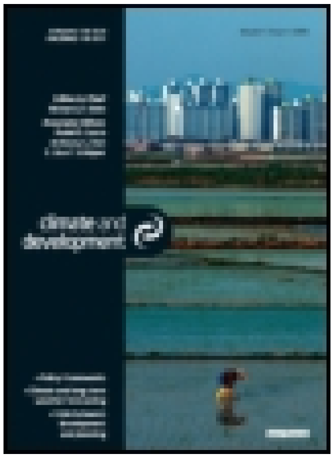

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RESEARCH ARTICLE

Farmers' perception of and adaptation to climate-change impacts in the Dry Zone of Myanmar

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In Myanmar, impacts of climate change have been apparent since 1977. Myanmar's economy, which exclusively depends on agriculture, is increasingly at risk due to climate change. Since farmers are often the first to confront climate change, they must adapt to new climatic conditions. Local adaptation practices, the possible starting points in developing new adaptation strategies, are currently occurring at a local scale, particularly based on the traditional knowledge. We used household survey, participatory histogram mapping and key-informant interviews to explore the farmers' perception and adaptation practices to climate change in the Myanmar Dry Zone. Ninety per cent of respondents perceived the changing climatic patterns in the Dry Zone, while increasing temperature and the erratic rainfall patterns were perceived as the predominant changes by 85% of the people. The farmers also perceived that there have already been several impacts of climate changes on agriculture. The common sesame/groundnut cropping pattern has been abandoned by the Dry Zone farmers in recent decades due to climate-change-driven agricultural production barriers. Farmers have been dealing with those barriers using their conventional agricultural practices, e.g. rainwater-collection, tube wells and water-harvesting techniques. They have also been using the traditional weather forecasting techniques to predict weather. Consequently, the study underlines the need to document existing agricultural practices that can prove to be successful adaptation measures, and it points out the crucial role of the extension strategy in disseminating agricultural techniques and weather information to support farmers to further adapt to climate-change impacts.

Keywords: adaptation; agriculture; climate change; Myanmar; perception

1. Introduction

In Myanmar, the agriculture sector, the backbone of Myanmar economy (NCEA, 2010a), contributed 34% of GDP in 2008 and 2009, 15.4% of total export earnings and employed 61.2% of the labour force in the year 2010 (DAP, 2010). Seventy per cent of the country's population reside in the rural areas and mainly depend on agriculture, livestock and fishery for their livelihoods (DAP, 2010). The economy of the country and the livelihoods of the majority of its people are increasingly at risk due to climate change.

In Myanmar, climate change has become apparent since 1977 and the climate data have indicated a general warming trend and a decreasing precipitation trend with the range of 2–339 mm per year (NCEA, 2010a). It is also observed that the rainfall pattern has changed from bimodal to unimodal distribution, with a reduced duration of the rainy season to 105 days from the normal 145 days, with the later onset of monsoon, with the lack of the dry-spell period in July and the earlier withdrawal of monsoon (Lwin, 2010). The lack of a dry spell in July has delayed the crop harvesting and decreased the crop yield. The scarcity of water has also become a serious issue in the Dry Zone of Myanmar (NCEA, 2010b). In addition, 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).

Climate-change adaptation programmes focusing on agriculture are urgently needed as the impacts of climate change on agriculture are already evident and the trend will continue in the foreseeable future even if greenhouse gases (GHGs) emissions are stabilized at the current levels (World Bank, 2006). Since farmers are the first actors confronting climate change and also the ones who need to adapt their farming systems to new climatic conditions, it is necessary to understand their perceptions of climate change (Chen, Zuo, & Rabina, 2010). It is even more important in the case of the Dry Zone of Myanmar, where there is dearth of information despite the fact that the area is highly vulnerable to the climate-change impacts.

The responses to climate change are currently occurring at the local scale (Adger, Arnell, & Tompkins, 2005) and traditional knowledge could also provide the efficient and time-tested measures for climate-change adaptation

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(UNFCCC, 2007). Adaptation practices that are suitable to the local context have to be regarded as the starting points in developing new strategies for adaptation. Therefore, in this article, we assessed the farmers' perception of climate change and their responses through farming practices to the climate-change impacts in the Dry Zone of Myanmar.

2. Climate-change impacts on agriculture and farmers' adaptation

Climate change is defined as changes in distributional patterns of weather over different time periods that may range from a few years to several decades. Rising global average temperature, increasing ocean temperature, changes in rainfall pattern and gradual melting of glaciers are the most prominent effects of climate change (UNFCCC, 2007). Atmospheric CO_2 concentrations have increased from 280 to 378 ppm over the last 150 years, causing an increase in global average temperature by 0.6°C over the past 100 years. According to the projections, it might rise anywhere from as little as 1.8°C to as much as 7.1°C over the next 100 years (Justus & Fletcher, 2007; Rahmstorf, 2004).

The agriculture sector is very sensitive and vulnerable to the impacts of climate change because agricultural production is controlled by climate and climatic factors (IPCC, 2007). Climate change could affect food production through different ways: (1) by changing overall growing conditions such as temperature, precipitation, carbon dioxide fertilization, climate variability and surface water runoff (World Bank, 2008); (2) by inducing more extreme weather such as floods, droughts and storms and (3) by increasing extent, type and frequency of infestations, including that of invasive alien species (Nellemann et al., 2009).

Temperature determines soil moisture loss, decomposition of organic matter, nutrient availability and water-holding capacity of soil (McCarl, Adams, & Hurd, 2001). In the tropical countries, even moderate warming can reduce yields significantly. Myanmar is one of those countries in which the agricultural production is projected to lose 15–50% of its total production by the end of this century (Cline, 2007). If the temperature increases above 3°C, the yield losses are likely to occur in most parts of the world and particularly severe in the tropical regions. In addition, increasing temperature may also influence the infestation and reproduction of pests and diseases, which in turn have a direct influence on food security and poverty (IPCC, 2007).

Precipitation variability could somewhat alter the availability of water for irrigation, while temperature variations affect evapotranspiration (McCarl et al., 2001). On the other hand, plant growth and yields are controlled by the climatic factors and CO_2 fertilization effects (McCarl et al., 2001) by responding positively to the elevated CO_2 in the absence of climate change (Ainsworth & Long, 2005; Jablonski, Wang, & Curtis, 2002). The combined influence of fertilization effect, the accompanying thermal stress and water scarcity will cause rice production to decline by 3.8% by the end of the twenty-first century (IPCC, 2007). However, the impacts on the crops are also highly variable in different regions and on different types of the crops (Lobell et al., 2008). About 2.5–10% decrease in crop yield is projected for many parts of Asia in the 2020s and 5–0% decrease in the 2050s along with the population growth and rising standard of living, which could adversely have an impact on more than a billion people in Asia by the 2050s (IPCC, 2007).

Societies can respond to climate change by adapting to its impacts (adaptation) and by reducing GHGs emissions (mitigation), thereby reducing the rate and magnitude of the change (UNFCCC, 2007). Adapting to climate change, by taking any proper measures to minimize the negative effects of the impacts of the climate change and/or by making any adjustments in the systems (UNFCCC, 2007), is currently occurring and is likely to occur with greater urgency in the future (Adger et al., 2005). Adapting agricultural systems to climate change is urgent because its impact on agriculture is already evident and the trends will continue even if emissions of GHGs are stabilized at current levels (World Bank, 2006). Adaptation in agriculture is clearly dependent on regional socio-economic conditions (Reidsma, Ewert, Lansink, & Leemans, 2010) and it varies depending on the climatic stimuli (to which adjustments are made), the different farm types and locations, and the economic, political and institutional conditions (Bryant et al., 2000; Smit & Skinner, 2002), the environmental circumstances, the availability of information and technology (UNFCCC, 2007).

