Climate Vulnerability Analysis Facilitating Transformation of Watersheds in Kerala, India

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Abstract: Watershed Development Programmes (WDP) receive enormous attention due to their capacity to enhance production in rain-fed agriculture along with restoration of ecological balance and sustainability. Many of these programmes are questionable in terms of building climate change adaptation strategies among the rural poor in watershed areas. This paper analyses vulnerability towards climate change on watershed community level in Kerala, India. A case study was conducted in a watershed, which was implemented by a Non Governmental Organisation (NGO). Primary data was collected using the Rapid Appraisal of Agricultural Knowledge System methodology with its main instruments household surveys, focus group discussions, key informant interviews and personal interviews with various stakeholders. Vulnerability due to climate variability is assessed by developing a Climate Vulnerability Index (CVI) which employs both qualitative and quantitative data. The composite index comprises of three dimensions of vulnerability - adaptive capacity, sensitivity, exposure -, and its ten major components: socio-demographic profile, socio-economic assets, agricultural, livelihood, social networks, health, food, water, climate variability and natural disasters. As a main result, the vulnerability due to adaptive capacity indicators/subcomponents holds the highest value among the three dimensions of climate vulnerability. This implies an urgent need for location specific micro level planning of the watershed programmes with emphasis on activities to address water scarcity, soil and water conservation, farm diversification, production enhancement and livelihood alternatives for better coping strategies and resilience.

Keywords: Adaptive capacity, CVI, climate change, sensitivity, watershed development

1. Introduction

According to the Maplecroft (2015) Climate Change Vulnerability Index, which evaluates the sensitivity of populations, the physical exposure of countries, and the governmental capacity to adapt to climate change over the next 30 years, India stands second among the growth economies under extreme risk category. The Centre for Climate Energy Solutions (2015) report states that India is the fourth largest greenhouse gas emitter, accounting for 5.8% of global emissions.

In India, 53% of the population depend on agriculture for their living. Among these, 55% of farmers rely on rain-fed systems in which "delayed, deficient or erratic rains" lead to a severe reduction in production and productivity with resource misutilisation and degradation (Planning Commission, 2012). These rain-fed areas constitute 62% of the total geographic area of the country which produce 40% cereals and 85% pulses to support 40% human and 60% livestock population (Planning Commission, 2012).

The Indian Watershed Development (WSD) programme is one important strategy to adapt with climate variability and extreme climate events and thus to build adaptive capacity and resilience among the rural communities especially in rain fed areas. According to Samuel et al. (2015), "Watershed Development is a multi-sectoral intervention aimed at enhancing the potential of ecosystem resources and the socio-economic situation of the community in a specific landscape unit". Various studies on watershed impact evaluation reveals WSD programmes have the capacity to reduce the risk associated with rain fed agriculture and as a tool for disaster management (Gandhi and Crase, 2012; Kerr, 2007).

Previous climate change studies conducted in India focus on gender based adaptation to climate change (Bokhoree et al. 2012), climate variability and farmer's vulnerability in flood prone district of Assam (Chaliha et al. 2012) climate vulnerability assessment in Himalayan communities (Pandey and Jha, 2012; Aryal et al. 2014), perception and knowledge level of climate issues (Nirmala and Aram, 2015) and climate change impacts on coastal ecosystem (Arul and Arul, 2015). However it is widely accepted that climate vulnerability studies should explore the socio-economic and institutional factors in depth (Gbetibouo et al. 2010) at local level (Vincent and Cull, 2010), integrate the sustainable livelihood approach and addresses the issue of sensitivity and adaptive capacity to climate change to a certain extent (Hahn et al. 2009). There is enormous heterogeneity within the districts with respect to resource access, poverty and coping strategies (Gbetibouo et al. 2010) so assessments at more disaggregated levels or at community level or to evaluate the potential programme/ policy effectiveness must be done (Hahn et al. 2009). Moreover, Wisner (2010) suggests integration of climate change in to ongoing efforts to give special attention to location specific knowledge for better adaptation strategies.

There is a large number of literature on climate vulnerability assessments which develop many indicators. Practical applications with an active involvement of community stakeholders are rarely undertaken. According to Smit and Wandel (2006) participatory vulnerability assessments enable recognition of multiple stimuli beyond climate and include political, cultural, economic, institutional and technological forces over time, scale and individuals.

The aim of this paper is to assess the climate vulnerability through a participatory bottom-up approach coupled with the development of a vulnerability index at watershed community level. This approach involves active participation of various stakeholders, integration of information from multiple sources (Smit and Wandel, 2006) and triangulation. The selected watershed programme has been implemented by one of the NGOs in Kerala state of India. This approach aims to bridge the gaps at the microlevel planning and implementation by recognising the importance of governance, equity, priorities of the vulnerable sections, expected risks and benefits along with diverse perceptions to various climatic shocks and policy making.

