Climate Change Resilience of Farmers of South West Coastal Bangladesh

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***Abstract*-Resilience and vulnerability are very much interlinked with each other in context of climate change. Resilience is measured by subtracting indexed vulnerability from ability to absorb shocks. Multiple regression analysis is used to identify determinants of resilience. It is observed that resilience index is the highest for households that have lower vulnerability and decreases slightly with increasing vulnerability. About 11% of households have very high resilience while around 9% has very low resilience to climate change. Multiple regression analysis has showed that land holding, livestock, income from agriculture, radio/mobile, irrigation, saving, infrastructure like school and market significantly increases the resilience. The increase in land holding, on-farm and off-farm income, livestock and radio/mobile possession will increase the resilience with the coefficient of 0.47, 0.82, 0.96, 0.51 and 0.2 respectively having p-value of 0.00. Saving money will significantly increase the resilience with the coefficient of 0.11 and p-value of 0.09, nearness of infrastructure like school and market will significantly increase the resilience with the coefficient of -0.18 and -0.17, respectively with p-value of 0.03 and 0.02. The analysis shows that analyzing only from the perspective of vulnerability will only show the households as mere sufferer but will not capture their capability. Further understand from resilience point of view will also capture their capability to observe those shocks.**

***Keywords*- Climate Change, Vulnerability, Resilience, Regression analysis, Farmers, Southwest coastal Bangladesh**

I. INTRODUCTION

Climate change is posing challenges to human as well as natural system especially in the least developed countries. The impact of climate change differs according to different regions and environmental condition. The developing countries are more vulnerable to climate change as they lack resources for adaptation [1]. Vulnerability is not only dependable on the effect of climatic stress but also on socio-economic structure, which mainly contributes to adaptive capacity and sensitivity [2]. There has been number of studies regarding vulnerability in different sectors such as water, agriculture and taking different aspect such as socio-economic, environmental and so on. To understand local level vulnerability, there is need to take account the household level vulnerability which will help to tackle climate change problems by better understanding their needs [2]. On the other hand, resilience to climate change is important issue to understand the farmers' ability to deal with the climatic stresses and disturbances. The study uses the integrated assessment approach, which combines both socio-economic vulnerability as well as biophysical vulnerability.

There are different methods and practices for combining socioeconomic and environmental indicators. For first instance, it is considered that all indicators of vulnerability have equal importance and thus equal weight [3]. The second approach includes using different weights for different indicators. This approach includes different methods like expert judgment, PCA and so on. Principal component analysis is used in this study as it identifies the similarities and differences in the data [4]. The analysis of vulnerability to climate change in this research is based on integrated assessment method taking into consideration of both socioeconomic and environmental aspect.

Resilience and vulnerability are very much interlinked with each other in context of climate change. As climate change is overlying and interacts with non-climatic factors, taking its impact as starting point of analysis has serious limitations [5]. This is mainly because the impact of climate change is uncertain, with GCM sending confusing signals and treating mainly the symptoms and not the cause, especially by focusing just the impact [5]. Therefore, for measuring the impact of climate change another approach has to be taken, i.e., vulnerability and resilience approach. Therefore, for this we need to understand the relationship between vulnerability and resilience.

Understanding and assessing vulnerability and resilience from the multi-sector view and combining them is very important for any policy intervention or planning for the adaptation to climate change impact in the local level. According to reference [6], communities offer understanding of change in environment based on multiple knowledge systems, including local and traditional knowledge, and how these have impact on their ability to adapt to changes [7]. Reference [8] describe how indigenous communities of the Arctic that follow traditional lifestyles have been shown to be disproportionately vulnerable to climate change; however, they have also been shown to possess considerable capacity, or adaptability, to address climate change. "Studies that are highly localized can identify community specific concerns that may be overlooked in regional scale analyses and serve as a valuable tool for local empowerment and information exchange" [9],[7]. Also, it is important to understand impact of climate change at local level due to social differentiation

since the ones that can use resource more efficiently can adapt more to the climate change and be more resilient [10].

