Research Report No. 67
ICRISAT Research Program
Resilient Dryland System

Mapping of household vulnerability and identification of adaptation strategies in dryland systems of South Asia

K Palanisami, Krishna Reddy Kakumanu, CR Ranganathan,
Amare Haileslassie and Suhas P Wani

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International Crops Research Institute for the Semi-Arid Tropics
CGIAR RESEARCH PROGRAM ON Dryland Systems
IWMI International Water Management Institute

Citation: Palanisami K, Kakumanu KR, Ranganathan CR, Haileslassie A and Wani SP. 2015. Mapping of household vulnerability and identification of adaptation strategies in dryland systems of South Asia. Patancheru 502 324, Telangana, India: International Crops Research Institute for the Semi-Arid Tropics. 60 pp.

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This work has been undertaken as part of the CGIAR RESEARCH PROGRAM ON Dryland Systems

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2015

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Acknowledgments

We are grateful to the CGIAR Research Programs on Dryland Systems and Climate Change, Agriculture and Food Security for funding the baseline survey of the three action sites. We also acknowledge the technical support and guidance provided by Peter Craufurd, the then Director of the RDS, ICRISAT; Peter McCornick, DDG, IWMI; Mark Giordano, the then Theme Leader, IWMI; Madar Samad, acting Theme Leader, IWMI; and Shalander Kumar, Scientist, RDS, ICRISAT.

We also acknowledge the field-level support extended by the partners' organizations, viz., ANGRAU, Andhra Pradesh; University of Agricultural Sciences, and College of Agriculture, Dharwad and GRAVIS, Jodhpur.

Research support was provided by G Adinarayana, Scientific Officer, RDS, ICRISAT.

We also thank Mapedza Everisto, Researcher, IWMI, who is coordinating the CRP1.1 activities from IWMI.

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Executive Summary

Low amount and high variability of rainfall in South Asian dryland production system have affected the livelihood of small and marginal households. Therefore, a marginal change in the climate could challenge the livelihood resilience of millions of farmers and affect the healthy ecosystem function in South Asia. The CGIAR Consortium Research Program on Dryland Systems (DS) focuses on DS across the world in order to tackle these problems. The overall emphasis of the research involves understanding the problem, identifying and demonstrating technologies and searching for mechanisms to promote the adoption of promising technologies. In South Asia, the program selected six districts in Andhra Pradesh (Anantapur and Kurnool), Karnataka (Bijapur) and Western Rajasthan (Jaisalmer, Barmer, and Jodhpur) as action sites.

The overall objectives of the present study are to map the vulnerability at household level and examine the level of coping strategies adopted by them and to investigate the impact of different adaptation strategies in reducing the level of vulnerability in the South Asian DS action sites. The study covers all the six districts as mentioned earlier, and the data was collected from farmers in 15 villages located in the action districts. A total of 1019 farmers were randomly selected, and the survey was executed during 2012-13 and the data collected was related to the production year of 2011-12.

The household vulnerability analysis was mainly based on the per-capita income of farmers (agriculture, livestock and off-farm) and associated socio-economic factors. For this study, we defined household vulnerability in terms of expected poverty, which is measured by the difference between the household (per-capita) income and the poverty line. The per-capita net income of the farmers varied greatly across the three states; it was ₹ 15,472 in Andhra Pradesh, ₹ 65,428 in Karnataka and ₹ 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) ₹ 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 three-stage feasible generalized least squares procedure was applied, and the probability of a per capita income falling below the poverty line was worked out. Accordingly, four poverty transitions were computed. The first transition represented those households whose present income is below the poverty line, and there is more than 50% probability that they will continue to be vulnerable in the next year also (vulnerable to vulnerable). The second transition represented those households who are above the poverty line this year and have more than 50% probability to continue the same status in the next year also (less vulnerable to less vulnerable). The third transition represented those households who are vulnerable now and have less than 50% chances to move from that status next year (vulnerable to less vulnerable). The fourth transition specified those households who are less vulnerable now (that is, above poverty line) but have less than 50% chances to move from that status in the next year (less vulnerable to vulnerable). The results indicated that in all the regions, the probability of vulnerable to vulnerable transition decreased when the landholding size increased.

Given the current low level of adoption of improved technologies in the studied production systems, about 94% of the households in Andhra Pradesh, 62% in Karnataka and 87% in Rajasthan were vulnerable and the rest were under the less-vulnerable category. These vulnerable groups may move to the less-vulnerable groups if they adopt different strategies specific to their niches (regions, in this case). In Andhra Pradesh, suitable technologies or strategy for small farmers include the combination of livestock, additional skill development interventions, change in cropping pattern, alternative planting date and farm mechanization. Such interventions can fetch a net income of ₹ 111,616 per household with a marginal income of ₹ 63,136 in pure rain-fed situations. The combination of livestock, additional skill development interventions, change in cropping pattern and providing supplemental irrigation with farm

mechanization would be suitable for large farmers and can help them realize a net income of ₹ 534,370 per household with a marginal income of ₹ 252,284 in pure rain-fed situations.

In Karnataka, the possession of livestock is remunerative for landless farmers as it can fetch a net income of ₹ 37,519 per household. For marginal farmers, a combination of livestock, additional skill development interventions and change in cropping patterns seems to be a better strategy as it can fetch an annual household income of ₹ 60,388 with a marginal income of ₹ 20,970. Small farmers can get a higher income if they adopt a package of livestock, additional skill development interventions, change in cropping pattern, and improved crop production practices. They can get a household income of ₹ 174,235 and a marginal income of ₹ 30,452. Medium farmers can opt for owning livestock, additional skill development activities and improved crop production practices that can bring an annual household income of ₹ 355,868 with a marginal income of ₹ 54,817. Large farmers who own more than 4 hectares of land can obtain a maximum income of ₹ 1,899,021 and a marginal income of ₹ 429,657 if they adopt livestock, additional skill development activities, change in cropping pattern, and farm mechanization.

In Rajasthan, owning livestock and farm mechanization seems to be the most suitable strategy for marginal farmers that can result in a maximum household income of ₹ 49,541 and a marginal income of ₹ 22,841. For maximum revenue, small farmers should own livestock, maintain poultry and goats apart from mechanization that can fetch an income of ₹ 191,384 with a marginal income of ₹ 71,172. The next suitable strategy for them will be to own livestock and provide supplementary irrigation that can earn an income of ₹ 120,212 and a marginal income of ₹ 13,417. Medium-size landholding farmers can drive a maximum income of ₹ 238,045 with a marginal income of ₹ 32,867 if they use livestock, own farm ponds and use farm mechanization. Large farmers can also use this strategy to get a maximum income of ₹ 365,510 and a marginal income of ₹ 214,273. The next suitable strategy for them will be possession of livestock, poultry and goats, and farm mechanization that can provide a household income of ₹ 151,237 with a marginal income of ₹ 18,357.

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. However, when the adaptation strategies are followed, less number of households will fall under the vulnerable category.

The determinants of the vulnerability analysis from the three states also helped in identifying the appropriate adaptation strategies for addressing the household vulnerability. Farm size, household size, educational levels, age of the household, and earnings from male and female members were found to affect vulnerability. More specifically, the livestock-related interventions, farm mechanization, and supplemental irrigation are expected to play a major role in addressing the household vulnerability as well as risk in technology adoption. Major policy implications include piloting of adaptation strategies that yield comparatively higher income than the pure rain-fed situations as observed in the study regions. Enhancing and diversifying the skills of farmers through capacity building programs (such as targeted trainings for specific activities like micro irrigation, farm pond design and use, handling of small farm machineries, fodder production, etc.), investment in farm ponds for providing supplementing irrigation, developing public private partnership in small farm machinery and micro irrigation development will help elevate the most vulnerable to less vulnerable situations. Quantification of risks in the adoption of the proposed strategies and advocating an appropriate insurance product can enhance the adoption level. Convergence of the government programs on dryland agriculture will help achieve efficient implementation of the combination of activities and thus, enable the progressive transition from vulnerable to less vulnerable.

1. Introduction

1.1. Problem Setting

Agriculture continues to be the backbone of Indian economy, even though its share in Gross Domestic Product (GDP) has declined over the years; it provides employment to 52% of the workforce. Agriculture and its allied sectors, which accounted for 16.6% of the GDP in 2009, had a share of only 14% in 2011-12. Recent evidences show that many challenges exist in the agriculture sector; for example, about 80% of Indian farmers fall under small and marginal categories, having a share of 44% of the operated land area (Dev, 2012). The total sown area in India is 141.1 million hectare, and 68% of the sown area is rain-fed land that is spread over 177 districts. Rain-fed crops account for 48% of the area under food crops and 68% of the area under non-food crops. Nearly 50% of the total rural workforce and 60% of livestock in the country are concentrated in the rain-fed regions, where access to irrigation is only 15% compared to 48% in irrigated regions. Due to the scarcity and discrepancy of rainfall in the region, more farmers are vulnerable to system shocks, which is a threat to agriculture.

For example, the Planning Commission of India has estimated that 25.7% of the people in rural areas and 13.7% of the people in urban areas were below the poverty line during 2011-12. In total, 21.9% of the people are below the poverty line in the country (Govt. of India, 2013). The poverty ratio head count percentage for rain-fed regions is 37% while for irrigated regions, it is 33%. The prevalence of poverty in rain-fed areas is mainly attributed to crop failures due to frequent occurrences of mid-season and terminal droughts.

Agriculture, particularly, rain-fed agriculture, is affected by climate change because of its primary exposure to the environment (rainfall and temperature). The climate change projection for India up to 2100 indicates that the temperature will increase by 2–4 °C with no substantial change in precipitation (Kavikumar, 2010). Moreover, climate change affects not only the mean yield of the crops, but also induces variability in the yields (Palanisami et al., 2014). These research findings strengthen the hypothesis that rain-fed farming will be severely affected by climate change. Although rain-fed crops can tolerate high temperatures, the crops grown in these regions during the rabi season are vulnerable to changes with a minimum temperature (Venkateswarlu and Rama Rao, 2010). This has a strong implication for livestock feed quality and quantity and thus, their productivity.

Strategies that can help farmers to cope with vulnerability and increase their resilience will, therefore, be important for making appropriate interventions consisting of strategies ranging from technical, institutional strategies to policies. In this context, the analysis of the household level vulnerability could provide a basis on which interventions can be targeted and assessed for overall livelihood strategies and bio-physical characteristics of the production system.

The CGIAR-Consortium Research Program on DS argues that dryland agricultural and livelihood systems in any benchmark or target area will comprise a mixture or mosaic of households and communities with varying degrees of vulnerabilities and risks, and capacity to increase production and improve livelihoods. Their resilience is measured by the extent to which households or communities can manage vulnerabilities and risks, and exploit opportunities offered by favorable environments or institutional innovations. All households, whether rich or poor or in high or low potential agro-ecological zones, have to cope with risks. Indeed, households and communities move between different states temporally as well as spatially. This study contributes to the better understanding of these complex dynamics.

