Measuring Paddy Farmers' Vulnerability to Climate Change in Mahavillachiya Ds Division, Anuradhapura, Sri Lanka

M.N.F. Sakeena

Department of Zoology, Faculty of Science, University of Colombo

Corresponding author's email: sakeenizam@yahoo.com

Abstract

The objective of this study is to measure the paddy farmers' vulnerability to climate change. The indicator method was used to analyze the vulnerability of the paddy farmers in the Mahavilachchiya and Thanthrimale GN division of in Mahavillachiya DS division, Anuradhapura, Sri Lanka. The different socioeconomic and biophysical indicators of each area collected have been classified into three classes, based on the Intergovernmental Panel on Climate Change's (IPCC 2001) definition of vulnerability, which consists of adaptive capacity, sensitivity, and exposure. This study was conducted with active farmers who are involved in paddy farming for more than thirty years of experience and above fifty in age. Among them, 40 percent of the paddy farmers were selected by using the random sampling technique. Structured Questionnaires and focus group discussions were conducted to collect primary data and secondary data was collected from relevant institutions and libraries. Results indicated that Thanthrimale is relatively more vulnerable to climate change than Mahavilachchiya. Thus, investing in the development of the relatively underdeveloped area of Thanthrimale, enhance irrigation system, early warning systems to help farmers' better cope in times of drought, drought-tolerant varieties of crops can reduce the vulnerability of paddy farmers to climate change.

Keywords: climate change, vulnerability, paddy farmers, rain-fed and irrigation farming system

Introduction

Today, climate change has become a major concern to human society because of their potentially deleterious impacts, worldwide. It poses especially significant threats to sustainable development in developing countries, which have fewer resources and are more vulnerable (Munasinghe, 2010). Changing climate has been observed in many parts of the world. The Intergovernmental Panel on Climate Change (IPCC) in its fourth assessment report observed that, 'warming of climate system is now unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global sea level' (Kumar, &Balasubramanian, 2010). Sri Lanka's climate has also been changing for a couple of decades. As a result, the expected rainfall may not come at the expected time with correct amount and intensity, whereas more rainfall may be received when it is not really necessary and annual mean air temperature anomalies have also shown significant increasing trends during the recent few decades in Sri Lanka (Punyawardena,2009). People depend on a wide range of agricultural products in almost all aspects of their life. Climate is a major determinant of both the location and productivity of agricultural enterprises. Despite technological advances such as improved crop varieties and irrigation systems, weather and climate are still key factors in agricultural productivity (Smith, et al. 1996). Agricultural activities mostly depend on the climatic elements such as rainfall and temperature. It is thus not surprising that agriculture has been identified as an area of concern in the current public debate on the causes and effects of climatic change.

Agriculture has been the backbone of the Sri Lankan economy with one-thirds of the population being dependent on it. The Agricultural sector contributes about 11.1 percent of the country's Gross Domestic product (GDP) and 31.0 percent of total employment. Rice is the main crop cultivated by the majority of farmers in rural areas and it is the staple food of the 20.4 million inhabitants in Sri Lanka. Further, it is the livelihood of more than 1.8 million farmers. Rice contributes to 1.8 percent of the country's GDP (Sri Lanka Socio-Economic Data, 2013). Dry zone rice farming in Sri Lanka can be divided into two major categories, namely, major irrigation schemes and the rain-fed system (village tanks or minor irrigation systems). In major irrigation schemes, farmers carry out paddy farming, the main farming system activity, using the water supplied from large irrigation reservoirs on a year round basis. Rain-fed systems depend heavily on local rainfall. Being dependant on local rainfall without access to any substantial sources of supplementary water, rain-fed farmers are naturally more vulnerable to climate uncertainty than farmers in irrigated schemes. They are in a continuous struggle for livelihood security under water stress conditions due to rainfall uncertainty (Senaratne and Scarborough, 2011).

Due to climate change, tropical countries including Sri Lanka have more vulnerable because a greater fraction of its economy is in climate sensitive sectors such as agriculture. Apart from that, it is already in a hot climatic zone, and the economy relies on labour-intensive technologies with fewer adaptation opportunities (Rathnabharathi, 2009). The Action Impact Matrix (AIM) was used to rank climate change impacts and vulnerability in various sectors of Sri Lanka, among them traditional agriculture (rice farming) and tree crops (plantations) are identifies as the most vulnerable areas. (Munasinghe, 2010).