There can be four main adaptation categories: (1) farm production practices, (2) farm financial management, (3) technological developments and (4) government programmes and insurance (Smit & Skinner, 2002). In Asia, there are many traditional farming practices that can cope with climate variability, which are intercropping, mixed cropping, agro-forestry, animal husbandry and developing new varieties. Moreover, the strategies such as terracing, surface and ground water irrigation, and crop diversification in agriculture are also possible to deal with climate change, particularly to drought (UNFCCC, 2007). Precision farming and agricultural intensification are inevitably required in order to meet the food requirements in Asia because both techniques could improve yields per unit of resources used (IPCC, 2007). Further adaptation options for agriculture can be technology adaptation techniques such as transplantation methods to adapt to flooding (UNFCCC, 2007). However, there are still barriers among countries to adopt the practices. The barriers to adaptation include the lack of credits or savings in some countries and the lack of access to water in others (World Bank, 2006).

In Myanmar, the impacts of climate change are inevitable with increasing temperatures and decreasing precipitation trends, with frequent cyclones devastation almost every year after 2002 (except the year 2005), with the late onset and early withdrawal of the southwest monsoon (NCEA, 2010a). Some climate-modelling studies have shown that the temperature is likely to increase by 1.4–1.7°C in Myanmar by mid-century, with 4% increase in precipitation (NCEA, 2010a). In Myanmar, no previous studies on the vulnerability to climate change have been undertaken, and so no adaptation strategy or action plan has been developed (Win, 2010). A comprehensive approach for addressing vulnerability of communities to climate change is a basic need to enable that society to better adapt with future uncertainties (Adger, 1999). Therefore, Myanmar, a dominantly agriculture-based country, adaptation to climate change is particularly important to protect the staple food production (NCEA, 2010a).

People's experiences, knowledge and perceptions of extreme climatic events and their impacts motivate the people to follow the precautions (Grothmann & Reusswig, 2006; Siegrist & Gutscher, 2006, 2008; Thieken, Kreibich, Müller, & Merz, 2007) and influence whether to follow or not the adaptation practices (Alessa, Kliskey, Williams, & Barton, 2008; Berkes & Jolly, 2001). In addition, local observations and perceptions could reflect local concerns (Danielsen, Burgess, & Balmford, 2005) and the actual impacts of climate change (Laidler, 2006). Furthermore, public experiences and their views on the past climate-change events can help predict the possible impacts in the future (Lorenzoni & Pidgeon, 2006). Therefore, local observations and perceptions should be taken into account in the context of climate change for the successful implementation of climate-change initiatives (Byg & Salick, 2009).

3. Study area

The study area is situated in the Dry Zone of Myanmar, which occupies 13% (87240 sq.km.) of the country's area. Agriculture occupies more than half of the Dry Zone and accounts for 35% of the country's cultivable land (DMO & FD, 2009). The Dry Zone is a vast semi-arid lowland, which has a tropical monsoon climate with a rainy season from May until October and generally dry in the rest of the year. The area is especially different from the other regions in terms of dryness and hot weather. Although the mean temperature is about 27°C, the temperature often rises to above 40°C in the summer. The name Dry Zone is derived from the fact that rainfall in the area is low, where annual rainfall is about 600–1400 mm and less than 600 mm in the central core area of the Dry Zone.

Its poor adaptive capacity and increasingly unpredictable weather such as rainfall and temperature have made the area to suffer more from the impacts of climate change. The Central Dry Zone comprises 11 townships. Two villages, Shwe Twin and Takama, from two townships were randomly selected (Figure 1) for the study. Based on the availability of the respondents and their willingness to participate in the survey, 106 households out of 224 households from the two villages were selected as the final sample households.

4. Materials and methods

Household questionnaire survey, participatory histogram mapping and key-informants interview were employed as the primary data-collection methods. Altogether 106 farmers from the survey villages (67 farmers from Takama village and 39 farmers from Shwe Twin village) were interviewed from June to August of 2011, to analyse their perceptions of climatic trends over the past 30 years, the consequences of changes and farm-level adaptations to those consequences.

Participatory histogram mappings were carried out with a mixed group of people including the elders, the average and the youth in both survey villages to assess the common perceptions of the changes in the trends and correlation between their environment, agricultural production, food security and other socio-economic conditions. In addition, the key farmers who have many experiences in the Dry Zone farming were selected to do the in-depth survey about the current climate-change impacts and the farmers' responses to those changes. The data obtained from the key-informant interviews were utilized to identify the current agricultural problems of the farmers and their attempts to tackle with these problems. Descriptive statistics of the bar graph, column graph, pie graph and frequency distribution were mainly used to describe the analysed results of primary data sets derived from the questionnaire survey.

Climate data such as rainfall data and temperature data of the study area were acquired from the Department of Meteorology and Hydrology. In this case, climate data from the nearest weather stations to the study area, Nyaung Oo weather station nearby Shwe Twin Village and Kyaukpadaung weather station nearby Takama Village were collected in order to precisely represent the weather conditions of the survey villages. The trends in the climate data were analysed by performing Mann-Kendall's trend test (Mann, 1945; Kendall, 1975), which is the most recommended trend detection test (WMO, 1988) and which has been used in recent studies for climatic trend analysis (Kalanda-Joshua, Ngongondo, Chipeta, & Mpembeka, 2011). The results from the trend analysis were then compared with the farmers perceived rainfall and temperature trends so that the peoples' perception could be verified by the scientific trend analysis. In this case, 30 years monthly rainfall and monthly rainy days data from the two study townships were available to analyse the

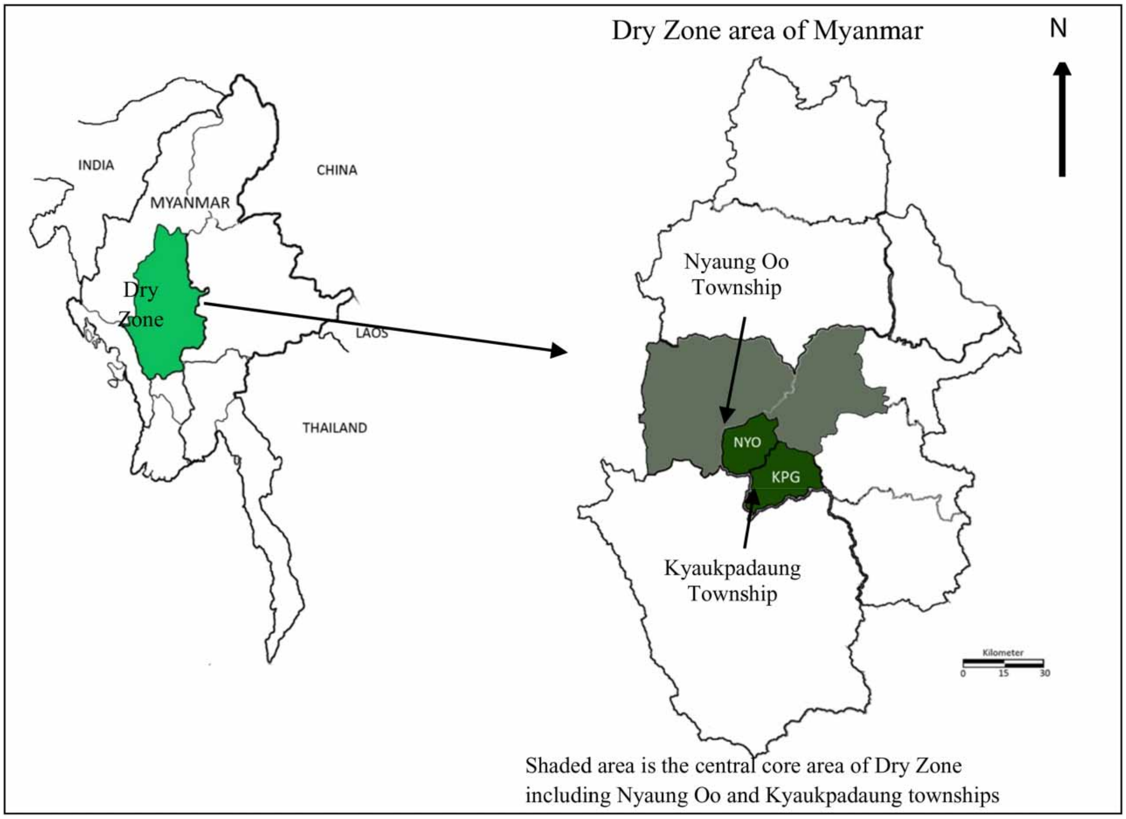


Figure 1. Location map of the study area.

rainfall trend. However, for temperature trend analysis, 30 years data sets of monthly minimum and maximum temperature from only Nyaung Oo weather station were available.

