Improving water use for dry season agriculture by marginal and tenant farmers in the Eastern Gangetic Plains

Analysis of Climate Change Perception, Vulnerability of Households and Adaptation Strategies in the Eastern Gangetic Plains (Nepal, Bihar and West Bengal)

Working Paper

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Executive Summary

In order to get an in-depth understanding on the household (hh) level climate change related shocks, their perception, the household vulnerability, and the adaptation strategies followed, a household level survey was undertaken during 2015 covering three regions, viz., Nepal, Bihar and West Bengal with a sample of 710, 852 and 507 households respectively from the three regions.

In the present study, the farm household income was computed as the total income for 12 months from i) skilled salaried income, ii) crops or livestock product sales (after deducting all input costs), iii) rental income from immovable properties, iv) rental income from agricultural assets, and v) agricultural labour income. The per-capital income was worked out by dividing the total income by household size. Household vulnerability was defined interns of the probability that the consumption (income) level of a farmer who encounters climatic shocks (such as drought, irregular weather, untimely rain etc.) falling below the poverty line. Two poverty levels were identified for the analysis: a) current income levels of households derived from the sample, and b) World Bank estimates of percapita income of US$ 1.90. Three step generalized least squares technique was used for the estimation of the vulnerability levels of the households.

Regarding the climate related shocks encountered, drought was the most severe shock encountered by the farmers followed by untimely rain and flood in all the regions. Majority of the farmers encountered a combination of these shocks. In all the regions, farmers responded in many ways to these climatic shocks which included: i) land related, ii) crop related, iii) livestock related, and iv) social activities. In all, these responses included mostly: a) providing supplemental irrigation, b) changing cropping pattern, c) following improved crop production practices, and d) selling livestock to supplement income that was last due to extreme climatic shocks.

Regarding the vulnerability of the households, in the case of Nepal, currently there are 425 farm households (hhs) whose per capita income is below the poverty line and 300 hhs will continue to be vulnerable in the next year also. Further, out of 285 hhs whose per-capita income is above poverty line, 173 hhs are liable to be vulnerable next year. In total, about 67 % of the hhs are vulnerable to poverty in the region. The key determinants of hh vulnerability are farm size, maritial status, main occupation and access to credit.

In the case of Bihar, currently there are 594 farm hhs (69.7% of the sample hhs) are below the poverty line and 569 hhs will continue to be vulnerable in the next year also. Further, out of 258 hhs whose per-capita income is above poverty line, 232 hhs are liable to be vulnerable next year. In total 801 hhs (94%) will be vulnerable next year. The key determinants of vulnerability include household's age, main occupation, livestock possession and access to credit.

In the case of West Bengal, currently 342 hhs (67.5% of the sample hhs) are having per capita income below the poverty line. Out of this, 249 hhs will continue to be vulnerable in the next year also. Further, out of 165 hhs whose per-capita income is above poverty line, 33 hhs are liable to be vulnerable next year. Hence out of 507 hhs, 282 hhs (55.6%) will be vulnerable next year. This means that there will be decline in the number of farmers below the poverty line from current year to next year. The key determinants of vulnerability are farm size, household age, educational level, main occupation, drought and market shock, livestock possession and access to credit.

Regarding the adaptation strategies followed to address the hh vulnerability, majority of the hhs who responded to drought with crop related responses (such as providing supplemental irrigation, change in cropping pattern and following improved crop production practices) got higher per-capital income compared to hhs who did nothing. Thus crop related responses provided maximum benefit to offset the negative effects of drought on the vulnerability of hhs.

Major policy prescriptions from the study include piloting of strategies that yield comparatively higher income than the current practices as illustrated by the results from the case study regions. Cluster approach (covering a group of adjacent villages) in piloting of the selected strategies will be more effective as this will minimize the transaction cost of technology adoption. Hence, a package of adaptation strategies should be made available to the hhs and based on their performance, up-scaling can be done through the government agricultural departments and NGOs.

Creating awareness and enhancing the skill development activities through capacity building programs is very important in enhancing the adoption levels.

As most of the farmers are facing the risk of rainfall variability, economics of investment in farm ponds and other storage structures (for providing 1-2 supplemental irrigations) needs to be examined in detail. As the investment in the construction of farm ponds and provision of supplemental irrigation through micro sprinklers with solar pumps may be costlier for small and marginal farmers, option for convergence of different government programs can also be examined.

Adoption of all these strategies will also enhance the off-farm income of the hhs which are currently below 10%. Using the pilots, successful business models should be identified for each region and should be made available to interested partners and implementing departments. A public private partnership (ppp) can also be initiated wherever possible.

1. Introduction

Agriculture sector is very much affected due to climate change (CC) because of its primary inputs, viz., rainfall and temperature. Climate change projection for India upto 2100 indicate that there will be an overall increase of 2-4°c temperature with no substantial change in precipitation (Kavikumar, 2010). CC affects not only mean yield of the crop but also induces variability in yield (Palanisami et al.2014). This has strong implication for livestock feed quality and quantity and thus to their productivity. Strategies that will help farmers to cope with vulnerability and to increase the resilience will therefore be important for making appropriate interventions comprising a range of interventions ranging from technical, institutional to policy. The extent to which HHs or communities are able to manage vulnerability and risk, and exploit opportunities offered by favourable environments or institutional innovations, is a measure of their resilience. All HHs, whether rich or poor, or in high or low potential agro-ecological zones, have to cope with risk. Indeed, HHs and communities will move between different states temporally and in any landscape there will be spatial variability and this study contributes toward better explanation of these arguments

In this context, the household (HH) level vulnerability analysis could provide a basis on which interventions can be targeted and assessed on HHs in the context of overall livelihoods. Thus the vulnerability analysis will be a key component of the theory of change as it provides a basis on which interventions can be targeted and assessed on households and communities in the context of overall livelihood strategies and the bio-physical characteristics of the production system.

In order to get an in-depth understanding on the household level climate change shocks, their perception, the household vulnerability, and the adaptation strategies followed, a hh level survey was undertaken during 2015 covering three regions, viz., Nepal, Bihar and West Bengal. The specific objectives were to:

1. Study the perception of the households about the climate change impacts;,
2. Examine the level of coping strategies adopted by them;
3. Map the household vulnerability based on the incidence of poverty; and
4. Examine the possible adaptation strategies for up-scaling

2. Review of studies

The term 'vulnerability' has various defines depending on the context of study. It is usually associated with natural hazards like flood, droughts, and social hazards like poverty, etc. Of late it is extensively used in climate change (CC) literature to denote the extent of damage a region is expected to experience from various factors affected by CC. According to Adger (1999) vulnerability is the extent to which a natural or social system is susceptible to sustaining damage from CC. It is generally perceived to be a function of two components: 1) the effect that an event may have on humans, referred to as capacity or social vulnerability, and 2) the risk that such an event may occur, often referred to as exposure. Kasperson et al.(2000) defined vulnerability as the degree to which an exposed unit is susceptible to harm due to exposure to a perturbation or stress and the ability or

lack of the exposed unit to cope, recover, or fundamentally adapt to become a new system or to become extinct. A brief outline of various definition in the context of CC can be found in Palanisami et al.(2014).

As stated by Deressa et al.(2009) there are two different approaches, viz., indicator approach and econometric approach to measure vulnerability. In indicator approach, which is very much used in CC studies, vulnerability is defined with respect to several indicators and these indicators are pooled to develop a composite index of vulnerability. For this, tools from multivariate analysis i.e. principal component analysis employed (Palanisami et al.(2014). The composite indices so developed for each region can be compared to assess the relative vulnerabilities of each region. The econometric approach is applied in the context of social vulnerability and mainly applied to economic survey data and it is best suited to study poverty of households. In this approach there are three assessments of vulnerability levels of social groups. They are vulnerability as expected poverty, vulnerability as low expected utility and vulnerability as uninsured exposure to risk (Deressa et al.2009). In the present study, vulnerability of household is considered as expected poverty. The approach formulated by Chaudhuri et al.(2002) and Christiaensen and Subbarao(2004) forms the basis. In this approach, vulnerability is defined in terms of probability. Vulnerability is the probability for a poor person today to continue to be poor tomorrow also or to become rich(not poor or above poverty line) tomorrow. In other words the approach specifies the transition probabilities between two states of wellbeing, viz., poor and rich.

Recently Palanisami et al.(2015) studied the household vulnerability of farmers belonging to Andhra Pradesh, Karnataka and Rajasthan. The per-capita net income of the farmers varied greatly across the three states; it was Rs. 15,472 in Andhra Pradesh, Rs.65,428 in Karnataka and Rs. 20,060 in Rajasthan. Two levels of poverty lines were used in the analysis: a) current income levels of households from the three selected states, and b) Rs.100/day based on the World Bank estimates of US$1.25 adjusted to US$1.5 for inflation. This is also equal to the wage rate of National Rural Employment Guarantee Act (NREGA) for 2010-11. The results also indicate that several of the vulnerable households will continue to remain vulnerable even with the adaptation strategies due to their low per-capita income. This is highly seen in rain-fed conditions of Andhra Pradesh and Rajasthan. In addition, simulation analysis was done by increasing the poverty line to ₹ 200/day in view of the increased demand for higher wages in the rural areas to meet the consumption requirements. The trends show that when the poverty level increases, more farmers will come under the vulnerable category if no adaptation strategies are followed.

3. Study area, sample and methodology

3.1 Study area, sample & variable definitions

The present study was taken during the year 2015. The location of the study was Saptari district of Nepal. A sample of 710 farmers from Koiladi and Khoksar Prabha villages of the district were interviewed. The location of the study was Madhubani district of Bihar. A sample of 852 farmers from the district were interviewed. The location of the study was Cooch behar and Alipurduar districts of West Bengal, State, India.. A sample of 507 farmers from the two districts were interviewed.

The following key variables have been defined for the study and used in the data analysis.

Climate shocks:

Farmers were questioned on the incidence of9 different climatic shocks they experienced during the past 5 years. The climatic shocks included were:

i) Drought defined as the amount of rain during the growing season significantly below or deviated from the expected rain for the period
ii) Untimely rain (rain arriving too early or too late affecting sowing, planting or harvest operations
iii) Irregular weather
iv) Hailstorm
v) Flood (heavy rains causing flooding situation in the fields)
vi) Animal diseases
vii) Serious pest damage to crops
viii) Market shock like collapse in prices
ix) Any others

Household income:

The household income was computed as the total income for 12 months from i) skilled salaried income ii) crops or livestock product sales (after deducting all input costs) iii) rental income from immovable properties iv) rental income from agricultural assets and v) agricultural labour income. The per-capital income was worked out by dividing the total income by household size.

Poverty level:
The estimates from the World Bank show that 1.29 billion people were living on less than 1.25 USD a day (World Bank 2008, Deressa et al.2009). The population on poverty line has dropped from 43% in 1990to 22% during 2005-08. The poverty line also varies from country to country and it is 2 USD for medium poverty line for the developing countries (World Bank, 2012). In the present study, two poverty levels are identified for the analysis: a)current income levels of farmers from the sample and b) World Bank estimates of 1.90 US$ (World Bank, http://povertydata.worldbank.org/poverty/country/NPL)

3.2 Methodology: Household vulnerability: Empirical model

In the expected poverty approach, vulnerability is understood as the prospect of a person who is now poor will continue to be poor in the future also or the prospect of a person who is not poor will become poor in the future. In the present study it refers to the probability that the consumption (income) level of a rain-fed farmer who encounters climatic shocks (such as drought, irregular weather, untimely rain etc.)falling below the poverty line.
The methodology proposed by Chaudhuri et al.(2002) was followed in the study. It helps to estimate vulnerability to poverty using cross-sectional data.The relationship between per capita consumption expenditure of a household h, denoted by c_h and his observable household characteristics denoted by X_h is specified by the equation

$$\ln c_h = X_h \beta + e_h \quad (1)$$

The observable household characteristics include many socio-economic variables like age, education, experience, farm size, household size, climatic shocks encountered etc. β is a vector of parameters and e_h is a random disturbance term with mean 0. The variables included in the present study and their descriptive statistics are given in Table 8.

