Applied Environmental Research

Journal homepage: http://www.tci-thaijo.org/index.php/aer

An Assessment of Climate Variability on Farmers' Livelihoods Vulnerability in Ayeyarwady Delta of Myanmar

Naw M. Lar[1,2], Nathsuda Pumijumnong[1,*], Raywadee Roachanakanan[1], Noppol Arunrat[1], Soe Tint[3]

[1] Faculty of Environment and Resource Studies, Mahidol University, Nakhon Pathom, Thailand
[2] Department of Geography, University of Yangon, Yangon, Myanmar
[3] Department of Geography, Dagon University, Yangon, Myanmar
[*] Corresponding author: Email: nathsuda.pum@mahidol.ac.th, nathsuda@gmail.com

Article History
Submitted: 26 July 2017/ Accepted: 31 August 2017/ Published online: 28 February 2018

*** Part of this manuscript was presented in the 4th EnvironmentAsia International Conference on Practical Global Policy and Environmental Dynamics, June 21-23, 2017, Bangkok, Thailand.

Abstract

This study assesses the vulnerability of farm households in the Ayeyarwady Region, Myanmar. Fifty-nine farm households were purposively sampled to conduct a questionnaire survey, and secondary data were collected in 2016. In order to assess variability in household vulnerability, the Livelihood Vulnerability Index (LVI), based on five types of 'capital' as identified in the Sustainable Livelihoods Framework, was adopted and modified according to the local context. Vulnerability scores ranged from 0 (low vulnerability) to 1 (highly vulnerable), with an average LVI of 0.442, indicating moderate overall vulnerability across the study area. Regarding the five types of 'capital', households were most vulnerable in terms of financial capital with an average value of 0.530, followed by natural capital (0.515) and physical capital (0.418). Households were classified into three vulnerability groups (low, moderate, and high) to identify those households most likely to need special attention. The survey found that the vulnerability of each asset they suffered was different across the township. The results also revealed that the production area of households classed as highly financially vulnerable found in the flood-prone and saline intrusion areas. It is clear that in order to reduce the vulnerability of farm households, more interventions are needed to enhance access to agricultural credit, diversifying livelihoods, provision of farm technology, inputs and knowledge as well as upgrading of basic infrastructure.

Keywords: Livelihoods; Vulnerability; Capitals; Climate variability; Ayeyarwady Region

Introduction

The impact of climate change is emerging as a critical issue worldwide. Average global temperatures are projected to increase between 1.8 °C and 4 °C over the period 2090-2099 relative to 1980-1999 levels [1]. Climate change is expected to have adverse effects on all economic activity, especially the agricultural sector; smallholder farmers will be the hardest hit [2-4].

Rice is central to the economy and food security of Myanmar [5]. Not only does it support about 69 % of rural farmers but it is also key to the national economy, accounting for a 31 % share of GDP in 2014 [6]. The sown area of rice in Myanmar is about 71,700 km^2, with 18,700 km^2 (26.14 %) under irrigation, and the remainder produced under rainfed conditions [7]. Climate-induced extreme weather events have battered Myanmar in recent years; in 2008 Cyclone Nargis devastated 40,000 km^2 of rice paddy fields, with an estimated cost of over US$ 4 billion [8]. In 2015 severe flooding devasted crops over 20% of the country's cultivated area, with damage estimated at US$ 1.51 billion [9].

In recent years, a variety of methods have been developed to assess climate change vulnerability [10-12]. The Livelihood Vulnerability Index (LVI) was first used by Hahn et al [12]. in Mozambique, and later applied in other countries. LVI uses multiple indicators to assess exposure to natural disasters due to climate variability, social and economic characteristics of households that affect their adaptive capacity, and current health, food, and water resource characteristics that determine their sensitivity to climate change impacts [13].

The objectives of the study are first to assess the vulnerability of farm households and their livelihoods to the impacts of climate change, particularly in rice-growing areas prone to flooding and saline intrusion, and secondly to develop a climate change vulnerability map for households in Myaungmya Township, Ayeyarwady Region, Myanmar. Such a map will offer important guidance to development practitioners to assist them in targeting their strategies and interventions at both household and community levels. The findings of the study can support development of effective adaptation measures to cope with climate change impacts and protect livelihoods of farm households. The study will also contribute to a knowledge base that will inform policymaking and support effective management responses to reduce vulnerability of rural households to climate change impacts.

Materials and methods

1) Study area

This study was conducted in Myaungmya Township, located on the eastern bank of the Ngawun River, a township in the Ayeyarwady Region, Myanmar. It is located at 16° 19´ and 16° 44´ north latitudes and 94° 40´ and 95° 05´ east longitudes, covering an area of 1,152.23 km^2, with a total population of 291,390 and 18,328 farmer households in 2014 [14]. The township is located in a major rainfed rice production area, and also includes the highest irrigated rice area in the Ayeyarwady Region, providing 69 % of the township's labour force [8]. Although the township has not previously suffered documented natural disasters since decades, in 2015 widespread flooding caused devastating damage to the township and the surrounding agricultural areas, with serious impacts for many people whose crops and livelihoods were ruined.