2. Methodology

2.1 Description of the study area

Kerala, the south western state in India, is severely threatened by climate change. It is unique in social, economic, environmental and physical conditions such as high population density, integrated farming system, humid tropical monsoon with excessive rainfall, and hot summers (Government of Kerala, 2014). Kerala is known as the “Gate way of the summer monsoon” to India and it is one of the wettest places in the world, where annual rainfall is of the order of 3000mm (Raj and Azeez, 2010). Homestead farming is a key feature of land use in this area, which includes a large number of species grown such as spices, medicinal plants, plantation trees, fruit plants, vegetables and tuber crops. In recent years, there is a major shift in rainfall pattern in Kerala, with significant decreases of the southwest monsoon (Guhathakartha and Rajeevan, 2008; Krishnakumar et al. 2009; Nikhil Raj and Azeez, 2012), and increases of the northeast monsoon in Kerala (Krishnakumar et al. 2009).

Palakkad is listed as one of the highly vulnerable districts to climate change in Kerala due to its specific geographic location, humid climate, high percentage of population relying on agriculture, a low ranking in the human development index, high social deprivation and a high degree of vulnerability to natural hazards like flood and drought with impacts on biodiversity and human life (Government of Kerala, 2014).The annual rainfall in this region is comparatively lesser than other parts of the state. Daytime temperatures often exceed 40°C in Palakkad with reports of severe sunburn in 2010 (Gopakumar, 2011).

The watershed selected for the study was Akkiyampadam watershed. It was implemented by The Peoples Service Society NGO in Kerala. The Akkiyampadam watershed lies between10° 58’ 13” to 11° 00’ 10” N and 76° 29’ 27” to 76° 31’ 06” E, located in Kanjirampuzha Grama Panchayat (bottom level self government institution in Kerala). The treatable watershed area is 520 ha. The main soil types include Laterite and Red soil. Important water holding structures in the area are open wells, borewells, tanks and ponds. Farmers cultivate coconut, cashew, arecanut, paddy rice, rubber, banana, pepper, vegetables and tapioca. 92% of the farmers are marginal farmers with <1 ha of landholdings and are depend on subsistence farming.

2.2 Vulnerability framework

This part of the paper develops the conceptual framework to analyse the components of vulnerability and their relations. Vulnerability assessment is a common tool for indicating the potential for harm to occur within human and ecological systems in response to global climate change (Fussel and Klein, 2006).Vulnerability thereby is "…the degree to which a system is susceptible to, or unable to cope with, the adverse effects of climate change, including climate variability and extremes" (Fellmann, 2012). Moreover, vulnerability is an "… integrated measure of the expected magnitude of adverse effects to a system caused by a given level of certain external stressors" (Preston et al. 2011). This external dimension is represented as *exposure* which relates to "the nature and degree to which a system is exposed to significant climatic variations". The *sensitivity* of a system to climate change reflects the "degree to which a system is affected, either adversely or beneficially, by climate variability or change" (Fellmann, 2012). It shows the "responsiveness of a system to climate change" (IPCC, 2007). Sensitive system is affected by even small climatic variations. Adaptive capacity is the ability of a system to adjust to climate change to moderate potential damages, to take advantage of opportunities, or to cope with the consequences (Fellmann, 2012). It is intrinsically linked with socio-economic factors of the system with other determinants such as institutions, knowledge and technology (Adger et al. 2007). *Adaptation* is the adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities.

Measurement of vulnerability includes social processes as well as material outcomes within the system (Adger, 2006), which makes the quantification process difficult. The Climate Vulnerability Index (CVI) used here is developed based on the framework given in Figure 1. It implies that "a system is vulnerable if it is exposed and sensitive to the effects of climate change and at the same time has only limited capacity to adapt" (Mearns and Norton, 2010). On the contrary, a system is less vulnerable if it is less exposed, less sensitive or has a strong adaptive capacity (Smit and Wandel, 2006). Therefore, building adaptive capacity enables communities to mobilise resources needed to reduce vulnerability and adapt to climate change (Nelson et al. 2007).

The approach places importance on local community level knowledge and facilitate integrative, consultative and gender sensitive participation of all sectors of stakeholders in WSD programmes to express the impact and extend of climate variability. The Climate Vulnerability Index is based on three dimensions of vulnerability and its ten components as given in the Figure 1.

