Future Food Security and Crop Income in a Changing Climate: A Case of Farmer Households in Myaungmya Township, Ayeyarwady Region, Myanmar

Naw Mar Lar[1], Soe Tint[2]

Abstract

Climate change poses a considerable threat to food security all over the globe. Climate change is becoming a major concern in Myanmar because its economy depends on agriculture and majority of farmers mainly rely on agriculture for their living. Therefore, this study assessed the impact of potential climate change on future food security and crop income of farmers in Myaungmya Township using the two climate change scenarios RCP4.5 and RCP8.5 and the population projection. The analysis revealed that the climate is changing at the rate of +0.04ºC, -0.02ºC and +18 mm per annum for mean maximum and minim temperatures and rainfall during the observed year (1986-2015). The GCM showed that an increase in mean minimum ranges 0.60-1.37ºC under RCP4.5 and 0.72-2.87ºC under RCP8.5, whereas the mean maximum temperature ranged 0.61-1.05ºC under RCP4.5 and 0.45-2.46 under RCP8.5 and the mean annual precipitation increase slightly with 4.17% under RCP4.5 and 5.21% under RCP8.5 by the period of 2020-2099. The results also showed that about 60% - 40% of farm household potential income loss along with the decline in the rice production and growth of the population in Myaungmya Township found to be by the year 2080-2099. To offset these losses, the farmers in the study area should follow the adaptation measures like shifting planting dates, changing climate resistant varieties, more irrigation and diversifying livelihood activities to response the climate change.

Keywords: Climate change, food security, population growth, Myaungmya Township

Introduction

Climate change and its adverse consequences are the serious threat to agriculture, global food security, sustainable development and poverty eradication especially in many developing countries (Ojwang, Agatsiva, & Situma, 2010; Enete, & Amusa, 2010; IPCC, 2014). Crop models suggest that these deteriorate in their agricultural yields and income in tropical regions (Karfakis, Lipper, & Smulders, 2012). The estimation for economic losses range between 0.5% and 23.5% of GDP (IPCC, 2007). There are increasing concerns about the impact on crop income and consumption in Developing Countries (Foresight, 2011).

The world's population is growing rapidly mainly in developing countries, however, the production of food is unable to meet with the increasing demand. According to the United Nations' report, the world's population is projected to grow from 7.7 billion in 2019 to 9.7 billion in 2050 (26%) and to 10.9 billion in 2100 (42%) (DESA, 2019). Beddington (2010) suggests that the world will need to increase crop production to feed the projected 9 billion people, in the face of changing consumption patterns, the impacts of climate change and the growing scarcity of water and land by 2050.

Myanmar is second country in the world most affected by climate change (Kreft, Eckstein, Junghans, Kerestan, & Hagen, 2014). Extreme climate events affect the agriculture especially in rice production (UNFCCC, 2012). For instance, Cyclone

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Nargis in 2008, 783,000 ha of the rice field were submerged and 85% of seed stocks were destroyed (FAO, 2009). The flood in 2015 inundated 0.52 m ha, and 50,000 ha were damaged (MOALI, 2015).

Agriculture plays an important role in the Myanmar economy which contributes about 38% GDP to the country and daily diet for the people. The total cultivated area of Myanmar was 13.39 m ha and rice alone was 7.27 m ha with the production of 25.62 m tons and average rice yield was 3.85 t/ha. Among the rice growing area, the Ayeyarwady Region is the largest rice area (28%). The smallholder famers mainly dominate the rice cultivation, and 80% of the rice grown is under the rain harvesting system, making it vulnerable to climate change (CSO, 2018).

Although a large number of studies have been conducted climate change impacts on agriculture across the world, its impacts on crop yields and food security and associated impacts are under-researched in Myanmar. For this reason, the main aim of the study is to assess the impact of potential climate change on future food security and crop income of farmers in Myaungmya Township within Ayeyarwady Region. The specific objectives are to examine the future climate of Myaungmya Township, and to estimate the future population, and the food security and famers' crop income under the changing climate of Myaungmya Township.

Methodology

Study Area

Myaungmya Township lies between 16°19´-16°44´N and 94°40´-95°05´E (Figure 1). It is one of the largest rice growing areas, which occupies the southwestern part of the Ayeyarwady Region. Myaungmya Township has an area of 1,152.23 km^2. During the period of 1986-2015, the annual mean maximum temperature was 32.6°C, the annual mean minimum temperature was 22.3°C and the average annual rainfall was 2,894 mm. About 95% of rainfall receives during the monsoon period; May to October (Lar, Arunrat, Tint, & Pumijumnong, 2018). Most of the area is flat alluvial plain with an elevation of about 8 m above sea level. The gleysols and fluvisols, the dominant soil types cover much of the area (Myint, 2010). The total population of the study area was 220,351 in 1973, rose to 291,390 in 2014 and the total farmer households were 18,328 in 2014 (DOP, 2015). The farmers cultivate the rain-fed rice and irrigated rice as double cropping for their major livelihood. Rain-fed rice (66,708.44 ha) occupies the majority of the sown area, and one of the largest irrigated rice area (45,760.27 ha) among the townships. The rain-fed rice yield in 2015-16 was 4.2 ton/ha and the production was accounted for 280,574.87 Mt whereas irrigated rice yield was 5.05 t/ha and the production was accounted for 231,130.42 Mt (DALMS, 2016).