Climate change is making some regions of the world more vulnerable than others and the most vulnerable are Arctic, sub-Saharan Africa, small islands, and the Asian mega deltas [11]. Bangladesh is a low-lying deltaic country in South Asia formed by the Ganges (Padma), the Brahmaputra (Jamuna) and the Meghna rivers and their respective tributaries. Due to its geographical location Bangladesh already is vulnerable and frequently affected by many natural disasters. Frequencies of natural disasters in the last three decades have increased in the country. The impacts of these natural phenomena are enormous hindering human development [12].In the last 30 years Bangladesh has been hit by more than 100 cyclones and about 60 flash floods with other natural disasters like epidemics, drought, and heat waves and these impacts are adding stress to national development as well as environmental resources and livelihood practices [13]. Natural disasters are damaging economic assets, infrastructure and increasing risk to lives and livelihoods.

II. Materials and Methods

A. Study Area

Three districts of the south west coastal Bangladesh naming Khulna, Bagerhat and Satkhira are selected for the study. The Dacope Upazila of the Khulna district, Rampal Upazila of Bagerhat district and Shayamnagar of Satkhira has been studied. Dacope Upazila (khulna district) area 991.57 sq km, located in between 22°24' and 22°40' north latitudes and in between 89°24' and 89°35' east longitudes. It is bounded by Batiaghataupazila on the north, PasurRiver on the south, Rampal and Monglaupazilas on the east, Paikgachha and Koyraupazilas on the west [14]. Rampal Upazila (Bagerhat district) area 291.22 sq km, located in between 22°30' and 22°41' north latitudes and in between 89°32' and 89°48' east longitudes. It is bounded by Bagerhatsadar and Fakirhatupazilas on the north, Mongla and Morrelganjupazilas on the south, Morrelganj and BagerhatSadarupazilas on the east, Batiaghata and Dacopeupazilas on the west [15]. Shyamnagar Upazila (Satkhira district) area 1968.24 sq. km, located in between 21°36' and 22°24' north latitudes and in between 89°00' and 89°19' east longitudes. It is bounded by Kaliganj(Satkhira) and Assasuniupazilas on the north, West Bengal state of India and the Bay of Bengal on the south, Koyra and Assasuniupazilas on the east, West Bengal state of India on the west [16].

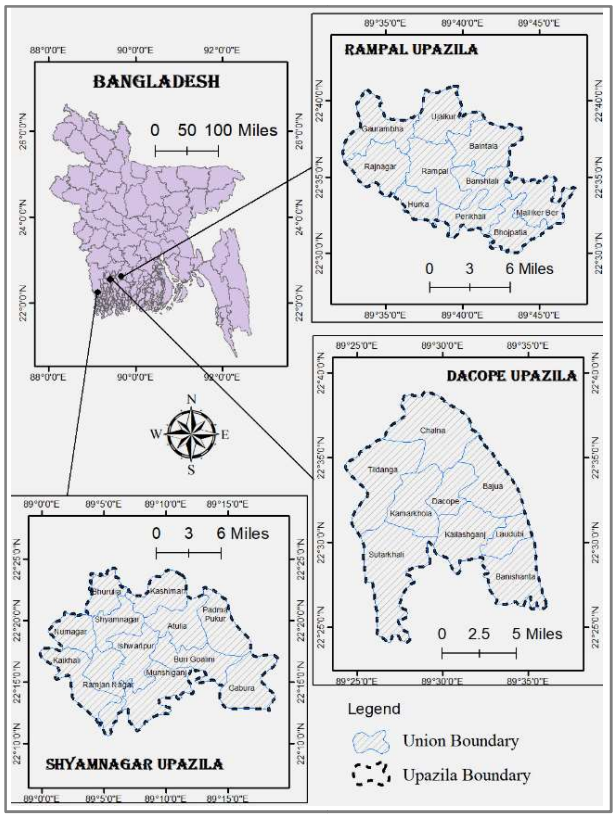

Fig. 1: Study area in the context of Bangladesh

B. Vulnerability and Resilience

Resilience and vulnerability are interlined with each other and can be embedded in one another. This means one component can be embedded into another. So, there is need to understand how changes in the climate will have an impact for which we need to consider vulnerabilities. Resilience means reducing the vulnerabilities but it also adds other dimensions of time and dealing with uncertainties [17]. According to IPCC Fourth Assessment Report vulnerability may be formulated as:

Vulnerability = Exposure + Sensitivity – Adaptive Capacity.....2

In this study adaptation practices adopted by the farmers are taken as the ability to absorb shocks which they have been practicing for long period. Further vulnerability to climate change will cover the aspect of self-organization and adaptive capacity. Hence resilience is measured as:

Resilience Index = Ability to absorb shocks – Vulnerability.....2

PCA is used to give weights to the indicators. To ensure that high index values indicate high vulnerability in all cases, we reverse the index values by using [1 – index value] for indicators hypothesized to increase vulnerability. The indicators of vulnerability are taken from literature review.