5. Results and discussions

5.1. *Farmers' perceived changes in climate variables*

A study by Win (2010) stated that 80% of the surveyed population in the country perceived the changes of climatic patterns in Myanmar. In our study area, 90% of the respondents perceived the changing climatic patterns in their environment. The two major changes perceived in the Dry Zone, according to 85% respondents, are "Increasing temperature" and the erratic rainfall patterns including "Uneven rainfall distribution" and "Increasing and decreasing rainfalls" (Figure 2). Moreover, other perceived climatic changes such as "Unseasonal rainfall", "The later onset of monsoon", "High intensity rainfall" and "Changes in wind intensity" were also reported by the farmers. In addition, there were many contradictory perceptions such as "Increasing rainfall" versus "Decreasing rainfall" and "Strong wind intensity" versus "Weak wind intensity" as the result of different localities of the villages where the study was conducted.

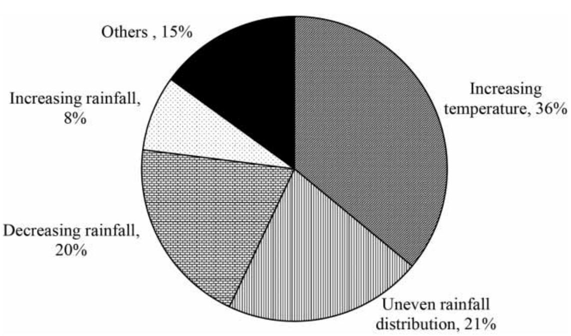


Figure 2. Farmers' perceived climate changes in the Dry Zone of Myanmar ($n = 124$).

5.2. *Farmers' perception of the climatic trends*

5.2.1. *Rainfall*

Ninety per cent of the respondents perceived that annual rainfall and rainfall intensity have changed over to either an increasing trend or a decreasing trend in the Dry Zone of Myanmar. Seventy per cent of the respondents also perceived the irregular onset and withdrawal of the monsoon in the study area (Table 1).

The 30 years rainfall data (1981–2010) show a slight increasing trend in both study villages (Figure 3). However, Mann-Kendall's trend test does not show any

Table 1. Farmers' perception of the climate trends in the Dry Zone of Myanmar.

Variables	Per cent responses ($n = 106$)		
		Unusual trend	
	Usual trend	Decreasing	Increasing
Annual rainfall	9	51	40
Rainfall intensity	10	60	29
Onset of the monsoon	31	19[a]	50[b]
Withdrawal of the monsoon	30	30[a]	41[b]
Summer temperature	12	16	71
Rainy season temperature	30	16	54
Winter temperature	18	16	66
Frequency of the heat waves	17	10	73
Intensity of the heat waves	24	10	67
Duration of the heat waves	46	18	36

[a]Late onset or withdrawal of monsoon.
[b]Early onset or withdrawal of monsoon.

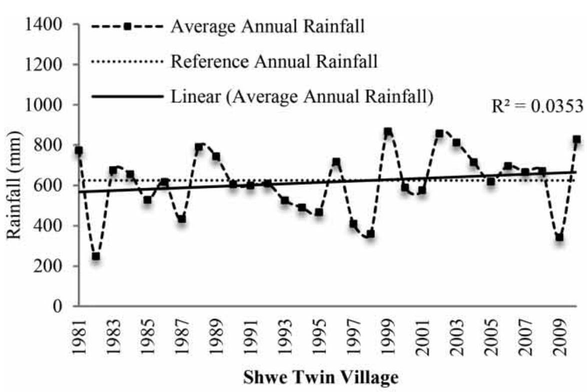
significant changes for the rainfall data. On the other hand, the trend test shows a significant increasing trend for the annual rainy days in both study villages (Table 2). This means the regular amount of annual rainfall was distributed in more than usual number of days in the study area in last 30 years. Although Mann-Kendall's test does not show any statistically significant change in the annual rainfall, the erratic behaviour of rainfall pattern with over all slight increases is discernible and it coincides with the farmers' perceived climatic changes.

The rainfall anomalies from their reference annual rainfalls (average annual rainfall from 1960 to 2010), 625 mm in Shwe Twin Village and 713 mm in Takama Village, indicate that there were 14 positively deviated years in Shwe Twin Village and 18 years in Takama Village in last 30 years (Figure 3). Although positively deviated rainfalls were more common in the latter, it could be said that the rainfall was more erratic in the latter than that of the former in the last 30 years. Therefore, those 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 Dry Zone of Myanmar.

5.2.2. *Temperature*

Changes in temperature patterns seem to be more consensual among interviewed farmers with 71% of the respondents perceiving an increase in temperature in summer, 54% in the rainy season and 66% in winter. In addition, increasing frequency and intensity in heat wave were also perceived by the farmers with the responses of about 70% for each category, whereas almost half of the respondents answered that heat wave duration remains the same (Table 1).

The temperature data indicate that average maximum temperature in the Dry Zone increased progressively in the last 30 years, whereas average minimum temperature remained stable (Figure 4). In this case, both of the



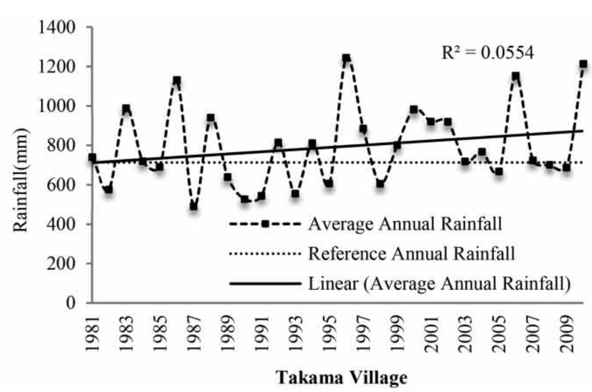


Figure 3. Annual rainfall of Shwe Twin and Takama villages in last three decades (1981–2010).

Table 2. Mann-Kendall's test of the annual rainfall and annual raining days trends in 1981–2010.

Study Village	Test variable	Mean	Mann-Kendall's test: Data points	Test (S)	p Value	Trend at 95% significant level
Shwe Twin (Nyaung Oo)	Rainfall (mm)	616	30	29	0.621	No trend
	Raining days	42	30	165	0.002	Increasing
Takama (Kyaukpadaung)	Rainfall (mm)	792	30	56	0.306	No trend
	Raining days	49	30	131	0.015	Increasing

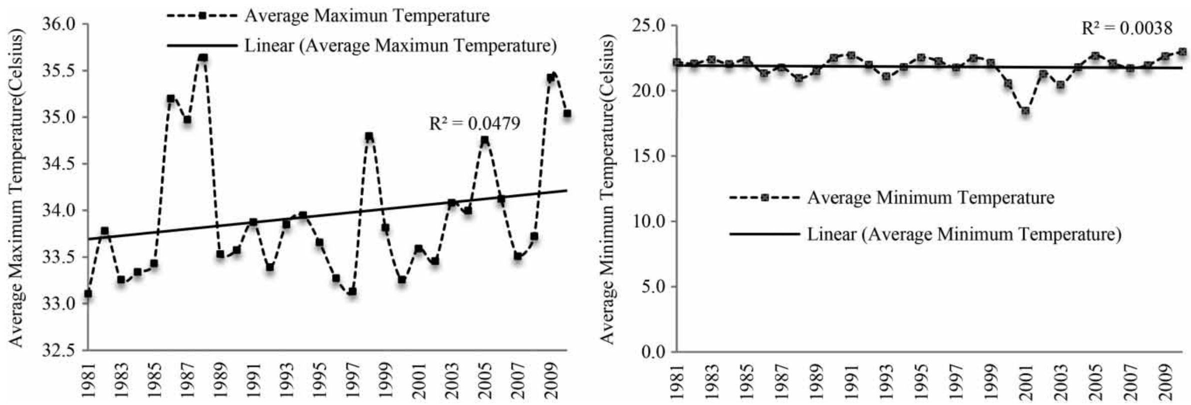


Figure 4. Average maximum and minimum temperature of Nyaung Oo township in 1981–2010.