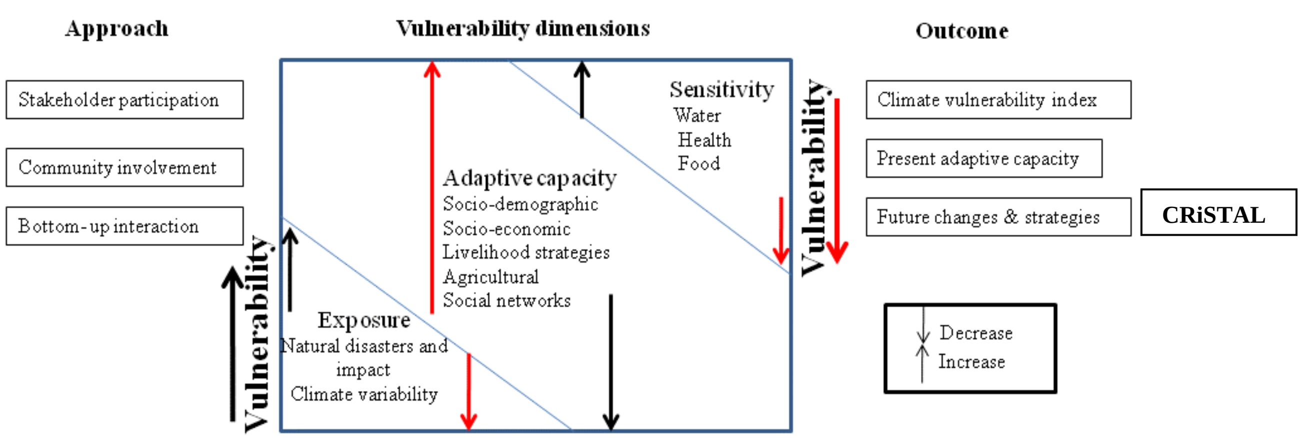

Figure 1. Framework for participatory climate vulnerability analysis

The CRiSTAL (Community based Risk Screening Tool-Adaptation and Livelihoods) allow to analyse existing activities and the extent to which the community resources are influenced by the climate hazards. The final analysis helps to propose actions and adaptation strategies for affected communities and resources. The CRiSTAL will be used in the later part of this research.

2.3 Vulnerability index

Climate vulnerability is multidimensional with complex interrelationships of multiple factors which are difficult to quantify. The proposed CVI includes three different dimensions: adaptive capacity, sensitivity and exposure. Each dimension comprises of major components and under which relevant indicators or subcomponents specific to the watershed area are included. The selection of subcomponents and indicators is very crucial in developing such an index with validity and reliability. The selected indicators were then pretested and checked within key informant interviews. Here, under adaptive capacity dimension there are five major components namely socio-demographic profile, socioeconomic assets, livelihood strategies, agricultural and social networks. The major components and its subcomponents are depicted in Table 1. For calculating CVI, each major component contributes equally to the overall index (Hahn et al. 2009) while each major component is calculated based on weighted average approach (Sullivan et al. 2002). The functional relationship of each subcomponent/indicator is considered whether it contributes positively or negatively to the overall vulnerability. For subcomponent/indicators with a negative relationship it has been hypothesized to decrease the vulnerability and calculated the hypothesised value by using (100-index value). The subcomponents/indicators are measured on different scales, and were therefore normalized between 0 and 1 so as to bring the values within a comparable range and thus to form an index (Hahn et al. 2009).

Table 1. Climate vulnerability index: Dimensions, major components and subcomponents

Dimensions of vulnerability	Major components	Subcomponents/indicators	Explanation of subcomponents
	Socio-demographic profile	Family dependency index	Ratio of population between 0-14 years and population of 60 years & above to the population between 15-59 years
		House type diversity index	Simpson's diversity index (1-D)[#]
		Family Decision Index	Percentage of literate household head
		Poverty index	Percentage of families below poverty line
		Indebtedness index*	Percentage of families with debt
		Percent of high income households	Percentage of households with income of >2250 $/year
		Percent of male headed households	Percentage of households with male as head of the family
		Religious diversity index	Simpson's diversity index (1-D)[#]
	Socio-economic assets	House hold asset possession index	Inverse of (household asset+1)
		Farm asset possession index	Inverse of (farm asset +1)
		Average farm holding size	Average land holding size[§]
		Percent of households with own water holding structures	Percentage of households with at least one water holding structure