The township experiences a tropical monsoon climate with annual mean temperature of 27.42 °C, the hottest month in April with a mean temperature of 30.41 °C and the coolest month in January with 24.71 °C. Average annual rainfall is 2,894 mm [15]. Most of the area comprises flat alluvial plain with an elevation of only 10 m above sea level (Figure 1).

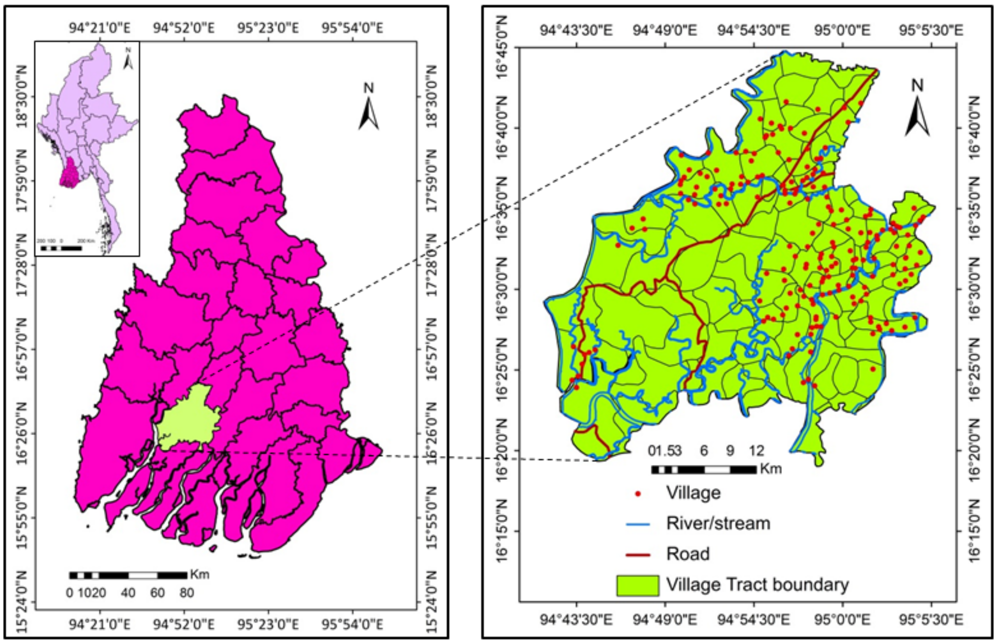

Figure 1 Study area location: Myaungmya Township, Ayeyarwady Region, Myanmar.

2) Data and analytical tools

Due to limitations on available data on the populations of each village, district and logistics, the study area was divided into 11×11 km grids. Grids where rice is grown over 50 % or more of the grid area were selected. The samples area comprised a total of 59 of 11×11 km grids grow rice under both rainfed and irrigated conditions, by pumping water out of nearby rivers and streams. Farmers in each grid were selected for interview, with a total of 59 respondents. Structured questionnaires were used, comprising five sections; household socio-economics, farm characteristics, institutional support, farmers' perception on climate change, and adaptation options. The survey was conducted during February and May in 2016. Data were processed in Excel 2007 and SPSS 18, and the outputs were displayed in tables and graphical form.

3) Calculating the livelihood vulnerability index

To assess the vulnerability of farm households, LVI was applied, incorporating five distinct categories of capital/assets as defined in the Sustainable Livelihoods Framework (SLF) [16]. It can be used to assess local vulnerability and adaptive capacity through analyzing the level of five assets or types of capital. The more assets the farmer possesses, the lower their vulnerability.

The indicators used in this study were developed from previous literatures [12, 17-19]. They were subsequently modified under five different asset categories in the SLF: human, natural, physical, financial and social capital, with each type of capital weighted equally. First, sub-components shown in Table 1 were transformed into appropriate measurements such as ratios, percentages, and indices. Secondly, since indicators were measured using different scales, it was necessary to standardise them as an index. To calculate the index, the equation used in the Human Development Index (Eq. 1) was applied. In the case of some indicators that reduce vulnerability, the inverse index was used (e.g. education). The maximum and minimum values were also transformed using Eq. 1.

$$Index_{S_t} = \frac{S_t - S_{\min}}{S_{\max} - S_{\min}} \quad \text{(Eq. 1)}$$

Where S_t is the value of sub-component for township t, S_{min}, S_{max} are the minimum and maximum values, respectively. Third, to estimate the indices for each livelihood asset, the average of the standardised index of each component was calculated by using Eq. 2.