In order to get an in-depth understanding of the household-level climate change shocks, their perceptions, household vulnerabilities, and the adaptation strategies followed, a baseline survey was conducted in the action sites during 2012-13. Here, three sets of hypothesis were explored. The first hypothesis stated that the vulnerability of households can be reduced with the adoption of different adaptation practices. The second hypothesis stated that households with poor access to technologies and resources will remain vulnerable and those having access to resources, such as lands, will move from the vulnerable category to the less-vulnerable category. The third hypothesis stated that, at different scales, the drivers of change and the required strategies will be different. At the household level, the major drivers of change include access to technologies, income levels, etc. In line with these, the general objective was to map vulnerability at household levels across the three study regions. The specific objectives were to:

- Study the perception of the households about the climate change impacts,
- Examine the level of coping strategies adopted by them,
- Map the household based on the incidence of poverty and analyze the relationship between the farm size and the household vulnerability, and
- Study the impact of different adaptation strategies in reducing the level of vulnerability.

1.2. Description of Study Regions

Many target regions in South Asia were discussed and proposed during the DS workshop in Dubai in 2011[1]. By using information layers such as aridity index, length of growing period (<90 days, <180 days), land use/land cover, and resource degradation, three regions, i.e., Rajasthan, Andhra Pradesh and Karnataka, were selected and grouped under the Strategic Research Themes (SRT2 and SRT3). The SRT2 aims at reducing vulnerability and SRT3 aims at sustainable intensification[2]. Among the selected regions, SRT2 is represented by Rajasthan and Andhra Pradesh, and SRT3 is represented by Karnataka. The DS action districts are shown in Figure 1.

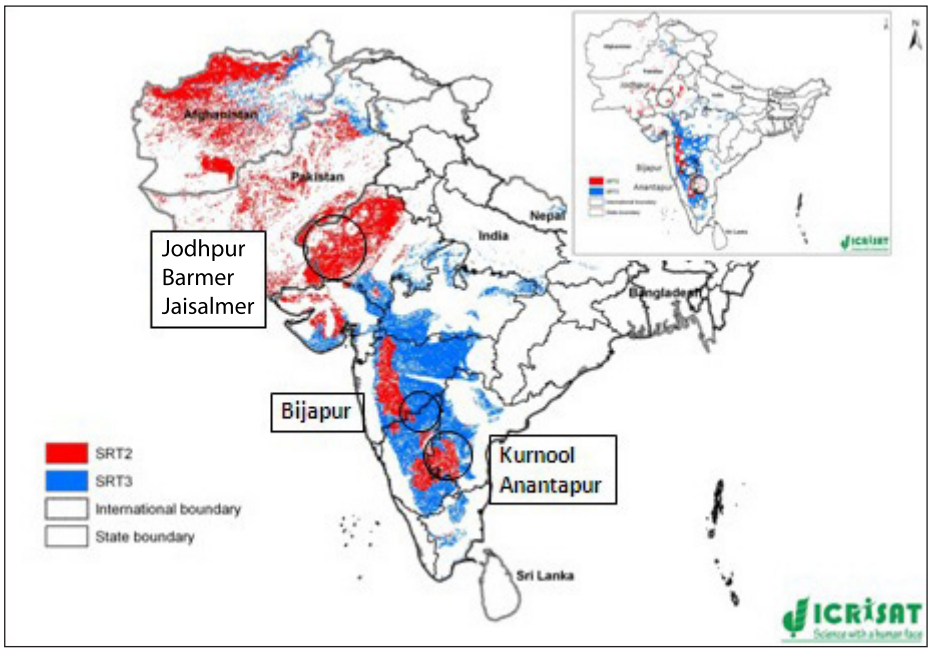

Figure 1. Location of action sites

1. CRP1.1 Dryland Systems Framework Development Workshop. Integrated Agricultural Systems for Food Security and Improved Livelihoods in Dry Areas (Dryland Systems) 30 January – 1 February 2012, Dubai.

2. In the same manner, the Intermediate Development Output 1 (IDO 1) refers to the more resilient livelihoods for vulnerable households in marginal areas whereas IDO2 refers to the more sustainable and higher income per capita for intensifiable households.

In terms of production systems, SRT2 type environments include low rainfall rangelands, where pastoral and agro-pastoral systems predominate. The SRT3 type environments are dominant in India, except for a large SRT2 area in peninsular India, including parts of Maharashtra, Andhra Pradesh, and Karnataka. In all SRT2 and SRT3 type environments in India, except western Rajasthan, mixed crop-livestock systems predominate. In these mixed systems, a major determinant of agricultural systems is soil type. There are two major tropical soil types-based agricultural systems: red soil (*Alfisols*) and black clayey soil (*Vertisols*) based systems. Red soils make up to 60–65% of the cropping belt in South India, followed by black soils. Andhra Pradesh represents the red soil areas, and Karnataka represents the black soil area (Table 1).

Table 1. Action sites and the production systems

Action Site	Sub-District (Mandal, Tehsil, Taluk, Block)	SRT	System
Jodhpur, Barmer & Jaisalmer (Rajasthan)	Osian, Chohtan, Jaisalmer	2	Rangeland, agro-pastoral
Bijapur (Karnataka)	Mannur, Balaganur, Nandihal	3	Mixed crop-livestock, black soils
Anantapur & Kurnool, (Andhra Pradesh)	Kalyandurg, Dhone	2 & 3	Mixed crop-livestock, red (and black) soils

Different households have different perceptions of climate changes depending on the climatic shocks they have encountered. They follow different adaptation techniques and coping strategies to minimize vulnerability due to climate change. The present study summarizes such perceptions of climatic shocks, its effects on livelihood activities (e.g. crop production), various coping mechanisms followed by households and finally, the degree of household vulnerability.

2. Review of Literature: Framework for Vulnerability Assessment

The term ‘vulnerability’ has various definitions depending on the context of the study. It is usually associated with natural hazards such as floods, droughts, and social hazards like poverty, etc. Recently, it has been extensively used in climate change-related literature to denote the extent of damage a region has experienced or is expected to experience from various factors affected by climate change. According to Adger (1999), vulnerability is the extent to which a natural or social system is susceptible to sustaining damage from climate change. It is perceived to be a function of two components: 1) the effect that an event may have on humans, which is referred to as capacity or social vulnerability, and 2) the risk that such an event may occur, which is 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 the various definitions in the context of climate change can be found in Palanisami et al. (2014) study.

As stated by Deressa et al. (2009), there are two different approaches, viz., indicator approach and econometric approach, to measure vulnerability. In the indicator approach, which is mostly used in climate change studies, vulnerability is defined with respect to several indicators that pooled to develop a composite index of vulnerability. For this, tools from multivariate analysis, i.e., principal component analysis, are employed (Palanisami et al., 2014). Thus, the composite indices developed can be used to assess the relative vulnerabilities of each region. The econometric approach is applied in the context of social vulnerability and is mainly applied

to economic survey data. It is best suited to study poverty of households. In this approach, there are three assessments of vulnerability levels of social groups: vulnerability as expected poverty, vulnerability as low expected utility, and vulnerability as uninsured exposure to risk (Deressa et al., 2009). The present study adopted the econometric approach and considered the vulnerability of household as expected poverty. This approach was formulated by Chaudhuri et al. (2002) and Christiaensen and Subba Rao (2004), and it forms the basis of our analysis. In this approach, vulnerability is defined in terms of probability for a poor person today to continue to be poor tomorrow or to become rich (not poor or above poverty line) tomorrow. In other words, the approach specifies the transition probabilities between two states of well-being, viz., poor and rich.

3. Model Estimation and Data Sources

3.1. Household Vulnerability: Empirical model

In the expected poverty approach, vulnerability is understood as the prospect of a person who is now poor and will continue to be poor in the future or the prospect of a person who is not poor currently but 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.), falls below the poverty line.

The methodology proposed by Chaudhuri et al. (2002) was followed in the study 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 the observable household characteristics denoted by X_h is specified by equation 1.

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

The observable household characteristics include many socio-economic variables such as age, education, experience, farm size, household size, climatic shocks encountered, etc. β is a vector of parameters and e_h is assumed to be normally distributed, i.e., a random disturbance term with mean zero.

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 farm income fluctuates due to climatic shocks and other socio-economic factors is 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. In other words, the variance of the error term is assumed to be related to the household characteristics, X_h, by the relation given below:

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

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 the Ordinary Least Squares (OLS) procedure and using its residuals, the $e^2_{OLS,h}$ is computed. These residuals are then regressed on X_h, using OLS, to estimate the following:

$$e^2_{OLS,h} = X_h\theta + \eta_h \tag{3}$$

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 follows:

$$\frac{e^2_{OLS,h}}{X_h\theta_{OLS}} = \frac{X_h\theta}{X_h\theta_{OLS}} + \frac{\eta_h}{X_h\theta_{OLS}} \tag{4}$$

This equation is estimated using OLS, and the estimate of the vector θ, denoted by $\hat{\theta}_{FGLS}$, is an asymptotically efficient estimate. $X_h\hat{\theta}_{FGLS}$ 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 follows:

$$\frac{\ln c_h}{\sigma_{e,h}} = \left(\frac{X_h}{\sigma_{e,h}}\right)\beta + \frac{e_h}{\sigma_{e,h}} \tag{5}$$

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:

$$E[\ln c_h \mid X_h] = X_h\beta_{FGLS} \tag{6a}$$

$$V[\ln c_h \mid X_h] = \sigma^2_{e,h} = X_h\theta_{FGLS} \tag{6b}$$

We now make the assumption that consumption is log-normally distributed as explained in Chaudhuri et al. (2002). This assumption leads to computing the probability of a household's consumption below a threshold limit, *Z*. In other words, the probability that the household will be poor is given as below:

$$v_h = \Pr(\ln c_h < \ln z \mid X_h) = \Phi\left(\frac{\ln z - X_h\beta_{FGLS}}{\sqrt{X_h\theta_{FGLS}}}\right) \tag{7}$$

This approach requires per-capita consumption expenditure of each farmer. So in this approach, each farmer's net income from farm and livestock was computed, and the per-capita income was derived. We have assumed that most of the rain-fed farmers do not have any savings due to their low per-capita income and hence, the full income is used as a proxy for consumption.

3.2. Study Sample and Data Sources

The data for the present study were collected from the farm households in the action villages in Anantapur and Kurnool districts of Andhra Pradesh, Bijapur district of Karnataka and Jodhpur, Jaisalmer and Barmer districts of West Rajasthan (Fig. 1). A total of 1019 households were surveyed during 2012-13, and the data collected from households were related to the crop year 2011-2012 (Table 2).

Table 2. Sample distribution across the study region.