The vulnerability to poverty depends not only on the average consumption of the individual but also on the variance of consumption. For example, a farmer whose income from farm fluctuates due to many climatic shocks and other factorsis more vulnerable to poverty than a government salaried person whose average income is similar to that of the farmer. Hence the variance of the consumption expenditure is also assumed to be related to socio-economic factors. That is, the variance of the error term is assumed to be related to the household characteristics, X_h by the relation

$$\sigma_{e,h}^2 = X_h \theta \quad (2)$$

Where, θ is a set of parameters. The three-stage Feasible Generalized Least Squares (FGLS) approach suggested by Amemiya (1977) is followed to estimate the parameter vectors β and θ. The approach is briefly explained below.

Equation (1) is first estimated by Ordinary Least Squares (OLS) procedure and using its residuals, $e_{OLS,h}^2$ are computed. These residuals are then regressed on X_h , using OLS, to estimate

$$\hat{e}_{OLS,h}^2 = X_h \theta + \eta_h \quad (3)$$

The predicted value of the residual is given by $X_h \hat{\theta}_{OLS}$. These values are used in equation (3) to transform it as

$$\frac{\hat{e}_{OLS,h}^2}{X_h \hat{\theta}_{OLS}} = \frac{X_h \theta}{X_h \hat{\theta}_{OLS}} + \frac{\eta_h}{X_h \hat{\theta}_{OLS}} \quad (4)$$

This equation is estimated using OLS and the estimate of the vector θ, denoted by $\hat{\theta}_{FGLS}$ is asymptotically efficient estimate of θ and $X_h \hat{\theta}_{FGLS}$ gives a consistent estimate of $\sigma_{e,h}^2$, the variance of idiosyncratic component of household consumption(Chaudhuri et al.2002). Now the equation (1) can be transformed as

$$\frac{\ln c_h}{\hat{\sigma}_{e,h}} = \left(\frac{X_h}{\hat{\sigma}_{e,h}} \right) \beta + \frac{e_h}{\hat{\sigma}_{e,h}} \quad (5)$$

This equation can be estimated by using OLS to provide a consistent and asymptotically efficient estimate, $\hat{\beta}_{FGLS}$, of the parameter vector β. Finally, for each household h , the estimated mean log consumption and variance are given by

$$E\left[\ln c_h \mid X_h\right] = X_h \hat{\beta}_{FGLS} \quad (6)$$
$$V\left[\ln c_h \mid X_h\right] = \hat{\sigma}_{e,h}^2 = X_h \hat{\theta}_{FGLS}$$

We now make the assumption that consumption is log-normally distributed. This assumption leads to computing the probability of a household's consumption below a threshold limit, z , that is, the probability that the household will be poor as

$$\hat{v}_h = \Pr(\ln c_h < \ln z \mid X_h) = \Phi\left(\frac{\ln z - X_h \beta_{FGLS}}{\sqrt{X_h \hat{\theta}_{FGLS}}}\right) \quad (7)$$

This approach requires per-capita consumption expenditure of each farmer. So in this approach, each farmer's net income from farm and livestock were computed and per-capita income was derived. For some farmers, the net income was negative, that is loss. In order to include these farmers also into further analysis, the net income for each of them was put as Re.1. We assume that farmers don't save and hence the full income is used for consumption.

Estimation of HH vulnerability

Given the climate related shocks and the several coping strategies followed by the households in the study regions, it is important to analyse how vulnerable they are in generating adequate income to meet the household requirements. The household vulnerability is defined in terms of expected poverty as proposed by Chaudhuri et al.(2002). It is assumed that farmers don not save and so the entire farm income is treated as expenditure. Three step generalized least squares technique was used for the estimation of the parameters of the models in equations (1) and (2). In the first stage, logarithm of per capita income was regressed (using ordinary least squares(OLS)) on the household characteristics, X_h and the residuals from the regression, $e^2_{OLS,h}$ were computed. These residuals are then again regressed on X_h using OLS to estimate equation (3). The predicted values of the residuals are used in equation (3) to obtain equation (4).

This equation is estimated using OLS and the estimate of the vector θ, denoted by $\hat{\theta}_{FGLS}$ is asymptotically efficient estimate of θ and $X_h \hat{\theta}_{FGLS}$ gives a consistent estimate of $\sigma^2_{e,h}$, the variance of idiosyncratic component of household consumption(Chaudhuri et al.2002). Now the equation (1) can be transformed as equation (5).

This equation was estimated by using OLS to provide a consistent and asymptotically efficient estimate, $\hat{\beta}_{FGLS}$, of the parameter vector β. Finally, for each household h, the estimated mean log consumption and variance are obtained as specified in equation (6).

We now make the assumption that consumption is log-normally distributed. This assumption leads to computing the probability of a household's consumption below a threshold limit, z , as given in equation (7).

4. Results and Discussion

4.1. Nepal:

4.1.1 Perception of farmers on Climate Change:

i) Shocks Encountered

Farmers were questioned on the major shocks (as described earlier) encountered by them during the past 5 years. Multiple responses were observed across the regions and many of the HHs replied that they have encountered more than one shock due to CC (Table 1). Drought is the most severe shock encountered by farmers with a percentage of 29. The next severe shock is untimely rain which was observed by 79 farmers (17.6%). Flood, the third severe shock, has a percentage of 11.4. Percentages of other shocks range between 1.6 to 8.0

Table 1 Major shocks encountered by surveyed farmers

ShockName	Number of farmers
Drought	130 (29.0)
Untimely rains	79 (17.6)
Irregular weather	34 (7.6)
Hailstorm	36 (8.0)
Flood	51 (11.4)
Animal disease	30 (6.7)
Serious Pest Damage	15 (3.3)
Market Shock	7(1.6)

Figures in brackets denote percentages

Since some farmers observed more than one shock, an in depth analysis of data is required to know the combination of shocks encountered by them. Analysis of data revealed that farmers encountered 49 combinations of shocks. Table 2 provides the percentage of farmers who encountered various combinations of shocks.

Table 2 Combinations of Shocks Encountered by the Farmers

Combination of shocks	Percentage of farmers
No shock	59.7
Drought alone	8
Flood alone	3.6
Untimely rain alone	3.6
DR+UR+IW	3.6
DR+UR	3.1
DR+Flood	2.4
Other 42 combinations	16

It is evident from the above table, that drought alone was observed from 8% of the farmers while flood alone and untimely rain alone were each observed by 3.6% of farmers. The combination of

these three shocks were noticed by 3.6% of farmers. Thus we conclude that the important climate related shock experienced by the farmers are drought, flood and untimely rain.

Given the importance of these shocks, the frequencies of occurrence of shocks as observed by farmers during the past 5 years were also analysed. Based on their replies, percentages of farmers who encountered a shock with a particular frequency were computed. Table 3 provides the percentage of farmers and the corresponding frequencies for the three major shocks.

Table 3 Frequencies of occurrence of shocks

Frequency of shock in the last 5 years	Number of farmers who encountered		
	Drought	Untimely rain	Flood
1	22(17)	14(18)	5(10)
2	50(39)	34(43)	13(26)
3	41(32)	18(23)	14(27)
4	14(11)	11(14)	5(10)
5	3 (2)	1(1)5	14(27)

Figures in brackets denote percentages to respective totals

It is clear from the table that out of 130 farmers who observed drought, 50 farmers (39%) opinioned that it occurred two times in the last five years whereas 41 farmers encountered it three times. Similarly 34% of the farmers who observed untimely rain encountered it two times in the last five years. The third important shock, viz., flood was encounted three times in the last five years by about 27% of the farmers.

4.1.2 Severity of climate shocks

Farmers who encountered a particular shock were questioned on the severity of its impact.

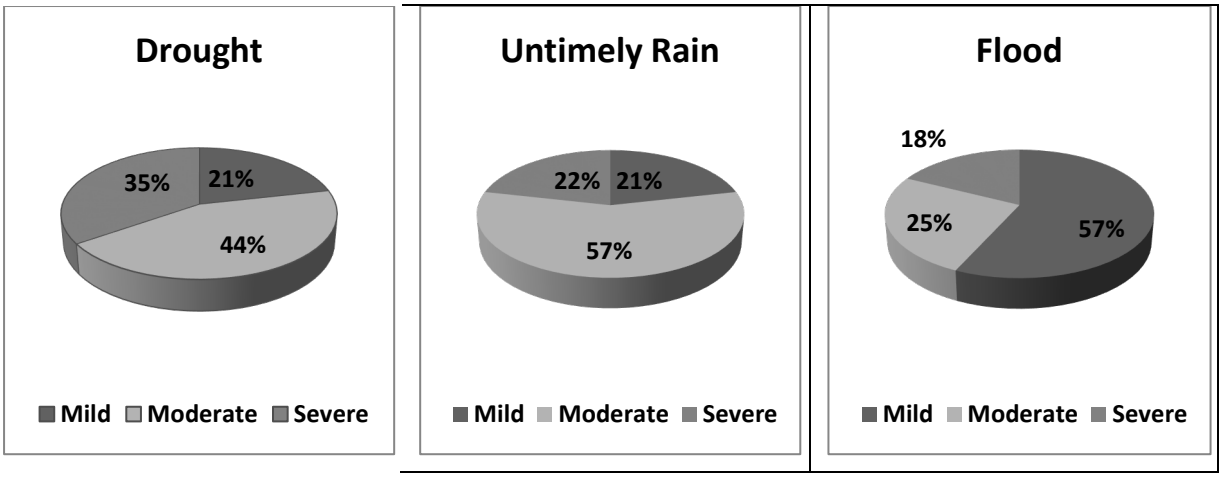

Fig.1 Severity of Climatic Shocks as opinioned by farmers

Fig.1 gives the distribution of the severity of the three major shocks. About 35%, 22% and 18% of the farmers who respectively encountered the three major shocks felt that these shocks had severe impact on their agriculture. The shocks had moderate impact on 44%,57% and 25% respectively of the farmers who encountered them.