C. Classification of Household

Households were classified into five different groups depending upon vulnerability for descriptive analysis as:

i. Very High Vulnerable (V.H.V)
ii. High Vulnerable (H.V)
iii. Moderate Vulnerable (M.V)
iv. Low Vulnerable (L.V)
v. Very low vulnerable (V.L.V)

Further resilience of household is analyzed as a function of absorption of shock and vulnerability. The absorption of shock is taken as function of adaptation index. The adaptation index implies how they are adapting to the current changes after they have absorbed the shocks of natural hazards. Also, households were classified into five different classes based on their resilience as:

i. Very High Resilience (V.H.R)
ii. High Resilience (H.R)
iii. Moderate Resilience (M.R)
iv. High Resilience (H.R)
v. Very High Resilience (V.H.R)

D. Determinants of Resilience

Multiple regression analysis is used to identify the determinants of households' resilience to climate change.

$$Yj = \alpha + \beta 1X1j + \ldots\ldots\ldots + \beta kXkj + Uj \ldots\ldots\ldots\ldots\ldots\ldots\ldots 3$$

Where,

Yj is the level of resilience.

The Xij are the explanatory variables for resilience while

β are the coefficient of the explanatory variables and

α is the constant and Uj error term.

III. Results and Discussion

The integrated vulnerability assessment approach here focused on both the social as well as climatic factors. As individual differ from each other from perspective of both being affected by climate change as well as socio-economic factors, their vulnerability also differs from households to households. The PCA analysis for vulnerability shows that eight components having Eigen value greater than 1 and accounting for around 70% of the total variance (Fig.2). The heaviest factor loading from these eight components are used to give weights to the variables for vulnerability analysis.

Further based on the nine principal component scores adaptive capacity can be categorized as infrastructure, income, resources and information, education, asset possession and agricultural diversification, institution, school, perception. Similarly, sensitivity can be categorized as sensitivity due to damages to resources and sensitivity due to food security. Further, exposure can be categorized as climatic extremes due to rainfall, and increasing natural hazards with temperature.