Data and Methods of Analysis

The observed climate data (1986-2015) were derived from the Department of Meteorology and Hydrology (DMH) Myanmar, which were used to examine the past climate trend. To estimate the future climate changes, the Representative Concentration Pathways (RCPs), RCP4.5 and RCP8.5 from the Fifth Assessment Report (AR5) of the Intergovernmental Penal on Climate Change, were chosen to cover both medium and extreme scenarios (IPCC, 2014). The General Circulation Model (GCM), the BCCCSM1.1 model was downloaded from http://sdwebx.worldbank.org/climate portal/. It was divided into the four-future time slices; near future (NF) between 2020 and 2039, mid future (MF) between 2040 and 2059, far future (FF) between 2060 and 2079 and very far future (VFF) between 2080 and 2099 (hereafter NF, MF, FF and VFF). Due to the course resolution of the GCM, two steps of downscaling were performed to match the spatial resolution of the study area. First, the monthly data were spatially downscaled into 3km x 3km grids by using the kriging method. Then, linear scaling which is shown in Equation 1 and 2 were used to correct monthly 3 km-data based on the differences between observed and raw GCM data (Babur, Babel, Shrestha, Kawasaki, & Tripathi, 2016).

$$T_{future,daily} = T_{GCM,daily,future} + \left(T_{(observed,monthly)} - T_{(GCM,observed,monthly)}\right) \quad \text{Eq. 1}$$

$$P_{future,daily} = P_{GCM,daily,future} \times \left(\frac{P_{(observed,monthly)}}{P_{(GCM,observed,monthly)}}\right) \quad \text{Eq. 2}$$

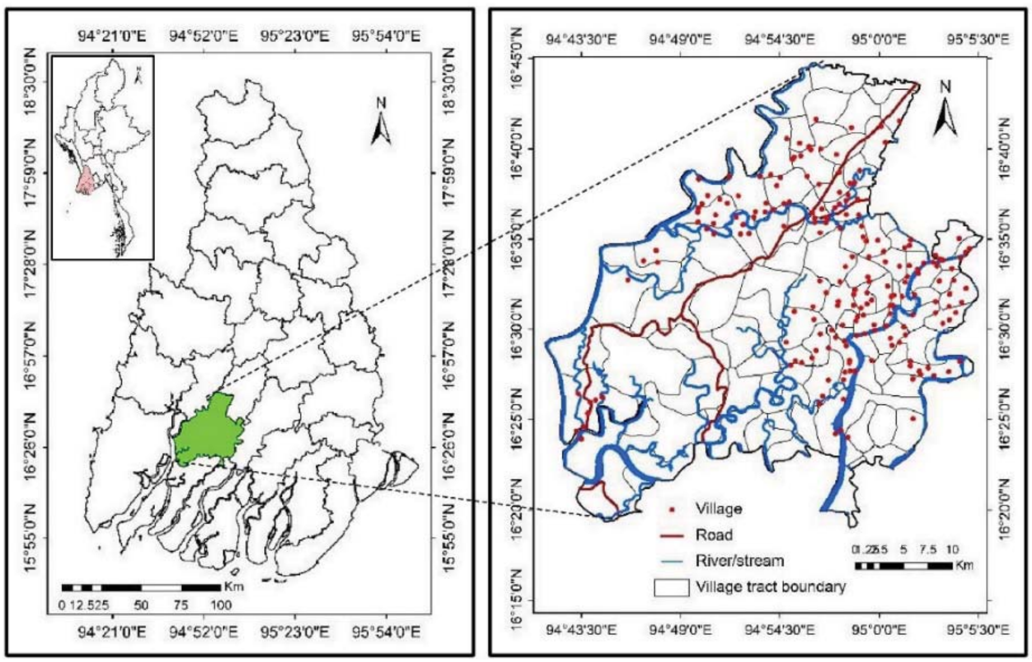

Figure 1 Location of the Myaungmya Township, Ayeyarwady Region
Source: Lar et al. (2018)

To evaluate the performance of the GCM, the coefficient of determination (R^2) was used. The R^2 value of monthly mean minimum temperature and maximum temperatures, and precipitation were determined between the GCM data and the observed data (1986-2015). If the R^2 value will be close to 1, there is the strong relationship between the variables, in other word, it gives strong confidence to use the model.

Agricultural statistics were derived from the Central Statistical Organization (CSO) and Department of Agricultural Land Management and Statistics (DALMS). The future rice yields were obtained from the results of the study conducted by Lar et al. (2018) by using the Environmental Policy Integrated Climate (EPIC) Model.

To examine the farm characteristics and consumption pattern, a farmer household head in each grid were selected for interview, hence a total of 59 respondents was obtained. The survey was conducted during February and May in 2016. To estimate the future population, the exponential growth projection (Dianne, 2018) was used in this study. It also estimated the total consumption of the study area. In so doing, it gave how much it can support rice consumption and how much surplus or deficit is for the future food security using Equation 3 and 4.

$$P_t = P_0 (e^{rt}) \quad \text{Eq. 3}$$

Where, P_0 = present population

P_t = population at a future time t

r = annual rate of growth

e = base of the natural logarithm

t = time period

To estimate food security for study area

Rice surplus/deficit = rice production – (per capita consumption x total number of population) Eq. 4

Data were processed and analysed by using Excel, SPSS and ArcMap. The outputs were displayed in tables and graphical form.

Results and Discussion

Climate Change and Variability in Myaungmya Township

Due to the limitation of climate parameters required for this study, the Pathein Station which is nearest station of study area was used to investigate the climate of the study area. As evidence from the observed climate data for 30 years (1986-2015) in Pathein station, the average mean annual temperature was 27.43ºC, the lowest and the highest mean annual temperature ranged between 25.69ºC and 28.47ºC. The highest mean annual temperature, 28.47ºC was recorded in 2005 and the lowest mean annual temperature, 25.69ºC in 2001. The average minimum temperature was 22.28ºC, the range of minimum temperature was 19.02ºC and 23.10ºC. The lowest minimum temperature was recorded in 2001 and the highest minimum temperature was observed in 2010 (Figure 2).