State	District	Number of households
Andhra Pradesh	Anantapur	259
Andhra Pradesh	Kurnool	254
Karnataka	Bijapur	250
Rajasthan	Jodhpur	60
Rajasthan	Jaisalmer	127
Rajasthan	Barmer	69
	Total	1019

The data collected, among others, include household characteristics (e.g. age, education, experience in farming, profile of household members), trainings undergone, crops grown in each season (rabi and kharif), quantities of inputs (e.g., seed, fertilizer, labor, bullock and machine power, fuel and electricity cost), main and sub-product outputs, input and output prices, different adaptation practices followed, their costs and returns, perception of climate change and their effects on livelihood, etc. The variables included in the present study are discussed in Section 4.2.

3.3. Definition of Poverty Level

The estimates from the World Bank show that 1.29 billion people in the developing world are living on less than US$1.25 a day (World Bank, 2008; Deressa, 2009). Globally, the proportion of population on the poverty line has dropped from 43% in 1990 to 22% during 2005-08. The poverty line also varies from country to country, and it is US$2 for medium poverty line for the developing countries (World Bank, 2012). In India, the Planning Commission has estimated the poverty line that varies from state to state. As per the Planning Commission estimate of 2011-12, the monthly per-capita income for Andhra Pradesh, Karnataka and Rajasthan was ₹ 860, ₹ 902 and ₹ 905, respectively (Government of India, Planning Commission, July 2013), which is close to the actual average per-capita income of Andhra Pradesh and Rajasthan based on the cross-sectional data of 2011. In order to make meaningful inferences on the incidence of household vulnerability, two poverty levels were used in this study: a) current average income levels of farmers from these three states (as derived from the farm household level cross section data); and b) World Bank estimates of US$1.25 adjusted to US$1.5 due to the inflation, which is equivalent to ₹ 100 per day. This is also equal to the wage rate of NREGA for 2010-11 (NREGA, 2014). Additionally, the enhanced rate of ₹ 200/day in view of increased demand for higher wages in the rural areas was also considered for simulating the vulnerability grouping[3].

4. Results and Discussions

4.1. Perception of Farmers on Climate Change

4.1.1. Shocks encountered

The climatic shocks with droughts and uncertain rainfalls are common in the study regions. The shocks can render the poor farmers to lose their livelihood in the arid and semi-arid regions (Singh et al., 2012). In this connection, farm households were questioned on the major shocks they encountered during the past 10 years (Table 3). Multiple responses were observed across the regions on climatic shocks. Many of the households have encountered more than one shock due to climate changes (Table 3). Drought was a universal challenge and was the most severe

3. In 2013-14, it is expected that the wage rate will go up to Rs. 173/day in the study regions.

Table 3. Major shocks encountered by farm households.

Shock	Number of farmers located in the region			
	Andhra Pradesh	Karnataka	Rajasthan	Total
Drought (DR)	470 (92)	246 (98)	253 (99)	969 (95)
Hailstorm (HA)	185 (36)	44 (18)	252 (98)	481 (47)
Flood (FL)	17 (3)	11 (4)	36 (14)	64 (6)
Animal disease (AD)	98 (19)	62 (25)	228 (89)	388 (38)
Untimely rain (UR)	114 (22)	233 (93)	206 (80)	553 (54)
Irregular weather (IW)	317 (62)	171 (68)	160 (63)	648 (64)
Temperature fluctuation – High (TH)	6 (1)	9 (4)	148 (58)	163 (16)
Temperature fluctuation – Low (TL)	2 (0)	0 (0)	85 (33)	87 (9)

Figures in bracket denote percentages

shock that the sample farmers encountered. The percentage of farmers who experienced drought ranged from 92% (Andhra Pradesh) to 99% (Rajasthan) with an average of 95% in the three regions. The next severe shock was irregular weather that was reported by 64% of the farmers. Untimely rain was the third severe shock and had an overall percentage of 54%, ranging from 22% (Andhra Pradesh) to 93% (Karnataka). The fourth important shock was hailstorm, which was encountered by 47% of the sample farmers. The proportion of study farms that faced hailstorms varied by regions: ranging from 18% (Karnataka) to 98% (Rajasthan).

The spread of animal disease was associated with high-temperature fluctuations. For example, 89% of the sample farms in Rajasthan reported the problems of animal disease, where high-temperature fluctuation was encountered by about 58% of the sample farmers. This implies that high-temperature fluctuations have an impact on the health of animals. In other regions, the percentage of farmers who encountered animal disease was less than 25%. Flood and low-temperature fluctuations were not the major concerns for the farmers in all the regions.

Since many farmers observed more than one shock, an in-depth analysis of data was required to examine the trend in combination of shocks encountered by the sample farmers. Analysis of data revealed that farmers encountered 72 combinations of shocks. Fig. 2 provides the percentage of farmers who encountered the first 15 combinations of shocks.

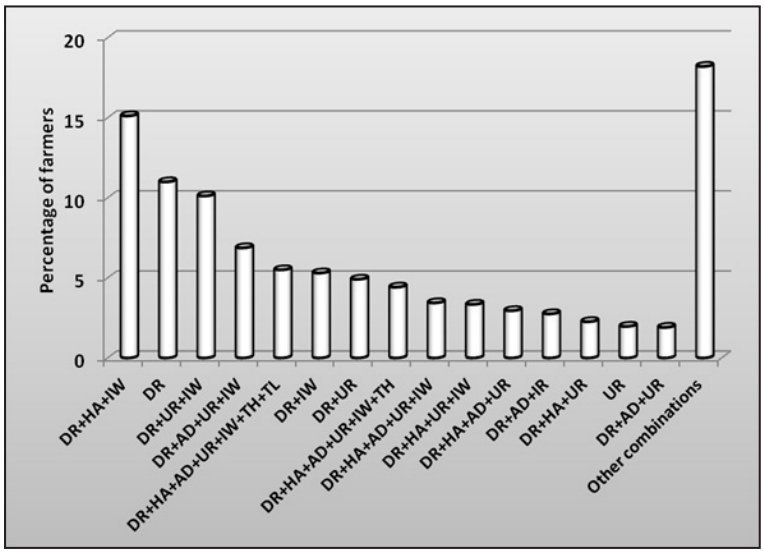

Figure 2. Combinations of shocks encountered by the farmers.

Table 4. Frequencies of occurrence of shocks.

Frequency of shock in the past 10 years	Number of farmers who encountered				
	Drought	Irregular weather	Untimely rain	Hailstorm	Animal disease
Less than or equal to 1 year	208 (22)	74 (11)	81 (15)	193 (40)	99 (26)
Two years	260 (28)	103 (16)	294 (53)	79 (16)	115 (30)
Three years	210 (22)	60 (10)	74 (13)	35 (7)	59 (15)
More than 3 years	291 (28)	411 (63)	104 (19)	174 (37)	115 (29)
Total	969	648	553	481	388

Figures in brackets denote percentages to respective totals.

Accordingly, about 15% of the farmers faced drought, hailstorm and irregular weather, whereas 11% of the farmers were affected by drought only. Drought, untimely rain and irregular weather were encountered by about 10% of the farmers while drought, animal disease, untimely rain and irregular weather were observed by about 7% of farmers. Thus, the analysis shows that drought, irregular weather, untimely rain, hailstorm and animal disease are the major shocks encountered by farmers.

Given the importance of these shocks, the frequency of occurrence of shocks during the past 10 years was also explored. Based on the responses of the farmers, the percentages of farmers who encountered a shock with a particular frequency were computed. Table 4 provides the percentage of farmers and the corresponding frequencies for the five major shocks.

4.1.2. Effects of climate shocks

Data related to the perceptions of farmers on the effects of climate-related shocks on agriculture, health and income was also collected. The study revealed that crop failure, pest damage to crops, loss of income, depletion of groundwater and food insecurity/shortage were major effects of climate shocks (Table 5).

Table 5. Effects of shocks as perceived by surveyed farmers.

Effects	Number of farmers in the region				
	Andhra Pradesh	Karnataka	Rajasthan	Total	Rank
Pest damage to crops	361	169	155	685	2
Illness of family member due to extreme weather	107	52	182	341	6
Change in soil salinity and decrease/increase in soil moisture	34	72	108	214	9
Major changes in crop pattern	60	45	12	117	11
Major changes in livestock asset	24	10	22	56	13
Major changes in farm investment	37	6	10	53	14
Crop failure	387	240	189	816	1
Depletion of groundwater	147	179	80	406	4
Loss of assets	41	60	41	142	10
Loss of income	273	218	160	651	3
Food shortage	164	46	175	385	5
Death of livestock	31	26	204	261	7
Decline in consumption	37	6	45	88	12
Decline in health	54	32	130	216	8

4.1.3. Coping strategies adopted by farmers

In order to tide over the negative effects of climate change shocks, farmers adopted different coping strategies, including both farm-based and non-farm-based strategies. These strategies varied across the regions. For example, in Andhra Pradesh, additional skill development activities (FS1), change in cropping patterns (FS2) and selling livestock (FS3) were the popular coping strategies. In Karnataka, additional skill development activities (FS1), change in cropping patterns (FS2) and change in planting date (FS11) were important strategies. In Rajasthan, more than half of the farmers (52%) let their land fallow (FS4) and remaining farmers sold their livestock. Overall, the first three farm-based coping strategies, viz., FS1, FS2 and FS3, were the most prominent (Table 6).

Borrowing money (NFS1), shifting to non-farm employment (NFS4), less food consumption (NFS6), relying on assistance from the government (NFS2) and reduction in education level of children (NFS5) and outmigration to cities (NFS3) were important non-farm based strategies in Andhra Pradesh. Borrowing money (NFS1), relying on assistance from government (NFS2) and outmigration to cities (NFS3) were the non-farm based strategies by farmers in Karnataka. In Rajasthan, borrowing money (NFS1), shifting to non-farm employment (NFS4) and relying on assistance from government (NFS2) were the key strategies. Across the regions, borrowing money (NFS1) was the most common strategies, followed by relying on assistance from government (NFS2), outmigration to cities (NFS3) and shifting to non-farm employment (NFS4).

Table 6. Adaptation strategies followed by farmers.