4.1.3 Response to shocks

Farmers responded in many ways to climatic shocks. In this section the responses for major shocks(drought, untimely rain and flood) are discussed. Respectively 30%, 18% and 20% of the farmers who were hit by the three major shocks did nothing at all to tide over the negative effects. Rest of the farmers responded to climatic shocks. Their responses can be classified as i) land related

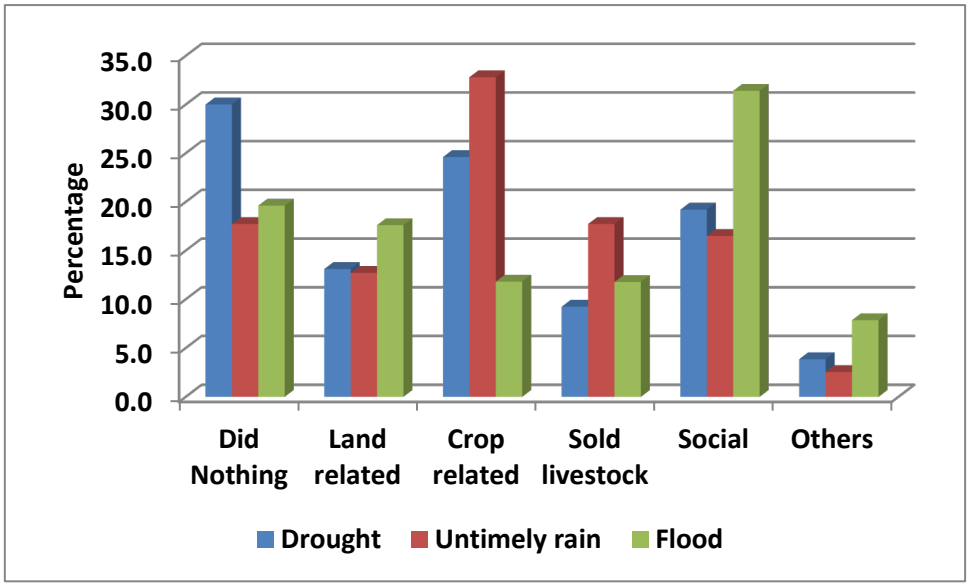

Fig.2. Major Climatic Shocks and distributions of responses by the farmers

ii) crop related iii) sold livestock iv)social and v) others. The land related response consists of a) leaving land fallow b)selling part of land and leasing out part of land. About 13%, 13% and 18% respectively of the farmers who encountered the three shocks, responded to land related strategies to get over the effects of climatic shock. The crop related responses which were followed respectively by 25%, 33% and 12% of the farmers (Fig.2)who were affected by drought, untimely rain and flood include a) providing supplemental irrigation b) changing cropping pattern and following improved crop production practices. Selling livestock to supplement income last due to extreme climatic shocks is a common practice. Among the surveyed farmers who were affected by the three major shocks, respectively 9%, 18% and 12% of the farmers sold livestock to compensate the lost incomes. Social related responses consist of a) borrowing money b) drawing from savings c) reducing food consumption d)shifting to non-farm employment e) reduction in education level of children and f)out migration to cities. This type of response was followed by 19%, 17% and 31% of the farmers respectively who encountered the major shocks. To summarise, crop related strategies is most important response by farmers and it is next to no response.

4.1.3 Loss of income due to climatic shocks

The climatic shocks resulted in loss of income for majority of farmers who encountered the major shocks. The percentage of farmers who lost their income ranged from 82% to 89%(Fig.3). This indicates the severity of climatic shocks on agriculture.

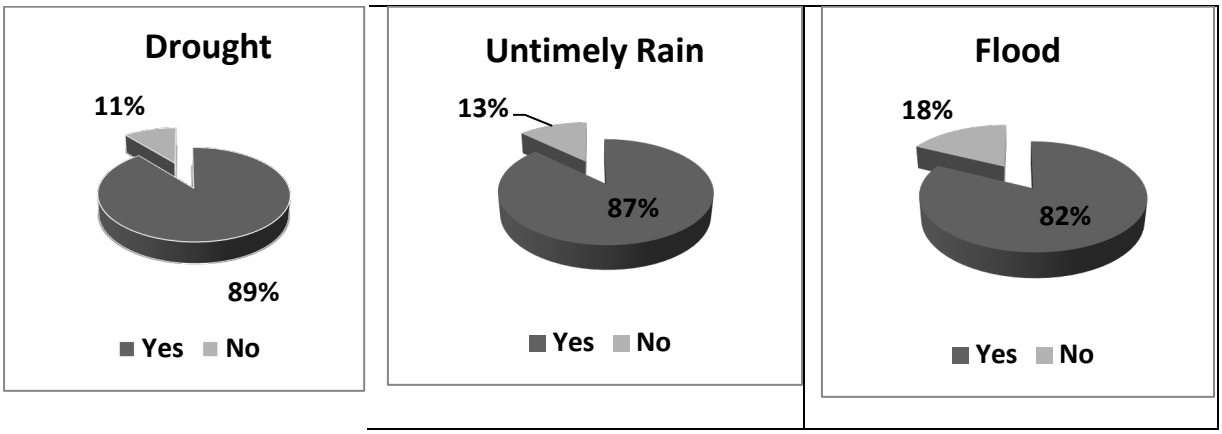

Fig. 3 Percentages of farmers who lost their income due to climatic shocks.

4.1.4 Coping (adaptation) strategies

Farmers were questioned on the assistance received by them from various organizations. like government, relieg agency/NGO, Community/Social group, landlord,extended family etc. Only five farmers reported that they received assistance. Out of the five farmers, two of them got advice from government, one farmer got food and medical expenses from extended family, one farmer got a reduction in the amount he has to pay for landlord and another farmer got 50% less paddy to pay. Thus it is very clear that these assistances are very meagre.

4.1.5 Mapping the Household Vulnerability

The probabilities of transition from vulnerable to vulnerable, vulnerable to less vulnerable, less vulnerable to less vulnerable and less vulnerable to vulnerable were worked out using equations(6) and (7).

Per-capita income (logarithm) of each farmer was used as the dependent variable and socio-economic variables and climate shocks experienced, were used as independent variables. The average per-capita income for the farm holdings is 42877 NPR.. Table 4 below gives the descriptive statistics of the variables used for the present study.

The three stage feasible least squares procedure was applied to the survey data and probability of a percapita income falling below the poverty line was worked out as per the methodology. Two cut-off limits, viz. 1.9US$ per day (NPR 74,720 per year) and average per-capita income from sample 1.09US$ per day (NPR 41,911per year) were used to estimate the probabilities of poverty transitions. The results are plotted in Fig. 4 and Fig.5. Logarithm of income is plotted against probability in these figures. The horizontal line specifies the 50% probability and the vertical line corresponds to logarithm of poverty threshold of NPR 41,911 and NPR 74,720 respectively in Fig. 4and Fig. 5. These two lines divide the figure into 4 parts. The upper left part corresponds to those farmers whose

Table 4 Descriptive statistics of variables used in household vulnerability analysis

Dependent Variable	Mean	SD	Description
Per-capita income (NPR)	41911	54936	Continuous
Explanatory Variables			
Farm Size	0.741	1.230	Continuous
Household size	6.376	3.082	Discrete

Household sex	1.110	0.313	DV=1 for male and 0 for female
Household Age in years	47.548	14.052	Continuous
Martial Status of household	2.121	0.509	Discrete with Unmarried=1;Married=2; Divorced/Separated=3;Widowed/Widower=4
Education level of household	1.714	0.870	Discrete with 6 point scale with 1 for no formal education;5 for University and 6 for anyother qualification
MainOccupation	3.463	2.634	Discrete with 10 point scale
Experienced drought	0.183	0.387	DV=1 for experiencing drought and 0 otherwise
Experienced untimely rain	0.111	0.315	DV=1 for experiencing untimely rain and 0 otherwise
Experienced flood	0.072	0.258	DV=1 for experiencing flood and 0 otherwise
Acredit	0.568	0.496	DV=1 if availed loan in the last year and 0 otherwise
LivestockP	0.845	0.362	DV=1 if in possession of livestock and 0 otherwise
AssetP	0.608	0.488	DV=1 if in possession of consumer good and property and 0 otherwise
Trainings	0.044	0.204	DV=1 if undergone any training in agricultural technology and 0 otherwise

present income is below the threshold and there is more than 50% probability that they will continue to be vulnerable. Points lying in the upper right part correspond to those HHs who are above the poverty threshold this year and have more than 50% probability to continue the same status next year also(less vulnerable – less vulnerable). HHs who are vulnerable now and have less than 50% change to move from that status next year are represented by the lower left part(vulnerable to less vulnerable). The lower right part specifies those HHs who are less vulnerable now (that is, above poverty threshold) but less than 50% change to move from that status next year(less vulnerable to vulnerable).

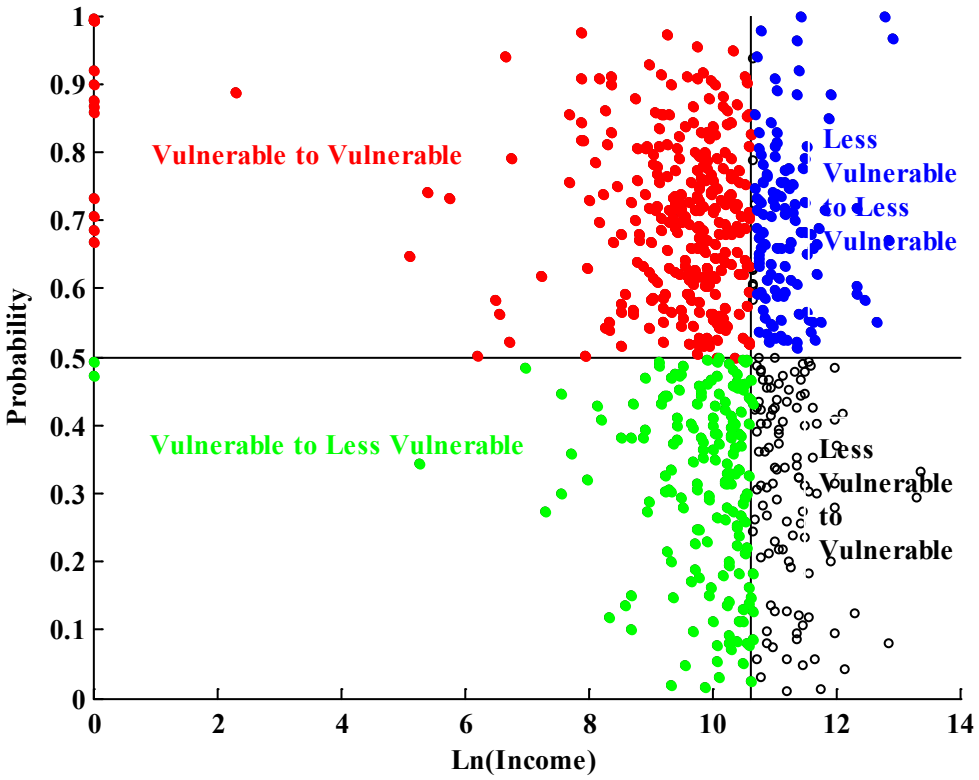

Fig.4 Household Vulnerability –Nepal (income at NPR 41,911 per year) plotted against Ln(income)

Table 5 gives the possible number of HHs in Nepal under the four different transitionsat two levels of per-capita income. Currently there are 425 HHs whose per capita income is below the poverty line of NPR 41,911 per year (i.e. US$ 1.09 per day). It shows that with probability greater than 0.5, 300 farmers (out of 425), will continue to be vulnerable in the next year also. Further, out of 285 farmers whose per-capita income is above NPR 41,911 per year, 173 farmers are liable to be vulnerable next year. Hence out of 710 farmers, 473 farmers will be vulnerable next year with probability greater than 0.5. This means that 66.6 % of the farmers are vulnerable to poverty. Also the remaining 237 (33.4%) of the farmers are likely to be less vulnerable.

When the poverty line is fixed at the US$ 1.9 per day (i.e., NPR 74720 per year (One US $ = 107.74NPR)), the situation changes. Current number of farmers whose income falls below the poverty line is 616 (86.8%) The number of households who will become vulnerable next year (with more than 50% probability) becomes 560 (78.9%) and there is more than 50% chance for the remaining 21.1% will be less vulnerable to poverty next year.