The average maximum temperature was 32.58ºC and the lowest and the highest maximum temperatures ranged between 31.12ºC and 33.85ºC. The lowest maximum temperature was recorded in 1992, while the highest maximum temperature occurred in 2005 (DMH, 2016).

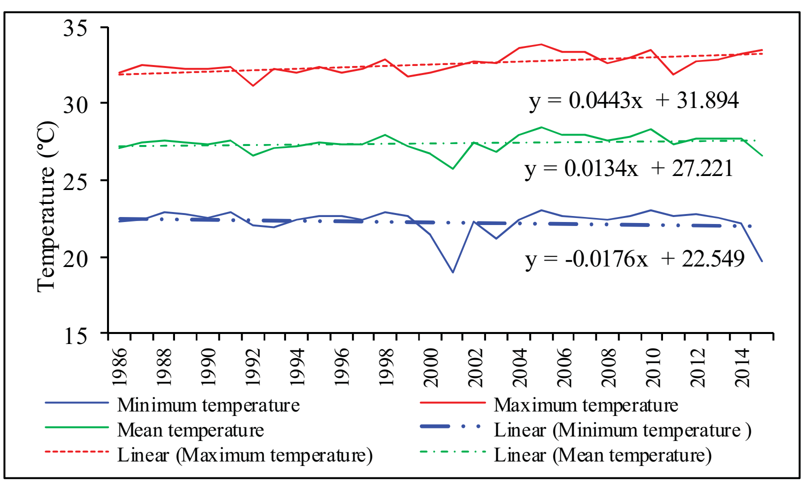

Figure 2 Temperature trend of Pathein Station (1986-2015)

Source: Department of Meteorology and Hydrology, Myanmar (2016)

The linear trend line for 30 years showed that the annual mean temperature was increasing at the rate of 0.01°C per annum whereas the maximum temperature at the rate of 0.04°C per annum. However, the mean minimum temperature was slightly decreasing at the rate of 0.02°C per annum. It is important to note that temperatures for 30 years fluctuated significantly.

The average total annual rainfall for the observed period (1986-2015) was 2894 mm and the ranged between 1876 mm and 3698 mm. The highest peak of total rainfall was recorded with the value of 1230 mm in August 1994. From December to April, especially during the irrigated rice season, the amount of rainfall was less than 100 mm per month. The highest annual rainfall, 3689 mm was recorded in 2002 and the lowest annual rainfall was observed in 1998 with the value of 1876 mm. The trend line for 30 years shows that the rainfall trend is slightly increasing with about 18 mm per annum but it fluctuates significantly (Figure 3).

The mean monthly minimum temperature was highest in May with 24.95ºC, while the lowest temperature was in January with 17.45ºC. The mean monthly maximum temperature was highest in April with 36.65ºC, while the lowest temperature was in August with 30.06ºC. The mean annual rainfall was highest in July 683.27 mm and the lowest rainfall was found in January with 2.76 mm (Figure 4). About 95% of rainfall have occurred during May to October which is sufficient for rain-fed rice. It thus not sufficient for irrigated rice which grown in December to May (DMH, 2016).

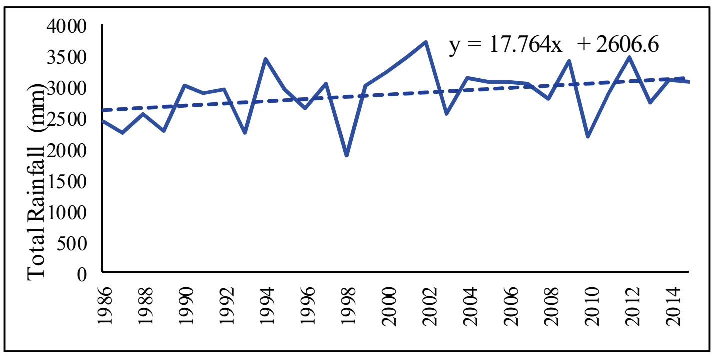

Figure 3 The rainfall trend of Pathein Station (1986-2015)
Source: Department of Meteorology and Hydrology, Myanmar (2016)

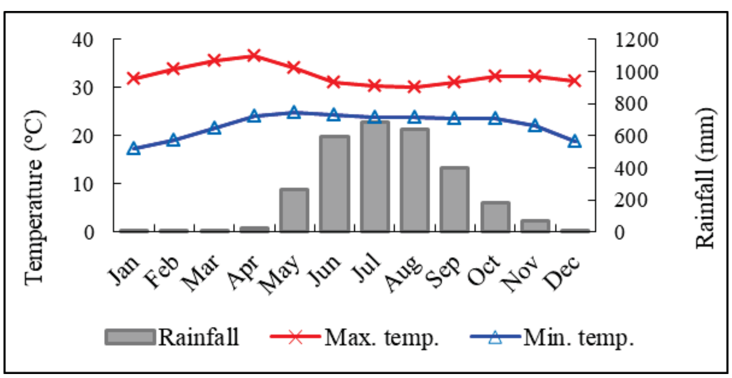

Figure 4 The mean monthly temperatures and rainfall of Pathein Station (1986-2015)
Source: Department of Meteorology and Hydrology, Myanmar (2016)

Projected Climate Change in Myaungmya Township

In this study, the RCP4.5 and RCP8.5 were chosen and analysed for four future periods; NF, MF, FF and far VFF using BCCCSM1.1 model. When evaluating the performance of GCM, the R^2 value of monthly mean minimum temperature, maximum temperature and precipitation were determined between the reference GCM data and the observed data for the baseline period (1986-2015). The R^2 values of three parameters were 0.99, 0.89 and 0.98, giving that the higher value hence it is reliable to use the GCM.