	Number of farmers at Region				
Adaptation strategy	Andhra Pradesh	Karnataka	Rajasthan	Total	Rank
Farming based					
Did nothing (FS0)	59	0	22	81	10
Additional skill development activities (FS1)	94	204	1	299	1
Change in cropping pattern (FS2)	104	141	6	251	2
Sold livestock (FS3)	94	34	122	250	3
Land left fallow (FS4)	52	12	133	197	4
Sold part of land for alternative (FS5)	71	4	21	96	9
Leased out part of land for alternative/leased in (FS6)	38	5	14	57	11
Maintained poultry, goats (FS7)	46	17	44	107	8
Provided supplemental irrigation (FS8)	54	46	12	112	7
Invested in farm ponds (FS9)	24	8	8	40	13
Followed improved crop production practices (FS10)	49	61	3	113	6
Change in planting date (FS11)	67	107	3	177	5
Any other adaptation measure (FS12)	19	21	13	53	12

continued

Table 6. continued

Adaptation strategy	Number of farmers at Region				Rank
	Andhra Pradesh	Karnataka	Rajasthan	Total	
Non-farm based					
Borrowed money from relatives/ others (NFS1)	446	217	193	856	1
Relying on assistance from government/NGOs (NFS2)	187	189	117	493	2
Out migration to cities (NFS3)	209	164	62	435	3
Shifted to non-farm employment (NFS4)	163	93	161	417	4
Reduction in education level of the children (NFS5)	133	118	86	337	5
Less food consumption or changed food habits (NFS6)	157	6	92	255	6

In reality, farmers follow both farm-based and non-farm based coping strategies. The coping strategies followed by them are largely related to the climatic shocks they have experienced. In the study, 8% of the total sample farmers did not adopt any farm-based coping strategy. Among those who observed drought, 28% followed no coping mechanism. Similarly, 36%, 30%, 22% and 19% of the farmers who encountered hailstorms, irregular weather, animal disease and untimely rain, respectively, did not adopt any coping strategies to mitigate the impacts of the respective shocks (Fig. 3). This indicates the need for awareness of mechanisms and the advantages of using various coping strategies (Gbetibouo, 2009).

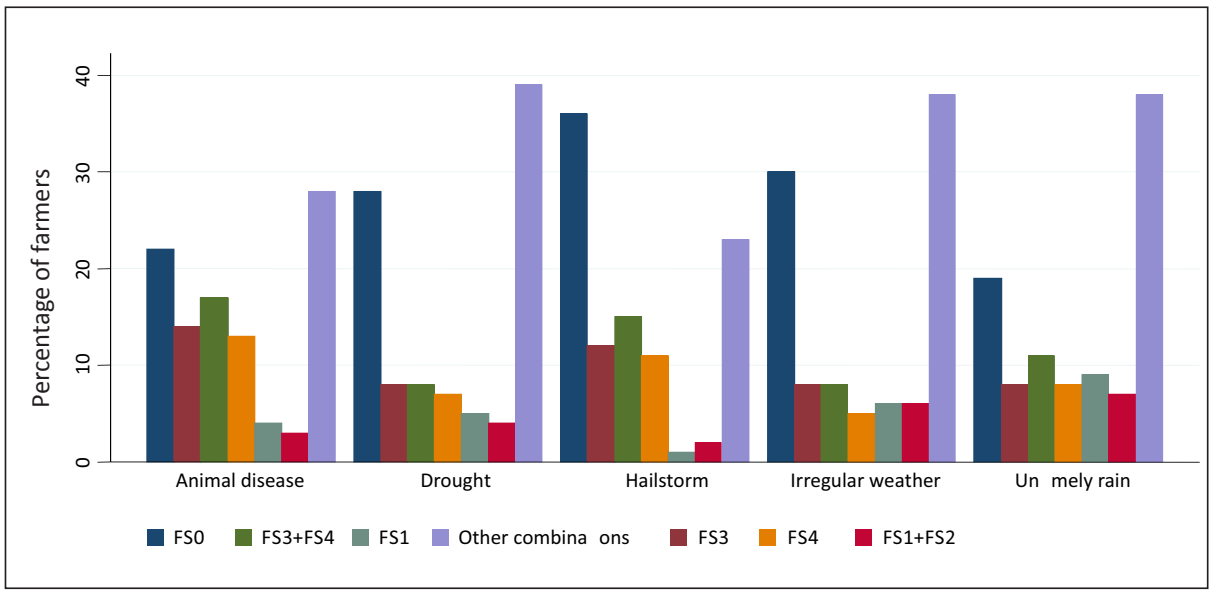

Figure 3. Farm-based coping strategies followed by the farmers to mitigate the impacts of climatic shocks.

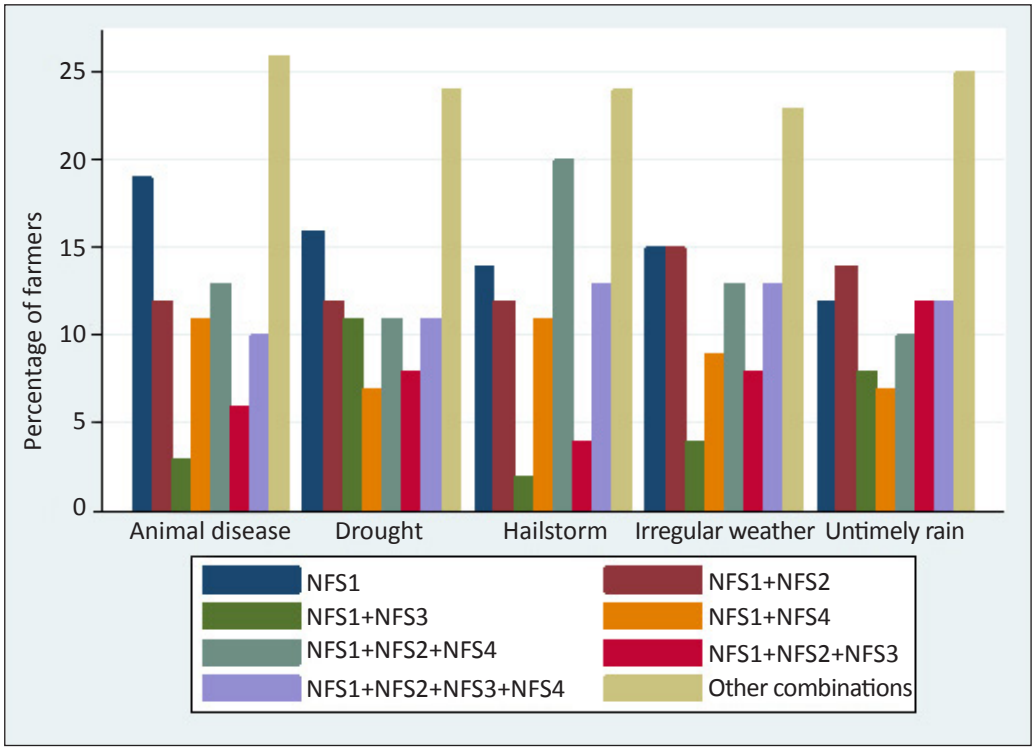

Figure 4. Non-farm based coping strategies followed by the farmers to get over climatic shocks.

The coping mechanisms popular among those farmers who took action to mitigate the impacts of climate change-related shocks included either selling of livestock or leaving land fallow or both, and change in cropping pattern or additional information gained or combination of both (Gbetibouo, 2009). Other combinations of strategies were followed by a small percentage of farmers.

In the case of major non-farm based strategies, it seems farmers used mixed strategies to deal with the climate change related shocks, which means they followed more than one non-farm strategy. As previously stated, there are four major non-farm based strategies, and thus, there will be 16 combinations of those strategies. Figure 4 provides information on the first seven combinations of strategies with the highest percentage of adoption for each climate change-related shock. However, among these four strategies, borrowing money from relatives/friends is the most common strategy irrespective of the type of shock encountered. The next popular strategy was relying on assistance from the government. In the present study, only farm-based strategies were considered as non-farm strategies are not directly linked to agriculture (livestock and crop production) and household income.

4.2. Estimation of Household Vulnerability

Given the climate-related shocks and the several coping strategies followed by the households in the DS, it is important to analyze 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). Farmers are assumed to have no savings; therefore, the entire farm income is treated as expenditure. The three-stage FGLS technique was used to estimate the parameters of the models in equations (1) and (2). In the first stage, the logarithm of per-capita income was regressed (using OLS) on the household characteristics, X_h, and the residuals from the regression, $e^2_{OLS,h}$, were computed. These residuals are then 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 an 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 to 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 (6a and 6b).

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

The probabilities of transition from vulnerable to vulnerable, vulnerable to less vulnerable, less vulnerable to less vulnerable and less vulnerable to vulnerable categories were worked out using equations (6a & 6b) and (7). As the vulnerability to poverty differs across states, the analysis was done separately for each state.

The per-capita income of each farmer was used as a dependent variable and indicators related to socio-economic variables, climate shocks experienced by sample farms, and the adaptation strategies followed were used as independent variables. The average per-capita incomes for the three states by farm holdings are given in Table 7. Accordingly, the per-capita (annual) income of the farmers varied from ₹ 15,472 for Andhra Pradesh to ₹ 65,428 for Karnataka.

Table 8 gives the descriptive statistics of the variables used for all the three states. Farm size ranged from 2.22 hectares to 3.67 hectares. Similarly, household size ranged from 4.38 for Andhra Pradesh to 5.54 for Karnataka. Farmers of Andhra Pradesh travelled on an average of 6.5 km to sell the farm output. The travelling distances for Karnataka and Rajasthan farmers were 31.0 and 12.4 km, respectively. In all the locations, about 89 to 96% of the study households had male heads. In all three states, the study households had an average age of 50 years and were poorly educated. Farmers in Andhra Pradesh had an average of 24 years of farming experience, those at Karnataka had 22 years and those at Rajasthan had 32 years of experience. Farmers in the three states had experienced different combinations of shocks, which were included as dummy variables in the analysis. In Rajasthan, 99% of the farmers owned livestock since it was the major component of farm income. However, in Andhra Pradesh, only 54% farmers owned livestock, and in Karnataka, only 40% farmers owned livestock. The farmers had employed several farm level adaptation strategies; however, only the major strategies were included in the model by using dummy variables for each of such strategy (See Table 8 for more details).

Table 7. Per-capita income of rain-fed farmers across different farm holding size in the study area.

	Andhra Pradesh					Karnataka					Rajasthan				
Farm category	Number of farmers	Mean Income from Crop (₹)	Mean Income from Livestock (₹)	Mean Off Farm Income (₹)	Total (₹)	Number of farmers	Mean Income from Crop (₹)	Mean Income from Livestock (₹)	Mean Off Farm Income (₹)	Total (₹)	Number of farmers	Mean Income from Crop (₹)	Mean Income from Livestock (₹)	Mean Off Farm Income (₹)	Total (₹)
Landless	28	0	2538	830	3368	9	0	4750	1229	5978	33	0	5540	1938	7477
Marginal	103	1202	1675	856	3734	35	4009	1486	1432	6927	51	1750	5956	2537	10243
Small	151	4374	2531	2433	9337	70	21729	2712	6324	30764	58	5887	9314	5031	20231
Medium	164	8746	4594	4533	17873	69	42023	3909	12052	57985	64	5667	9689	5088	20443
Large	67	29720	6060	11804	47584	67	111659	4824	31015	147497	50	18213	9286	9104	36602
Total	513	8206	3480	3785	15472	250	48168	3510	13749	65428	256	6656	8247	5157	20060

Table 8. Descriptive statistics of variables used in household vulnerability estimation.