$$M_t = \frac{\sum_{i=1}^{n} index_{s_t i}}{n} \quad \text{(Eq. 2)}$$

Where M_t is the value of major component for township t, $index_{sti}$ represents the value of sub-component in major component. M and n is the number of sub-components. Finally, the balanced weighted average of all components was generated for final LVI score for the community. The weights of the each component were determined by the number of indicators of such components (Eq. 3).

$$LVI_t = \frac{\sum_{i=1}^{5} w_{Mi} M_{ti}}{\sum_{i=1}^{5} w_{Mi}} \quad \text{(OR)}$$

$$LVI_t = \frac{w_H H_t + w_N N_t + w_P P_t + w_F F_t + w_S S_t}{w_H + w_N + w_P + w_F + w_S} \quad \text{(Eq. 3)}$$

Where, LVI_t is the Livelihood Vulnerability Index of the township t, w_{Mi} is the weight value of major component i, $w_H + w_N + w_P + w_F + w_S$ are the weighted values of Human *(H)*, Natural *(N)*, Physical *(P)*, Financial *(F)* and Social *(S)* capitals of township t, respectively. The LVI is scaled from 0, representing least vulnerable, to 1, representing most vulnerable [19].

Table 1 Contributing factors of major components and subcomponents of livelihood assets used in LVI

Capitals	Major components	Subcomponents
Human capital	Health	Households with members suffering chronic illness, distance to health care
	Knowledge and skills	Education of household heads, farming experience of households heads, ownership of TV, radio, mobile phone, access to awareness raising
	Livelihood strategies	Crop diversification, households depending on agriculture as a major source of income
Natural capital	Natural resources	Landholdings, barriers to access land, growing third crop, salt water intrusion, access to non-farm products, crop area affected by flood
	Climate variability and natural disaster	Household perception on climate variability, Mean standard deviations of monthly mean maximum, minimum temperatures and precipitation
Social capital	Demography	Dependency ratio, age of household head, family members
	Social networks	Household participation in community, contribution in community, voting, membership in organization
Financial capital	Finance and income	Income from rice sale, household expenditure, saving, credit loan, debt, and remittances
Physical capital	Transportation	Distance to agricultural market, ownership of motorcycle
	Production means	Water pump, trailer, farming equipment, application of fertilizer, extension service

Source: Hahn et al., [12], Sisay [17] and Can et al., [19] but some indicators are modified to the context of the study area.

Results and discussion

1) General characteristics of the sampled households

The average age of the sampled farmers was 51 years old, with the youngest aged 26 and the oldest 70 years old. Over 80 % of the sampled household heads were within the active working age group of 33-60 years. Among the respondents, 88.14 % were male-headed households and 11.86 % were female-headed households. The education level of sampled farmers was generally, low with average schooling of 5.92 years, representing middle school education. The average household size of farmer was 4.93 members, which was higher than the national average for Myanmar (4.4 members per household). The members of the household, having 4-6 family members were the highest number (66.10 %). The average dependency ratio of sampled households was 58.78 %, which was higher than the country average (52.5 %) and 37.29 % of sampled households had the highest dependency ratio. Landholdings of respondents ranged from 0.004 to 0.3845 km^2, with an average holding size of 0.718 km^2 above the country average of 0.024 km^2 per household [7]. Approximately 75 % of sampled households had a farming experience over 20 years. For over half of the households, per capita rice income was less than US$ 1,300 (Table 2).

Table 2 Characteristics of sampled farmers' household in Myaungmya Township

Characteristics	Categories	Frequency	Percentage	Mean	Min	Max
Gender	Female	7	11.86			
	Male	52	88.14			
	Total	59	100.00			
Age (year)	18-32	1	1.69	26.00	26	26
	33-46	18	30.51	40.50	35	46
	47-64	31	52.54	54.59	47	64
	> 64	9	15.25	66.17	65	70
	Total	59	100.00	50.98	26	70
Education (year)	< 5	19	32.20	3.84	3	4
	5-8	36	61.02	6.58	5	8
	9-10	4	6.78	9.75	9	10
	Total	59	100.00	5.92	3	10
Household size (person)	< 4	9	15.25	2.67	2	3
	4-6	39	66.10	4.64	4	6
	7-9	10	16.95	7.60	7	9
	> 9	1	1.69	10.00	10	10
	Total	59	100.00	4.93	2	10
Dependency ratio (%)	0	10	16.95	0.00	0	0
	1-30	15	25.42	21.29	13	25
	31-60	12	20.34	36.66	33	50
	> 60	22	37.29	123.11	67	500
	Total	59	100.00	58.78	0	500
Land holdings (10^{-2} km^2)	0.01-5.00	27	45.76	2.74	0	4
	5.01-10.00	20	33.90	6.87	5	10
	> 10.00	12	20.34	17.71	10	38
	Total	59	100.00	7.18	0	38
Farming experience (year)	1-10	7	11.90	7.71	2	10
	11-20	8	13.60	19.00	15	20
	> 20	44	74.60	35.05	22	50
	Total	59	100	29.63	2	50
Farm income (US$)	< 1,300	32	54.24	690.63	190.22	1,271.74
	1,300-2,600	12	20.34	1,866.06	1,354.35	2,548.70
	> 2,600	15	25.42	5,517.38	2,747.83	1,5014.49