ADAPTIVE CAPACITY	Livelihood strategies	Migration	Percentage of households in which at least one member migrated for better income
		Percent of households introduced new crop	Percentage of households introduced at least one new crop in farming
		Percent of households solely depend on Agriculture for income	Percentage of households with agriculture as the only source of income
		Farm diversification index	Inverse of (types of enterprises+1)
		New livelihood strategies adoption	Percentage of households which adopted new livelihood strategies since last five years
		Percent of households introduced livestock	Percentage of households which adopted livestock in farming since last five years
	Agricultural	Percent of rainfed farming	Percentage of households which has not following any irrigation methods
		Percent of net sown area	Percentage of cultivated land area
		Crop diversification index	Inverse of (types of crops+1)
		Percent of households adopt new varieties	Percentage of households which introduced new varieties in farming
		Decline in Farm production	Percentage of households reported decreasing trend in farm production
		Soil erosion perception index	Percentage of households opined moderate to severe soil erosion in their land
		Non adoption of Soil and water conservation works	Percentage of households where farmers not adopted any soil and water conservation works
		Households with <0.2 ha of land	Percentage of households with less than 0.2 ha of land
	Social networks	Percent of beneficiaries	Percentage of households received benefits from the WSP
		Cooperation	Percentage of households provided help to others during distress
		Percent of households with Membership in co-operative institutions	Percentage of households which has membership in societies
		Percent of households received help from others	Percentage of households which received assistance
		Watershed committee membership	Percentage of households with members in WS committee
		No beneficiary contribution	Percentage of Farmer's not contributed any beneficiary share
		Percent of households lack ICT access	Percentage of households with no access to ICT
		Participation in Grass root planning	Percentage of Farmers participated in Grass root planning
		Trainings	Percentage of farmers received training on climate change
SENSITIVITY	Water	Water scarcity	Percentage of households with problems of drinking water during summer
		Dependency on water resources	Percentage of households depend on other's water resources
		Public water sources	Percentage of households depend on Public tap for drinking water
		Groundwater decline	Percentage of households reported decrease in Ground water
		Gender inequality	Percentage of households where female fetch potable water
		Decreased availability of water	Percentage of households reported decreased availability of water

	Health	Water resource depletion index	Percentage of households reported severe depletion of water resources
		Waterborne diseases	Percentage of households reported waterborne diseases to the family
		New disease incidence	Percentage of households reported with new disease
		Poor quality drinking water	Percentage of households reported decreased quality of drinking water
		Sunburn	Percentage of households with Sun burn problems reported
	Food	Death due to climatic variabilities	Percentage of households with death due to climate variations
		Off-farm dependency	Percentage of households depends only on off farm for food
		Food insufficiency	Percentage of households reported food insufficiency
EXPOSURE	Natural disaster & impact	Poor support from Govt.	Percentage of households reported poor support from Govt. through PDS
		Death or injury due to natural disaster	Percentage of households with death or injury due to natural disaster
		Crop loss	Percentage of households reported crop loss
		Housing or property damage	Percentage of households reported housing or property damage
	Climate variability	Heavy wind	Percentage of households reported heavy wind
		Temperature increase perception	Percentage of households reported very High temperature increase
		Hot months increase perception	Percentage of households reported hot months increase
		Erratic rainfall perception	Percentage of households reported erratic rainfall
		Less rainy days perception	Percentage of households reported less rainy days
		Extreme climate events	Percentage of households reported atleast one extreme climate event

Following, the values of each subcomponent/indicator are normalized using the equation (Eq. 1).

$$Index_{sw} = \frac{S_w - S_{min}}{S_{max} - S_{min}} \qquad \text{(Eq. 1)}$$

where,

$S_w$is the original subcomponent/indicator value for the watershed community,

S_{min} and $S_{max}$are the minimum and maximum values for the subcomponent/indicator.

After the standardization, each subcomponent/indicator is averaged to calculate its value.

$$M_w = \frac{\sum_{i=1}^{n} Index_{swi}}{n} \qquad \text{(Eq. 2)}$$

where,

M_w is one of the major components under the three dimensions of vulnerability,

$Index_{swi}$is the subcomponent value of the watershed community and

n is the number of subcomponents under major component

After calculating the major component, the next step is assigning weights. The balanced weighted approach[33, 14] has been used in this study. The number of subcomponents under major components has been taken as the weight for calculating the index for major components. For example the index for Adaptive capacity (Ada. cap), Sensitivity (Sen) and Exposure (Exp), has been calculated according to Eqs. 3, 4 and 5:

$$Ada.cap=\frac{W_{a1}SD+W_{a2}SE+W_{a3}LS+W_{a4}A+W_{a}SN}{W_{a1}+W_{a2}+W_{a3}+W_{a4}+W_{a5}} \qquad Eq.\ 3$$

Where,
W_{a1}, W_{a2}, W_{a3}, W_{a4}, and W_{a5} are the weights for socio-demographic profile, socio-economic assets, livelihood strategies, agricultural and social network, respectively.

$$Sen = \frac{W_{s1}H+ W_{s2}F+ W_{s3}Wa}{W_{s1}+W_{s2}+W_{s3}} \qquad Eq.\ 4$$

where,
W_{s1}, W_{s2}, and W_{s3} are the weights for the components health, food and water, respectively.

$$Exp = \frac{W_{e1}ND+ W_{e2}CV}{W_{e1}+W_{e2}} \qquad Eq.\ 5$$

where,
W_{e1} and W_{e2} are the weights for natural disaster and climate variability respectively. The indicator values vary between 0 and 1and may be interpreted as 0 for least vulnerable and 1 for the most vulnerable.