Dependent Variable	Andhra Pradesh		Karnataka		Rajasthan		
	Mean	SD	Mean	SD	Mean	SD	Description
Per-capita income from farm(₹)	15472	29269	65428	78984	20060	25568	Continuous
Explanatory variables							
Farm size in hectares	2.22	2.50	3.67	4.82	2.64	3.08	Continuous
Household size	4.38	2.00	5.54	2.63	5.48	2.54	Continuous
Distance to market for output in km	6.48	30.81	31.03	17.03	12.43	9.88	Continuous
Household gender	0.96	0.19	0.94	0.25	0.89	0.31	DV = 1 for male and 0 for female
Household education	1.56	1.01	1.70	1.08	1.43	0.69	Discrete with 7 point scale with 1 for no formal education and 7 for Post-graduation
Household Age in years	47.81	13.47	51.80	13.02	50.79	13.68	Continuous
Household's marital status	0.97	0.16	0.96	0.20	0.86	0.35	DV = 1 if married and 0 otherwise
Households married years	27.39	14.59	29.62	13.89	30.32	15.99	Continuous
Male earning members	1.88	1.12	1.58	0.70	1.73	1.15	Continuous
Female earning members	1.69	1.00	1.28	0.65	0.77	1.04	Continuous
Household's health status	1.53	0.94	1.42	0.65	1.80	1.29	Discrete with 6 point scale with 1 for can perform agricultural activities and 6 for bad
Farming experience in years	24.14	12.37	22.40	12.01	32.27	15.05	Continuous
SC1AK	0.30	0.46					DV = 1 if the shocks drought, hailstorm and irregular weather encountered and 0 otherwise
SC2AK	0.22	0.41					DV = 1 if the shock drought alone encountered and 0 otherwise

Continued

Table 8. continued

Dependent Variable	Andhra Pradesh		Karnataka		Rajasthan		Description
	Mean	SD	Mean	SD	Mean	SD	
SC4AK	0.06	0.23					DV = 1 if the shocks drought, animal disease, untimely rain and irregular weather encountered and 0 otherwise
SC1B			0.33	0.47			DV = 1 if the shocks drought, untimely rain and irregular weather encountered and 0 otherwise
SC2B			0.16	0.37			DV = 1 if the drought, animal disease, untimely rain and irregular weather alone encountered and 0 otherwise
SC3B			0.16	0.37			DV = 1 if the shocks drought and untimely rain encountered and 0 otherwise
SC1R					0.22	0.41	DV = 1 if all the shocks except flood encountered and 0 otherwise
SC2R					0.18	0.38	DV = 1 if all the shocks except flood and temperature fluctuation low are encountered and 0 otherwise
SC3R					0.11	0.32	DV = 1 if the shocks droughty, hailstorm, animal disease and untimely rain are encountered and 0 otherwise
Livestock ownership	0.54	0.50	0.40	0.49	0.99	0.09	DV = 1 if owns livestock and 0 otherwise
CFaig	0.18	0.38	0.82	0.39			DV = 1 if the additional information gained is used as a coping strategy and 0 otherwise
CFcpd	0.12	0.33	0.43	0.50			DV = 1 if change in planting date is used as a coping strategy and 0 otherwise

Continued

Table 8. continued

Dependent Variable	Andhra Pradesh		Karnataka		Rajasthan		Description
	Mean	SD	Mean	SD	Mean	SD	
Cfic	0.09	0.29	0.24	0.43			DV = 1 if improved cropping production practices are followed and 0 otherwise
Cpsi	0.10	0.30					DV = 1 if provided supplementary irrigation and 0 otherwise
Fmech	0.79	0.41	0.28	0.45	0.36	0.48	DV = 1 if tractor is used for cultivation and 0 otherwise
CFsls	0.18	0.39			0.48	0.50	DV = 1 if selling livestock is used as a coping strategy and 0 otherwise
CNFbm	0.87	0.34	0.87	0.34	0.75	0.43	DV = 1 if borrowed money from relatives/ friends and 0 otherwise
CNFrag	0.36	0.48	0.76	0.43	0.46	0.50	DV = 1 if relaying on assistance from government and 0 otherwise
CNFomc			0.66	0.48			DV = 1 if out migration to cities is used as coping strategy and 0 otherwise
CFlf					0.52	0.50	DV = 1 if left land fallow and 0 otherwise
Cfmpoultry				0.17	0.38		DV = 1 if maintaining poultry and goats is used as a farm based coping strategy and 0 otherwise
CNFsnfe					0.63	0.48	DV = 1 if shifting to non-farm employment is used as a non-farm based coping strategy and 0 otherwise
CNFlfc					0.36	0.48	DV = 1 if less food consumption or changed food habits is used as a coping strategy and 0 otherwise

DV = dummy variable; SD = Standard Deviation

4.2.1. Vulnerability mapping of households in Andhra Pradesh

The three-stage FGLS procedure was applied to the survey data, and the probability of a per-capita income falling below the poverty line was worked out as per the methodology outlined in Section 3. Two cut-off limits, viz. ₹ 100 per day and average per-capita income from sample (₹ 15,472 per annum, i.e., ₹ 42.40 per day) were used to estimate the probabilities of poverty transitions for Andhra Pradesh. The per-capita values were cross-checked with the statistical records of Anantapur and Kurnool, and the results showed that they are similar to the values obtained during 2002-03 and 2010-11 (Statistical abstract of Andhra Pradesh, 2008 and 2013). The results are plotted in Fig. 5 and Fig. 6. Logarithm of income is plotted against the probability in these figures. The horizontal line specifies the 50% probability and the vertical line corresponds to the logarithm of poverty threshold of ₹ 36,500 per annum. These two lines divide the figure into four parts. The upper left part corresponds to those farm households 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 households who are above the poverty threshold this year and have more than 50% probability to continue having the same status in the next year also (i.e., less vulnerable to less vulnerable). Households who are vulnerable now and have less than 50% chance to move from that status next year are represented by the lower left part (i.e., vulnerable

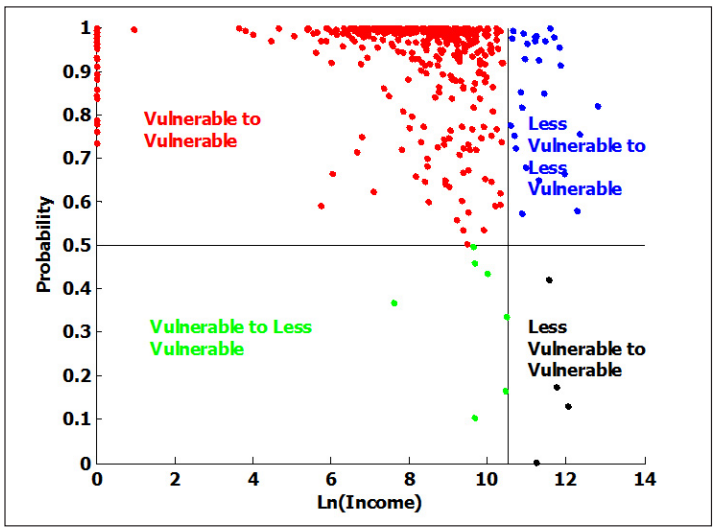

Figure 5. Household vulnerability – Andhra Pradesh (income at ₹ 36,500 per year) plotted against Ln (income)

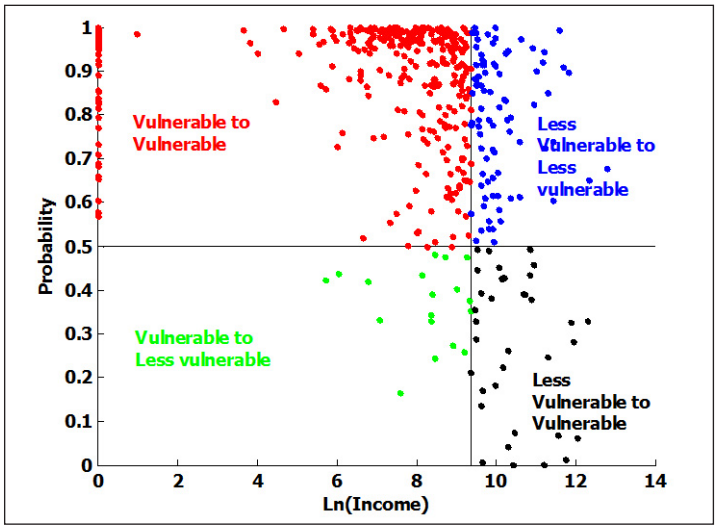

Figure 6. Household vulnerability - Andhra Pradesh (income at ₹ 15,472 per year) plotted against Ln (income)

to less vulnerable). The lower right part specifies those households who are less vulnerable now (i.e., above poverty threshold) but have less than 50% chance to move from that status in the next year (i.e., less vulnerable to vulnerable).

Table 9 gives the possible number of households in Andhra Pradesh under the four different transitions at two levels of per-capita income. Currently, there are 482 households whose per-capita income is below the poverty line of ₹ 36,500 (i.e. ₹ 100 per day). Of them, 475 households have a probability greater than 0.5, which indicates that they will continue to be vulnerable in the next year also. Furthermore, out of 31 farmers whose per-capita income is above ₹ 100 per day, four farmers are liable to be vulnerable in the next year also. Hence, out of 513 farmers, 479 farmers will be vulnerable next year with a probability greater than 0.5. This means that 93.4% of the farmers may probably remain vulnerable to poverty. The rest of the transitions are insignificant.

When the poverty line is fixed at the current average per-capita income, viz., ₹ 15,472 (or ₹ 42.4 per day), the situation is improved to a certain extent. The percentage of households that are vulnerable reduces to 79%, and there is more than 50% probability for 87 households who are less vulnerable this year to continue to be less vulnerable in the next year also.

The four transitions mentioned above were analyzed with respect to their landholdings and per-capita income of ₹ 100/day (Table 10). The analysis shows that vulnerable to vulnerable transition percentage decreases when the landholding size increases. It is 100% for landless and marginal farmers while it is 68.7% for large farmers. Similarly, the less vulnerable to less vulnerable transition percentage increases across the farm categories (landless to large farms). The results also indicate that 20.9% of large farmers who are less vulnerable will continue to be less vulnerable in the next year also with a probability of more than 0.5.

Table 9. Possible poverty transitions (with probability > 0.5) among households of Andhra Pradesh for two levels of per capita income.

Per-capita income	Transition From				Total
	Vulnerable to		Less vulnerable to		
	Vulnerable	Less vulnerable	Vulnerable	Less vulnerable	
₹ 36,500 per year	475	7	4	27	513
₹ 15,472 per year	371	19	36	87	513

Table 10. Distribution of percentage of transitions across different categories of farmers for income of ₹ 36,500 per year.