Table 3. Mann-Kendall's test of maximum and minimum temperature trend in 1981–2010.

			Mann-Kendall's test			
Study area	Temperature	Mean (°C)	Data points	Test (*S*)	*p* Value	Trend at 95% significant level
Shwe Twin (Nyaung Oo)	Maximum	34	30	73	0.177	No trend
	Minimum	21.8	30	8	0.897	No trend

farmers' perception and the graphs revealed the same finding of increasing temperature trend in the Dry Zone, which is also in line with the gradual warming trend in Myanmar reported by the DMH (NCEA, 2010a). However, Mann-Kandell's test did not show any trend either for the maximum temperature or the minimum temperature in last 30 years (Table 3). In this case, the farmers' perceived temperature trend was opposed to the trend test result of empirical data. It could be as the results of the frequent occurrence of the highest average annual temperature, which are about 35.4°C and 35°C, respectively, in two successive years of 2009 and 2010. In addition, the highest average monthly temperature of the last decade was 42°C, which also occurred in April of 2010. Therefore, these rather high average monthly and annual temperatures occurring in the recent years might well have led farmers to have perceived uniquely about the increasing temperature trend in the Dry Zone.

Therefore, the farmers perceived that annual rainfall is changing with either an increasing trend or a decreasing trend regardless of the trend analysis results of the secondary climatic data, while they perceived that the temperature is predominantly increasing along with frequent heat waves nearly all year round in the Dry Zone of Myanmar.

5.3. *Farmers' perception of the causes of climate change*

Factors affecting climate change can be categorized into four groups. Among them, deforestation and related causes were mostly cited as the major causes of climate change by 70% of the respondents. Deforestation has occurred in the Dry Zone for various reasons, such as land conversion, logging, charcoal making and dam construction. Fourteen per cent of the respondents perceived that human behaviours and its related causes, which comprises deteriorating human ethics, population growth and their excessive uses of natural resources, were the cause of climate change. Eight per cent of the respondents believed that climate change has been caused by industrial development, while 7% of the respondents thought it was a natural phenomenon (Figure 5). All in all, more than 90% of the reported causes of climate change fall under the category of anthropogenic causes. It means the Dry Zone farmers are aware of that climate change has happened as a result of anthropogenic causes.

5.4. *Impacts of climate change on agriculture*

More than 95% of the respondents agree that there have already been several impacts on the Dry Zone agricultural production as a result of climate change. According to farmers' perception, decreasing yield and increasing pest infestation are the most prominent impacts of climate change in the Dry Zone (Figure 6). Water scarcity, a climate-change impact, is regarded as the most important factor causing the crops' yields to have declined in the study area and it accounted for more than 60% of the impacts reported by the respondents. It was also found that the majority of those respondents (nearly 80%) were the ones who perceived annual rainfall is decreasing in the Dry Zone. In addition to the direct impacts, the indirect

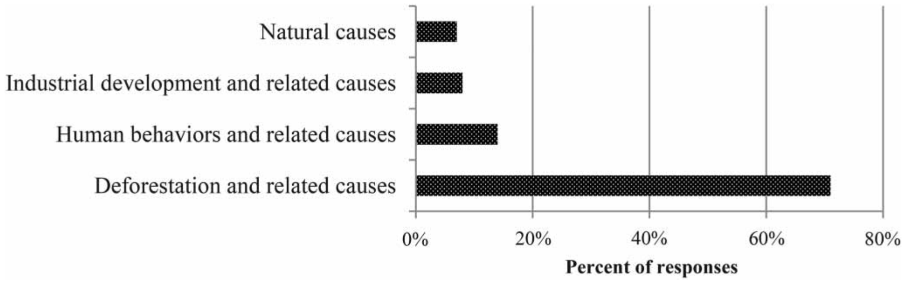


Figure 5. Farmers' perceived causes of climate change in the Dry Zone ($n = 106$).

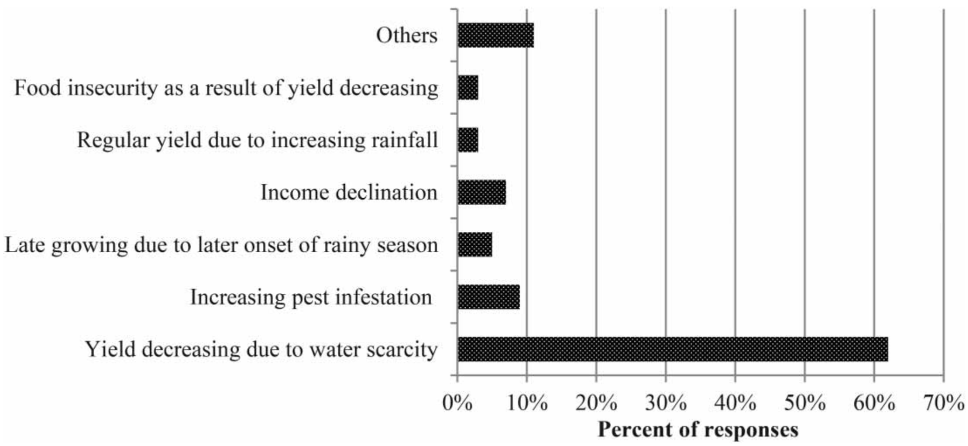


Figure 6. Impacts of climate change on agriculture in the Dry Zone ($n = 106$).

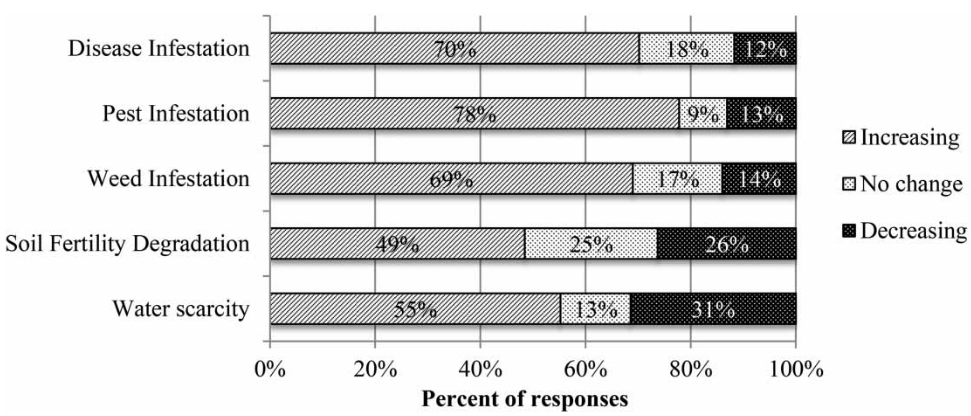


Figure 7. Trends of farmers' perceived barriers in agricultural production of the Dry Zone ($n = 106$).

impacts such as food insecurity, income declination and changes in crop variety were also reported. Other impacts amounting to 11% of the responses include crop damages due to intense rainfall, variety changes due to irregular rainfall, poor seed germination due to high temperature, the scarcity of animal feed, increasing water requirement due to high temperature and changes in the growing season due to irregular rainfall.

The above farmers' perceived impacts were then cross-validated by the farmers' perceived trends of agricultural production barriers. Majority of the farmers (50 to 78%) also perceived that many production barriers such as pest and disease infestations, weed infestation, water scarcity and soil fertility degradation have increasingly occurred in the Dry Zone due to climate change (Figure 7). On the other hand, it was interestingly observed that 10–25% of the respondents perceived otherwise in those trends, i.e. decrease in those barriers.