However, limited information exists on vulnerability to climate change in rice farming in Sri Lanka, especially at the micro level.Given this knowledge gap, there is a need to systematically evaluate the rain fed and irrigation based paddy farmers' vulnerabilities to climate change. Hence, the objective of this study is to measure paddy farmers' vulnerability to climate change.

Table 1: Vulnerability indicators, units of measurement and expected direction with respect to vulnerability (Cont.)

Determinants of vulnerability	Vulnerability Variables	Description of each indicator selected for analysis	Unit of Measurement	Hypothesized functional relationship between indicator and vulnerability
Adaptive capacity	Wealth	Quality of residential home	Percentage of total population who own or have access to	The higher the percentage of total population with asset ownership , and access to these income sources the lesser the vulnerability
		Livestock ownership		
		Ownership of machineries and vehicles		
		Nonagricultural income/ gift and remittance		
	Education level	Farmers' education level (secondary)	Percentage of the total population	The higher the education level the lesser the vulnerability
	Technology	Insecticide and pesticide supply	Percentage of total population within 1-6 km of these institutions	The higher the percentage of total population of the region within 1-6km the lesser the vulnerability
		Fertilizer supply		
		Improved seed supply		
	Institutions and infrastructures	Health services	Percentage of total population within 1-6 km of these institutions	
		Bank		
		Primary and secondary schools		
		Market		
		Member of farm organization	Percentage of the total population	The higher the percentage of total population in the member of farm organization and participation of training programmes the lesser the vulnerability
		Participation of training programmes		
		Road density	(length in km/km2)	The higher the road density the higher the connectivity and access to markets; and the lower the vulnerability
		Communication (the number of landlines, the number of cellular subscribers, the number of internet users)	Percentage of the total population	The higher the communications, the higher the opportunities for information flow; and the lower the vulnerability.

		Transport facilities	Percentage of the total population	The higher the percentage of total population who access availability of transport facilities satisfactory and either private or public transport, the lower the vulnerability
Sensitivity	Human sensitivity	Rural population density	Population/km^2	The livelihood of being a vulnerable to climate shocks is greater in rural areas and higher the population density, the larger the number of lives exposed to climate shocks. Therefore, the higher the vulnerability
	Livelihood sensitivity	Small scale farmers	Percentage of total population who hold less than 1 ha	The higher the percentage of small scale farmers, the higher the vulnerability
		Paddy area served by irrigation	Percentage of total paddy area under irrigation	The higher the land under irrigation, the lower the vulnerability
Exposure	Change in climate	Change in temperature Change in rainfall	Percentage change from 1951 -1980 to 1981 - 2010	Increasing temperature and decreasing precipitation increase vulnerability
	Extreme climate	Frequency of droughts and floods	Number of occurrences (counts of the occurrences of drought and flood in areas last 30 years)	The higher the frequency, the more the vulnerability

Methodology

Conceptual Framework for Measuring the Vulnerability Index

The Intergovernmental Panel on Climate Change (IPCC, 2001) definition of vulnerability was adopted for this study. The IPCC defines vulnerability to climate change as follows:

> *The degree to which a system is susceptible, or unable to cope with adverse effects of climate change, including climate variability and extremes, and vulnerability is a function of the character, magnitude and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity*

The indicator method was used to analyze the vulnerability of the paddy farmers in the study areas. The indicator method of quantifying vulnerability is based on selecting some indicators from the whole set of potential indicators and systematically combining the selected indicators to indicate the levels of vulnerability (Deressa, Hassan, &Ringler, 2008; Gbetibouo, &Ringler, 2009).

Based on the IPCC (2001) definition of vulnerability to climate change which is described by three elements: Exposure, sensitivity, and adaptive capacity (Gbetibouo, &Ringler, 2009; Heltberg, 2011), as follows:

1. Exposure can be interpreted as the direct danger (i.e., the stressor), and the nature and extent of changes to a region's climate variables (e.g., temperature, precipitation, extreme weather events).

2. Sensitivity describes the human–environmental conditions that can worsen the hazard, ameliorate the hazard or trigger an impact.
3. Adaptive capacity represents the potential to implement adaptation measures that help avert potential impacts.