Category of farmer	Transition				Total
	Vulnerable to vulnerable	Less vulnerable to less vulnerable	Vulnerable to less vulnerable	Less vulnerable to vulnerable	
Landless	100.0	0.0	0.0	0.0	100
Marginal	100.0	0.0	0.0	0.0	100
Small	98.2	1.2	0.0	0.6	100
Medium	91.5	6.7	1.8	0.0	100
Large	68.7	20.9	6.0	4.5	100
Total	92.6 (475)	5.3 (7)	1.4 (4)	0.8 (27)	100 (513)

Values in parenthesis denote the total number of farmers

Effects of adaptation strategies on household vulnerability

The different adaptation strategies adopted by households to climate change will help minimize the vulnerability of the households as illustrated earlier. Hence, it is important to examine how the adaptation strategies could influence the vulnerability grouping of the households. The distribution of farmers according to their land holdings and adaptation strategies are depicted in Table 11.

As shown in Figure 7, out of 513 farmers in Andhra Pradesh, 120 (23%) farmers owned livestock and mechanized their farms, particularly, cultivation. Moreover, 101 farmers used farm mechanization, whereas 42 (8.2%) farmers used no technology at all and were purely dependent on rain-fed and traditional farming practices. Medium-sized farmers who owned farm area between 2 to 4 hectares were the maximum users of tractors and also owned livestock. Only 38 farmers owned livestock without agriculture and new technology. The next adaptation strategy was change in cropping pattern and use of farm mechanization, which was followed by 18 farmers only. Other strategies used by farmers in Andhra Pradesh were: i) livestock + additional skill development activities + use of tractor; ii) additional skill development activities + use of tractor; iii) livestock + additional skill development activities + change in cropping pattern + tractor for cultivation; and iv) change in planting date + use of tractor for cultivation (Table 11). All other typologies were used by less than 14 farmers. Given that, only three medium-sized farmers had used all the technologies.

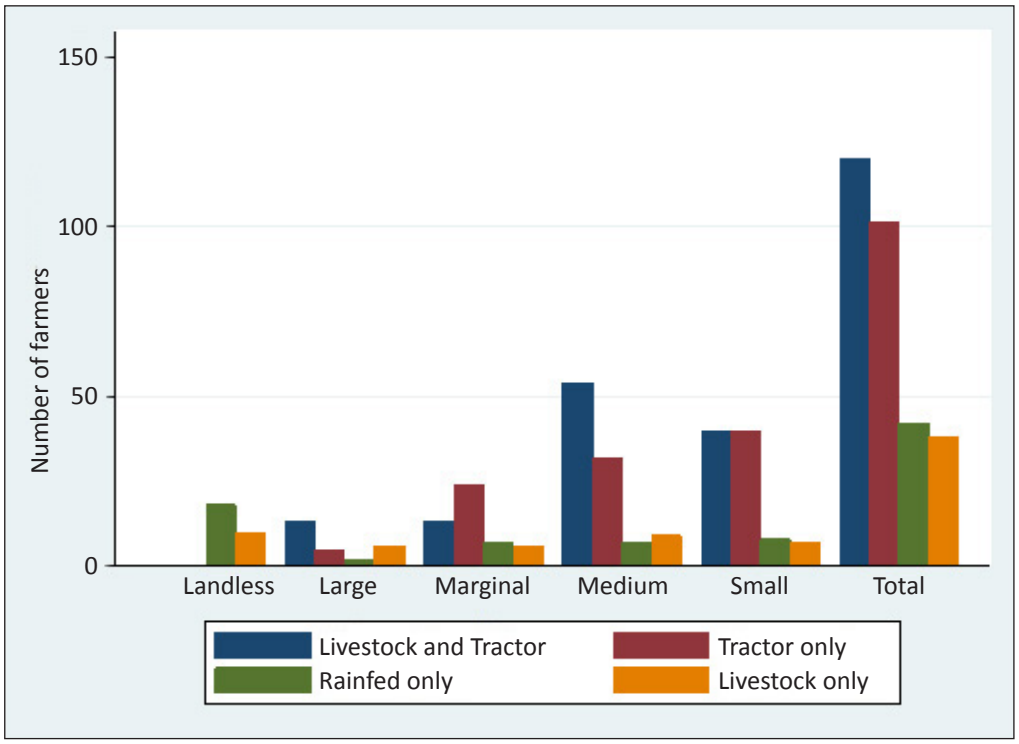

Figure 7. Distribution of farmers of different categories who use farm mechanization and own livestock in Andhra Pradesh

Table 11. Distribution of farmers in Andhra Pradesh according to different adaptation strategies.

Category	Livestock + Fmech	Fmech only	Rainfed only	Livestock only	CFccp + Fmech	Livestock + Cfaig + Fmech	Cfaig + Fmech	Livestock + Cfaig + CFccp + Fmech	CFcpd + Fmech	Livestock + CFccp + Fmech	Livestock + CFcpd + Fmech	Livestock + Cpsi + Fmech	Cpsi + Fmech	Livestock + CFccp + CFcpd + Fmech	Livestock + Cfaig + CFccp + CFcpd + Fmech	Livestock + Cpsi	CFcpd only	CFccp + Cfic + Fmech	Cfaig + CFccp + Fmech	Livestock + Cfic	Livestock + Cfic + Fmech	Livestock + CFccp + CFcpd + Cfic + Cpsi + Fmech	Livestock + Cfaig + Cfccp + Cpsi + Fmech	Livestock + Cfaig + CFccp + CFcpd + Cfic + Cpsi + Fmech	Others	Total
Landless	0	0	18	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	28
Marginal	13	24	7	6	4	1	7	1	5	1	0	0	3	0	3	0	2	0	1	0	0	0	0	0	6	84
Small	40	40	8	7	13	4	4	3	7	2	4	3	3	1	1	2	1	3	1	2	2	1	0	0	18	170
Medium	54	32	7	9	1	6	4	7	1	6	4	5	1	3	1	0	0	0	1	0	1	2	1	3	15	164
Large	13	5	2	6	0	6	0	4	1	3	3	2	1	1	0	2	0	0	0	1	0	0	2	0	15	67
Total	120	101	42	38	18	17	15	15	14	12	11	10	8	5	5	4	3	3	3	3	3	3	3	3	54	513

Note: Fmech = Farm Mechanization, CFccp = Change in cropping pattern, Cfaig = Additional skill development activities, CFcpd = change in planting date, Cpsi = providing supplemental irrigation, Cfic = followed improved cropping production practices

Table 12. Most profitable adaptation strategies for farmers of Andhra Pradesh.

Symbol	Adaptation Strategy
A1	Livestock + Farm Mechanization
A2	Livestock + Change in Cropping Pattern + Farm Mechanization
A3	Livestock + Following Improved Crop Production Practices + Farm Mechanization
A4	Livestock + Providing Supplemental Irrigation + Farm Mechanization
A5	Livestock + Additional Skill Development Activities + Change in Cropping pattern + Farm Mechanization
A6	Livestock + Additional Skill Development Activities + Change in Cropping Pattern + Change in Planting Date + Farm Mechanization
A7	Livestock + Additional Skill Development Activities + Change in Cropping Pattern + Change in Planting Date + Providing Supplemental Irrigation + Farm Mechanization
A8	Livestock + Additional Skill Development Activities + Change in Cropping Pattern + Change in Planting Date + Following Improved Crop Production Practices + Providing Supplemental Irrigation + Farm Mechanization

For each farmer, the net incomes from farm, livestock, and off-farm sources were computed, and the average net income per household was then estimated. For each landholding size, Appendix-A1 presents an average income per household and marginal income for switching to the next profitable adaptation strategies. Among the different adaptation strategies, the most profitable adaptation strategies are summarized in Table 12.

For landless farmers, livestock is a good source of farm income as it can fetch an average of ₹ 27,459. For marginal farmers, a combination of livestock, additional skill development activities, change in cropping pattern and use of tractor for cultivation (A5) will be suitable as it can give the highest income of ₹ 63,738 and marginal income of ₹ 31,234. The suitable strategy for small farmers will be a combination of livestock, additional skill development activities, change in cropping pattern and planting date and use of tractor for cultivation (A6). This can fetch an income of ₹ 111,616 with a marginal income of ₹ 63,136. For farmers with a landholding of 2 to 4 hectares, using all the strategies recommended for small farmers and following improved crop production practices (A8) can fetch a household income of ₹ 260,323 with a corresponding marginal income of ₹ 143,821. Large farmers can realize a net income of ₹ 534,370 from the combination of strategies such as livestock, additional skill development activities, change in cropping pattern, providing supplemental irrigation and farm mechanization (A7). The marginal income for this combination can be ₹ 252,284 (Fig. 8).

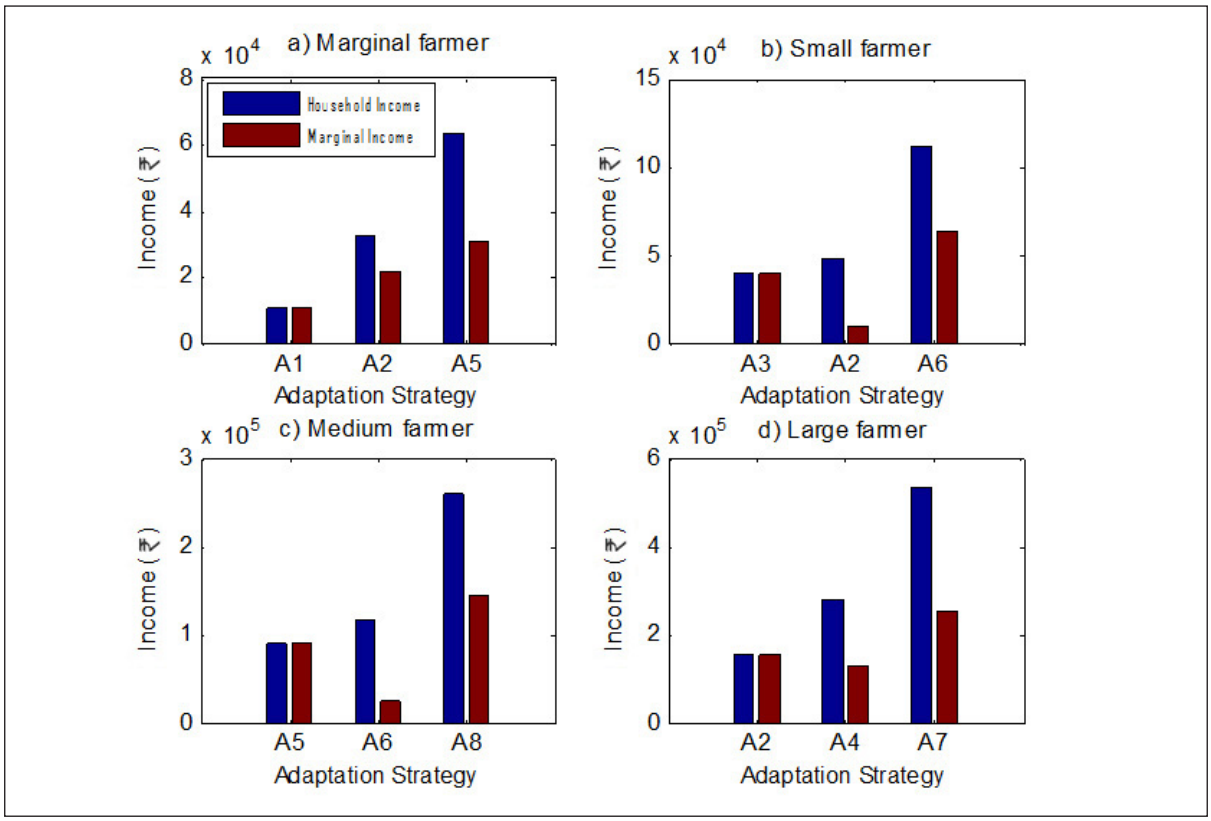

Figure 8. Income and adaptation strategies followed by different categories of farmers in Andhra Pradesh

Using these profitable strategies, the four transitions of poverty categories were analyzed, and the results are presented in Table 13.