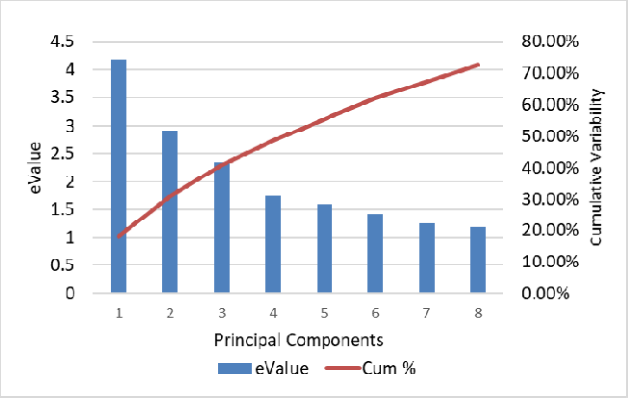

Fig. 2: Principal component having Eigenvalue more than 1

A. Vulnerability of Farmers of SW Coastal Bangladesh

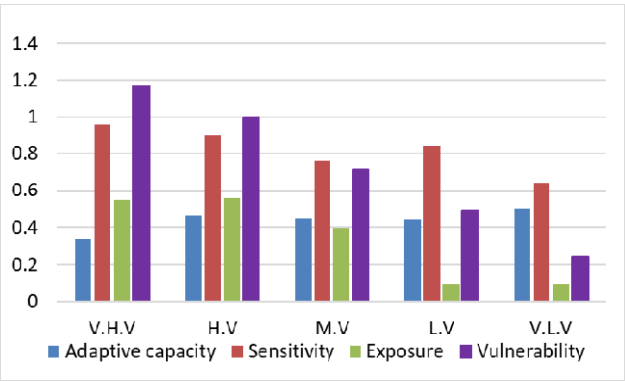

Fig.3: Vulnerability of households according to different categories

After obtaining the weight from PCA vulnerability is calculated as the function of exposure, sensitivity and adaptive capacity. From PCA it is seen that infrastructure like school and health service center and education of the household head played an important role in increasing the household adaptive capacity as it has higher weights. Further, the study categorized the households into five different groups according to their vulnerability (Fig. 3). The analysis shows that vulnerability mainly dependent on the adaptive capacity of the households as well as their exposure (Fig.3).

In addition to this, the analysis shows that around 15% of households have relatively very low vulnerability while 14% household belongs to very highly vulnerable in the study area (Fig.4). The majority of households are in the group ranging from low vulnerability to moderate vulnerability. In Fig.5, it is seen that vulnerability is highest for Dacope since it has the

lowest adaptive capacity and high exposure. Shyamnagar has the lowest vulnerability as it has the highest adaptive capacity and the lowest exposure (Fig.5). Vulnerability of Rampal lies between Shyamnagar and Dacope as it has moderate adaptive capacity and highest exposure Upazila (Fig.5). This further adds to the earlier finding that vulnerability is determined mainly by adaptive capacity, while exposure also plays a crucial role.

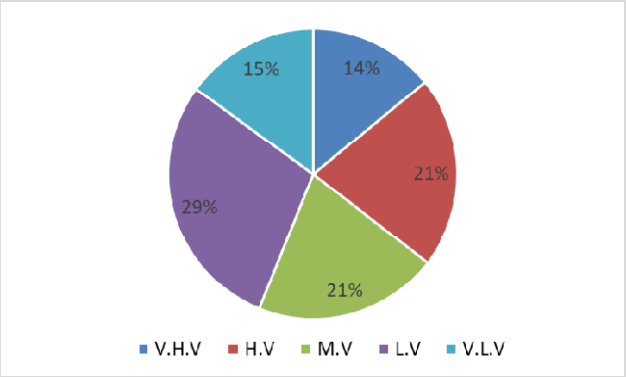

Fig.4: Percentage of Households in different category of Vulnerability of households

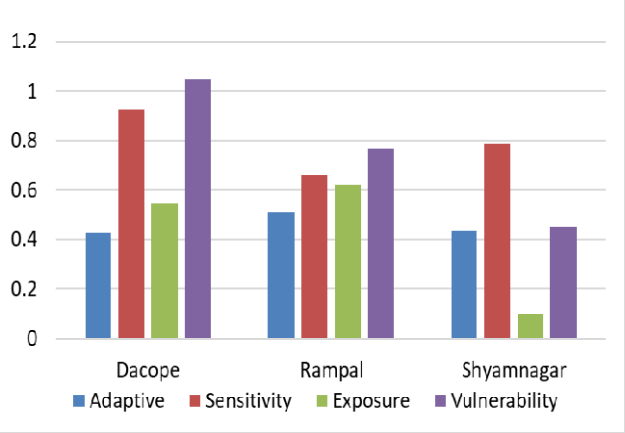

Fig. 5: Adaptive capacity, exposure, sensitivity and vulnerability of households according to study Upazila

In addition to this, households are classified according to vulnerability in each Upazila. In Dacope and Rampal there are no households that fall in the category of very low vulnerable and low vulnerable while in Shyamnagar there are no households that fall in category of very high vulnerability and high vulnerability (Fig.6). The analysis shows that with increasing vulnerability there is steady decrease in adaptive capacity in all the upazilas while sensitivity also plays an important role.

B. Resilience of Farmers of Southwest Coastal Bangladesh

The resilience index is classified according to different vulnerable groups. It is seen that resilience index is the highest for households that have lower vulnerability and decreases slightly with increasing vulnerability. This indicates that household's adaptation practices are helping farmers to decrease their vulnerability (Fig.7). As most of the households are mainly practicing the traditional adaptation practices, with additional burden of climate change they might not be able to cope in the future.