Source: Field survey, 2016

2) Climate hazard in agriculture of Myaungmya Township

Myanmar is prone to multiple natural hazards such as cyclones, floods, drought, landslides and earthquakes. From a historical average incidence of about once in every three years, since the year 2000 cyclones have crossed the Myanmar coast every year. The Ministry of Agriculture, Livestock and Irrigation reports that the devastating flooding brought by Cyclone Komen in 2015 was the most damaging in recent history, destroying 80 % of the cultivated area in the Ayeyarwady Region, or over 1,000 km^2 [8].

The 2015 cyclone struck at the end of July, when most of the rice had already been sown or transplanted and were at an early stage of growth. About 25 % of sampled respondents in Myaungmya Township reported that their cultivated area was affected by the flood; about 14 % of sampled households reported damage to up to 20 % of their rice area, and 10 % of farmers responded damage from 21 % to 50 % of their rice area. However, 98 % of all affected households were able to replant their rice soon after the water receded, while the remaining 2 % had no money to purchase replacement seed.

3) The farmers' vulnerability index: the result of LVI

As a single asset or capital can generate multiple benefits, deterioration of that asset can affect other assets [16]. Although it is clear that those who depend most on natural capital are likely to be most affected by climate change, the level of vulnerability may differ, depending on the types of capitals possessed by the individual.

Since the overall result of LVI for the study area is 0.442, this result classifies the study area in the category "moderate vulnerability to flood and climate variability". Figure 2 shows that financial capital makes the highest contribution to farmer vulnerability, with a value of 0.530, followed by natural capital (0.515), physical capital (0.418), human capital (0.389) and social capital (0.337).

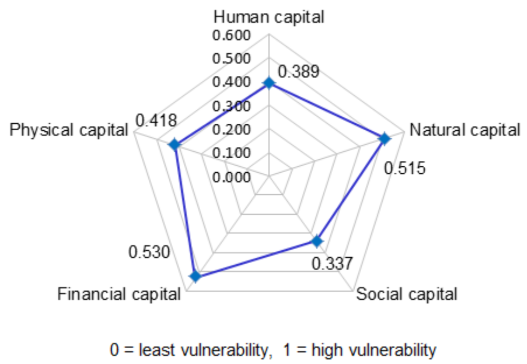

Figure 2 Spider graph showing the vulnerability of sampled farmers in terms of five capitals in 2016.

3.1) Financial capital vulnerability

The financial capital is the key determinant of vulnerability, with a value of 0.530. This finding is in agreement with the work of Vincent and Cull [20]. Since 84.75 % of the farmer households received no remittances from any family member living outside the area, these families were extremely vulnerable to the impacts of any natural disaster or extreme weather event (Supplementary material). Other factors contributing to their financial vulnerability are their agricultural loans, limited saving and very low incomes. About 66 % of sampled households had not received sufficient credit from the Myanmar Agricultural Development Bank. Loan plans are allocated to farm households at the rate of 100,000 kyats/acre (US\$ 21,400/km^2) for holdings of up to 0.04 km^2. Estimated cost of rice production in 2016 was about US\$ 5,000/km^2. With insufficient income from rice sales to cover household expenditures, per capita income was less than US\$ 1,300 for 54.24 % of respondents.

Although annual per capita income from rice is estimated at about US\$ 2,100 per farm household, and per capita household expenditure at about US\$ 600, small farmers with smallholding could not cover their costs from rice sales. Late provision of credit loans is one of most important challenges faced by farmers, leading to late delivery of farm inputs and impacts on productivity, (as reported by Makondo et al. [21]). Hence, the limited institutional loan forces to use private lender [22]. A 59.30 % of respondents had no saving last year, while 37.29 % of sampled farmers had not repaid their loans. This situation can lead to a vicious debt cycle and ultimately, forfeiture of land and other assets. Therefore, farmers' access to finance is the most important factor, with improved access to credit leading to reduced vulnerability. The finding is as expected, and is consistent with studies by Can et al. [19] and Shwemake [23].