Table 13. Distribution of poverty transitions (for Andhra Pradesh study sites) across different adaptation strategies for an income of ₹ 36,500 per year.

Adaptation strategies	Vulnerable to vulnerable	Less vulnerable to less vulnerable	Vulnerable to less vulnerable	Less vulnerable to vulnerable	Total
Rain-fed only	42	0	0	0	42
Livestock + Fmech*	117	3	0	0	120
Fmech only	94	6	0	1	101
Livestock only	36	2	0	0	38
CFccp + Fmech	18	0	0	0	18
Livestock + Cfaig + Fmech	15	0	2	0	17
Cfaig + Fmech	15	0	0	0	15
Livestock + Cfaig + CFccp + Fmech	13	1	1	0	15
CFcpd + Fmech	14	0	0	0	14
Livestock + CFccp + Fmech	11	1	0	0	12
Livestock + CFcpd + Fmech	9	2	0	0	11
Livestock + Cpsi + Fmech	6	1	2	1	10
Others	85	11	2	2	100
Total	475	27	7	4	513

* Notations are similar to Table 11

Table 13 presents interesting results that can be useful for the policy makers. All the 42 rain-fed farmers who are vulnerable this year are liable to be vulnerable in the next year. The table also shows that 97.5% of the farmers who own livestock and use farm mechanization may remain vulnerable, implying that the adaptation strategies are not effective in lowering the vulnerability of the farmers due to their large households size and less per-capita income. Similarly, 93.1% of the farmers who use farm mechanization, have more than 50% probability of remaining in poverty (i.e., vulnerable to vulnerable). There are only three strategies that may lead to the vulnerable to less vulnerable transitions. They are i) livestock, additional skill development activities, and farm mechanization; ii) livestock, additional skill development activities, farm mechanization, and change in cropping pattern; and iii) livestock, providing supplemental irrigation, and farm mechanization.

An analysis was similarly done to determine the distribution of each of the four poverty transitions among landholdings of the farmers and different adaptation strategies. The results are presented in Table 1 of Appendix-B. All the marginal farmers in Andhra Pradesh remain vulnerable even after adopting different management practices. The situation is similar in the small farmers except for one or two strategies. However, in the case of medium and large farmers, the vulnerable farmers can move from vulnerable to less vulnerable category by adapting livestock, knowledge gained, change in cropping pattern and farm mechanization, and livestock and supplementary irrigation with farm mechanization. They can also remain less vulnerable by adopting various strategies such as livestock with farm mechanization, change in the cropping date and cropping pattern, etc.

Vulnerability changes can also depend on various other factors such as household characteristics. In our study, equation (1) specifies the relationship between consumption expenditure and household's observable characteristics. Vulnerability to poverty is the probability that the consumption expenditure is below the poverty line. Therefore, the higher the consumption level, the lesser will be the vulnerability to poverty. Therefore, equation (1) can be used to find the household's observable characteristics, which can increase the consumption level, and thus, reduce the vulnerability. As already stated in the methodology section, equation (1) is estimated by using the three-stage FGLS technique. Table 14 gives the fitted equation for Andhra Pradesh.

Table 14. Determinants of vulnerability (consumption level)-Andhra Pradesh.

Variable	Coefficient	SE	p-value
Constant	0.224	0.2972	0.4513
Farm size	0.2253	0.0709	0.0016
Household size	−0.3078	0.1059	0.0038
Distance to market for sales	0.0115	0.0031	0.0003
Household gender	0.2131	1.0783	0.8434
Education level	0.2771	0.1239	0.0258
Age	0.0662	0.0169	0.0001
Marital status	1.6345	1.147	0.1548
Married years	−0.0563	0.0163	0.0006
Number of male earning members	0.0378	0.151	0.8022
Number of female earning members	0.2485	0.1522	0.1031
Health status	0.0316	0.1607	0.8441
Experience in farming	0.0203	0.0145	0.1621

continued

Table 14. continued

Variable	Coefficient	SE	p-value
SC1AK	−0.821	0.3992	0.0403
SC2AK	−0.6156	0.4301	0.153
SC3AK	−1.3097	0.5354	0.0148
SC4AK	−0.3175	0.5153	0.5381
Livestock ownership	3.3445	0.43	0
CFaig	0.6414	0.3295	0.0521
CFccp	0.0745	0.401	0.8526
CFcpd	0.2056	0.429	0.6319
Cfic	−0.4945	0.5311	0.3522
Cpsi	0.679	0.4049	0.0942
Fmech	1.0228	0.348	0.0035
CFsls	0.1429	0.3344	0.6693
CNFbm	−0.1806	0.3361	0.5914
CNFrag	−0.2447	0.3034	0.4204
Anantapur	0.6696	0.4305	0.1205
R-square	0.9016		

Dependent variable: logarithm of per-capital consumption; For explanation of symbols, refer to Table 8.

The table shows that the farm size has a positive effect on consumption level because an increase in farm size will increase the farm income, which in turn will increase the consumption level, reducing the vulnerability to poverty. The coefficient of household size is significant and negative, implying that the higher the household size, the lesser will be the per-capita consumption level. This will, in turn, increase the vulnerability. Other socio-economic variables that have an effect on vulnerability are distance to market for sales, education level, age of the household, and the number of married years. The climate change shocks encountered by the farmers have significant negative effect on households' consumption, thus, increasing the vulnerability. Livestock possession has a significant positive effect on per-capita consumption as it generates additional income to the farmers. Other farm-specific variables that have a positive effect on per-capita consumption are farm mechanization and providing supplemental irrigation as these interventions help farmers to get higher yields and income compared to farmers without these activities.

4.2.2. Vulnerability mapping of households in Karnataka

In Karnataka, the net income from farm and livestock for each farmer were computed, and the per-capita income was derived. The net income was negative for two farmers, which is considered a loss. The average per-capita income of the farmers was determined to be ₹ 65,428 per year (i.e., ₹ 179.3 per day). The values are more or less similar to that of the Karnataka state statistics (Statistical abstract of Karnataka, 2012). The per-capita income of the sampled farmers was high when compared to the district per-capita incomes. This may be due to the high-valued crops in the selected sites. The results of the three-stage FGLS procedure for two levels of annual income, viz., ₹ 36,500 (100/day) and ₹ 65,428 (179.3 ₹/day), are shown graphically in Figure 9 and Figure 10. The summary of poverty transition across farm categories for the two levels of per-capita income is shown in Figure 11.

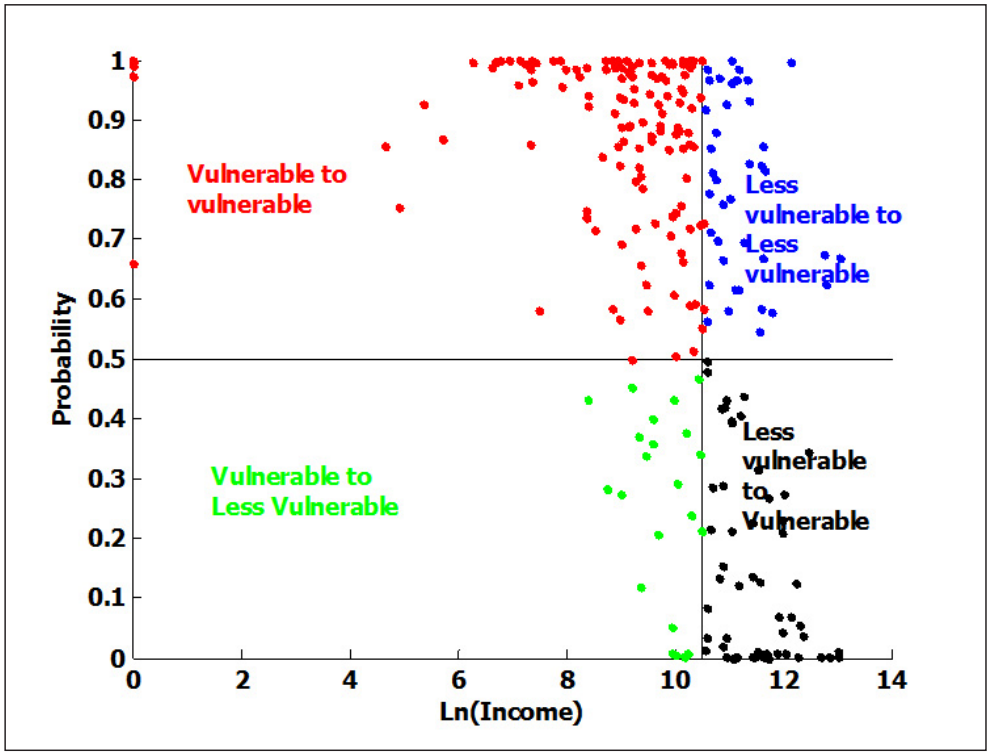

Figure 9. Study of farm household vulnerability in Karnataka (income at ₹ 36,500 per year) plotted against Ln (income).