Table 5 Possible poverty transitions (with probability > 0.5) among HHs of Nepal for two levels of per capita income

Percapita income	Transition From				Total
	Vulnerable to		Less vulnerable to		
	Vulnerable	Less vulnerable	vulnerable	less vulnerable	
NPR 41,911 per year	300	125	173	112	710
NPR 74,720 per year	539	77	21	73	710

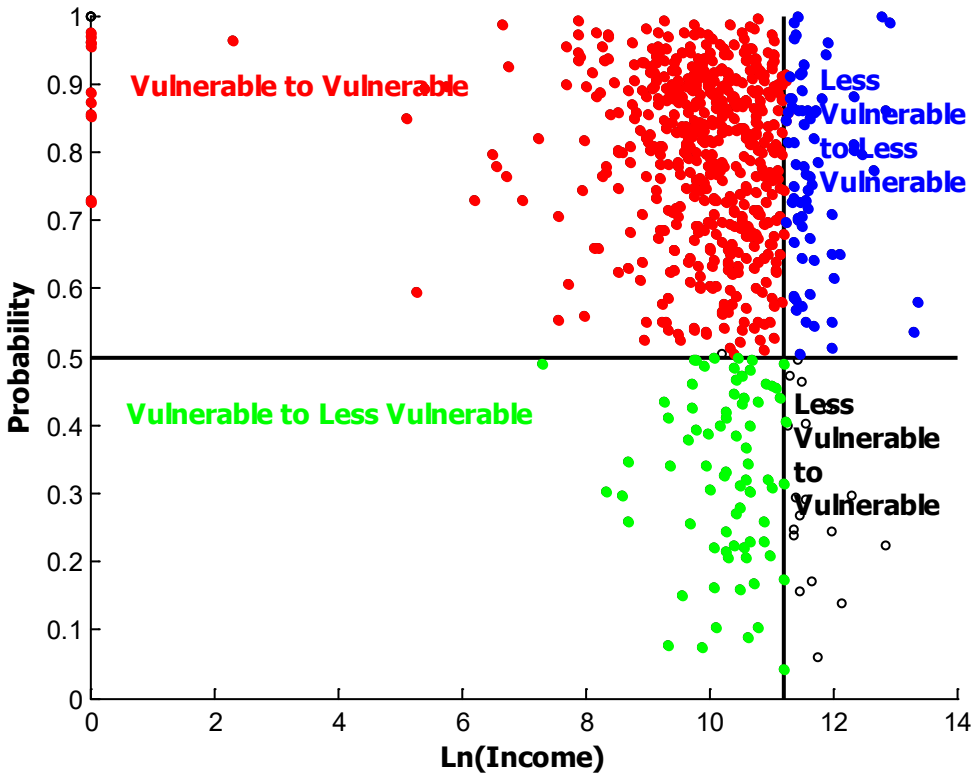

Fig. 5 Household Vulnerability –Nepal (income at NPR 74,720 per year) plotted against Ln(income)

The determinants of vulnerability for Nepal was also assessed against the consumption level with the household characteristics and the results are presented in Table 6. The results show that farm size, martial status, main occupation and access to credit are the important determinants of household vulnerability of farmers in Nepal.

Table 6 Determinants of household vulnerability

Variable	Coeff	SE	t-value	p-value
Constant	16.670	5.412	3.080	0.000
Farm Size	1.248	2.960	0.421	**0.003**
Household size	-0.114	-0.699	0.164	0.485
Household sex	-1.071	-0.661	1.620	0.509
Household Age in years	-0.033	-0.847	0.038	0.397
Martial Status of household	-2.242	-2.104	1.066	**0.036**
Education level of household	-0.841	-1.454	0.579	0.146
MainOccupation	-0.405	-2.127	0.190	**0.034**
Experienced drought	-2.233	-1.495	1.494	0.135
Experienced untimely rain	0.380	0.217	1.750	0.828
Experienced flood	-1.058	-0.556	1.903	0.578
Acredit	-1.661	-1.706	0.974	**0.088**
LivestockP	-1.890	-1.340	1.410	0.181
AssetP	-0.572	-0.527	1.086	0.599
Trainings	-0.509	-0.221	2.302	0.825

4.1.6 Economics of different adaptation strategies

It is generally believed that the responses to climatic shocks followed by the farmers to overcome the effects of climatic shocks will help to minimize the vulnerability of the households. That is, responses will help to increase the per-capital income of the households. The three major shocks encountered by the farmers are drought, untimely rain and flood. Hence it is important to examine how the responses for each one of the climatic shocks will influence the vulnerability. This section addresses this issue.

The first major climatic shock is drought and it was experienced by 130 farmers. Table 7 gives the average per-capital income for the different responses to drought. The table shows that the per-capita income of the 39 farmers who did nothing for drought (even though they experienced it) is NPR 23,689 which is the lowest among the per-capita incomes for the 5 different responses. This means that the per-capita incomes are severely affected if no adaptation strategy is taken to nullify the effect of drought. This is quiet natural because if no action is taken, drought will induce loss in crop yield which inturn will affect the income of the farmer. For the other 4 responses, farmers who sold livestock are most affected and their per-capital income is the lowest with NPR of 23,724. The net incomes of the farmers whose responses are crop related or social related responses are almost same with NPR of 35,341 and 35,607 respectively. However the per-capital income is directly related to farm size holdings. Hence it is more pertinent to compare the per-capital per unit area of farm size. The last column gives these figures. It shows that farmers who respond to drought with crop related responses (providing supplemental irrigation, change in cropping pattern and following improved crop production practices) get maximum per-capital income per unit farm size holding. Thus crop related responses provide maximum benefit to offset the negative effects of drought on the vulnerability of farmers.

Table 7. Economics of major responses to climatic shocks

Climatic Shock	Response to Climatic Shocks	Number of farmers	Average per-capita income	Average per-capita income per unit area of landholding
Drought	Did nothing	39	23,689	25,324
	Land related	17	30,744	43,166
	Livestock selling	12	23,724	40,036
	Crop related	32	35,341	1,00,094
	Social and others	30	35,607	45,220
Untimely rain	Did nothing	14	27,131	23,908
	Land related	10	29,801	29,423
	Livestock selling	14	21,252	31,859
	Crop related	26	37,564	95,966
	Social and others	15	37,316	84,098

Flood	Did nothing	6	15,789	28,154
	Land related	5	49,863	44,803
	Livestock selling	3	12,946	17,343
	Crop related	3	52,309	46,353
	Social and others	12	27,301	30,960
	landless	22	33,100	--

In the case of untimely rain also the pattern is almost same. When no action or strategy is followed, the per-capita income reduces to NPR 27,131. The per-capita income for crop related and social related activities are nearly same with respective incomes being NPR 37,564 and 37,316. The per capital income per unit of farm size is highest for crop related responses with an income of NPR 95,966. So crop related responses provide maximum benefit.

In the case of flood also, the pattern is similar. There were 51 farmers who were affected by flood. Out of them, 22 are landless. Crop related response provides maximum average per-capita income of NPR 52,309.The per-capital income per unit area of farm size is also highest with NPR 46,353.

Thus it can be concluded that crop related responses seem to be the best strategy irrespective of the climatic shocks to derive maximum per capita income.

4.2 Bihar

4.2.1 Perception of farmers on Climate Change

i) Shocks Encountered

Farmers were questioned on the major shocks (as described earlier) encountered by them during the past 5 years. Multiple responses were observed across the regions and many of the HHs replied that they have encountered more than one shock due to CC (Table 8). Drought is the most severe shock encountered by farmers with a percentage of 50.1. The next severe shock is untimely rain which was observed by 265 farmers (31.1%). Animal Disease has a percentage of 8.3 followed by irregular weather with 5.2%. Percentages of other shocks range between 1.2 to 3.3.

Table 8 Major shocks encountered by surveyed farmers

Type of shocks	Number of farmers
Drought	427(50.1)
Untimely rains	265 (31.1)
Animal disease	71 (8.3)
Irregular weather	44 (5.2)
Others	45(5.3)

Figures in brackets denote percentages

Since some farmers observed more than one shock, an in depth analysis of data is required to know the combination of shocks encountered by them. Analysis of data revealed that farmers encountered 49 combinations of shocks. Table 9 provides the percentage of farmers who encountered various combinations of shocks.

Table 9 Combinations of Shocks Encountered by the Farmers

Combination of shock	Percentage of farmers
No shock	47.9
DR+UR	21.1
DR alone	12.8
DR+UR+AD	4.5
Other 36 combinations	13.7

It is evident from the above table, that both drought and untimely rain were observed by 21.1% of the farmers while drought alone was observed by 12.8% of farmers. Followed by drought, untimely rain and animal disease which was noticed by 4.5% of farmers. Thus we conclude that the important climate related shock experienced by the farmers are drought, untimely rain and animal disease.

Given the importance of these shocks, the frequencies of occurrence of shocks as observed by farmers during the past 5 years were also analysed. Based on their replies, percentages of farmers who encountered a shock with a particular frequency were computed. Table 10 provides the percentage of farmers and the corresponding frequencies for the three major shocks.

Table 10 Frequencies of occurrence of shocks

Frequency of shock in the last 5 years	Number of farmers who encountered		
	Drought	Untimely rain	Animal disease
1	83(19)	215(81)	68(96)
2	273(64)	44(17)	2(3)
3	69(16)	6(2)	1(1)
4	2(1)		

Figures in brackets denote percentages to respective totals

It is clear from the table that out of 427 farmers who observed drought, 273 farmers (64%) felt that it occurred two times in the last five years whereas 83 farmers(19%) encountered it one time and 69 farmers(16%) encountered it three times. Similarly 81% of the farmers who observed untimely rain encountered it one time in the last five years. The third important shock, viz., animal diseases encountered one time in the last five years by about 96% of the farmers.

4.2.2 Severity of climate shocks

Farmers who encountered a particular shock were questioned on the severity of its impact.

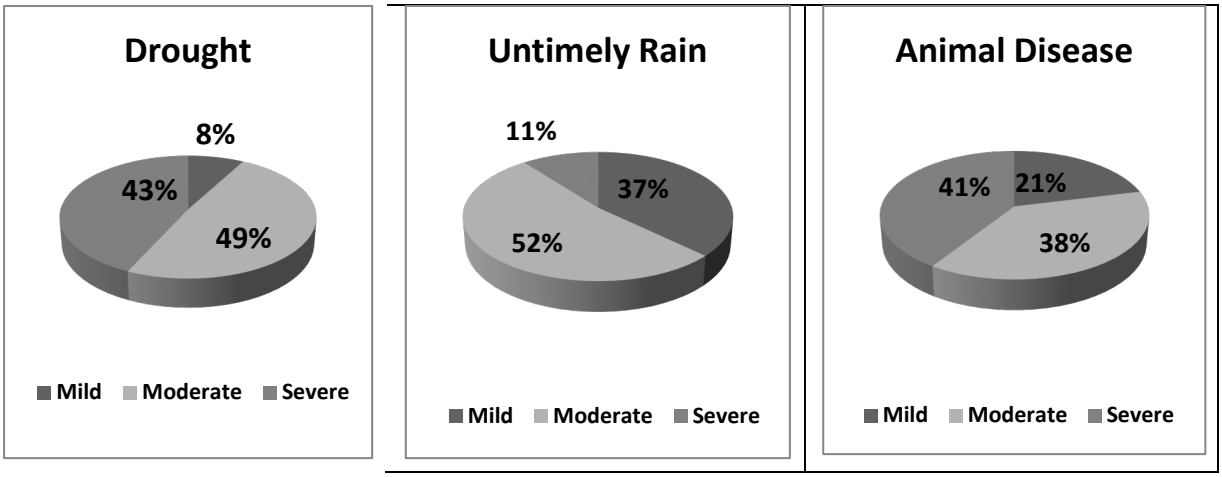

Fig.6 Severity of Climatic Shocks as expressed by farmers

Fig.6 gives the distribution of the severity of the three major shocks. About 43%, 11% and 41% of the farmers who respectively encountered the three major shocks felt that these shocks had severe impact on their agriculture. The shocks had moderate impact on 49%,52% and 38% respectively of the farmers who encountered them.