3.2) Natural capital vulnerability

The second most affected asset of sampled households is natural capital, with a value of 0.515. The survey indicates that the contributing sub-components for high vulnerability were farmers' opinion on climate variability, natural resources and access to non-farm products. Interviews reported a decrease in rainfall and changes in rainfall pattern over the past decade, which has altered farm calendars and agricultural practices. About 86 % of sampled households reported rising temperatures, and 84.7 % reported lower rainfall. About 73 % of farm households also confirmed that untimely rain and flooding had increased over the last 10 years. Their perceptions on climate change are consistent with observed data from the Department of Meteorology and Hydrology. For sampled households who could not grow a third crop (75.27 %) due to lack of irrigation and saline intrusion, adaptation measures such as rehabilitation of irrigation systems, use of improved rice varieties and provision of farm machinery would by diversifying income all help reduce vulnerability [24]. Furthermore, collecting non-farm products such as fruits and vegetables, fishing, and activities such as processing betel nuts, also play an important role in reducing vulnerability by diversifying incomes. However, a majority of households (74.58 %) have not been able to diversify in this way to earn non-farm income, suggesting that promotion of diversification of income sources offers another adaptation option to reduce vulnerability and increase resilience to climate change impacts [25-26].

3.3) Physical capital vulnerability

As the third affected component, physical capital had a value of 0.418 in this study. The absence of a functioning extension service apart from the Ministry of Agriculture Service (MAS) was found to contribute most to farmer vulnerability. In addition, 83.10 % of respondents did not own a small trailer, which is important for transportation of commodities and people, as the study area has only rudimentary road infrastructure. Additional factors contributing to vulnerability included sub-optimal fertilizer application and lack of water pumps. 38.89 % of respondents applied chemical fertilizers at rates lower than suggested by MAS, and often applied them incorrectly too. Provision of extension services and quality fertilizers can therefore be expected to play a vital role to help farmers recover from flooding losses and restore productivity and incomes. This is consistent with the studies of Can et al. [19] and Makondo [21]. Since the study area is well-endowed with rivers and streams, many farmers also grow irrigated rice, hence the water pump is an important asset for these households. However, 35.60 % of households reported they did not own a pump, and so are forced to pay charges for use of pumps owned by others. Additionally, the long distance from farm to market greatly increase the burden on farmers in terms of transportation costs and time, which is also exacerbated by the extremely poor road infrastructure. Clearly, physical access to markets is a key criterion [18, 21].

3.4) Human capital vulnerability

Human capital was found to have a low effect on farmers' vulnerability with a value of 0.389. In case of illness, patients have to travel to the township hospital, which is relatively far from their homes. This increases the vulnerability of farm households, which had a value of 0.424. It indicates that health facilities should be extended to more remote areas due to the poor infrastructure across the region. In terms of access to information and awareness on climate change and how to adapt to it, although 77.97 % of samples did not own a radio, the majority of respondents knew the information from television. However, 79.66 % of interviewees reported that they did not receive knowledge or training on coping with climate-related agricultural problems. The mass media therefore play an important role in enhancing public awareness on weather information [27-28]. Farm households mainly grow double cropped rice: rain-fed rice followed by irrigated rice. The irrigated rice would contribute more to reducing vulnerability than when only rainfed rice is grown. However, the majority of sampled households rely solely on rice cultivation, rendering them more vulnerable than those with several sources of income, including non-farm employment.

3.5) Social capital vulnerability

Of all types of capital studied, social capital had the least effect on household vulnerability, with a value of 0.337. This was attributed to the small proportion of female-headed household (11.90 %) and small proportion of households that did not contribute to community affairs (27.10 %); these reduced overall vulnerability. However, the high average age of sampled household heads contributed to increased vulnerability; the younger the age, the less vulnerable. Households that did not participate in community affairs (57.60 %) and one of the households' members not affiliating any organization (52.54 %) contributed to a relatively high level of vulnerability. However, respondents reported that household members were ready to participate or contribute some form of assistance such as labour exchange or cash aid that helps recovery of the household in case of need. In the Myanmar context, membership in organizations is not popular after over 50 decades of military rule; however, under the new civilian government participation in farmer's organizations has increased, suggesting that farmers find membership in such organizations useful in strengthening their knowledge on agriculture and climate change. Additionally, the number of household family members had a relatively strong effect on vulnerability (0.367). This finding is supported by Senbeta and Olsson [29], confirming that large family size are at most risk from the impacts of climate change-driven events.

4) Mapping vulnerability

Mapping household vulnerability is an important tool to help prepare and provide basic amenities and access resources to prepare for future climate-driven risks. The number of vulnerability categories could be simplified in order to simplify decision making by public authorities. Since the vulnerability index of a sampled farmer is assigned between 0 and 1, three categories: low (0-0.333), moderate (0.334-0.666) and high vulnerability (> 0.666) could be established for planning and disaster management purposes (Table 3). However, only 5.08 % of farm households were classified in the low vulnerability category, with 94.92 % in the 'moderate vulnerability' and none of the respondents in the 'high vulnerability' category (Figure 3a). All the assets are significantly different in affecting the vulnerability of all groups.