Annual changes of climate

Climate changes based on the BCCCSM1.1 model under RCP4.5 and RCP8.5 scenarios indicated that the temperature the study area is projected to increase than the baseline period (1986-2015) for all four future periods. Figure 5 and 6 show changes in the mean annual maximum, minimum temperatures and annual precipitation under RCP4.5 and RCP8.5.

The mean annual maximum temperature of the baseline period was 32.58°C and the mean minimum temperature was 22.28°C. The mean annual maximum temperature is projected to increase by 0.61 to 1.05°C under RCP4.5, while 0.45 to 2.46°C under RCP8.5 for all future periods. The mean annual minimum temperature is projected to increase by 0.6 to 1.37°C under RCP4.5, while 0.72 to 2.87°C under RCP8.5 for the same periods. In comparison, the minimum temperature is likely to increase than that of the maximum temperature with the ranges of 2.7 to 12.90% and 1.38 to 7.54% under both RCPs.

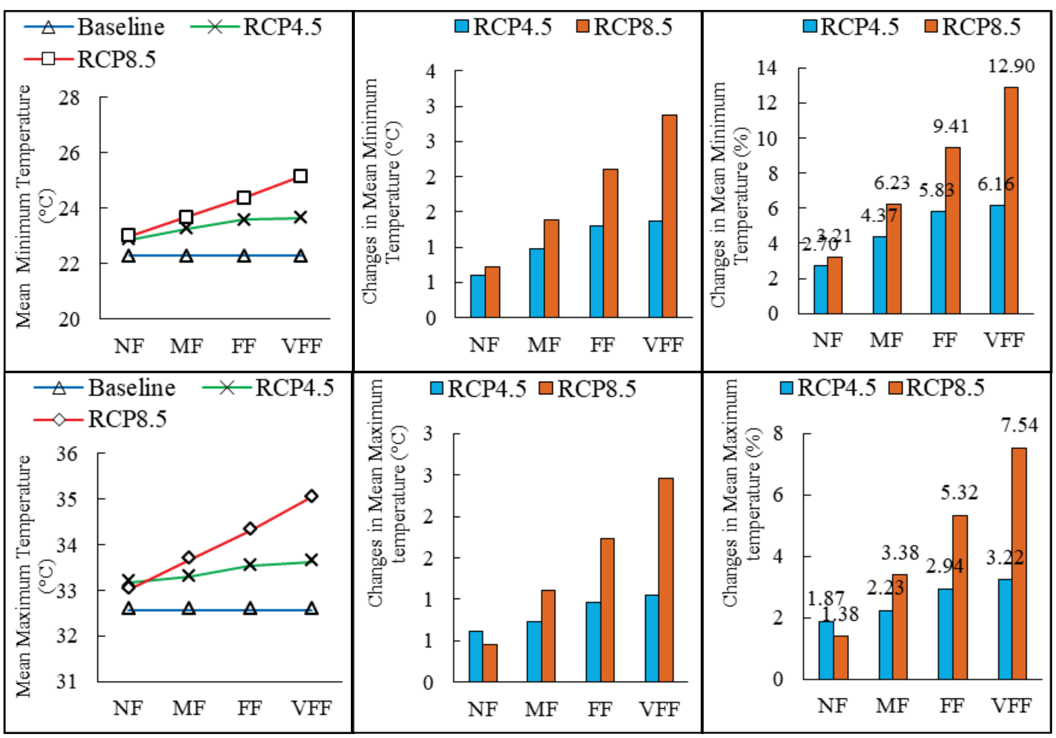

Figure 5 Projected annual mean minimum and maximum temperatures and changes in four future periods under two climate change scenarios of Myaungmya Township

Source: Calculation by researchers

The total annual precipitation of the baseline period was 2894 mm and the projected changes of the annual precipitation would vary widely. Under the RCP4.5 scenario, the annual precipitation of NF is projected to decrease than that of the baseline period with the changes of -124.06 mm (-4.29%). The projected changes of the annual precipitation of other three periods were found to be 302.51 mm (+10.45%), 138.76 mm (+4.79%) and 165.34 mm (+5.71%) respectively. Under the RCP8.5, the projected changes of annual precipitation for all future periods would increase by the ranges of 61.87 to 239.13 mm. However, the FF is expected to increase with the lowest rate (2.14%) compared to NF, MF and VFF which were 6.32%, 4.51% and 8.26%, respectively.