Exposure and sensitivity are intrinsically linked and together affect potential impact. To assess farming vulnerability to climate change, we look at exposure to climate change, sensitivities to those changes, and societal coping and adaptive capabilities. Our vulnerability indicator approach is integrated, in that the selected indicators represent both the biophysical conditions of the farming regions and the socio-economic conditions of the farmers. The selection of indicators was done through an extensive review of previous reports; in particular, its draw from Deressa , Hassan, &Ringler, (2008), Gbetibouo,&Ringler, (2009), Eriyagama, et al, (2010), and Heltberg, 2011. Table 1shows the details of the vulnerability indicators with functional relationship. Source: Deressa et al, 2008; Eriyagama, 2010;Gbetibouo, et al, 2009.

Study Area

This study was carried out in Thantirimale and MahavilachchiyaGramaNiladhar (GN) divisions in Mahavilachchiya Divisional Secretariat Division (DSD) in Anuradhapura District in Sri Lanka.

Both Thanthrimale and Mahavilachchiyaare located in the dry zone, which receive less than 1800 mm average annual rainfall during Yala and Maha seasons. The mean annual temperature is 30^0 C although maximum temperature may even exceed 37^0 C occasionally. Thanthrimale's paddy farmers depend on rain fed system (dependent on local rainfall without access to any substantial sources of supplementary water) and Mahavilachchiya'spaddy farmers depend on an irrigation system (water is supplied from large irrigation reservoirs on a year round basis) (Divisional Sectorial office).The total land extent in Mahavilachchiya is 1213 acres where paddy land extent is 486 acres. It consists of two hamlets, Yaya 2 and Yaya 3 (both hamletsare selected for this study) and an estimated population of 699 and 502 respectively (MahawilachchiyaDSD, 2012). Thanthirimaleconsists of seventeen hamlets (three hamlets are selected for this study namely: Kosbevava, Thanrimalaiand Medavacheliya) with an estimated population of 1,043 and total number of 320 households. Amongst the total population majority of them are (95 percent) residing in selected three hamlets.

Population and Sample

This study was conducted with the active farmers who are involved in paddy farming activities for more than thirty years and are above fifty in age. Among them forty percent (40%) of paddy farmers were selected as a sample for this study. Random sampling technique was applied for selecting the samples and it was based on electoral lists using a random table. The characteristics of the sample are given in Table 2.

Table 2: Details of the sample

Name of the study area	Population (above fifty in age + 30 years' experience in farming)	Sample (40%)
Mahawilachchiya (Yaya 2, Yaya 3)	87	35
Thanthrimale (Kosbevava, Thanrimalai, Medavacheliya)	82	33
Total	169	68

Data Collection

Data was collected through both primary and secondary sources and the following methods were used.

- Questionnaire survey was conducted to collect the information from farmers to identify the vulnerability indicators' details.

- Focus Group Discussions (FGDs) were conducted with farmer groups of 05-08 in size, from the selected GN areas. Discussions were held in a semi-structured, yet flexible focus guide. The discussions were inquired about the physical profile of the resources in the villages, about the farming systems, local water management, formal and informal institutional arrangements, experience in climate change.

- Secondary data was collected from a number of key institutes. The major types of secondary data collected include: information on water sources, agricultural base data, rainfall, temperature and other meteorological data, physiographic information of resources and studies on socio-economic and institutional aspects.

Analysis and Results

A vulnerability index was used for assessment of the paddy farmers' vulnerability to climate change. vulnerability is defined as a function of a range of biophysical and socio-economic factors, commonly aggregated into three components that estimate the exposure (change in climate and extreme events), sensitivity (human and livelihood sensitivity), and adaptive capacity (wealth, education level, technology and intuition and infrastructure) to climate variability and change.