Further, analysis shows that only 11% of households have very high resilience while around 9% has very low resilience to climate change (Fig.8). Most of the households belong to the group of high resilience and then low and moderate resilience group.

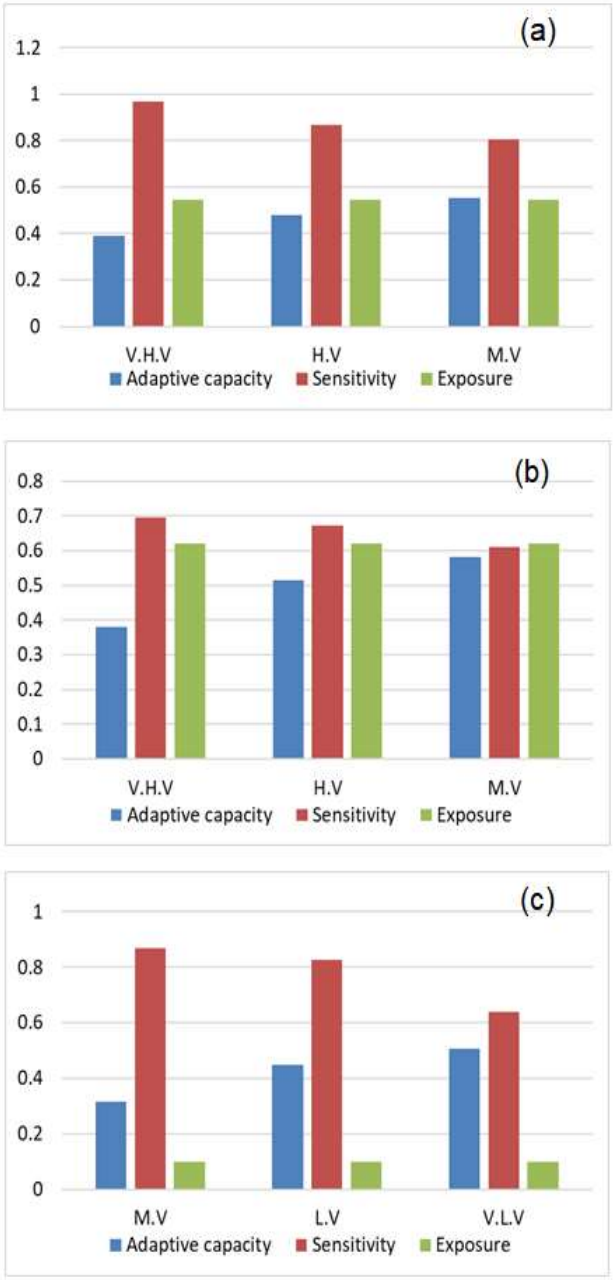

Fig. 6: Category wise household vulnerability of Dacope (a), Rampal (b), and Shyamnagar (c) Upazila

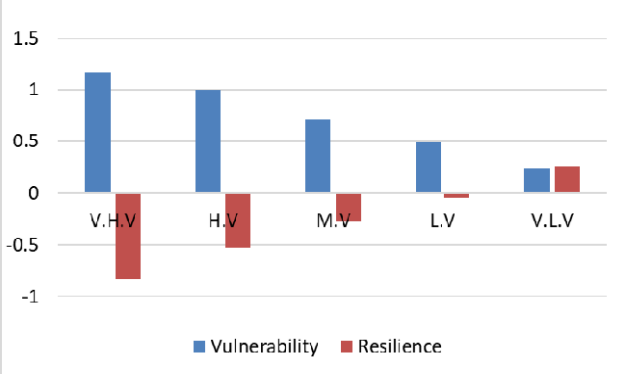

Fig. 7: Resilience index according vulnerable groups

In addition to this, households in the study area also stated that they have been able to cope with small-scale natural hazards but with recent increase in natural hazard, they are not able to manage it properly. This shows that climate change has added additional challenges, increasing their vulnerability while reducing their resilience.