4.2.3 Response to shocks

Farmers responded in many ways to climatic shocks. In this section the responses for major shocks(drought, untimely rain and flood) are discussed. Respectively 72%, 84% and 83% of the farmers who were hit by the three major shocks did nothing at all to tide over the negative effects. Rest of the farmers responded to climatic shocks. Their responses can be classified as i) land related

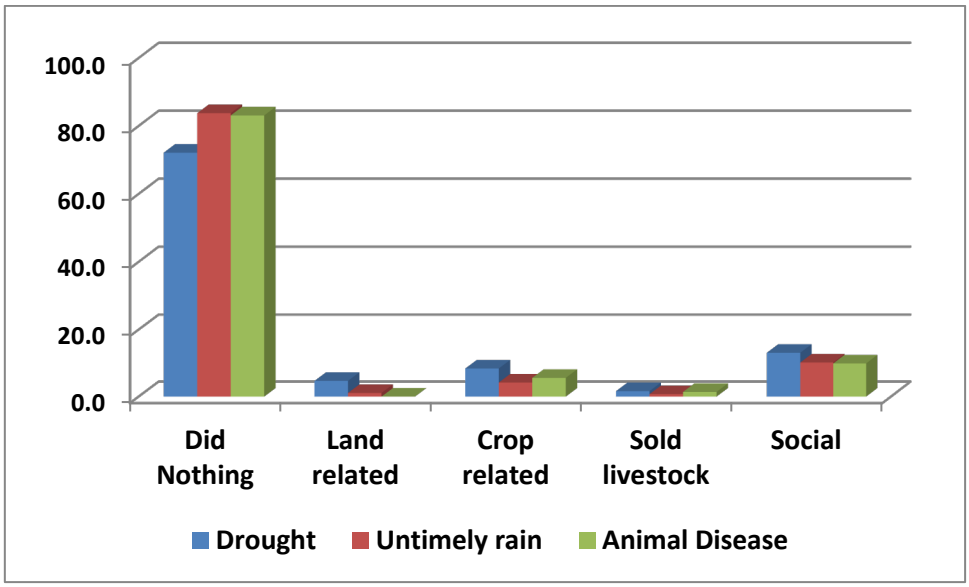

Fig.7. Major Climatic Shocks and distributions of responses by the farmers

ii) crop related iii) sold livestock iv)social and v) others. The land related response consists of a) leaving land fallow b)selling part of land and leasing out part of land. About 5%, 1% and 0% respectively of the farmers who encountered the three shocks, responded to land related strategies to get over the effects of climatic shock. The crop related responses which were followed respectively by 8%, 4% and 6% of the farmers (Fig.7)who were affected by drought, untimely rain and flood include a) providing supplemental irrigation b) changing cropping pattern and following

improved crop production practices. Selling livestock to supplement income last due to extreme climatic shocks is a common practice. Among the surveyed farmers who were affected by the three major shocks, respectively 2%, 1% and 1% of the farmers sold livestock to compensate the lost incomes. Social related responses consist of a) borrowing money b) drawing from savings c) reducing food consumption d)shifting to non-farm employment e) reduction in education level of children and f)out migration to cities. This type of response was followed by 13%, 10% and 10% of the farmers respectively who encountered the major shocks. To summarise, social related strategies followed by crop related strategies are most important response by farmers.

4.2.4 Loss of income due to climatic shocks

The climatic shocks resulted in loss of income for majority of farmers who encountered the major shocks. The percentage of farmers who lost their income ranged from 92% to 96%(Fig.8). This indicates the severity of climatic shocks on agriculture.

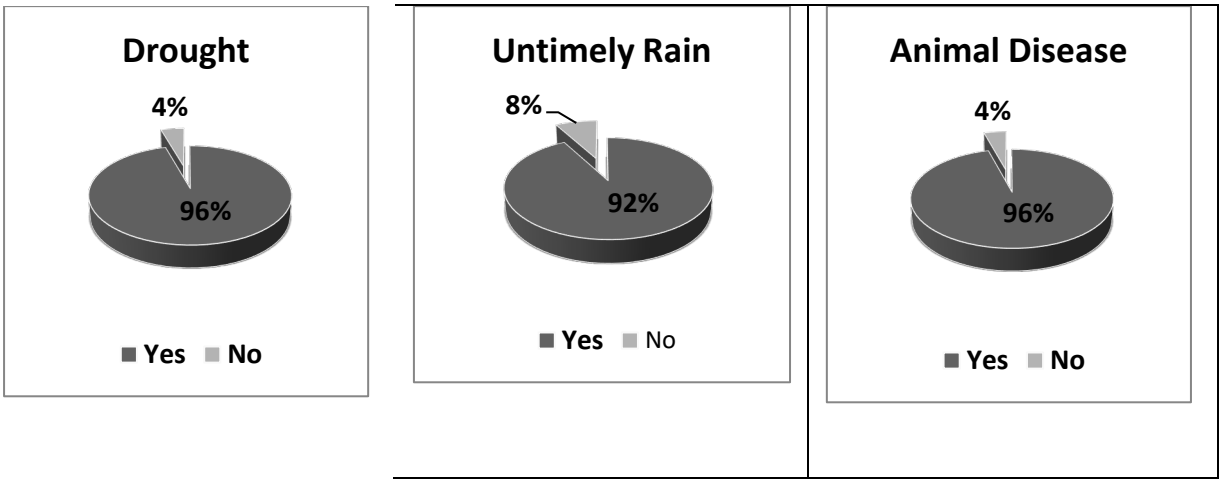

Fig. 8 Percentages of farmers who lost their income due to climatic shocks.

4.2.5 Coping (adaptation) strategies

Farmers were questioned on the assistance received by them from various organizations. like government, relieg agency/NGO, Community/Social group, landlord,extended family etc. Out of 853 farmers, only 55 farmers(6%) reported that they received assistance (Table 11).

Table 11. Farmers and sources of assistance

Organisation	Number of farmers who got assistance
Government/district	7
Relief agency/NGO	4
Community/Social group	8
Landlord	11
Extended family	25
Total	55

Out of these 51 farmers, 25 of them got assistance from extended family, 11 from landlords. Government assistance was received only by seven farmers. The assistance was in the form of cash or advice or food. Thus it is very clear that these assistances are very meagre.

4.2.6 Mapping the Household Vulnerability

Per-capita income (logarithm) of each farmer was used as the dependent variable and socio-economic variables and climate shocks experienced, were used as independent variables. The average per-capita income for the farm holdings is 42877 INR. Table 12 below gives the descriptive statistics of the variables used for the present study.

Table 12 Descriptive statistics of variables used in household vulnerability analysis

Dependent Variable	Mean	SD	Description
Per-capita income (INR)	16623	19313	Continuous
Explanatory Variables			
Farm Size	0.516	0.817	Continuous
Household size	5.198	2.596	Discrete
Household sex	0.949	0.219	DV=1 for male and 0 for female
Household Age in years	43.992	16.951	Continuous
Martial Status of household	2.162	0.548	Discrete with Unmarried=1;Married=2; Divorced/Separated=3;Widowed/Widower=4
Education level of household	1.899	1.250	Discrete with 6 point scale with 1 for no formal education;5 for University and 6 for anyother qualification
MainOccupation	3.863	2.688	Discrete with 10 point scale
Experienced drought	0.501	0.500	DV=1 for experiencing drought and 0 otherwise
Experienced untimely rain	0.311	0.463	DV=1 for experiencing untimely rain and 0 otherwise
Experienced Animal Disease	0.083	0.277	DV=1 for experiencing flood and 0 otherwise
Acredit	0.697	0.460	DV=1 if availed loan in the last year and 0 otherwise
LivestockP	0.439	0.497	DV=1 if in possession of livestock and 0 otherwise
AssetP	0.254	0.435	DV=1 if in possession of consumer good and property and 0 otherwise

The three stage feasible least squares procedure was applied to the survey data and probability of a per capita income falling below the poverty line was worked out as per the methodology. Two cut-off limits, viz. 1.9US$ per day (INR 42,997 per year) and average per-capita income from sample 0.735$ per day (INR 16,623per year) were used to estimate the probabilities of poverty transitions. (The conversion rate used was 1 US$=INR 62 in 2015).The results are plotted in Fig. 9 and Fig.10. Logarithm of income is plotted against probability in these figures. The horizontal line specifies the 50% probability and the vertical line corresponds to logarithm of poverty threshold of INR 16,623 and INR 42,997 respectively in Fig. 4and Fig. 5. These two lines divide the figure into 4 parts. The upper left part corresponds to those farmers whose present income is below the threshold and there is more than 50% probability that they will continue to be vulnerable. Points lying in the upper right part correspond to those HHs who are above the poverty threshold this year and have more than 50% probability to continue the same status next year also(less vulnerable – less vulnerable). HHs who are vulnerable now and have less than 50% change to move from that status next year are represented by the lower left part(vulnerable to less vulnerable). The lower right part specifies those

HHs who are less vulnerable now (that is, above poverty threshold) but less than 50% change to move from that status next year(less vulnerable to vulnerable).

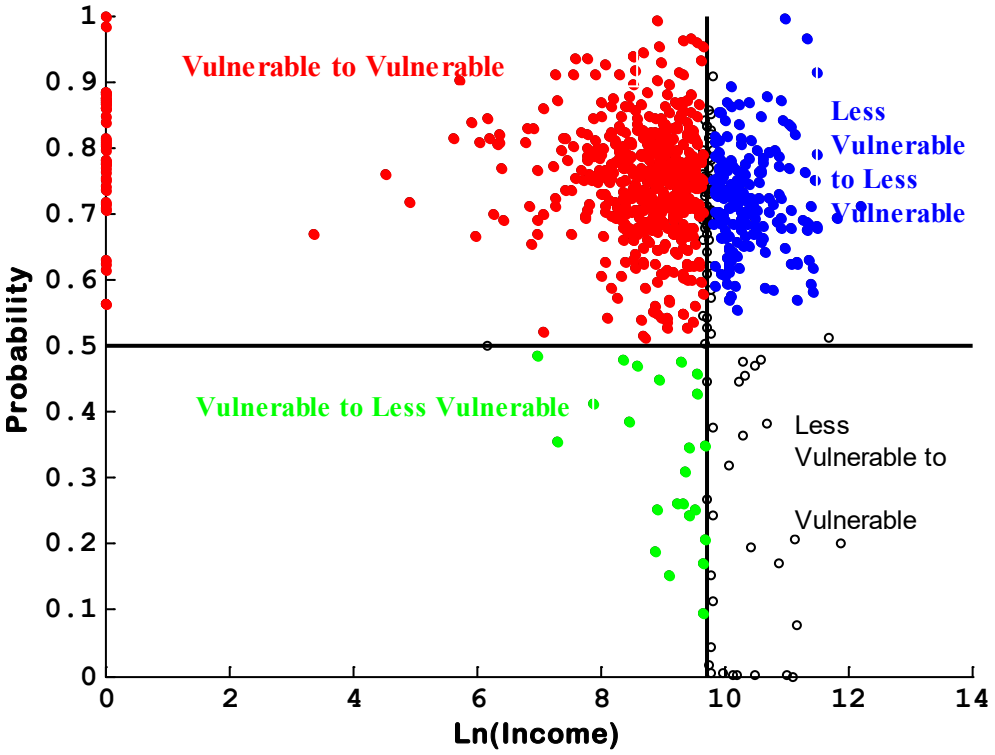

Fig.9 Household Vulnerability –Bihar (income at INR 16,623 per year) plotted against Ln(income)

Table 13 gives the possible number of HHs in Bihar under the four different transitions at two levels of per-capita income. Currently there are 594 HHs (69.7% of the sample HHs) whose per capita income is below the poverty line of INR 16,623 per year (i.e. US$ 0.735 per day). It shows that with probability greater than 0.5, 569 farmers (out of 594), will continue to be vulnerable in the next year also. Further, out of 258 farmers whose per-capita income is above INR 16,623 per year, 232 farmers are liable to be vulnerable next year. Hence out of 852 farmers, 801 farmers(94%) will be vulnerable next year with probability greater than 0.5. This means that 94 % of the farmers are vulnerable to poverty. Also the remaining 51 (6%) of the farmers are likely to be less vulnerable.

