima DJ, Galloway MK, Thulstrup HD, Ramos CA, Rubis JT. Weathering Uncertainty: Traditional Knowledge for Climate Change Assessment and Adaptation. Paris, UNESCO;. 2012. p. 120.
- National Adaptation Programme of Action (NAPA). Myanmar's National Adaptation Programme of Action to Climate Change. Nay Pyi Taw, Myanmar: National Environmental Conservation Committee, Ministry of Environmental Conservation and Forestry; 2012.
- National Commission for Environmental Affairs (NCEA). Myanmar's Initial National Communication Report. Nay Pyi Taw, Myanmar: Environmental Conservation Department, Ministry of Natural Resources and Environmental Conservation, Government of Myanmar; 2010a.
- National Commission for Environmental Affairs (NCEA). Myanmar's Initial National Communication Report. Nay Pyi Taw, Myanmar: Environmental Conservation Department, Ministry of Natural Resources and Environmental Conservation, Government of Myanmar; 2010b.
- Norton GW, Alwang J, Masters WA. Economics of Agricultural Development: World Food Systems and Resource Use. 2nd ed. Routledge; 2010.
- Ole M, Mbow C, Reenberg A, Diouf A. Farmers' perceptions of climate change and agricultural adaptation strategies in rural Sahel. *Environmental Management* 2009;43:804-16.
- Oo AT, Huylenbroeck GV, Speelman S. Determining factors for the application of climate change adaptation strategies among farmers in the Magwe District in the Dry Zone region of Myanmar. *International Journal of Climate Change Strategies and Management* 2017;9(1):36-55.
- Ratner BD, Smith WE. Collaborating for Resilience: A practitioner's guide. Manual. Collaborating for Resilience; 2014.
- Siegrist M, Gutscher H. Flooding risks: A comparison of lay people's perceptions and expert's assessments in Switzerland. *Risk Analysis* 2006;26:971-9.
- Shongwe P, Masuku MB, Manyatsi AM. Factors influencing the choice of climate change adaptation strategies by households: a case of Mpolonjeni Area Development Programme (ADP) in Swaziland. *Journal of Agricultural Studies* 2014;2(1):86-98.
- Slagle JT. Climate Change in Myanmar: Impacts and Adaptation [dissertation]. Naval Postgraduate School: Monterey, California, USA; 2014.
- Swe LMM, Shrestha RP, Ebberts T, Jourdain D. Climate and Development Farmers' perception of and adaptation to climate-change impacts in the Dry Zone of Myanmar. *Climate and Development*; 2015.
- Swiderski K, Song Y, Li J, Reid H. Adapting agriculture with traditional knowledge. International Institute for Environment and Development (IIED); 2011.
- System for Analysis, Research and Training (START). Assessing the Adaptation Mechanisms of Smallholder Farmers to Climate Change and Agro-biodiversity Losses in Northern Ghana. START, University of Ghana, Legon; 2012.
- Tessema YA, Aweke CS, Endris GS. Understanding the process of adaptation to climate change by smallholder farmers: the case of east Hararge Zone, Ethiopia. *Journal of Agricultural and Food Economics* 2013;1(13).
- Thieken AH, Kreibich H, Müller M, Merz B. Coping with floods: Preparedness, response and recovery of flood-affected residents in Germany in 2002. *Hydrological Sciences Journal* 2007;52:1016-37.
- Tin SM. Climate of the Dry Zone of Myanmar [dissertation]. Department of Geography, University of Mandalay: Government of Myanmar; 1990.
- United National Framework Convention on Climate Change (UNFCCC). Climate change: Impacts, vulnerabilities and adaptation in developing countries. Bonn, Germany; 2007.
- Vaughan E, Levine E. Report on the strategic assessment of resilience of farming community in Dry Zone of Myanmar. USAID Technical and Operational Performance Support (TOPS) program and the Livelihoods and Food Security Trust Fund (LIFT), Myanmar; 2015.
- Wiegiers K. Best Practices for Change Impact Analysis [Internet]. 2017. Available from: <https://www.jamasoftware.com/blog/change-impact-analysis-2/>.
- Win MT. Survey report of public awareness on climate change. EcoDev, Yangon: Myanmar; 2010.
- Wisconsin Initiative on Climate Change Impacts (WICCI). Adaptation to Climate Change: Why Adaptation Policy is more difficult than We Think (and what to do about it). Adaptation Working Group: WICCI; 2011.
- World Bank (WB). Turn down the Heat, why a 4C warmer world must be avoided. A report for the World Bank by the Potsdam Institute for Climate Impact Research and World scientists warning to Humanity. Washington, DC: World Bank; 2012.

- World Bank (WB). The World Bank Participation Sourcebook, Appendix I: Methods and Tools 1996. p. 186-93.
- Yi T. Drought Annual Report of Department of Meteorology and Hydrology. Ministry of Transport and Communications, Government of Myanmar; 2015.
- Yusuf M, Falco DS, Deressa T, Ringler C, Kohlin G. The Impact of Climate Change and Adaptation on Food Production in Low-income Countries. Ethiopia Development Research Institute, International Food Policy Research Institute, Discussion Paper No.828, Washington, DC; 2008.