Then the overall index for vulnerability can be expressed as

$$CVI_{W}=\frac{\sum_{i=1}^{10} W_{mi}M_{wi}}{\sum_{1=1}^{10} W_{mi}} \qquad Eq.\ 6$$

where,
W_{mi} is the weight and
M_{wi} is the average value of each subcomponent.

2.4 Data collection

The selection criterion for the watershed was the one which completed the project activities before the year 2014 and for this we contacted the Western Ghat Development Cell, Palakkad.

The Akkiyampadam watershed began in 2009 and completed the activities in 2013. The household interviews were conducted by us in August- September 2015 with the help of an assistant to survey within the watershed boundaries. Once arrived in the village, the Community Development Society members, the Grama Panchayat Secretary, and elected Grama Panchayat members were consulted to explain the purpose of the study and to obtain preliminary information regarding implemented programme. Cluster sampling method was used in the selection of farm households i.e formed clusters of small, medium and large farmers (n=70) based on the primary and secondary data collected from Agricultural Office of the watershed area. Maximum care has taken to ensure participation from different levels of respondents: farmers, landless, labourers, self-help group members and women during data collection. A few key informant interviews were conducted namely with Panchayat President, Agricultural Officer, elected members of Panchayat, Community Development Society member of women self-help group, progressive farmers and secretary of the watershed committee to study about their role, extend of participation and contribution in the planning and implementation of the programme. Two focus group discussions were conducted with men and women group each to get an overview about existing problems, alternative solutions, future expectations on climate variability risk mitigation and adaptation strategies.

3. Results and discussion

Table 2 shows results of the subcomponents/indicator values, hypothesized values, normalized values, and the average indicator values at the watershed community. Under socio-demographic components, there are eight subcomponents and among these, religious diversity index holds the highest value (0.905) because there is heterogeneity in the belief system and people belong to three different religions i.e. Hindus, Christians and Muslims. This may create difference in opinion and disagreement among the community member in developmental issues. The family decision index (0.100) contributes least to the socio-demographic vulnerability indicator because 90% of the household heads are literate which shows the progressive nature of the community. The family dependency index (0.505) shows a high value with 33% of the household members depends on others in the family for their means of living. Furthermore, 37.14% of the households are below poverty line while rural poverty for the whole state is 7.3% (Government of Kerala, 2012). It clearly depicts the economic deprivation of the area, which has a positive functional relationship to the climate vulnerability.

Table 2.Normalised values of indicators with average indicator values of major components

Major components	Indicators/subcomponents	Akkiyampadam			Average indicator
		Value	Hypothesized	Normalised	
Socio-demographic profile	Family dependency index	0.50	0.50	0.505	0.517
	House type diversity index	0.58	0.58	0.580	
	Family Decision Index	90.00	10.00	0.100	
	Poverty index	37.14	37.14	0.371	
	Indebtedness index	65.71	65.71	0.657	
	Percent of high income households	11.40	88.60	0.886	
	Percent of male headed households	87.14	12.86	0.129	
	Religious diversity index	0.90	0.90	0.905	
Socio-economic assets	House hold asset possession index	0.16	0.16	0.160	0.156
	Farm asset possession index	0.47	0.47	0.468	
	Average farm holding size	0.37	0.37	-0.105	
	Percent of households with own water resources	90	10	0.1	
Livelihood strategies	Migration	2.86	2.86	0.029	0.579
	Percent of households introduced new crop	5.71	94.29	0.943	
	Percent of households solely depend on Agriculture for income	5.71	5.71	0.057	
	Farm diversification index	0.69	0.69	0.69	
	New livelihood strategies adoption	12.86	87.14	0.871	
	Percent of households introduced livestock	11.43	88.57	0.886	
Agricultural	Percent of rainfed farming	42.9	42.9	0.429	0.488
	Percent of net sown area	90.16	9.84	0.098	
	Crop diversification index	0.42	0.42	0.420	
	Percent of households adopt new varieties	1.43	98.57	0.986	
	Decline in farm production	8.60	8.60	0.086	
	Soil erosion perception index	44.29	44.29	0.443	
	Non adoption of soil and water conservation works	75.71	75.71	0.757	
	Households with <0.2 ha of land	68.57	68.57	0.686	
Social networks	Percent of beneficiaries	45.71	54.29	0.543	