When the poverty line is fixed at the US$ 1.9 per day (i.e., INR 42,997 per year (One US $ = 62 INR)), the situation worsens. The percentage of households that are vulnerable becomes 93.3%(795 out of 852 HHs) .

Table 13 Possible poverty transitions (with probability > 0.5) among HHs of Bihar for two levels of per capita income

Percapita income	Transition From				Total
	Vulnerable to		Less vulnerable to		
	Vulnerable	Less vulnerable	vulnerable	less vulnerable	
INR 16,623 per year	569	25	232	26	852
INR 42,997 per Year	792	5	3	52	852

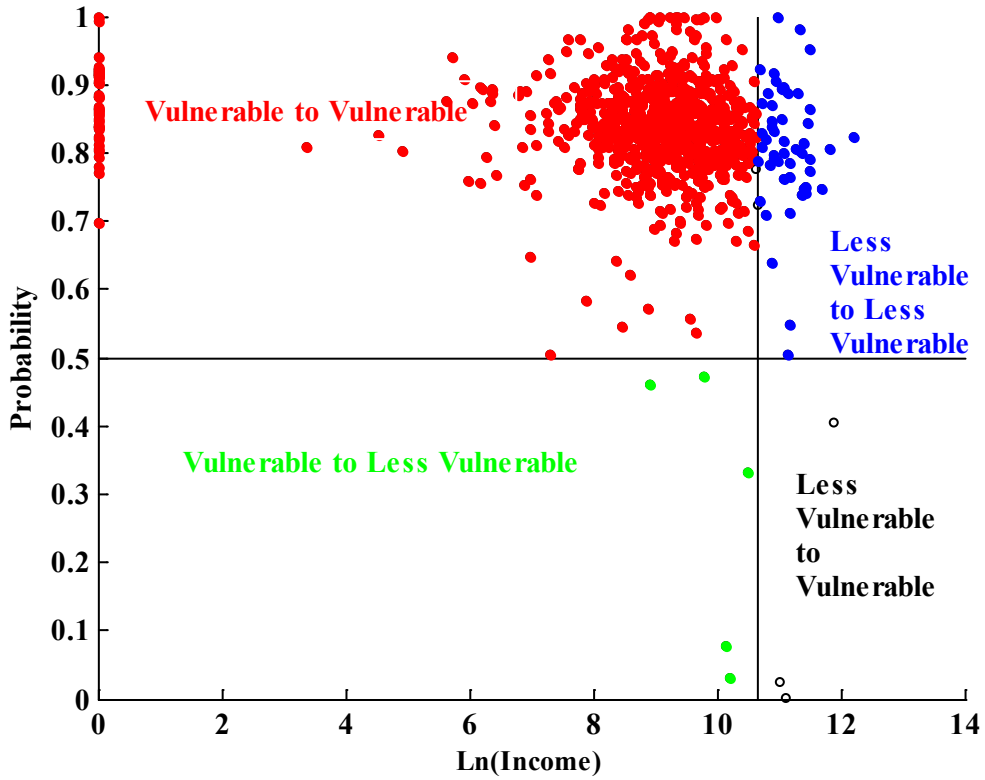

Fig.105 Household Vulnerability –Bihar (income at INR 42,997 per year) plotted against Ln(income)

The determinants of vulnerability for Bihar was assessed against the household characteristics and the results are presented in Table 14. The results show that household age, main occupation, livestock possession and access to credit are the important determinants of household vulnerability of farmers in Bihar.

Table 14 Determinants of household vulnerability

Variable	Coeff	SE	t-value	p-value
Constant	15.749	2.877	5.474	0.004
Farm Size	0.357	0.485	0.737	0.628
Household size	-0.142	-0.691	0.206	0.490
Household sex	-3.156	-1.043	3.027	0.297
Household Age in years	0.109	3.622	0.030	**0.000**
Martial Status of household	-1.717	-1.394	1.232	0.164
Education level of household	-0.674	-1.433	0.470	0.152
MainOccupation	-0.549	-2.808	0.195	**0.005**
Experienced drought	0.421	0.289	1.455	0.772
Experienced untimely rain	-0.703	-0.506	1.389	0.613
Experienced flood	-1.209	-0.635	1.905	0.526
Acredit	-5.696	-5.017	1.135	**0.000**
LivestockP	-2.064	-1.788	1.154	**0.074**
AssetP	-0.357	-0.265	1.347	0.791

4.2.7 Economics of different adaptation strategies:

It is generally believed that the responses to climatic shocks followed by the farmers to overcome the effects of climatic shocks will help to minimize the vulnerability of the households. That is, responses will help to increase the per-capital income of the households. The three major shocks encountered by the farmers are drought, untimely rain and flood. Hence it is important to examine how the responses for each one of the climatic shocks will influence the vulnerability. This section addresses this issue.

The first major climatic shock is drought and it was experienced by 427 farmers. Table 15 gives the average per-capital income for the different responses to drought. The table shows that the per-capita income of the 29 farmers who did nothing for drought (even though they experienced it) is INR 10,207 which is the lowest among the per-capita incomes for the 5 different responses. This means that the per-capita incomes are severely affected if no adaptation strategy is taken to nullify the effect of drought. This is quiet natural because if no action is taken, drought will induce loss in crop yield which in turn will affect the income of the farmer. For the other 4 responses, farmers who did land related responses like leaving land fallow, selling part of land etc, are most affected and their per-capital income is the lowest with INR of 12,509. The net incomes of the farmers whose responses are crop related is highest INR of 21,514. However the per-capital income is directly related to farm size holdings. Hence it is more pertinent to compare the per-capital per unit area of farm size. The last column gives these figures. It shows that farmers who respond to drought with crop related responses (providing supplemental irrigation, change in cropping pattern and following improved crop production practices) get maximum per-capital income per unit farm size holding. Thus crop related responses provide maximum benefit to offset the negative effects of drought on the vulnerability of farmers.

Table 15 Economics of major responses to climatic shocks

Climatic Shock	Response to Climatic Shocks	Number of farmers	Average per-capita income	Average per-capita income per unit area of landholding
Drought	Did nothing	29	10,207	31,025
	Land related	20	12,059	41,682
	Livestock selling	7	12,781	35,262
	Crop related	36	21,514	60,767
	Social and others	335	15,070	31,348
Untimely rain	Did nothing	42	9,164	6,781
	Land related	1	9,873	8,789
	Livestock selling	2	9,164	9,570
	Crop related	6	15,796	46,356
	Social and others	214	14,700	8,410
Animal Disease	Did nothing	18	12,174	10,616
	Land related	0	---	---
	Livestock selling	1	7,114	9,785
	Crop related	4	13,461	17,810
	Social and others	48	12,406	16,380

In the case of untimely rain also the pattern is almost same. When no action or strategy is followed, the per-capita income reduces to INR 9,164. The per-capita income for crop related activities gives the maximum per-capita income of are nearly same with respective incomes INR 15,796. The per capital income per unit of farm size is highest for crop related responses with an income of INR 46,356. Similarly in the case of response to animal disease, crop related response gives highest per-capita income of INR 13,461and per-capita income for unit farm size is also highest with INR 17,810. Thus it can be concluded that crop related responses seem to be the best strategy irrespective of the climatic shocks to derive maximum per capita income.

4.3 West Bengal

4.3.1 Perception of farmers on Climate Change

i) Shocks Encountered

Farmers were questioned on the major shocks (as described earlier) encountered by them during the past 5 years. Multiple responses were observed across the regions and many of the HHs replied that they have encountered more than one shock due to CC (Table 16). Drought is the most severe shock encountered by farmers with a percentage of 15.2. The next severe shocks are untimely rain and market shock which were each observed by 43 farmers (8.5%). Hailstorm has a percentage of 5.5. All other shocks are negligibly felt by the farmers and the percentages of other shocks range between 0.4 to 2.6.

Table 16. Major shocks encountered by surveyed farmers

Shock Name	Number of farmers
Drought	77 (15.2)
Untimely rains	43(8.5)
Market Shock	43(8.5)
Hailstorm	28 (5.5)

Figures in brackets denote percentages

Since some farmers observed more than one shock, an in depth analysis of data is required to know the combination of shocks encountered by them. Analysis of data revealed that farmers encountered 28 combinations of shocks. Table 17 provides the percentage of farmers who encountered various combinations of shocks.

Table 17 Combinations of Shocks Encountered by the Farmers

Combination of shocks	Percentage of farmers
No shock	69.2
DR alone	8.3
MS alone	6.7
UR alone	2.2
DR+UR	2.2
Other 23 combinations	11.4

It is evident from the above table, that drought alone was observed by 8.3% of the farmers while market shock alone was observed by 6.7% of farmers. Also untimely rain alone was noticed by 2.2% of farmers. Combination of drought and untimely rain was also experienced by 2.2% of farmers. Other 23 combinations of shocks are not important as the percentages of these shocks ranged from 0.2 to 1.8%. Thus we conclude that the important climate related shocks experienced by the farmers are drought, market shock and untimely rain.

Given the importance of these shocks, the frequencies of occurrence of shocks as observed by farmers during the past 5 years were also analysed. Based on their replies, percentages of farmers who encountered a shock with a particular frequency were computed. Table 18 provides the percentage of farmers and the corresponding frequencies for the three major shocks.

Table 18 Frequencies of occurrence of shocks

Frequency of shock in the last 5 years	Number of farmers who encountered		
	Drought	Market Shock	Untimely rain
1	37(48.1)	38(88.3)	20(46.6)
2	21(27.3)	2(4.7)	9(20.9)
3	16(20.8)	3(7.0)	13(30.2)
4	3(3.9)	--	1(2.3)

Figures in brackets denote percentages to respective totals

It is clear from the table that out of 77 farmers who observed drought, 37 farmers (48.1%) expressed that it occurred one time in the last five years whereas 21 farmers (27.3%) encountered it two times and 16 farmers (20.8%) encountered it three times. Similarly 88.3% of the farmers who observed market shock encountered it one time in the last five years. The third important shock, viz., untimely rain encountered one time in the last five years by about 46.6% of the farmers.

4.3.2 Severity of climate shocks

Farmers who encountered a particular shock were questioned on the severity of its impact.

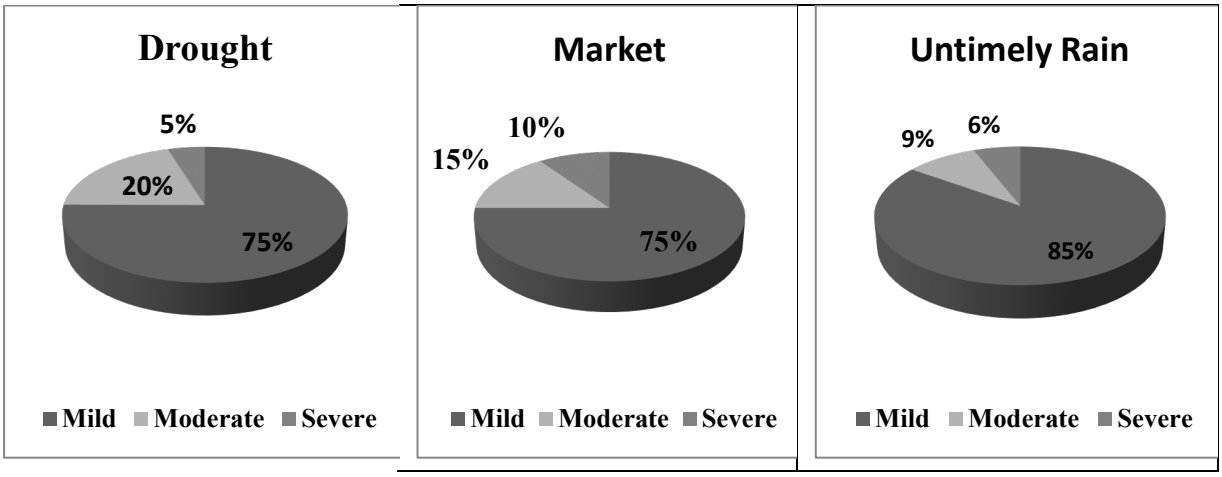

Fig.11 Severity of Climatic Shocks as expressed by farmers

Fig.11 gives the distribution of the severity of the three major shocks. About 75%, 75% and 85% of the farmers who respectively encountered the three major shocks felt that these shocks had mild impacts. The shocks had moderate impact on 20%,15% and 9% respectively of the farmers who encountered them.