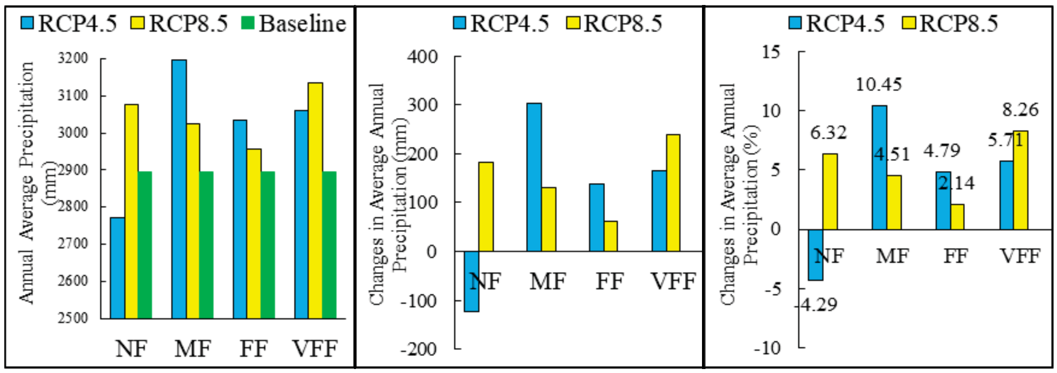

Figure 6 Projected annual precipitation and changes in four future periods under two climate change scenarios of Myaungmya Township
Source: Calculation by researchers

Seasonal changes of climate

The Figure 7, and 8 show the projected changes of mean monthly maximum temperature, minimum temperature and precipitation for all periods under RCP4.5 and RCP8.5 scenarios. The lowest and highest mean monthly maximum temperatures of the baseline period were 30.08ºC and 36.65ºC which were recorded in August and April. The lowest and highest mean monthly minimum temperatures of the baseline period were 17.46ºC and 24.95ºC which were recorded in January and May. The seasonal trends of temperature that projected under RCP4.5 and RCP8.5 are consistent with the baseline period. However, the model has overestimated the mean monthly minimum temperature of historical reference GCM compared to the baseline period. The lowest and highest mean monthly minimum temperatures of historical GCM were 18.21ºC and 25.16ºC which were recorded in January and May. In contrast, the model has underestimated the mean monthly maximum temperature of historical reference GCM under both scenarios. The lowest and highest mean monthly maximum temperatures of historical GCM were 29.57ºC and 35.67ºC which were recorded in July and April.

The highest mean monthly minimum temperature was found to be in May with the increase rate of 0.70 to 1.38ºC and 0.75 to 2.87ºC under RCP4.5 and under RCP8.5 respectively. The projected lowest mean monthly maximum temperature under RCP4.5 would be in January which is projected to increase by 0.25 to 1.09°C for all periods. However, the highest rate of increase would be found in October and is projected to increase by 0.91 to 1.52°C in the same period under RCP4.5. Similarly, the highest rate of increase likely to be found in October and is projected to rise by 1.14 to 3.07°C in all future periods under RCP8.5.

The mean monthly maximum temperature is expected to be highest in April and was found to increase by 0.55-1.33ºC under RCP4.5 and 0.51-3.06ºC under RCP8.5, while the lowest mean maximum temperature was found to be in July for NF and with the increase rate of 0.43ºC, but it is projected to be lowest in August for MF, FF and VFF under RCP4.5 with the ranges of increase from 0.88 to 1.24°C. However, the highest rate of increase likely to be found in September and NF was among the highest with an increase of 1.52°C under RCP4.5. Similarly, the highest rate of increase was found to be in September and is projected to rise by 0.87 to 1.75°C for all future periods under RCP8.5.

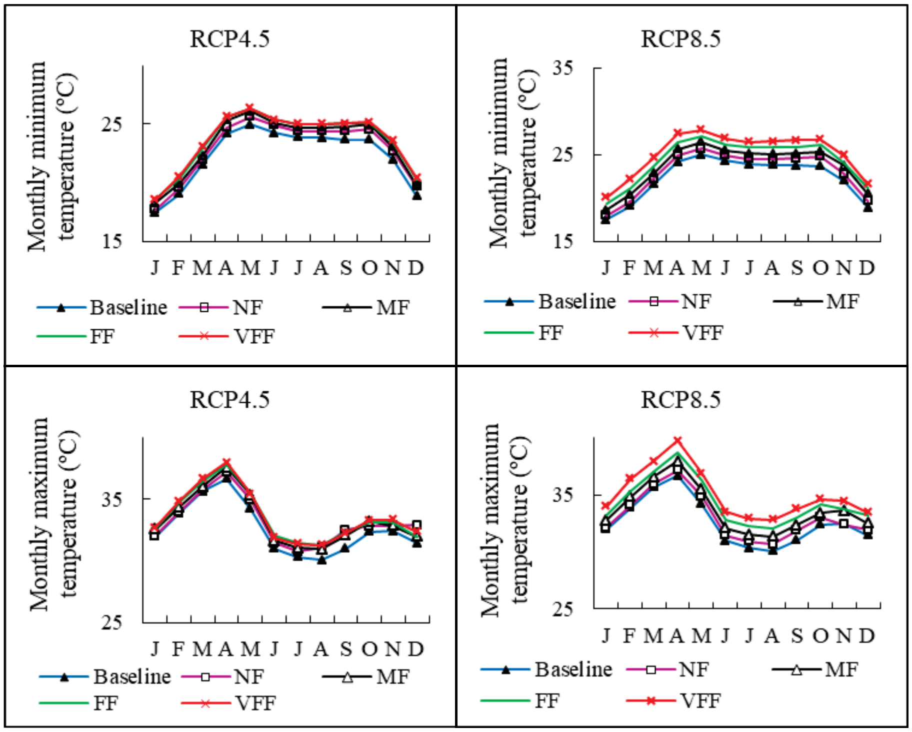

Figure 7 Projected mean monthly minimum and maximum temperatures in four future periods under two climate change scenarios of Myaungmya Township
Source: Calculation by researchers