5.4.1. *Crop yield and variety*

The current average yields of all major crops reported by the farmers are generally lower than the National Targeted Yields (NTY). Although rice yield was reported to have increased by 62% respondents, the observed rice yield in the area was found at 60% of the NTY but other crops are very far from the NTY (sesame 17% with 0.2 mt/ha, groundnut 50% with 0.7 mt/ha, green gram 38% with 0.6 mt/ha and pigeon pea 25% with 0.5 mt/ha). Moreover, the farmers reported that the current crop yields except groundnut are declining (Figure 8). Rice is an exception with cases of both decreasing as well as increasing trends, which depend mainly on the availability of water and application of manure for rice production.

Agricultural production is impossible without water. Accordingly, it was clearly found that irregular rainfall and inadequate water for crops production were among the most serious factors affecting yield decreases in the Dry Zone. Evidently, 58% of the respondents highlighted that irregular rainfall negatively affected sesame yield. Similarly, more than half of the respondents also perceived that irregular rainfall is the most serious factor causing yield decreasing for all major crops in the Dry Zone. On the other hand, changing growing time to the late monsoon season, according to the farmers' knowledge and according to 50% of the respondents, has become the most common coping strategy for increasing yield particularly in groundnut production because the late monsoon season ensured the crops to obtain adequate moisture (Table 4). Pest infestation is another important factor affecting yield decreasing in sesame and pigeon pea productions, whereas pursuing proper crop management practices are regarded as the most useful techniques causing yield increases in the Dry Zone.

Ba Pan, Myauk Yein and Sinyadanar-1 are the most common sesame varieties in the Dry Zone. In the last 10 years, sesame was mostly grown for oil production. Nowadays, there have been more and more markets for export demand. Therefore, white sesame has become popular with increasing export demand. Consequently, Dry Zone farmers have increasingly grown "Myauk Yein", a white sesame, for its rather high yield since last five years, regardless of its high sensitivity to the climate. "Ba Pan" is still regarded as the most suitable sesame variety in the Dry Zone because of its rather stable yield even under extreme climate as well as its unique seed quality and market stability. Therefore, it could be said that variety of sesame planted in the area is closely related to its market demand as well as its suitability with the local climate.

Once, a spreading type was a sole groundnut variety in the Dry Zone. In order to overcome inadequate water resulting from irregular rainfall, Dry Zone farmers attempted to grow a short-lived and erected groundnut variety instead of a long-lived normal spreading type. The longer the lifespan of the groundnut, the longer the vegetative growth. Therefore, the short-lived groundnut could produce a rather high yield even with less rainfall in early growth stage, whereas the normal spreading types need a considerable amount of rainfall for its relatively long vegetative period. Accordingly, Sinpadathar-7, one of the short-lived and erected groundnut varieties, has become the most dominant groundnut variety in the Dry Zone, which is currently grown by nearly half of the Dry Zone farmers. Therefore, the groundnut variety change in the Dry Zone was influenced by yield and its lifespan.

5.4.2. *Cropping pattern change*

Sesame–groundnut, the traditional cropping pattern, was substantially substituted in the last two decades by other

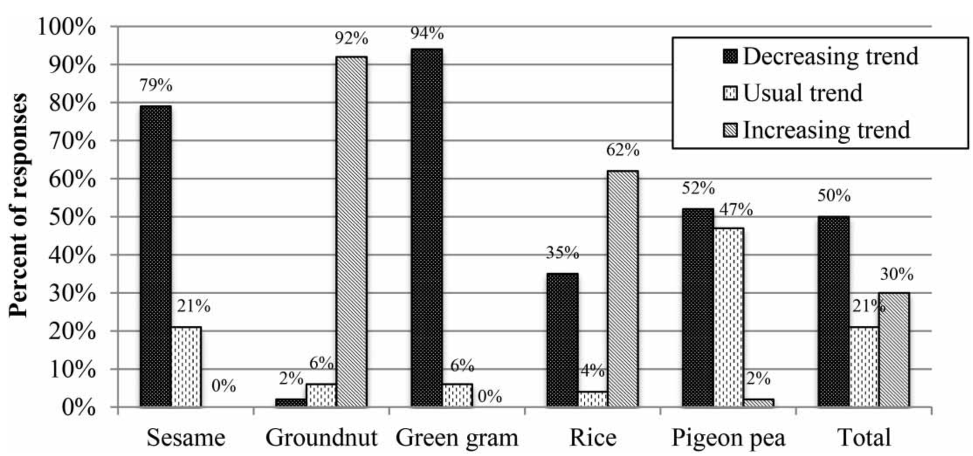


Figure 8. Farmers' perceived yield trend of some major crops in the Dry Zone ($n = 106$).

Table 4. Farmers' perceived reasons for changing crop yields in the Dry Zone.

Reasons	Major crops (per cent of responses)					
	Sesame ($n=115$)	Groundnut ($n=107$)	Green gram ($n=60$)	Rice ($n=56$)	Pigeon Pea ($n=60$)	Total[a]
Reasons for decreasing yield trend ($N=232$)						
Irregular rainfall	58	3	48	0	36	53
Inadequate water for crop production	5	2	35	14	1	21
Pest infestation	17	2	3	0	17	14
Poor fertility/fertilizer application	3	0	10	7	2	8
Rodent infestation	0	4	2	0	1	3
Inadequate water resulted from rotation based water access system	0	0	0	4	0	1
Late weeding	1	0	0	0	0	0
Reasons for increasing yield trend ($N=166$)						
Changing growing time (late monsoon growing season ensure to have adequate moisture)	1	56	0	0	3	15
Pursuing proper crop management practices	8	25	2	13	7	12
Manure application during land preparation	4	1	0	25	1	5
Adequate water requirement	0	6	0	21	0	4
Familiarity with the crop practices	0	0	0	16	0	2
Fertilizer application	3	1	0	0	0	1
Gypsum application	0	1	0	0	0	0

[a]Total per cent is calculated based on *N* value.

cropping patterns such as Sesame–pigeon pea, fallow–groundnut and mixed system between these two patterns. Nearly half of the farmers abandoned the sesame–groundnut cropping pattern in the last 10 years although it was still practised in last 5 years by 18% of the farmers (Figure 9). Water scarcity accompanied by irregular rainfall caused the sesame–groundnut cropping pattern to disappear from the Dry Zone. Furthermore, water-related issues (less rainfall and inadequate water) and establishment of new water access, such as river water pumping project, were the major factors that accounted for 40% of the factors causing cropping pattern change in the Dry Zone.

Traditionally, groundnut was grown as the second crop after sesame. But in the last 20 years, the sesame–groundnut cropping pattern was gradually abandoned by the Dry Zone farmers because of poor yields in both crops, which were even less than the seeds they used for planting in some years. Poor rainfall in early monsoon led to the abandonment of early monsoon sesame and also caused water

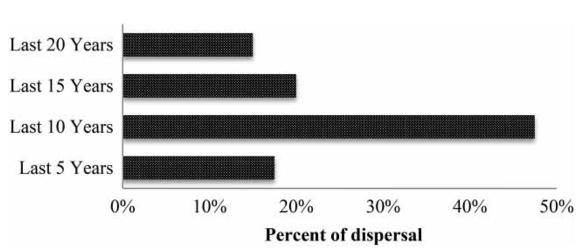


Figure 9. Dispersal of Sesame–Groundnut cropping pattern in last 20 years ($n=106$).

shortage for groundnut especially in its later crop development period. At that time, the farmers tried to keep producing groundnut by different means. Accordingly, some farmers found that changing growing time of groundnut to July from its normal growing time of August was the best way to cope with poor production because it ensured adequate moisture for groundnut throughout the crop growing period. In this way, early monsoon sesame production slowly disappeared and, late monsoon groundnut production (July groundnut production, also known as "War-So-Pe" in Burmese) has spread out across the Dry Zone.

5.5. *Agricultural development and climatic trends in participatory histogram mapping*

The histograms, which were drawn in both study villages in a participatory way, also proved that deforestation was very common in the Dry Zone. The forest cover has gradually decreased due to the grabbing of forest lands for agriculture and urbanization, and due to cutting of trees for firewood. Twenty years ago, the Dry Zone people encountered a serious shortage of firewood for cooking. At that time, there was no alternative but to cut the trees around the villages in order to fulfil the immediate needs. Therefore, it was the main reason to have lost the forest areas in the Dry Zone. On the other hand, the Dry Zone people with the help of an UNDP project started to grow a fast-growing forest plant namely "Me-Za-Le" (the Kassod tree) along the border of agricultural fields and near the villages. Likewise, they cultivated pigeon pea together with sesame for the sake of crop yield and firewood. By doing so, the firewood demands could be eventually solved in the Dry Zone. Consequently, the Dry Zone farmers think that they will have more chances to get firewood in the future due to growing Kassod trees and cultivating pigeon pea.