4.3.3 Response to shocks

Farmers responded in many ways to climatic shocks. In this section the responses for major shocks(drought, market share and untimely rain) are discussed. Respectively 39%,9.3% and 39.5% of the farmers who were hit by the three major shocks did nothing at all to tide over the negative effects. Rest of the farmers responded to climatic shocks. Their responses can be classified as i) land related

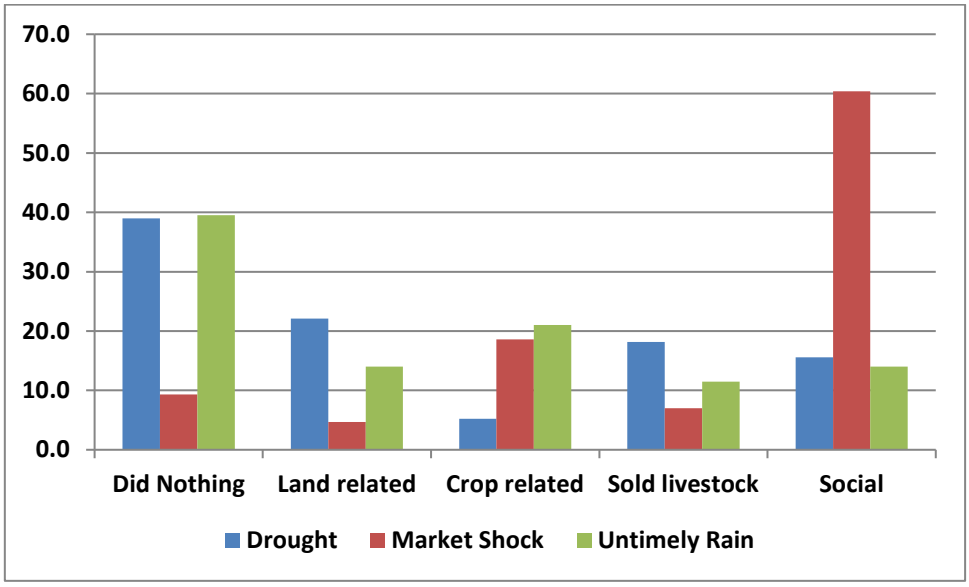

Fig.12. Major Climatic Shocks and distributions of responses by the farmers

ii) crop related iii) sold livestock iv)social and v) others. The land related response consists of a) leaving land fallow b)selling part of land and leasing out part of land. About 22.1%, 4.7% and 14% respectively of the farmers who encountered the three shocks, responded to land related strategies to get over the effects of climatic shock. The crop related responses which were followed respectively by 5.2%, 18.6% and 21.0% of the farmers (Fig.12) who were affected by drought, untimely rain and flood include a) providing supplemental irrigation b) changing cropping pattern and following improved crop production practices. Selling livestock to supplement income last due to extreme climatic shocks is a practice in the study area. Among the surveyed farmers who were affected by the three major shocks, respectively 18.2%,7.0% and 11.5% of the farmers sold livestock to compensate the lost incomes. Social related responses consist of a) borrowing money b) drawing from savings c) reducing food consumption d)shifting to non-farm employment e) reduction in education level of children and f)out migration to cities. This type of response was followed by 15.6%, 60.4% and 14.4% of the farmers respectively who encountered the major shocks. Among the social related responses, the major activity was to borrow money to tide over market shocks. To summarise, social related strategies followed by crop related strategies are the most important responses by farmers.

4.3.4 Loss of income due to climatic shocks

The climatic shocks resulted in loss of income for majority of farmers who encountered the major shocks. The percentage of farmers who lost their income ranged from 86% to 91% (Fig.13). This indicates the severity of climatic shocks on agriculture.

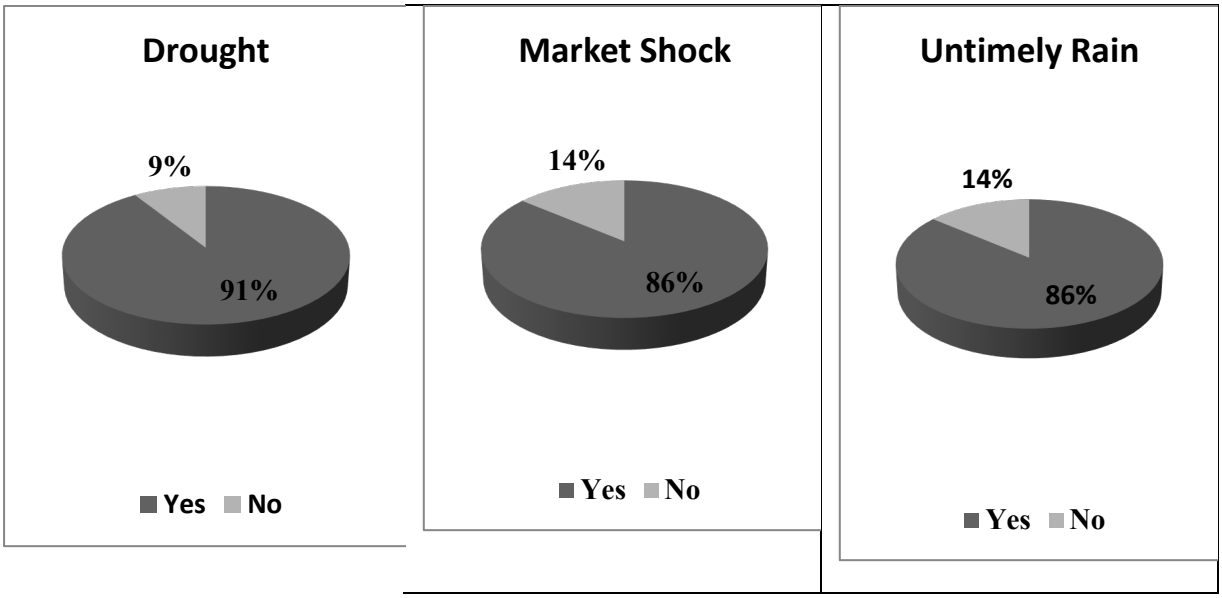

Fig.13 Percentages of farmers who lost their income due to climatic shocks.

4.3.5 Coping (adaptation) strategies

Farmers were questioned on the assistance received by them from various organizations. like government, relief agency/NGO, Community/Social group, landlord, extended family etc. Out of 507 farmers, 458 farmers (90%) reported that they have not received any assistance from any organization and the remaining 10% didn't respond at all. Thus it is very clear that there was no assistance to the farmers, not even from government, to face the loss of income/resources due to climate change. This has very serious implications and suitable measures must be taken up by government and other relief agencies such as NGOs.

4.3.6 Mapping the Household Vulnerability

Per-capita income (logarithm) of each farmer was used as the dependent variable and socio-economic variables and climate shocks experienced, were used as independent variables. The average per-capita income for the farm holdings is 42877 INR. Table 19 below gives the descriptive statistics of the variables used for the present study.

The three stage feasible least squares procedure was applied to the survey data and probability of a percapita income falling below the poverty line was worked out as per the methodology. Two cut-off limits, viz. 1.9US$ per day (INR 42,997 per year) and average per-capita income from sample 0.915$ per day (INR 20,705 per year) were used to estimate the probabilities of poverty transitions. (The conversion rate used was 1 US$=INR 62 in 2015).The results are plotted in Fig. 14 and Fig.15. Logarithm of income is plotted against probability in these figures. The horizontal line specifies the 50% probability and the vertical line corresponds to logarithm of poverty threshold of INR 20,705 and INR 42,997 respectively in Fig. 4and Fig. 5. These two lines divide the figure into 4 parts. The upper left part corresponds to those farmers whose

Table 19. Descriptive statistics of variables used in household vulnerability analysis

Dependent Variable	Mean	SD	Description
Per-capita income (INR)	20705	37617	Continuous
Explanatory Variables			
Farm Size	0.547	0.803	Continuous
Household size	4.442	1.676	Discrete

Household sex	0.887	0.317	DV=1 for male and 0 for female
Household Age in years	39.657	14.602	Continuous
Martial Status of household	2.066	0.611	Discrete with Unmarried=1;Married=2; Divorced/Separated=3;Widowed/Widower=4
Education level of household	1.707	0.853	Discrete with 6 point scale with 1 for no formal education;5 for University and 6 for any other qualification
Main Occupation	3.940	3.098	Discrete with 10 point scale
Experienced drought	0.152	0.360	DV=1 for experiencing drought and 0 otherwise
Experienced market shock	0.085	0.279	DV=1 for experiencing untimely rain and 0 otherwise
Experienced Untimely rain	0.084	0.279	DV=1 for experiencing flood and 0 otherwise
Acredit	0.435	0.496	DV=1 if availed loan in the last year and 0 otherwise
LivestockP	0.749	0.434	DV=1 if in possession of livestock and 0 otherwise
AssetP	0.218	0.413	DV=1 if in possession of consumer good and property and 0 otherwise

present income is below the threshold and there is more than 50% probability that they will continue to be vulnerable. Points lying in the upper right part correspond to those HHs who are above the poverty threshold this year and have more than 50% probability to continue the same status next year also(less vulnerable – less vulnerable). HHs who are vulnerable now and have less than 50% change to remain in that status next year also are represented by the lower left part(vulnerable to less vulnerable). The lower right part specifies those HHs who are less vulnerable now (that is, above poverty threshold) but less than 50% change to remain in that status next year(less vulnerable to vulnerable).

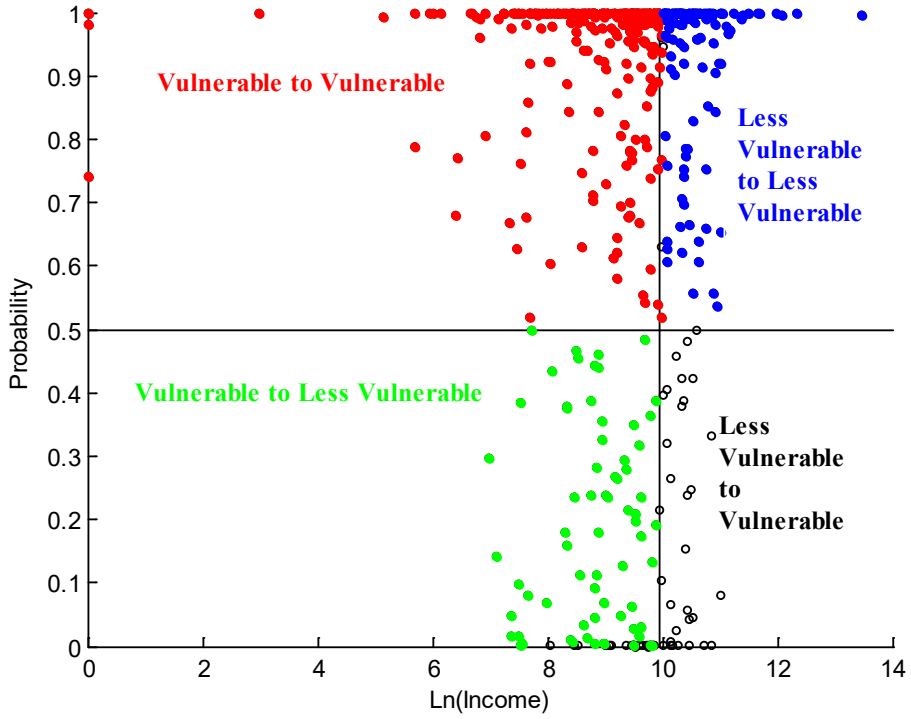

Fig.14 Household Vulnerability –West Bengal (income at INR 20,705 per year) plotted against Ln(income)

Table 20 gives the possible number of HHs in West Bengal under the four different transitions at two levels of per-capita income. Currently there are 342 HHs (67.5% of the sample HHs) whose per capita income is below the poverty line of INR 20,705 per year (i.e. US$ 0.915 per day). It shows that with probability greater than 0.5, 249 farmers (out of 342), will continue to be vulnerable in the next year also. Further, out of 165 farmers whose per-capita income is above INR 20,705 per year, 33 farmers are liable to be vulnerable next year. Hence out of 507 farmers, 282 farmers(55.6%) will be vulnerable next year with probability greater than 0.5. This means that 55.6% of the farmers are vulnerable to poverty. Also the remaining 225 (44.4%) of the farmers are likely to be less vulnerable. This means that there will be decline in the number of farmers below the poverty line from current year to next year.