	Cooperation	12.86	87.14	0.871	
	Percent of households with Membership in co-operative institutions	80.00	20.00	0.2	
	Percent of households received help from others	5.71	94.29	0.943	
	Watershed committee membership	5.71	94.29	0.943	
	No beneficiary contribution	0.00	0	0.000	
	Percent of households lack ICT access	91.43	8.57	0.086	
	Participation in grass root planning	7.14	92.86	0.929	
	Trainings	1.43	98.57	0.986	
Water	Water scarcity	40.00	40.00	0.4	0.471
	Dependency on water resources	10.00	10.00	0.1	
	Public water sources	2.86	2.86	0.029	
	Groundwater decline	54.30	54.30	0.543	
	Gender inequality	100.00	100.00	1	
	Decreased availability of water	25.70	25.70	0.257	
	Water source depletion index	97.14	97.14	0.971	
Health	Waterborne diseases	0.00	0.00	0	0
	New disease incidence	0.00	0.00	0	
	Poor quality drinking water	0.00	0.00	0	
	Sunburn	0.00	0.00	0	
	Death due to climatic variabilities	0.00	0.00	0	
Food	Off-farm dependency	42.86	42.86	0.429	0.462
	Food insufficiency	1.43	1.43	0.014	
	Poor support from Govt.	94.30	94.30	0.943	
Natural disaster & impact	Death or injury due to natural disaster	0.00	0.00	0	0.011
	Crop loss	4.29	4.29	0.043	
	Housing or property damage	0.00	0.00	0	
	Heavy wind	0.00	0.00	0	
Climate variability	Temperature increase perception	94.30	94.30	0.943	0.749
	Hotmonths increase perception	92.90	92.90	0.929	
	Erratic rainfall perception	91.40	91.40	0.914	
	Less rainy days perception	91.40	91.40	0.914	
	Extreme climate events	4.29	4.29	0.043	

The socio-economic vulnerability of the area contributes less to the overall vulnerability index. The farm asset possession index (0.468) is the highest contributing factor to the socio economic vulnerability. The average farm holding size is 0.37 ha which is more than the per capita availability of land in the state of Kerala is 0.23 ha (Government of Kerala, 2012). 90.00% of the households possess their own water holding structures for routine activities, which contribute positive to the adaptive capacity.

The Livelihood strategy component has a major share (0.579) in the vulnerability value because households are reluctant to adopt new crops and even in farm diversification. Even in the midst of these negativities, only 5.7% of the farmers depend solely on agriculture for income.

The agricultural vulnerability status also indicates higher value (0.488) with less adoption in new varieties and crop diversification. The soil erosion perception index (0.443) shows the awareness of the households about soil erosion in the watershed area. Many of them complained about medium-severe soil erosion despite only 75.71% of the households adopted soil and water conservation measures in their fields. One of the main objectives of the WSD programme is soil and water conservation and it shows the pitfalls in facilitating adoption of such activities in the farmer's field or common land.

Eventhough, the social networking status (0.611) contributes higher value towards overall climate vulnerability, 80% of them are members in cooperative societies. Nearly half of the households received benefits from the programmes and all of them paid beneficiary contribution either in terms of money or kind. Over the last two decades, decentralized planning has been institutionalized in Kerala with the 'Panchayati Raj' system of administration and implementation. Despite of this, only 7.14% of the households participated in the grass root level planning. The households expressed reluctance to opine that they received help from others. Only 5.7% admitted that they seek help from neighbours, family members or governmental institutions.

Among the sensitivity major components, water contributes the highest (0.471) to the average vulnerability. 40% of the households face scarcity of water during drought season, the scarcity period varies between 2-6 months. These households depend on neighbour's well or public tap for drinking water during this period and water fetching is the sole responsibility of women in the house. 54.30% of the households reported decline in groundwater compared to past years. Severe depletion of natural water sources (0.971) also play a key role in contributing to the sensitivity dimension.

Health components show a positive trend to increase the resilience of watershed communities. There were no new disease incidence, waterborne diseases and complaints on poor quality drinking water.

Among food components, poor support from the government (0.943) contributes the highest to the average vulnerability (0.462). Only a very small percentage of households (1.43%) reported food insufficiency which also contributes positively to the resilience of the community. Natural disasters due to extreme events were not reported in the area since last five years.

Climate variability perceptions was more pronounced in temperature (0.943) and hot months perception indices (0.929). The extreme climate events perception index (0.043) is very less while erratic rainfall perception (0.929) and contributes to climate variability major component. The vulnerability due to adaptive capacity holds the highest value (0.504) while the sensitivity of the community is indexed as the least with value 0.312 and is plotted in Figure 2.