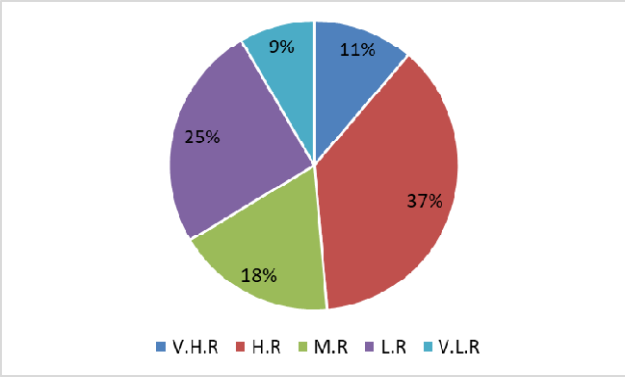

Fig. 8: Households according to resilience category

C. Determinants of Resilience

Multiple regression analysis has been used to find the determinants of resilience. From the analysis it is found that land holding, livestock, income from agriculture, radio/mobile, irrigation, saving, infrastructure like school and market significantly increases the resilience. The increase in land holding, on-farm and off-farm income, livestock and radio/mobile possession will increase the resilience with the coefficient of 0.47, 0.82, 0.96, 0.51 and 0.2 respectively having p-value of 0.00 (Table 1).

Table 1: Determinants of Resilience

Variables	Coefficient	P-value
Education of HHH	0.05	0.45
Land holding	0.47	0.00***
Income from agriculture	0.82	0.00***
Off-farm Income	0.96	0.00***
Savings	0.11	0.04*
Livestock	0.51	0.00***
Climate Change Perception	0.11	0.09*
Health service distance	-0.11	0.1
Distance of Upazila roads	-0.2	0.02*
Irrigation availability	0.04	0.72
Drinking water source distance	0.04	0.42
Radio/Mobile	0.2	0.00***
Dependency	-0.04	0.67
Primary School/ madrasa distance	-0.18	0.03*
Distance of market	-0.17	0.02*
No of Crops	-0.04	0.7

Livestock possession will significantly increase the resilience as it gives the opportunity for diversifying their income and as an alternative source of income during hazards. Radio/mobile possession will enable farmers to get the benefits of knowledge and awareness through information technology. Land holding will increase total income specially income from agriculture resulting a more resilient community of farmers. Saving will significantly increase the resilience with the coefficient of 0.11 and p-value of 0.09, as it provides safety net to absorb the shocks (Table 1). Additionally, any decrease in the time taken to reach the infrastructure like school and market will significantly increase the resilience with the coefficient of -0.18 and -0.17, respectively with p-value of 0.03 and 0.02 (Table 1). Availability of infrastructure close to dwelling will increase their access to information, inputs and resources, which will help to absorb shocks as well as decrease the vulnerability.

IV. Conclusion

The vulnerability of the households is determined mainly by adaptive capacity as it is observed that vulnerability increases especially with decrease in adaptive capacity. Exposure and sensitivity are also important factor in determining overall vulnerability. In addition to this, geographic factors are crucial factors determining the overall vulnerability as impacts of natural hazards and climatic factors differ according to area. This is particularly seen in Dacopeupazila whose majority of households are more vulnerable than in Rampal and Shyamnagar. Further, vulnerability also differs within the same geographic location due to adaptive capacity, which is mainly contributed by the socio-economic condition as well as exposure to natural hazards. It is found that adaptation practices are highest for low vulnerable households, indicating that households are able to overcome negative affect of hazards to some extend by using traditional adaptation practices. In addition, with increase in vulnerability, adaptation index decreases slightly. This indicates that climate change has added additional challenges to households by increasing their vulnerability and affecting their ability to cope with it.

Similarly, resilience mainly depends on the socio-economic condition and on the geographic location. The

resilience is significantly impacted by their land holding, agriculture, livestock, irrigation, saving, and infrastructure. Resilience significantly increases with increase in the saving which acts as safety net to absorb shocks as well as increase resources and inputs availability. Further, infrastructure plays crucial role in increasing the resilience as it will increase their reach to information as well as inputs. Further livestock possession will help households to diversify their income as well as to absorb shocks.

Finally, the analysis shows that analyzing only from the perspective of vulnerability will only show the households as mere sufferer but will not capture their capability. Further understand from resilience point of view will also capture their capability to observe those shocks. This emphasizes that for planning any development or adaptation program there is need to understand households' vulnerability as well as their resilience for better planning and implementation.

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