With respect to financial capital, 5.08 % of farmer households were involved in the low vulnerability, 55.93 % in the moderate vulnerability and 38.98 % in the high vulnerability. The highly vulnerable households settled in the western, northern and eastern part of the study area. Farmers in these areas faced major constraints to crop production because of saltwater intrusion and flooding from nearby rivers and streams, leading to low incomes, insufficient investment, unpaid debts and ensuing impacts on other household assets (Figure 3b).

In terms of natural capital, all sampled households were moderately affected by natural capital. In fact, moderately vulnerable farmers were found across the township (Figure 3c).

Regarding physical capital, 38.98 % of sampled households were in the low vulnerability, with 52.54 % classed as moderately vulnerable and only 8.47 % in the high vulnerability group. Production areas for the high vulnerable group was mostly located in the western and south-central part, which are relatively distant from the major agricultural markets and suppliers of agricultural inputs, facilities and services (Figure 3d). Physical vulnerability is further exacerbated by extremely poor road conditions and dependence on water transportation.

An average 27.12 % of sampled farm households were classed in the low vulnerability group, with 71.19 % moderately vulnerable and 1.69 % as highly vulnerable in terms of human capital. The moderately vulnerable households and their farms are located in the western, northern, eastern and central part of the township, which lies along the river banks (Figure 3e). These areas mostly rely on river transportation to reach major agricultural markets and access public and private services.

About 47.46 % of sampled households were classed as suffering from moderate social vulnerability, with 52.54 % classed in the low social vulnerability group. The homes and farms of those moderately vulnerable households were mostly located in the north-western and central parts of the township (Figure 3f).

It is interesting to note that the farms of households classified in the high financial vulnerability group were located within the flood and saline intrusion area, which accounts for their high level of vulnerability. In addition, household belonging to the moderately vulnerable group in terms of natural capital also settle in these area. This suggests that development practitioners need to give priority to sensitive areas in order to prepare and respond to future climatic impacts.

Table 3 LVI values by household capital and the vulnerable group of sampled farmers in Myaungmya Township in 2016

Household assets	Low vulnerable group (0-0.333)		Moderate vulnerable group (0.334-0.666)		High vulnerable group (> 0.666)	
	LVI value	Affected household (%)	LVI value	Affected household (%)	LVI value	Affected household (%)
Human capital	0.252	27.12	0.433	71.19	0.766	1.69
Natural capital	0.000	0.00	0.515	100.00	0.000	0.00
Physical capital	0.269	38.98	0.480	52.54	0.719	8.47
Social capital	0.258	52.54	0.424	47.46	0.000	0.00
Financial capital	0.229	5.08	0.404	55.93	0.751	38.98