Obviously the indicators of vulnerability will be in different units and scales. The methodology used in UNDP's Human Development Index (HDI) (UNDP, 2006; Anandh, et al., 1994) is followed to normalize them. That is, in order to obtain figures which are free from the units and also to standardize their values, first indicators are normalized so that they all lie between 0 and 1. Before doing this, it is important to identify the functional relationship between the indicators and vulnerability. Two types of functional relationship are possible: vulnerability increases with increase (decrease) in the value of the indicator. Assume that higher the value of the indicator more is the vulnerability. For example, suppose we have collected information on change in maximum temperature or change in annual rainfall or diurnal variation in temperature. It is clear that higher the values of these indicators more will be the vulnerability of the region to climate change as variation in climate variables increase the vulnerability. In this case, the normalization is done using the following equation 1:

eq 1:

$$X_{ij} = \frac{X_{ij} - \underset{i}{\mathrm{Min}}\{X_{ij}\}}{\underset{i}{\mathrm{Max}}\{X_{ij}\} - \underset{i}{\mathrm{Min}}\{X_{ij}\}}$$

On the other hand, consider adult literacy rate. A high value of this variable implies more literates in the region and so they will have more awareness to cope with climate change. So the vulnerability will be lower For this case the normalized score is computed using the following equation 2:

eq 2:

$$X_{ij} = \frac{}{\underset{i}{\mathrm{Max}}\{X_{ij}\} - \underset{i}{\mathrm{Min}}\{X_{ij}\}}$$

It is clear that all these scores will lie between 0 and 1. The value 1 will correspond to that region with maximum value and 0 will correspond to the region with minimum value.

Normalized scores were calculated based on the above formula for Kosbevava, Thanrimalai and Medavacheliya hamlets of Thanthrimale GN division and yaya 2 and yaya 3 hamlets of Mahavilachchiya GN division. After computing the normalized scoresthe vulnerability index is constructed by giving equal weights to all indicators. For that, simple average method is used for all the normalized scoresto construct the vulnerability index by using the following equation 3:

eq3:

$$VI = \frac{\sum x_{ij}}{K}$$

Finally, the vulnerability indices are used to rank the different areas in terms of vulnerability. An area with highest index is said to be most vulnerable and it is given the rank 1, the area with next highest index is assigned rank 2 and so on. vulnerability indices and ranks of the areas are shown below (Table 3)

Table 3: Vulnerability Index and rank

GN Name	Village Name	sum of the scores	Vulnerability Index	Rank
Thanthrimale	Kosbevava	16.3307	0.8595	1
	Thanrimalai	13.1717	0.6932	2
	Medavacheliya	13.1572	0.6925	3
Mahavilachchiya	Yaya 2	3.2371	0.1704	5
	Yaya 3	5.6647	0.2981	4

Table 3 shows that vulnerability Index and rank of Mahavilachchiya and Thanthrimale GN divisions. This study explored that that Mahavilachchiya is less vulnerable compared with Thanthrimale. Exposures (changes in temperature and rainfall and extreme weather events) of both the areas are relatively same due to the same geographical location. so, effects of climate change could be similar. At the same time, sensitivity and adaptive capacity of the both areas demonstrate a vast diversity in term of socio-economic conditions.

Sensitivity is divided as human (rural population density) and livelihood (small scale farmers and paddy areas served by irrigation) in this study. it is dissimilarity in both study areas. Irrigation is a main source for agriculture during the dry period in dry zone of Sri Lanka. Irrigation potential (99 percent) is higher in Mahavilachchiya GN division than Thanthrimale GN division.Farmers of Thanthrimale face difficulties in drought period due tolack of irrigation potential. Sometimes, they have cultivated inMaha season only. But, Farmers of Mhavilachchiya have cultivated in both seasons (Maha and Yala) even though they face the drought. Small scale farmers (less than 1 ha land; 57 percent)are higher in Thanthrimale GN compared with Mahavilachchiya GN. If their agricultural products have ruined due to extreme events of climate change they difficult to overcome from that damage. So they become more vulnerable.

The lesser vulnerability of Mahavilachchiya is associated with many socio, economic backgrounds such as relatively higher access to technology, education level (secondary), better economic background, infrastructure, institutional links, and systematic irrigation potential. It has the highest access to technology which makes farmers of this region the highest in terms of proximity to insecticide, pesticides, and fertilizer supplies, and improved seeds supplies. As well as it has better institutional facilities and infrastructure, especially in health services, schools, communication, road and transportation facilities. Farmers of Mahavilacchiya are doing off farming activities like white collar jobs and also enjoying better socio-economic background. So they can beovercome as quickly as from effects of climate change.

Comparing with Mahavilachchiya, farmers in Thanthrimale have the lowest access to supplies of inputs as well as the education level most of the farmer are primary education or no schooling. Thanthrimale farmers' livelihood depend only primary income source (agriculture) and also their socio –economic background is very poor. hence, they face stress during the climate risk periods. Fig 1 shows the adaptive capacity of study areas.