Similar trend is observed when the poverty line is fixed at the US$ 1.9 per day (i.e., INR 42,997 per year (One US $ = 62 INR)). Currently there are 463(91.3%) farmers are below poverty line. The percentage of households that are vulnerable next year becomes 76.7%(389 out of 507 HHs) .

Table 20. Possible poverty transitions (with probability > 0.5) among HHs of West Bengal for two levels of per capita income

Percapita income	Transition From				Total
	Vulnerable to		Less vulnerable to		
	Vulnerable	Less vulnerable	vulnerable	less vulnerable	
INR 20,705 per year	249	93	33	132	507
INR 42,997 per Year	386	77	3	41	507

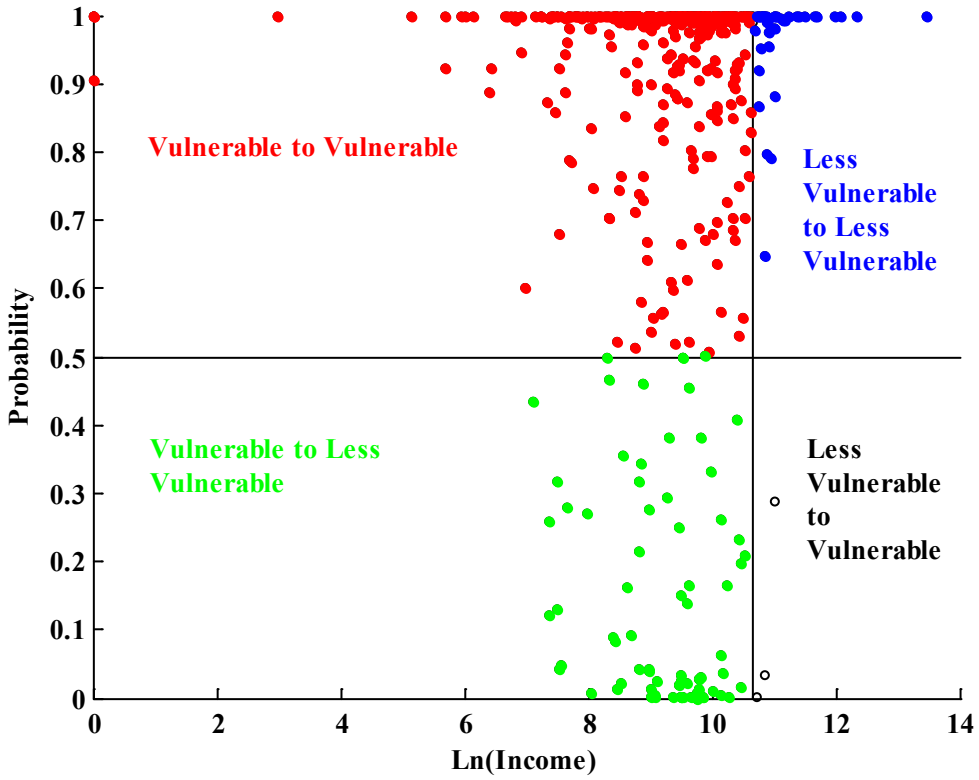

Fig. 15 Household Vulnerability –West Bengal (income at INR 42,997 per year) plotted against Ln(income)

The determinants of vulnerability for West Bengal were assessed against the household characteristics and the results are presented in Table 21. The results show that farm size, household age, educational level, main occupation, drought and market shock impacts, livestock possession and access to credit are the important determinants of household vulnerability of farmers in West Bengal.

Table 21. Determinants of household vulnerability

Variable	Coeff	SE	t-value	p-value
Constant	1.045	0.390	2.678	0.007
Farm Size	-0.235	-0.057	4.125	**0.000**
Household size	0.094	0.404	0.232	0.816
Household sex	-2.072	-1.661	1.248	0.212
Household Age in years	0.004	0.002	2.741	**0.006**
Martial Status of household	0.721	1.064	0.677	0.498
Education level of	-0.442	0.085	-5.223	**0.000**
Main Occupation	-0.050	-0.020	2.424	**0.015**
Experienced drought	-0.082	-0.016	5.024	**0.000**
Experienced market shock	-0.565	-0.071	8.010	**0.000**
Experienced untimely rain	-0.854	-0.584	1.462	0.144
Acredit	-0.044	-0.026	1.662	**0.097**
LivestockP	0.279	0.073	3.815	**0.000**
AssetP	0.529	0.587	0.900	0.368

4.3.7 Economics of different adaptation strategies:

It is generally believed that the responses to climatic shocks followed by the farmers to overcome the effects of climatic shocks will help to minimize the vulnerability of the households. That is, responses will help to increase the per-capital income of the households. The three major shocks encountered by the farmers are drought, untimely rain and flood. Hence it is important to examine how the responses for each one of the climatic shocks will influence the vulnerability. This section addresses this issue.

The first major climatic shock is drought and it was experienced by 77 farmers. Table 22 gives the average per-capital income for the different responses to drought. The table shows that the per-capita income of the 33 farmers who did nothing for drought (even though they experienced it) is INR 10,507 which is the lowest among the per-capita incomes for the 5 different responses. This means that the per-capita incomes are severely affected if no adaptation strategy is taken to nullify the effect of drought. This is quiet natural because if no action is taken, drought will induce loss in crop yield which in turn will affect the income of the farmer. For the other 4 responses, farmers who did social responses like borrowing money, are most affected and their per-capital income is the next lowest with INR of 11,927. The net income of the farmers whose responses are crop related is maximum (INR 15,051). However the per-capital income is directly related to farm size holdings. Hence it is more pertinent to compare the per-capital per unit area of farm size. The last column gives these figures. It shows that farmers who respond to drought with crop related responses (providing supplemental irrigation, change in cropping pattern and following improved crop production practices) get maximum per-capital income per unit farm size holding. Thus crop related responses provide maximum benefit to offset the negative effects of drought on the vulnerability of farmers.

Table 22. Economics of major responses to climatic shocks

Climatic Shock	Response to Climatic Shocks	Number of farmers	Average per-capita income	Average per-capita income per unit area of landholding
Drought	Did nothing	33	10507	15789
	Land related	17	13476	20296
	Livestock selling	14	12788	20695
	Crop related	2	15051	30057
	Social and others	11	11927	12073
Market Shock	Did nothing	27	8745	31304
	Land related	--	--	--
	Livestock selling	--	--	--
	Crop related	--	--	--
	Social and others	16	13325	28325
Untimely rain	Did nothing	43	8976	25548
	Land related	--	--	--
	Livestock selling	--	--	--
	Crop related	--	--	--
	Social and others	--	--	--

In the case of market shock, farmers either did nothing or responded with social related responses. When no action or strategy is followed, the per-capita income reduces to INR 8,745. Social responses give a better per-capital income of INR 13,325. In the case of untimely rain, which was experienced by 43 farmers, no farmer took any action. Thus it can be concluded that crop related responses seem to be the best strategy irrespective of the climatic shocks to derive maximum per capita income.

5. Conclusions and Recommendations

In the case of Nepal, currently there are 425 HHs whose per capita income is below the poverty line and 300 farmers will continue to be vulnerable in the next year also. Further, out of 285 farmers whose per-capita income is above poverty line, 173 farmers are liable to be vulnerable next year. In total, about 67 % of the farmers are vulnerable to poverty in the region. The key determinants of hh vulnerability are farm size, marital status, main occupation and access to credit. Among the different adaptation strategies followed to manage the drought, crop related responses (such as providing supplemental irrigation, change in cropping pattern and improved crop production practices) get maximum per-capital income/acre. In the case of untimely rain and floods, the farmers responses are almost same.

In the case of Bihar, currently there are 594 HHs (69.7% of the sample HHs) are below the poverty line and 569 farmers will continue to be vulnerable in the next year also. Further, out of 258 farmers whose per-capita income is above poverty line, 232 farmers are liable to be vulnerable next year. In total 801 farmers (94%) will be vulnerable next year. The key determinants of vulnerability include household's age, main occupation, livestock possession and access to credit. Farmers who respond to drought with crop related responses (providing supplemental irrigation, change in cropping pattern and adoption of improved crop production practices) get maximum per-capital income per acre. In the case of untimely rain and floods also the pattern is almost same. The per capital income per unit of farm size is highest for crop related responses. Similarly in the case of response to animal disease, crop related response gives highest per-capita income.

In the case of West Bengal, currently 342 HHs (67.5% of the sample HHs) are having per capita income below the poverty line. Out of this, 249 farmers, will continue to be vulnerable in the next year also. Further, out of 165 farmers whose per-capita income is above poverty line, 33 farmers are liable to be vulnerable next year. Hence out of 507 farmers, 282 farmers(55.6%) will be vulnerable next year. This means that there will be decline in the number of farmers below the poverty line from current year to next year. The key determinants of vulnerability are farm size, household age, educational level, main occupation, drought and market shock impacts, livestock possession and access to credit.

Regarding the adaptation strategies, farmers who respond to drought with crop related responses (providing supplemental irrigation, change in cropping pattern and following improved crop production practices) get maximum per-capital income per acre. unit farm size holding. Thus crop related responses provide maximum benefit to offset the negative effects of drought on the vulnerability of farmers. In the case of market shock, social responses give a better per-capital income. In the case of untimely rain, which was experienced by 43 farmers, no farmer took any action.

6. Recommendations

Major policy prescriptions include piloting of strategies that yield comparatively higher income than the current practices as illustrated by the results from these case study regions. Cluster approach in piloting will be more effective in technology adoption. Thus a package of adaptation strategies will be made available to the households and based on the performance of these pilots, up-scaling can be done through the government departments.

Creating awareness and enhancing the skill development activities through capacity building programs is very important.

Most of the farmers are facing the risk of rainfall variability and investment in farm ponds for providing supplementing irrigation and this can be examined in detail. As the investment in the construction of farm ponds and provision of supplemental irrigation through micro sprinklers may be costlier for small and marginal farmers, option for convergence of different government programs which can facilitate construction of farm ponds, provision of solar powered pumpsets and other water harvesting structures such as percolation ponds, checkdams etc., need to be examined.

Adoption of all these strategies could enhance the off-farm income of the households which are currently below 10%. Successful business models should be identified from the list of pilot projects implemented in different regions and should be made available to interested partners and implementing departments. In the long run, these models can be up-scaled through the public private partnership (ppp) initiative.

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