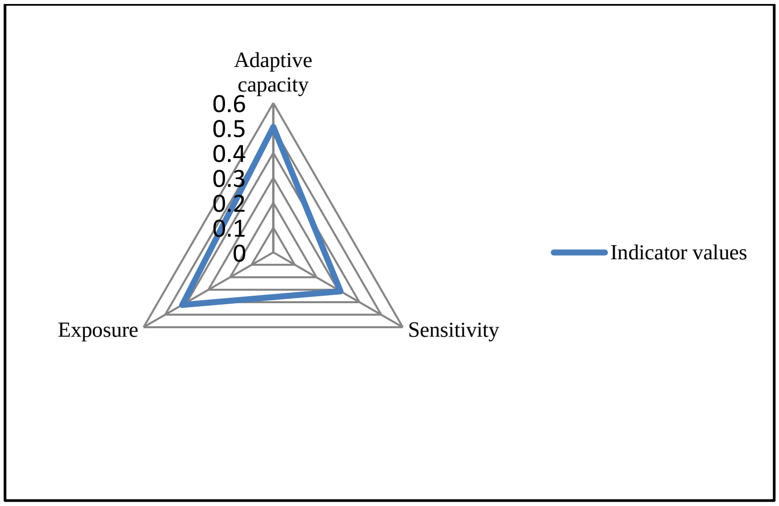

Figure 2. Vulnerability triangle diagram of the three dimensions of Climate Vulnerability Index (CVI)

The vulnerability of Akkiyampadam watershed is 0.443 and it is hypothesised that the CVI value varies between 0 and 1 in the analysis. The CVI for a single watershed can be expanded to comparative CVI assessment of multiple watersheds to provide deeper insights in to the three dimensions. This will be carried out in future part of the research.

4. Conclusion

The study quantitatively evaluated the climate vulnerability at watershed community level in one of the highly vulnerable districts of Kerala state. First and foremost, despite the watershed programme aims for livelihood support system, group mobilisation and production system improvement, vulnerability due to social networks and livelihood strategies contributes the highest to the adaptive capacity vulnerability dimension. Policy makers should give priority to develop location specific policies and thus to address climate change and variability at the bottom level. Socio-demographic profile vulnerability reveals that, priority should be given to incorporate more income generating activities to address rural poverty and indebtedness.

The farmers in the watershed area are very reluctant to adopt new crops, varieties and livestock into their farming. It may be solved by enacting measures to promote new crops suited to the agro-climatic conditions, drought resistant varieties and stimulate diversification of farm and livelihoods while formulating the action plans for implementation of the watershed programmes. Moreover, the programme aims on soil and water conservation measures while few farmers perceive the importance of soil erosion and adoption of such activities. This can be addressed

through conducting more awareness programmes to convey the importance of protecting natural resources for present and future generations. Water scarcity and depletion of natural resource are major contributing components to the overall sensitivity of the watershed area. Kerala is the state which receives the highest average rainfall and even in the midst of plenty of water, many regions faces extreme water scarcity. Indeed this should be considered as one of main agenda in future to include, for example rainwater harvesting structures in the WSD programme.
Limitations of our study include the subjectivity in selection of subcomponents and the direction of relationship between the subcomponents and vulnerability. This will be addressed by applying Principal Component Analysis in the future work of this research. In this context, we could just conclude with the value of CVI, but also comparison to other watersheds is needed to place results in a larger context.

Acknowledgement

We would like to gratefully acknowledge funding from DAAD (ST42- for Development-Related Post Graduate Courses, 50077057 & PKZ: 91538032) for conducting this research.

References

1. Adger, W. N. (2006). Vulnerability. *Global Environment Change,* 16(3), 268–281.
2. Adger, W. N., Agrawala, S., Mirza, M. M. Q., Conde, C., O'Brien, K., Pulhin, J., Pulwarty, R., Smit, B., & Takahashi, K. (2007). Assessment of adaptation practices, options, constraints and capacity. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 717-743.
3. Arul, A. I., & Arul, C. (2015). Climate Change and Coastal Eco-System, Review paper, *Journal of Environmental Research and Develop*ment, 10 (2), 353-359 .
4. Aryal, S., Cockfield, G., & Maraseni, T. N. (2014). Vulnerability of Himalayan transhumant communities to climate change. *Climate Change*, 125 (2), 193–208.
5. Bokhoree, C., Baldeo, R., Thomas, D. D., & Ramprosand, S. (2012). Gender based adaptation to climate change impacts on water resources: an analysis of the working personnel behavior. *Journal of Environmental Research and Development,* 6(3), 534-544.
6. Center for Climate and Energy Solutions. (2015). India's Climate and Energy Policies, retrieved on 09.04.16 www.c2es.org/docUploads/india-factsheet-formatted-10-2015.pdf.
7. Chaliha, S., Sengupta, A., Sharma, N., & Ravindranath, N. H. (2012). Climate variability and farmer's vulnerability in a flood-prone district of Assam. *International Journal of Climate Change Strategies Management*, 4 (2), 179–200.