In contrast, the projected changes for monthly precipitation is likely to be different from the baseline period. In the study area, about 95% of precipitation received during the monsoon season. The lowest precipitation of the baseline was recorded in January with 2.67 mm and the highest precipitation was observed in July with 683.27 mm. The lowest precipitation of historical GCM was recorded in January with 3.97 mm and the highest precipitation was observed in August with 595.13 mm. However, the highest projected monthly precipitation is likely to decrease in July for the NF and VFF, which are expected to increase by 1.13 and 44.77 mm and June for the MF and FF which would increase by 137.89 mm and 88.32 mm under RCP4.5 than that of the baseline period. The highest increase rate was found to be in month of November (176.28 mm, 95.52 mm) for the both MF and VFF, and October (117.01 mm) for the FF under RCP4.5. However, the highest projected precipitation likely to occur only in June for all the future which are projected to increase by 158.20, 91.95, 47.12 and 59.75 mm under RCP8.5. As a similar trend with the baseline, the lowest projected monthly precipitation would receive in January in all future under both scenarios.

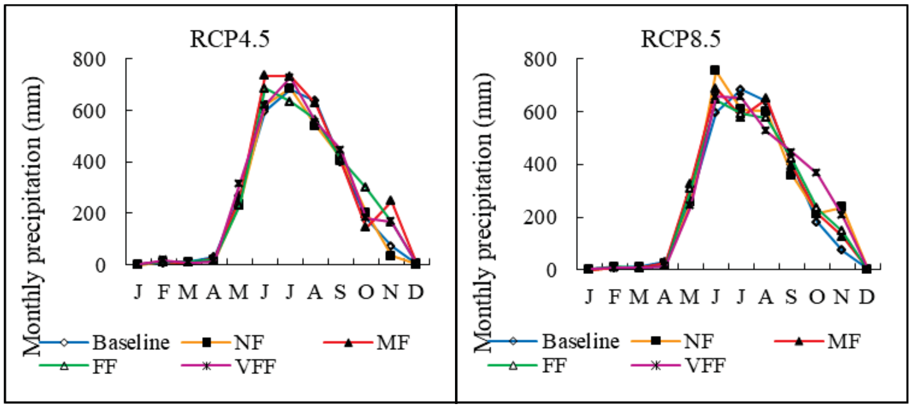

Figure 8 Projected mean total precipitation in four future periods under two climate change scenarios of Myaungmya Township

Source: Calculation by researchers

Estimation of Future Food Security and Crop Income

Over the last few decades, the global food security has been characterized by the large increases in population growth, climate change, arable lands and water resources (McLaughlin and Kinzelbth, 2015; Premanandh, 2011). Continuing population and consumption growth, adverse consequences of climate change in crop yield are major challenge to food security. In estimating the food security in the future, population projection was used to predict the future population. The population projection is an extrapolation of historical data into the future which attempt to describe what is likely to happen under certain explicit assumptions about the future as related to the immediate past.

To estimate the future population of the study area, the exponential growth projection was used. It was assumed that the growth rate of Myanmar, 0.38% in 2040 was constant for the all future periods. The total number of population was 291,390 in 2014 and per capita consumption was 200 kg (DOP, 2015; Denning, Baroang, & Sandar, 2013). Based on these information and the projected rice yield of the study area, it was estimated future rice consumption and rice surplus which is shown in Table 1 and Figure 9.

The projected population of the study area was steadily increasing, which was 320,429 person in NF, 345,731 in MF, 359,122 in FF and 402,487 in VFF respectively. In contrast, the projected rice yield was found to be decreasing trend but profoundly drop by the end of the 21st century. The result shows that although the projected rice production was decreasing trend, the study area would have food security in the future and still could provide rice to the other deficient area in the country or export to other countries. However, the crop income of the farm household would be significantly less because the percentage of rice surplus was lower than 40% at the VFF period than the present. As shown in Table 1, the potential income loss of the farm household, about 60% and 40% of their income loss found to be by the year 2080-2099 under RCP4.5 and RCP8.5 respectively.

Table 1 The projected population, the consumption, production and surplus of rice in Myaungmya Township

Year	Total Population		Rice Production	Rice Consumption	Rice Surplus	
	(Number)	%	(Mt)	(Mt)	(Mt)	%
2014*	291390	0.00	230296.95	58278.00	172018.95	100.00
NF (RCP4.5)	320430	9.97	207999.14	64085.91	143913.23	83.66
NF (RCP8.5)	320430	9.06	230440.03	64085.91	166354.12	96.71
MF (RCP4.5)	345731	16.96	225237.96	69146.30	156091.66	90.74
MF (RCP8.5)	345731	15.72	202304.88	69146.30	133158.58	77.41
FF (RCP4.5)	359122	19.59	201682.41	71824.42	129857.99	75.49
FF (RCP8.5)	359122	18.86	161668.20	71824.42	89843.78	52.23
VFF (RCP4.5)	402487	30.94	184341.20	80497.36	103843.84	60.37
VFF (RCP8.5)	402487	27.60	147202.60	80497.36	66705.24	38.78

* The latest census conducted by DOP (2015), Myanmar

Source: Calculation by the researcher based on the combination of potential rice production studied by Lar et al. (2018) and using the exponential growth projection of Myaungmya population

Impact of Future Climate Change on Spatial variation of Income Loss

The study of Lar et al. (2018) showed that there is some spatial variation of the rice yield reduction for prediction across the township. As shown in Figure 10, the simulation results showed that the majority of farmers in the production area of northern, eastern and south-central parts would benefit from the rain-fed rice production since the rice yield is projected to increase with 5-30% for all futures under RCP4.5. It suggests that farmers in such area under RCP4.5 would have food security and benefit from cultivating of both rice. On the other hand, under the scenario RCP8.5, the farmers in that area would still benefit from cultivating of rain-fed rice, however, the farmers in the south-central part would be more susceptible with growing irrigated rice than others over the period of VFF with the reduction rate of over 5%. It indicates that these farmers would have less crop income in the future.