Regarding weather trends, the farmers from both study villages responded that they had a fair climate until two decades ago, characterized by moderate rainfall and temperature which favoured agricultural production. For the last 10 years, the temperature has remarkably increased in their areas with decreasing rainfall. Since then, they have been experiencing erratic climatic patterns in the Dry Zone. Farmers are not certain about the future climate situation due to the lack of scientific knowledge, which is obvious. They, however, opined that technological development might be able to tackle the problems related to climate change.

The farmers from both study villages highlighted that they had a good harvest until two decades ago, without much difficulties in agricultural production. But the decline in crop production was more discernible for the last 10 years due to inadequate water, unfavourable climatic condition and severe pest infestation in crop production. Current farm implements in both villages are more diverse than those in the past. Some farm implements were invented locally by the farmers in order to cope with increasing agricultural problems particularly the weed problem (Table 5). The table presents a translated version of the original sketch prepared in the field by the farmers. This is to highlight that cross-validation of information generated through individual perception is well matched as evidenced by participatory mapping results in terms of perceived climate trend, such as increasing temperature, decreasing rainfall as the prominent climate changes in the Dry Zone due to deforestation, and increased water scarcity and pest infestation resulting in declining agricultural yield due to the impacts of climate change.

5.6. *Adaptations to climate-change impacts*

In the Dry Zone, there is almost no technological support to the farmers in order to be able to adapt to climate change. In addition, the poor extension strategy could not help the technical poor farmers to get the new techniques from the research and technical centres. However, the Dry Zone farmers have been attempting to adapt with increasing barriers for agricultural production by using their own means. The major barriers to agricultural production, in terms of importance, are water scarcity, soil fertility degradation, weed infestation, pest infestation, disease infestation and crop yield declination. In this section, the most common adaptation practices for those production barriers encountered in the Dry Zone agriculture are discussed.

Table 5. Histogram of the study villages (translated version).

Timeline	Agricultural area	Yield	Agricultural barrier	Farm implements	Climate	Water source	Forest cover	Disaster	Food security	Population	Education	Health
Last 20 years	Normal	High	No	Harrow and plough	Adequate rainfall with normal temperature	Rainfed	Dense	Few	Secure	Less populated	Poor	Poor
Last 10 years	Decrease	Moderate	Bad weather, pest and water scarcity	Harrow, plough, weeder and seedling harrow	Less rainfall with high temperature	Rainfed	Moderate	Few	Less Secure	Populated	Moderate	Good
Present	Decrease	Poor	Bad weather, pest and water scarcity	Harrow, plough, weeder, seedling harrow and tractor	Less rainfall with high temperature	Rainfed, Irrigated	Thin	Few	Less Secure	More populated	Good	Good
Next 10 years	Decrease	High	Bad weather, pest and water scarcity	Harrow, plough, weeder, seedling harrow and tractor	Adequate rainfall with high temperature	Rainfed, Irrigated	Moderate	Few	More Secure	More populated	Better	Better

Source: Field survey (2011).

Furthermore, how the Dry Zone farmers adapt to climatic variability is also elaborated.

5.6.1. *Water scarcity*

Rainwater collection, taking water from the common-used well and digging tube well are the topmost individual adaptation strategies to cope with water scarcity in the Dry Zone (Table 6). However, those strategies are only useful for household water consumption. Farmers in the Dry Zone usually collect rainwater as much as they can during the rainy season, with the varieties of collection tanks so that the collected rainwater could be utilized particularly in the non-rainy season. It was reported that the poor could not afford the collection tanks to store sufficient water for the whole year. In this regard, they take water from the common-used wells near the village. In addition, digging new tube well is also another common mean to cope with water scarcity in the Dry Zone.

In addition, some potential practices are prevalent among individual adaptations to water scarcity for agricultural production. These adaptations include pursuing water-harvesting techniques, changing growing season, application of gypsum and growing drought-resistant plant varieties. In addition, there is a traditional knowledge that pre-monsoon growing of the crops in the dry land helps the farmers to cope with water scarcity, particularly in sesame cultivation, through efficiently utilizing the available moisture in the first monsoon rain for germination as well as vegetative growth. It is especially instrumental for the years in which the onset of early monsoon is late. Accordingly, some farmers have still been using this practice in the Dry Zone to adapt to climate change; all the more so because there is an absolute risk if there is no rain within 7–10 days after the pre-monsoon cultivation. Other farmers, on the other hand, use the other practice, which is several tillage of land during summer so that the crops could be grown with the first monsoon rain.

5.6.2. *Soil fertility degradation*

The Dry Zone farmers are using chemical fertilizer as well as animal manure as the most common strategies in order to maintain soil productivity. In addition, other good agricultural practices such as proper land preparation, application of decomposed organic matter and crop rotation are also applied to cope with soil fertility degradation. Despite diverse practices currently being adopted, the Dry Zone farmers prefer animal manure application to other practices because of its sustained efficacy on crop growth and yield. This also helps build soil fertility in the long run.

5.6.3. *Weed infestation*

Although the Dry Zone farmers realize that herbicide is useful for weed control, most farmers are aware of its possible side effects on the main crop. Therefore, hand weeding and inter-cultivation are still the most common measures to control weed, among the Dry Zone farmers.

In addition, the farmers also have the knowledge that early weed control is beneficial not only to control weed throughout the crop growth but also to improve the crop yield. Furthermore, weeds are controlled by initiating different means such as earthing up along the pigeon pea rows, row-planting of crops instead of normal broadcasting and invention of new farm implements to control weeds effectively and efficiently (Box 1).

Table 6. Farmers' adaptation practices to the agricultural production barriers in the Dry Zone.

Agricultural production barriers	Adaptation practice	Per cent of responses
Water scarcity ($n = 205$)	Rainwater collection	31
	Taking water from the well	20
	Digging new tube well	16
Soil fertility degradation ($n = 229$)	Chemical fertilizer application	38
	Animal manure application	38
	Better land preparation	9
Weed infestation ($n = 196$)	Hand weeding	49
	Inter-cultivation	30
	Better land preparation	6
Pest infestation ($n = 151$)	Pesticide application	62
	Rodenticide application	11
	Burning crop residues	10
Disease infestation ($n = 64$)	Fungicide application	61
	Uproot and burn	31
	Selecting local variety	2
Crop yield declination ($n = 110$)	Chemical fertilizer application	32
	Foliage application of fertilizer	25
	Better land preparation	15

Box 1. History of the development of farming tools in the Dry Zone of Myanmar.

Dry Zone farmers have been using the "tun" from time immemorial. It is an ordinary farming equipment like harrow, which is used for land preparation, weed control, planting, thinning, etc. by just adjusting the number of tines in the harrow in accordance with the soil condition of the fields.

Around the 1980s, they found a farm tool called the "htal", known as the plough, which is more efficient and effective than harrows in land preparation. At first, the plough was used only in the alluvial agricultural lands in which the ordinary harrow could not work well. A few years later after having used the plough in the alluvial lands, the farmers started to use the plough even in the upland agriculture to till the land deeper so that more rainwater could infiltrate and be stored in the field. Since then, because of its great benefit, more and more farmers have used the plough in upland crop production together with harrows. Around 1993–1994, the Dry Zone farmers increasingly used the plough for pigeon pea cultivation especially to take out the root knob of pigeon pea. In some cases, the farmers invented a new farm equipment in order to tackle weed infestation. The establishment of the "Lay Yin Pyan Knife" known as the airplane-shaped weeding harrow, for instance, is the evidence of the development of farm implements to overcome the weed problem particularly in late monsoon groundnut production. In addition, the seeding harrow, groundnut-harvesting knife and iron-tapped harrows were also developed in the Dry Zone seeking to improve efficiency in crop production. By doing so, the Dry Zone farmers are adapting to weed infestation by cultural control through inventing new farm equipments rather than using chemical control.