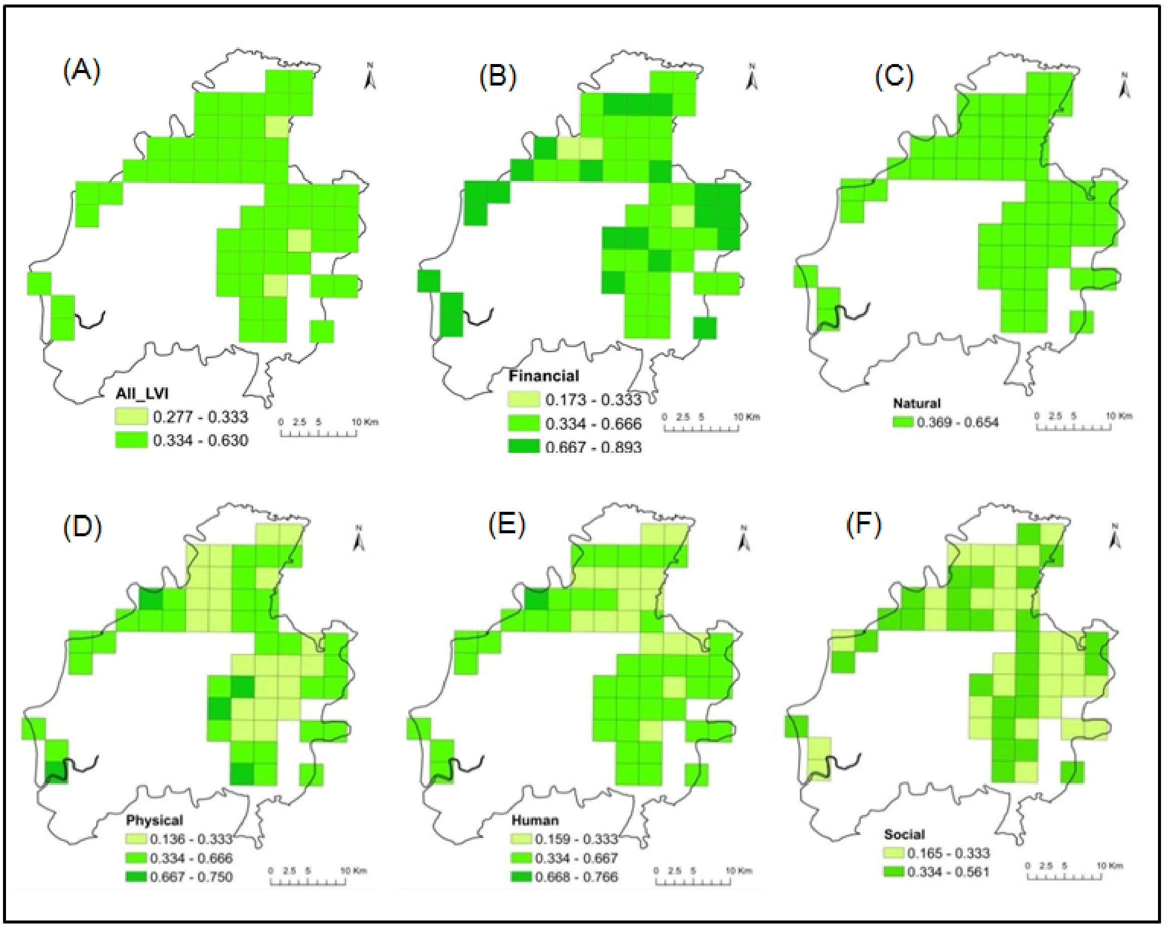

Figure 3 Spatial distribution of the LVI of overall assets (a), financial capital (b), natural capital (c), physical capital (d), human capital (e), and social capital (f) in Myaungmya Township.

Conclusion

This paper analyses the impact of climate change on the vulnerability of farmers' livelihoods using the LVI method based on SLF in Myaungmya Township, Ayeyarwady Region, Myanmar. As the overall result of LVI is 0.442, the study area can be categorized as moderately vulnerable to the impacts of climate change.

Based on an assessment of assets under the sustainable livelihood framework, the application of the LVI was used to gain an understanding of farmer's vulnerability to the impacts of climate variability and other stressors in the study area. In operationalizing the theory, indicator selection needs to be modified to the local context. The study approach should be further tested in other locations over time in order to develop a more robust empirical database for comparing communities. Such a study will serve to inform decision making and provide useful information for development practitioners in evaluating the vulnerability of communities and thereby facilitate the planning, design and implementation of effective development programs for these highly vulnerable to climate change impacts.

Acknowledgements

This research was financially supported by the Norwegian Government through the Capacity Building for Institutions in Myanmar (CBIM) program. The authors would like to express their sincere gratitude to all supporters who have contributed to this research work. The authors are also indebted to all authors and sources of materials used this research paper.

References

[1] IPCC (Intergovernmental Panel on Climate Change). Climate change. Synthesis report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change," (Eds. Core Writing Team, R. K. Pachauri and A. Reisinger), Geneva: IPCC, 2007. [Online] Available from: https://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4syrfullreport.pdf [Accessed 20 January 2016].

[2] Brown, D., Chanakira, R.R., Chatiza, K., Dhliwayo, M., Dodman, D., Masiiwa, M. …, Zvigadza, S. Climate change impacts, vulnerability and adaptation in Zimbabwe. International Institute for Environment and Development (IIED) Climate Change Working Paper No. 3, 2012.

[3] Kurukulasuriya, P., Rosenthal, S. Climate change and agriculture. World Bank Environment Department Paper, 2013. [Online] Available from: http:// www.c-ciarn.uoguelph.ca/updatesarchived/World BankPaper pdf [Accessed 2 January 2015].

[4] Harvey, C.A., Rakotobe, Z.L., Rao, N.S., Dave, R., Razafimahatratra, H., Rabarijohn, R.H. …, MacKinnon, J.J. Extreme vulnerability of smallholder farmers to agricultural risks and climate change in Madagascar. Philosophical Transactions of the Royal Society B, 2014, 369(1639), 1-12.

[5] Denning, G., Baroang, K., Sandar, T. M. Background paper No. 2 rice productivity improvement in Myanmar, 2013. [Online] Available from: http://fsg.afre.msu.edu/Myanmar/myanmar_branded_background_paper_21.pdf [Accessed 2 March 2015].

[6] FAO/WFP (Food and Agriculture Organization/World Food Program). Special report on crop and food security assessment mission to Myanmar, 2016. [Online] Available from: https://www.wfp.org/sites/default/files/2016KHM0.pdf [Accessed 3 August 2016].

[7] CSO (Central Statistical Organization). Myanmar: Statistical year book. Nay Pyi Taw, Myanmar: Ministry of National Planning and Economic Development, 2015.