8. Fellmann, T. (2012). The assessment of climate change-related vulnerability in the agricultural sector: reviewing conceptual frameworks, *Building Resilience for Adaptation to Climate Change in the Agriculture Sector*, *23*, 37-61.
9. Fussel, H. M., & Klein, R. J. T. (2006). Climate change vulnerability assessments: an evolution of conceptual thinking. *Climatic Change,* 75, 301–329.
10. Gandhi, V. P., & Crase, L. (2012). Determinants of Institutional Performance in Watershed Management: A Study of the Nature and Performance of Watershed Development Institutions in Andhra Pradesh, India. In 2012 *Conference (56th),* February 7-10, 2012*, Freemantle, Australia*. Australian Agricultural and Resource Economics Society.
11. Gbetibouo, G. A., Ringler, C., & Hassan, R. (2010). Vulnerability of the South African farming sector to climate change and variability: An indicator approach. *Natural Resource Forum*, 34, 175–187.
12. Gopakumar, C. S. (2011). Impacts of climate variability on agriculture in Kerala. Cochin University of Science and Technology.
13. Government of Kerala. (2012). Economic Review, Kerala State Planning Board, Trivandrum, http://spb.kerala.gov.in/images/er/er15/index.html.
14. Government of Kerala. (2014). Kerala State Action Plan on Climate Change, Department of Environment and Climate Change, Kerala.
15. Guhathakurta, P., & Rajeevan, M. (2008). Trends in the rainfall pattern over India. *International Journal of Climatoogy*, 28(11), 1453–1469.
16. Hahn, M. B., Riederer, A. M., & Foster, S. O. (2009). The Livelihood Vulnerability Index: A pragmatic approach to assessing risks from climate variability and change—A case study in Mozambique. *Global Environmental Change*, 19(1), 74–88.
17. IPCC. (2007). Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, (M. L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 976pp.
18. Kerr, J. (2007). Watershed management: lessons from common property theory. *International Journal of Commons,* 1 (1), 89–110.
19. Krishnakumar, K. N., Prasada Rao, G. S. L. H. V., & Gopakumar, C. S. (2009). Rainfall trends in twentieth century over Kerala, India. *Atmospheric Environment, 43*(11), 1940–1944.
20. Maplecroft. (2015). Climate Change and Environmental Risk Atlas 2015, Available on: http://maplecroft.com/portfolio/new-analysis/2014/10/29/climate-change-and-lack-food-security-multiply-risks-conflict-and-civil-unrest-32-countries-maplecroft/.
21. Nelson, D. R., Adger, W. N., & Brown, K. (2007). Adaptation to Environmental Change: Contributions of a Resilience Framework. *Annual Review of Environmental Research, 32*(1).

22. Nikhil Raj, P. P., & Azeez, P. A. (2012). Trend analysis of rainfall in Bharathapuzha River basin, Kerala, India. *International Journal of Climate*, 32(4), 533–539.
23. Nirmala, T., & Aram, A. I. (2015). Perception on and Knowledge Level of Climate Change Issues among Educated Adults in Chennai City, India. *Journal of Environmental Research and Development,* 10(1), 1- 6.
24. Pandey, R., & Jha, S. (2012). Climate vulnerability index - measure of climate change vulnerability to communities: a case of rural Lower Himalaya, India. *Mitigation Adaptation Strategies for Global Change*, 17(5), 487–506.
25. Planning Commission. (2012). Final report of minor irrigation and watershed management for the 12th five year plan (2012-2017), Government of India, New Delhi.
26. Preston, B. L., Yuen, E. J., & Westaway, R. M. (2011). Putting Vulnerability to Climate change on the Map: A Review of Approaches, Benefits and Risks, *Sustainability Sci*ence, 6, 177-202.
27. Raj, P. P. N., & Azeez, P. A. (2010). Changing rainfall in the Palakkad plains of South India. *Atmósfera*, 23(1), 75–82.
28. Samuel, A., Lobo, C., Zade, D., Srivatsa, S., Phadtare, A., Gupta, N., & Raskar, V. (2015). Watershed Development, Resilience and Livelihood Security: An Empirical Analysis, WOTR, Pune.
29. Smit, B., & Wandel, J. (2006). Adaptation, adaptive capacity and vulnerability. *Global Environmental Change,* 16 (3), 282–292.
30. Sullivan, C. A., Meigh, J. R., & Fediw, T. S. (2002). Derivation and Testing of Water Poverty Index phase 1, Final report, Department for International Development, UK.
31. Vincent, K., & Cull, T. A. (2010) Household Social Vulnerability Index (HSVI) for evaluating adaptation projects in developing countries. In *PEGNet*conference 2010*:* Policies to foster and sustain equitable development in times of crises, 2010 (pp. 02–03).
32. Wisner, B. (2010). Climate change and cultural diversity. *International Social Science Journal*, 61(199), 131–140. doi: 10.1111/j.1468-2451.2010.01752.x.