5.6.4. *Pest and disease infestations*

In the Dry Zone, there are no alternatives except to apply agrochemicals such as pesticide and rodenticide in controlling pests. Evidently, nearly 75% of the respondents said they use pesticide and rodenticide to control pests (Table 6). There is also a belief that burning crop residues helps to reduce disease and pest infestations despite the fact that there is no scientific approval for this practice and there is a great loss of organic matters when burning. Accordingly, 10% of the respondents are still practicing it. Intercropping of groundnut with green gram, uprooting and burning of the infested plants and striking the infested plants with bamboo are also practiced by some farmers to adapt with pest and disease infestations. There are also some farmers who traditionally use the *Virginia* leaves extract to control the pests.

Similarly, fungicide application is also perceived that it is quite helpful in disease control. Moreover, uprooting and burning of the infested plants are still used despite its low effectiveness. The Dry Zone farmers are also aware of the advantages of selecting local variety in reducing disease infestation and which is accordingly used to reduce disease infestation.

5.6.5. *Crop yield declination*

To deal with crop yield declination, the majority of the farmers are applying chemical fertilizer as basal application and foliar fertilizer as additional application. More than half of the farmers responded that they use chemical fertilizers to improve the crop yield. Proper land preparation is considered by the respondents as the best practice to maintain crop yield by improving soil condition and controlling weed. The strategies used for improving crop yield also overlap with the adaptation measures for improving soil productivity. Those overlapping practices include animal manure application, chemical fertilizer application, crop rotation and changing crop varieties. In addition, growing high yielding variety and growing pure variety are also adopted as the keystone for having a successful agricultural production.

5.6.6. *Climatic variability*

With regards to increasing short-term climatic variability, the farmers in the Dry Zone have realized that access to weather information is essential to overcome the upcoming adverse impacts of extreme climate. At present, the Dry Zone farmers use the traditional techniques to predict weather especially rainfall, based on the wild plants, the wild animals and the special natural phenomenon, rather than the weather information from the departments concerned (Table 7). Some methods could predict weather for several months up to a year, whereas other methods only tell a weather prediction for next few days or next few weeks.

The farmers realized that only a single prediction method could not tell the accurate weather information, whereas the prediction is perceived to be 100% accurate if the different forecasting methods tell the same prediction. The farmers have been using these weather prediction methods for several decades to make the preparedness for the upcoming growing season, also based on their farming experiences. For example, if the methods predict that there will be a poor early monsoon for a year, more farmers are likely to pursue pre-monsoon sesame cultivation for that year so that they can cope with water scarcity in the early monsoon. Despite the farmers having been practicing the traditional weather prediction techniques, the need for accurate and regular broadcasting of weather information was proposed by a large number of respondents to overcome the impacts resulting from changing climatic conditions.

5.7. ***Cooperative adaptation for climate change***

Cooperative actions are carried out where adaptation strategies cannot be afforded by an individual alone. To cope

Table 7. Traditional weather prediction techniques.

No	Technique based on	Predictable period	Condition	Weather prediction
Based on wild plants				
1.	Wild plum flowering (*Prunus americana*)	Year	The wild plum flowers three times a year. In this case, rainfall distribution is directly related to plum flowering. If the first plum flowering could yield nice fruiting	Rainfall will be normal or more than normal in early monsoon in next year
			If not	Rainfall will be poorly distributed in early monsoon
			Similarly, by seeing second and third flowering and fruiting, rainfall for monsoon and late monsoon would then be estimated. If nicely flowered and fruited	Monsoon and late monsoon will be normally distributed by rainfall
			If the year has three good flowering and fruiting in wild plum	There will be normal or more than normal rainfall distribution throughout the year
2.	Edible gigerwort (*Kaempferia candida*)	Year	Similar to plum-based forecasting method, rainfall distribution could be forecasted based on fruiting of edible gigerwort plant. Edible gigerwort usually flowers in April. If that plant yields very dense fruiting in a year	Normal or more than normal rainfall could be observed in coming monsoon
			If that plant bears only a few fruits	Rainfall for coming year would be very poor
3.	Amount of toddy palm juice (*Borassus flabellifer*)	Week	If toddy plants secrete more juice than normal before monsoon months	It means monsoon is arriving soon and rainfall could be observed within a week
4.	Colour of toddy juice	Week	Normally, toddy juice is clear in colour. In case of toddy juice in dirt colour	Monsoon rain could be observed within a week
Based on wild animals				
5.	Rabbit offsprings	Year	If wild rabbit delivered three offsprings	Normal or more than normal rainfall could be observed throughout early monsoon, monsoon and late monsoon in next year
			If there are only two offsprings	Normal rainfall could be observed only early monsoon and monsoon period while late monsoon rainfall could be very poor
6.	Signal from Indian cuckoo (*Caculus micropterus*)	Week	This kind of bird could be seen only the time near to rainfall. If that bird sings "Yauk Pha Khwe Call" "Yauk Pha Khwe Call" several times	Monsoon rainfall could be expected within two to three days
7.	Wild animal (Gecko-Tauk Te)	Week	A Gecko is world known as a predictor of weather because how many times that animal sings "Tauk Te" could tell whether rainfall is coming or not. If a gecko sings "Tauk Te" eight times	Rainfall could be obtained within more or less one week
			If a Gecko sings more or less than eight times	Rainfall could not be occurred and it may be far away
Other natural phenomena				
8.	Direction of wind blowing on first, second and third of Myanmar month Tabaung (February and March)	Year	Southern wind direction on first, secon and third of Month Tabaung is also regarded as another indicator of rainfall distribution for coming year. Month Tabaung coincides with February or March. There is normally a strong western wind in this month. However, if there is a southern wind on those three days	Rainfall for coming year could be predicted based on wind intensity that blown on these three days

(*Continued*)

Table 7. Continued.

No	Technique based on	Predictable period	Condition	Weather prediction
			If southern wind is coming with high intensity on first Tabaung	Early monsoon rainfall will be more than normal rainfall
			Similarly, if it is coming on second and third Tabaung	Monsoon and late monsoon rainfall will be as usual
			If there is a weak or no southern wind	Only poor rainfall could be obtained
9.	Morning sun	Days	When we look the sun at the morning and if there are some prominent straight strings emitting underneath the Sun	There will be a strong wind in the same evening
10.	The umbrella of the Sun and the Moon	Days	The umbrella means the shade around the Sun and the Moon, which is also an indicator for rainy and sunny day. If the Sun is surrounded some shade like an umbrella	There will be a raining day tomorrow
			If the Moon has an umbrella shape surrounding	There will be a sunny day tomorrow
11.	Fixed date rainfall	Every year	In the Dry Zone of Myanmar, there are two heavy raining days every year. It is widely perceived by the farmers. They are known as “Kyee Lwe Rain” and “Kan Sin Rain”. Those rains are date-fixed though there can be a slight variability. There is a Kyee Lwe Rain on the 146th day (traditionally records as Oo-Yay-Thaunk which means 1–4–6) after the first day of Myanmar New Year (April 17)	There is a Kyee Lwe rain (first heavy rain) around 9 September (146th day after the April 17). There is another rain namely Kan Sin rain (second heavy rain) within one month after the Kyee Lwe rain

with water scarcity, debris and sediments along the waterways to rainwater collecting ponds are collaboratively cleared on a voluntary basis before monsoon so that more rainwater can be collected in the ponds during the rainy season. Although this attempt is not effective for agricultural water uses, it is very effective to have water for domestic water uses.

In addition, farmers' cooperatives were usually formed in some Dry Zone villages as an attempt to cope with increasing weed and rodent problems. By forming groups, hand weeding was cooperatively carried out in agricultural fields of group members on the rotational basis because it was very beneficial not only to control weed but also to save money.