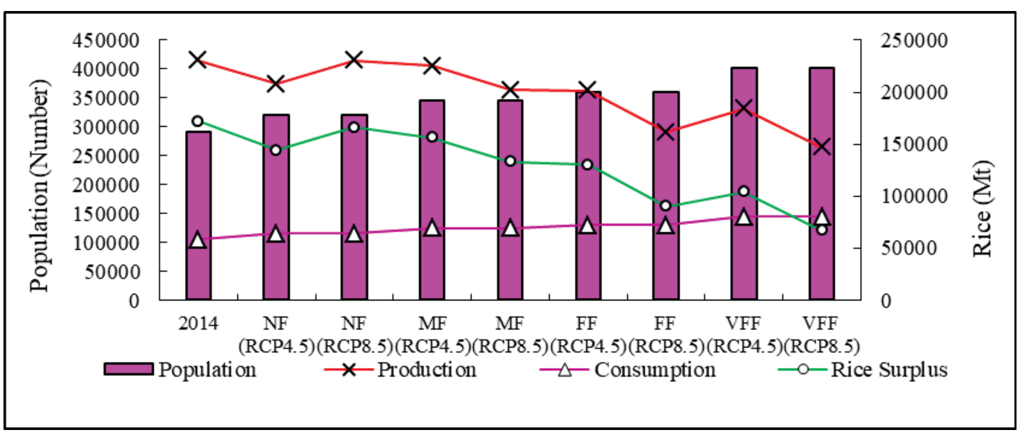

Figure 9 The projected population, consumption, production and surplus of rice in Myaungmya Township

Source: Based on Table 1

To offset these losses of the farmers, they should use some of the adaptation measures such as shifting planting dates, changing climate resistant varieties, more irrigation and diversifying livelihood activities.

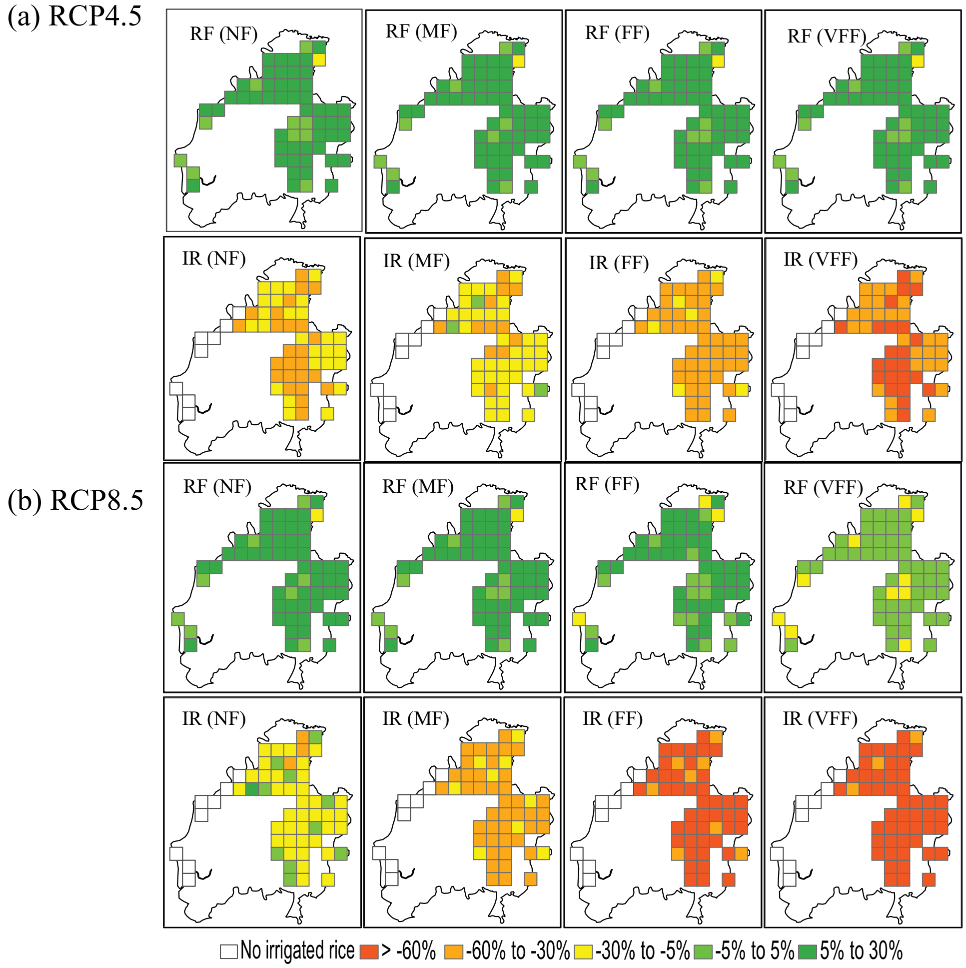

Figure 10 Spatial variation of rice yield change in Myangmya Township under RCP4.5 (a) and RCP8.5 (b)
Source: Lar et al. (2018)

Limitations of the study

This study used only the projected results of rice production based on one rice variety Thee Htat Yin, which is high yield variety widely grown in Myaungmya Township. Regarding future population estimation and food security in the study area, it was assumed that the growth rate of population will be the same and there will be no in and out migration in the future.