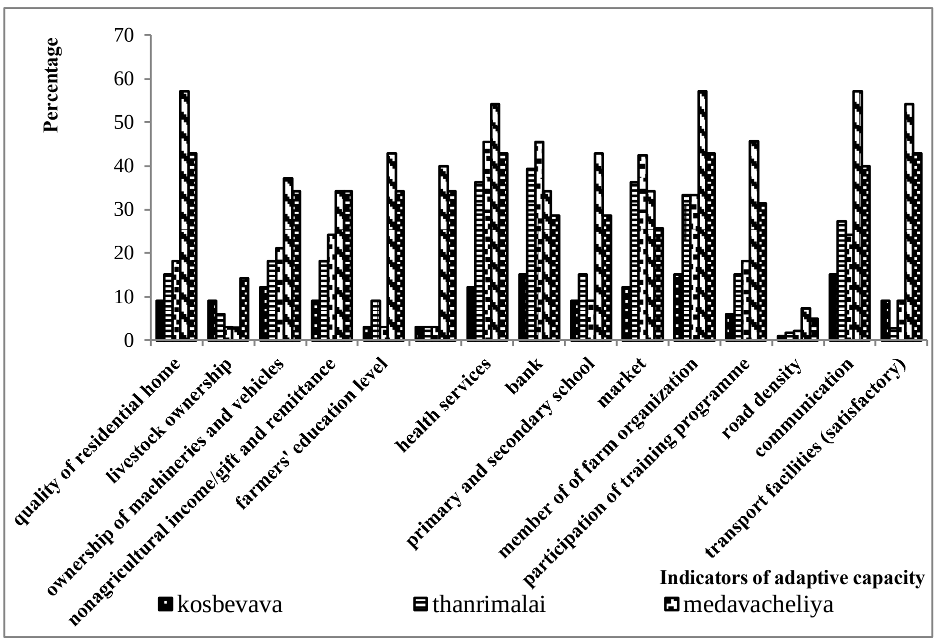

Figure 1: Indicators of adaptive capacity in study areas.

Above figure shows the indicators of adaptive capacity in both study areas. It is very clear that when considering the indicators comparatively, Mahavilachchiya have more potential to adapt when they face any climate risks. As mentioned earlier their socio, economic background is the main pillar for their potential. But according to the adaptive capacity indicators farmers are Thanthrimale are have very least indicators. Because of lack of adaptive capacity in farmers of Thanthrimale GN division causes to comparatively more vulnerable during the climate risk periods.

Conclusion and Recommendations

This study has calculated paddy farmer's vulnerability to climate change in Mahavilachchiya and Thanthrimale. Generally both irrigation and rain-fed farmers are vulnerable to changing climate but comparatively, farmers who cultivate rain-fed rice as a primary source of food and income are particularly vulnerable. The vulnerability index has been calculated based on the Intergovernmental Panel on Climate Change (IPCC) definition, which explains it as a function of adaptive capacity, sensitivity and exposure. The twentythree(23) socio-economic and environmental indicators of the Mahavilachchiya and Thanthrimale were included in developing the vulnerability index. Results indicated that Thanthrimale is relatively more vulnerable to climate change than Mahavilachchiya due to the poor economic background, technology, education and infrastructure. Frequency of drought and flood are slightly different in both areas. But Thanthrimale is affected by drought very severely due to the lack of irrigation potential. They find it difficult to overcome from this.

In order to reduce the paddy farmers' vulnerability to climate change and variability the following recommendations may be considered.

- Thanthrimale is more vulnerable when compared with Mahavillachchiya based on the vulnerability Index. This is due to the lack of education, infrastructure and information technology. Hence, relevant authorities must pay attention and take necessary action to overcome these disparities.
- Depending entirely on agriculture as a primary income source makes farmers more vulnerable particularly during climatic risk periods. Therefore, it is better to provide some off-farm trainings which can be used to earn some income especially during climatic risk period.
- In Thanthrimale, small tanks are scattered here and there which provide a limited amount of water for the agriculture of this area. There is possibility of enhancing the water storing capacity by improving small tanks that are identified.
- early warning systems to help farmers' better cope in times of drought and drought-tolerant varieties of crops can reduce the vulnerability of paddy farmers to climate change

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