[8] MoALI (Ministry of Agriculture, Livestock and Irrigation). Agriculture and livelihood flood impact assessment in Myanmar, 2015. [Online] Available from: https://www.wfp.org/sites/default/files/FinalImpactAssessmentReportfinal.pdf [Accessed 10 February 2017].

[9] World Bank. Myanmar - Post-disaster needs assessment of floods and landslides: July - September 2015. Washington, D.C.: World Bank Group, 2015. [Online] Available from: http://documents.worldbank.org/curated/en/646661467990966084/pdf/ 103631 -WP-P157276-PUBLIC-PFLNA-Report-2016.pdf [Accessed 5 February 2017]

[10] Sullivan, C. Global change impacts: Assessing human vulnerability at the sub-national scale. Paper presented at the International River Symposium, Brisbane, 2006.

[11] Vincent, K. Gendered vulnerability to climate change in Limpopo province, South Africa, University of East Anglia, 2007, 1-16.

[12] Hahn, M.B., Riederer, A.M., Foster, S.O. The livelihood vulnerability index: A pragmatic approach to assessing risks from climate variability and change-A case study in Mozambique. Global Environmental Change, 2009, 19(1), 74-88.

[13] Legese, S.A., Olutayo, O.A., Sulaiman, H., Rao, P. Assessing climate change impacts in the Lake Tana Sub-Basin, Ethiopia using livelihood vulnerability approach. Journal of Earth Science and

Climatic Change, 2016, 7(368), 1-10, doi: 10.4172/2157-7617.1000368.

[14] Census. The 2014 Myanmar population and housing Census: Ayeyarwady Region. Department of Population, Ministry of Immigration and Population, Nay Pyi Taw, Myanmar, 2016.

[15] DMH (Department of Meteorology and Hydrology). Myanmar climate data. Department of Meteorology and Hydrology, Yangon, Myanmar, 2016.

[16] DFID, (Department for International Development). Sustainable livelihoods guidance sheets. Department for International Development, UK, 1999. [Online] Available from: http://www.eldis.org/vfile/upload/1/document/0901/section2.pdf [Accessed 13 January 2016]

[17] Sisay, T. Vulnerability of smallholder farmers to climate change at Dabat and West Belesa Districts, North Gondar, Ethiopia. Journal of Earth Science and Climatic Change, 2016, 7(8), 1-5.

[18] Shah, K.U., Dulal, H.B., Johnson, C., Baptiste, A. Understanding livelihood vulnerability to climate change: Applying the livelihood vulnerability index in Trinidad and Tobago, Geoforum, 2013, 47, 125-37.

[19] Can, N.D., Tu, V.H., Hoanh, C.T. Application of livelihood vulnerability index to assess risks from flood vulnerability and climate variability-A case study in the Mekong Delta of Vietnam. Journal of Environmental Science and Engineering A, 2013, 2(8A), 476-486.

[20] Vincent, K., Cull, T. A household social vulnerability index (HSVI) for evaluating adaptation projects in developing countries. PEGNet conference, 2010.

[21] Makondo, C.C., Chola, K., Moonga, B. Climate change adaptation and vulnerability: A case of rain dependent smallholder farmers in selected districts in Zambia. American Journal of Climate Change, 2014, 3(4) 388-403.

[22] Tewari, H.R., Bhowmick, P.K. Livelihood vulnerability index analysis: An approach to study vulnerability in the context of Bihar. Jàmbá. Journal of Disaster Risk Studies, 2014, 6(1), 1-13.

[23] Shewmake, S. Vulnerability and the impact of climate change in South Africa's Limpopo River Basin, 2008, 1-32.

[24] Dechassa, C., Simane, B., Alamirew, B. Farmers' livelihoods vulnerability to climate variability and change in Didesa Basin Southern Part of Abay Basin, Ethiopia. Climate Change Adaptation in Africa. Springer, 2017, 267-284.

[25] Urothody, A., Larsen, H. Measuring climate change vulnerability: A compareson of two indexes. Banko Janakari, 2010, 20(1), 9-16.

[26] Lindenberg, M. Measuring household livelihood security at the family and community level in the developing world. World Development, 2002, 30(2), 301-318.

[27] Manh, D.H., Huy, H.A., Phuong, T.T.L., Tuyen, L.T. Livelihood Vulnerability assessment to climate change at community level using household survey: A case study from Nam Dinh Province, Vietnam. Mediterranean Journal of Social Sciences, 2016. 7(3 S1), 358-366.

[28] Nazari, M.R., Hassan, M.S.B.H. The role of television in the enhancement of farmers agricultural knowledge. African Journal of Agricultural Research, 2011, 6(4), 931-936.

[29] Senbeta, A.F., Olsson, J. Climate change impact on livelihood, vulnerability and coping, mechanisms: A case study of West-Arsi Zone, Ethiopia. Lund University, Lund, 2009, 1-54.