Furthermore, rodent hunting is carried out by the group of farmers to control rodents, which is usually accompanied by late monsoon groundnut. It is also reported that the Dry Zone farmers usually hunt rodents especially during non-agricultural months (December to May). In addition, the farmers also feel that experience and knowledge sharing to each other about weather information and its possible impacts could also help them adapt to climate change. There was a good example in the past. Once, there was a fungal disease outbreak in the dozens of groundnut fields in a village because of successive rainy days. The farmers shared their experiences with the farmers of the neighbouring villages. Consequently, the farmers from the neighbouring villages could avoid the severe disease infestation in their groundnut fields by pre-applying some preventive fungicides. Therefore, it was a good lesson for the farmers that timely information is very useful in taking adequate preventive measures in agricultural production.

In addition, the necessity of new water access for agricultural water uses and, the necessity of efficient and effective agricultural techniques for weed, pest and disease controls were also highlighted by the Dry Zone farmers.

5.7.1. *Future possible threats and preparedness in the Dry Zone*

Of all the possible threats to agricultural production, water scarcity is the most likely threat due to climate change in the future, which was perceived by 80% of the farmers in the Dry Zone. Also present in the future possible threats perceived by the farmers were the lack of a proper investment for agriculture, extreme temperature, the shortage of pure seed and pest infestation (Figure 10).

Even though the Dry Zone farmers are adapting to climate change using numerous strategies, it was found that they are very weak in anticipatory adaptation measures for the possible threats. They still rely on conventional agricultural practices. Individually, desired seed collection and summer land preparation are common among the Dry Zone farmers and they are practiced cumulatively by nearly 68%

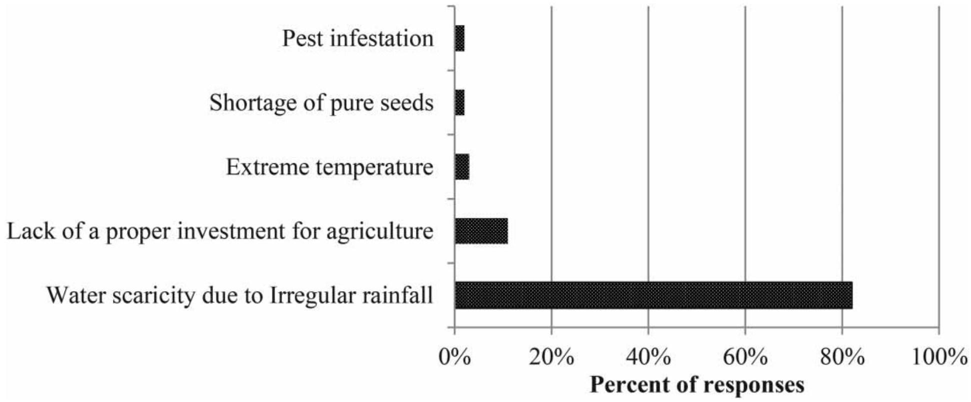


Figure 10. Future possible threats due to climate change in the Dry Zone ($n = 47$).

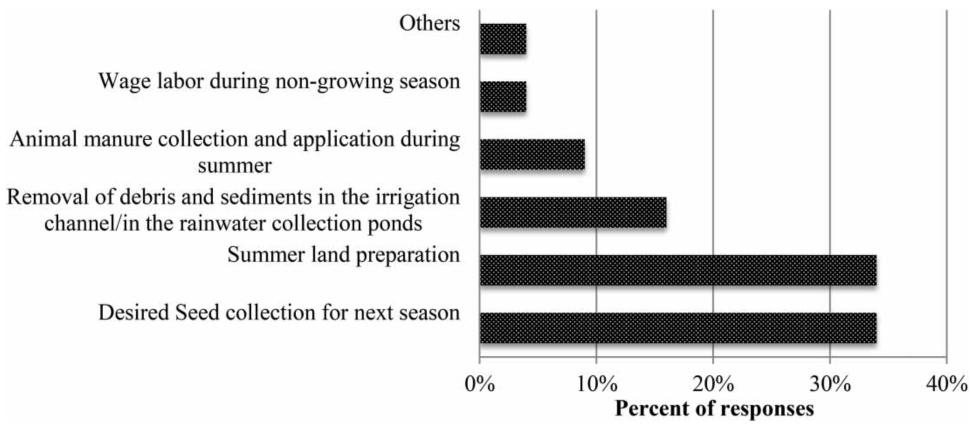


Figure 11. Preparedness for upcoming impacts of climate change ($n = 196$).

of the respondents (Figure 11). Some 16% of the respondents answered that they remove debris and sediment in the irrigation channel or in the rainwater-collection ponds so as to store more rainwater during the rainy season. Other 9% of the respondents prepare for the next growing season by collecting animal manure and application to the fields so as to save the fertilizers in the next growing season. The landless (4% of the respondents) said they earn money by working as wage labourers during the off-growing season. The rest 4% responded that they, based on their traditions and beliefs, pursue different other activities such as deep ploughing, pre-monsoon growing of sesame and playing the game namely "tug of war" as the preparedness to overcome the possible threats in the next growing season.

6. Conclusions

In the Dry Zone of Myanmar, 90% of the farmers perceived the changing climatic patterns. Increasing temperature and erratic rainfall patterns were predominantly highlighted by the farmers as the prominent climatic changes. The increasing trends are discernible in the Dry Zone even though the secondary rainfall and temperature data could not statistically prove these trends yet. Almost all farmers perceived that there have already been several impacts of climate changes on agriculture. Specifically, decreasing yield due to water scarcity and increasing pest infestation are the most prominent impacts of climate change in the Dry Zone's agricultural production. The farmers realize that water scarcity is the most implicating factor that decreases the yield in the Dry Zone and they believe that it will become more severe in the coming years. The farmers perceived that growing drought-resistant plant variety is helpful to cope with water scarcity while National Commission for Environmental Affairs also recommended developing climate-resistant crop species suitable for multi-season farming (NCEA, 2010a). Therefore, developing drought-resistant crop varieties is indispensable to help the Dry Zone farmers to better adapt to climate-change-induced water scarcity.

Changing growing season is sometimes the best solution to adapt to water scarcity accompanying climate change. July groundnut production, for example, has spread out across the Dry Zone (by changing growing season from August to July) and it could accordingly help the farmers to better adapt to climate change. Therefore, knowledge and experiences exchange among the farmers will be an asset to nurture the resilient society, to overcome the upcoming climate-change impacts.

Evidently, climate-change-driven agricultural production barriers have changed the cropping patterns in the Dry Zone. Major variety changes were closely related to yield potential, market demand, duration of the varieties and their suitability with local climate. More and more Dry Zone farmers have adopted Ba Pan (white sesame) and Sinpadathar-7 (short-lived and erected groundnut) for many years because of their adaptabilities such as short lifespan and high yield potential with the prevailing weather. The availability of pure lines is becoming a challenge and of crucial importance for the farmers to ensure production under changing weather conditions.

There is almost no technological adaptation in the Dry Zone because the poor extension strategy could not help the Dry Zone farmers adapt to climate change through advanced technologies. On the other hand, the farmers have been using only their conventional agricultural practices to react to climate-change impacts. The reported reactive adaptations for water scarcity include rainwater collection, digging tube wells and pursuing water-harvesting techniques. They make hand weeding and inter-cultivation to control weed, whereas they use pesticides and fungicides to control pests and diseases. They preferably use animal manure for its sustained efficiency, while chemical fertilizers are being used for its high efficiency for better yield. They have been also using the traditional weather forecasting techniques to predict weather. In addition to the individual adaptations, cooperative adaptations such as canal cleaning, hand weeding and rodent hunting are also carried out in order to cope with water scarcity and rodent problems. All in all, an effective and efficient extension strategy should also be laid down in order to disseminate agricultural techniques as well as weather information. Finally, the study is just the first step of a thousand miles and so it is absolutely necessary to conduct more researches in other geographical areas to collect their local adaption practices to climate change. The knowledge of the Dry Zone farmers on crop management practices regarding seed producing, weed, pest and disease controls should also be strengthened so that the better adaptive capacity can be built in order to further adapt to upcoming climate change and its impacts.

Disclosure statement

No potential conflict of interest was reported by the authors.

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