Conclusion

This paper analyses the impact of potential climate change on future food security and crop income of farmers in Myaungmya Township, Ayeyarwady Region. An evidence of observed climate during 30-year period (1986-2015), the observed maximum temperature is increasing at a rate of 0.04ºC per annum, however, the observed minimum temperature is slightly decreasing at a rate of 0.02ºC per annum, while the total annual rainfall is also a slightly increasing at a rate of 18 mm per annum. The GCM shows that an increase in mean minimum ranges 0.60-1.37ºC under RCP4.5 and 0.72-2.87ºC under the RCP8.5, whereas the mean maximum temperature ranges 0.61-1.05ºC under RCP4.5 and 0.45-2.46 under RCP8.5 and the mean annual precipitation increase slightly with 4.17% under RCP4.5 and 5.21% under RCP8.5 by the end of the 21st century.

Although the impact of climate change affects the reduction in rice production, the study area would have food security and surplus could provide to the other deficient area until at the end of the 21st century. The income of the farm household, however, would be significantly less because the decline of the rice surplus ranges 40% - 60% by the VFF period than the present surplus.

The methodology used in this study can contribute a guideline for analysing the impacts of climate change on the agriculture and population growth, hence the policy makers and practitioners can implement the effective policy for the sustainable agriculture. However, the different GCMs give the different results and should use the multi models to assess the future climate. In addition, the different regions and the geographic scales are impacted differently by the climate change. Therefore, future study should cover the various environment such as the drought area, salt affected area and various rice ecosystems.

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References

Babur, M., Babel, M. S., Shrestha, S., Kawasaki, A., & Tripathi, N. K. (2016). Assessment of climate change impact on reservoir inflows using multi climate-models under RCPs—The case of Mangla Dam in Pakistan. *Water, 8*(9), 389.

CSO (2018). Country Report; 2018, Central Statistical Organization, Nay Pyi Taw, Myanmar.

Beddington, J. (2010). Global food and farming futures. *Philosophical Transactions of the Royal Society B, 365*(1554), 2767-2767.

DALMS. (Department of Agricultural Management and Statistics) (2016). Rice Statistics: Myaungmya Township, Ayeyarwady Region, Myanmar.

DESA. (2019). "World Population Prospects 2019: Highlights." New York (US): United Nations Department for Economic and Social Affairs.

Dianne, J. (2018). How to Calculate Population Projections. Retrieved from https://sciencing.com/calculate-population-projections-8473012.html

Denning, G., Baroang, K., & Sandar, T. M. (2013). "Background paper No. 2 rice productivity improvement in Myanmar." Retrieved May 30:2014.DMH (Department of Meteorology and Hydrology). 2016. Myanmar Climate Data. Department of Meteorology and Hydrology, Yangon, Myanmar.

DOP. (2015). The 2014 Myanmar Population and Housing Census: Ayeyarwady Region. Department of Population, Ministry of Immigration and Population, Nay Pyi Taw, Myanmar.

Enete, A. A., & Amusa, T. A. (2010). "Challenges of agricultural adaptation to climate change in Nigeria: A synthesis from the literature." Field Actions Science Reports. *The Journal of Field Actions* 4:

FAO (Food and Agriculture Organization). (2009). FAO/WFP Crop and Food Security Assessment Mission to Myanmar. Retrieved from http://www.fao.org/docrep/011/ ai478e/ai478e00.htm

Foresight, UK. (2011). The Future of Food and Farming. Final Project Report. The Government Office for Science, London.

IPCC (Intergovernmental Panel on Climate Change). (2007). Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M.Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

IPCC (Intergovernmental Panel on Climate Change). (2014). Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (Eds.)]. IPCC, Geneva, Switzerland, pp. 151.

Karfakis, P., Lipper, L., & Smulders, M. (2012). "The assessment of the socioeconomic impacts of climate change at household level and policy implications." Building resilience for adaptation to climate change in the agriculture sector. Proceedings of a Joint FAO/OECD Workshop, Rome, Italy, 23-24 April 2012.

Kreft, S., Eckstein, D., Junghans, L., Kerestan, C., & Hagen, U. (2014). Global climate risk index 2015: who suffers most from extreme weather events? Weather-related loss events in 2013 and 1994 to 2013.

Lar, N. M., Arunrat, N., Tint, S., & Pumijumnong, N. (2018). Assessment of the Potential Climate Change on Rice Yield in Lower Ayeyarwady Delta of Myanmar Using EPIC Model. *Environment and Natural Resources Journal, 16*(2), 45-57.

McLaughlin, Dennis, & Wolfgang Kinzelbach. (2015). "Food security and sustainable resource management." *Water Resources Research* 51 (7):4966-4985.

MOALI (Ministry of Agriculture, Livestock and Irrigation). (2015). Agriculture and Livelihood Flood Impact Assessment in Myanmar. Retrieved from https://www.wfp.org/sites/default/files/FinalImpact AssessmentReport final.pdf

Ojwang, G. O., Agatsiva, J., & Situma. C. (2010). Analysis of climate change and variability risks in the smallholder sector: FAO.

Premanandh, J. (2011). Factors affecting food security and contribution of modern technologies in food sustainability. *Journal of the Science of Food and Agriculture, 91*(15), 2707-2714.

UNFCCC. (2012). Myanmar's Initial Communication under the United Nations Framework Convention on Climate Change, Nay Pyi Taw, Myanmar.

Myint, W. M. (2010). *A Geographical Analysis on Agriculture in Myaungmya Township.* (PhD (Dissertation)), University of Yangon, Yangon, Myanmar.