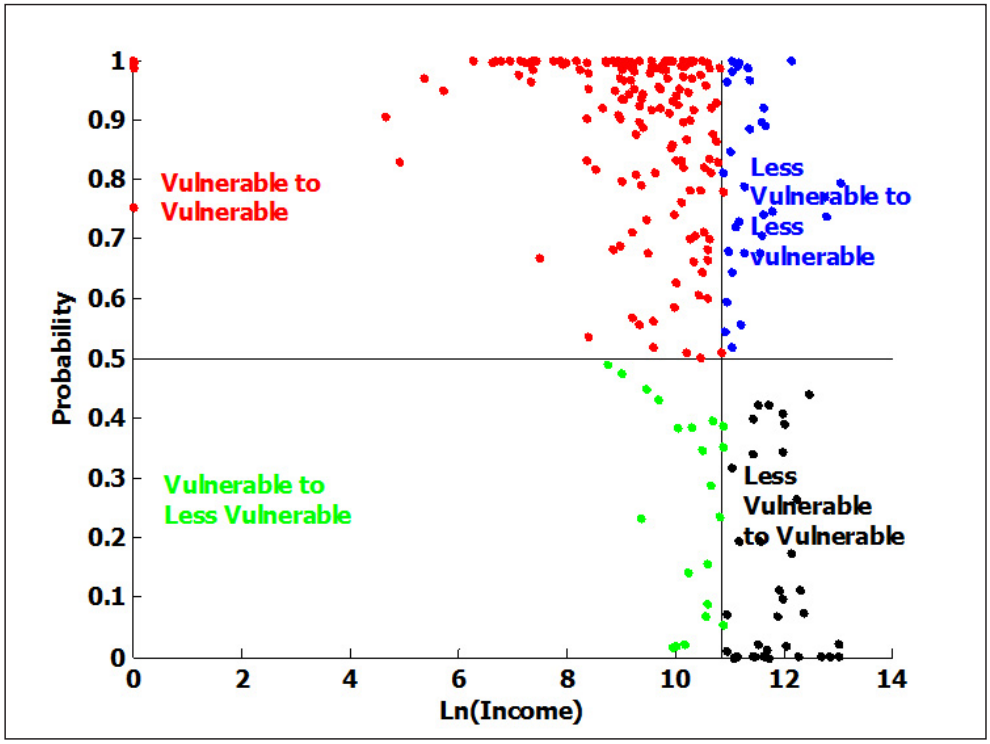

Figure 10. Study of farm household vulnerability in Karnataka (income at ₹ 65,428 per year) plotted against Ln (income).

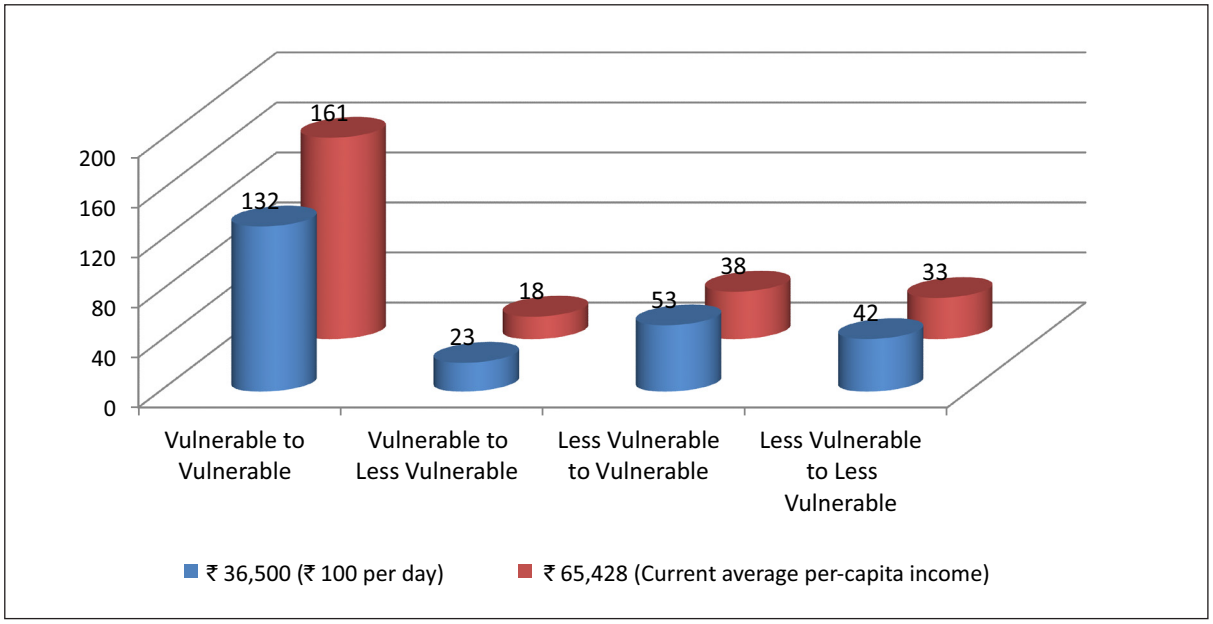

Figure 11. Possible poverty transitions (probability > 0.5) for study households in Karnataka

The result illustrates that with probability greater than 0.5, 199 farmers (79.6%) who are vulnerable this year will continue to be vulnerable in the next year also when the per-capita income of the farmer is fixed at the current annual average income level (i.e. ₹ 65,428). Similarly, about 74% of the vulnerable farmers will continue to be vulnerable when the per-capita income is fixed at ₹ 100 per day. A comparison of the analysis of wealth transitions among farmers belonging to Andhra Pradesh and Karnataka shows that the rain-fed farmers of Karnataka are less vulnerable to poverty than those from Andhra Pradesh.

The four poverty transitions mentioned above were analyzed with respect to the landholdings of the farmers (Table 15). The results are similar to that of Andhra Pradesh (see Table 10). The analysis shows that the vulnerable to vulnerable transition percentage decreases as the landholding size increases from small to large. For example, in the case of marginal farmers, all (100%), the farmers will remain vulnerable whereas in the case of large farmers, only 13.4% will be under the vulnerable category in the next year. Similarly, the transition from less vulnerable to less vulnerable category increases across the farm categories. Only 28.4% of the large farmers who are currently less vulnerable will continue to be less vulnerable in the next year also with a probability of more than 0.5.

Table 15. Distribution of percentage of transitions across different category of vulnerability by farmers' categories in Karnataka for an income at ₹ 36,500 per year.

	Transition				
Category of farmer	Vulnerable to vulnerable	Less vulnerable to less vulnerable	Vulnerable to less vulnerable	Less vulnerable to vulnerable	Total
Landless	88.9	11.1	0.0	0.0	100
Marginal	100.0	0.0	0.0	0.0	100
Small	73.0	10.8	12.2	4.1	100
Medium	43.5	23.2	14.5	18.8	100
Large	13.4	28.4	6.0	52.2	100
Total	52.8	17.6	9.2	20.4	100

Effects of adaptation strategies and household vulnerability

As most of the households were under the vulnerable group, it is expected that the adaptation strategies will help to reduce the vulnerability of the households. Farm size-wise adaptation strategies, which includes possession of livestock, application of technologies such as farm mechanization, providing supplementary irrigation, change in cropping pattern, etc., are provided in Table 16. Most of the farmers in Karnataka have a good access to information as revealed from the table. Out of the 250 farmers surveyed, 23 farmers had adopted good additional skill development activities and the practices of changing cropping pattern and planting date. In addition, 21 farmers who were aware of the available technologies have adapted to change in cropping pattern. Response was also seen from 20 farmers who have gained additional skill development activities but have not gone for adaptation. A total of 101 farmers owned livestock and possessed additional skill development activities. Thus, this indicates that livestock is the most common adaptation strategy and farmers are aware of this technology.

The net incomes from farm and livestock were computed for each farmer, and the average net income per household was estimated. Appendix-A2 presents the average income per household and marginal income for switching to next profitable adaptation strategies. The identified adaptation strategies that yield higher income are given in Table 17.

Farm income increases with an increase in size of land holdings. For landless farmers, having a livestock is remunerative as it can fetch a net income of ₹ 37,519 per household. For marginal farmers, possession of livestock, additional skill development activities and change in cropping pattern (B5) are the most suitable adaptation strategy as it can fetch an annual household income of ₹ 60,388 with a marginal income of ₹ 20,970 (Fig. 12). The optimum strategy for small farmers will be a combination of technologies such as livestock, additional skill development activities, change in cropping pattern and following improved crop production practices (B8). The estimated household income for this strategy is ₹ 174,235 with a marginal income of ₹ 30,452. Medium farmers can opt for owning livestock, additional skill development activities and follow improved crop production practices (B6). This strategy will bring an annual farm income of ₹ 355,868 and a marginal income of ₹ 54,817. Large farmers who own more than four hectares of land can obtain a maximum farm income of ₹ 1,899,021 and a marginal income of ₹ 429,657 if they adopt livestock, additional skill development activities, change in cropping pattern and farm mechanization (B10).

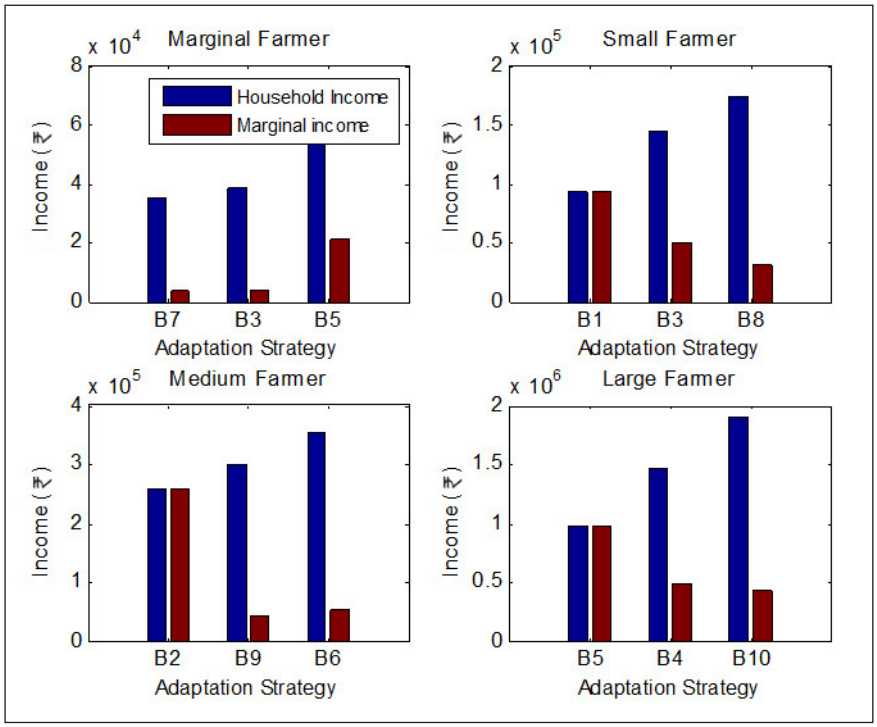

Figure 12. Adaptation strategies followed by farmers in Karnataka.

Table 16. Distribution of study farms across the different adaptation strategies in Karnataka.

Category of farmer	Cfaig + CFccp + CFcpd	Cfaig + CFccp	Cfaig (B1)	Cfaig + CFcpd	Livestock + Cfaig + Cfccp (B5)	Livestock + Cfaig (B3)	Livestock + Cfaig + CFcpd (B7)	Livestock + Cfaig + CFccp + CFcpd (B9)	Livestock + Cfaig + CFccp + Fmech	CFccp	Cfaig + CFccp + Cfic	Livestock + Cfaig + CFccp + Cfic	CFccp + CFcpd	Cfaig + Fmech	Cfaig + Cfic (B2)	Cfaig + CFcpd + Fmech	Cfaig + CFccp + Fmech (B10)	Livestock + CFccp (B4)	Livestock + Cfaig + Cfic (B6)	Livestock + Cfaig + CFcpd + Fmech (B8)	Others	Total
Landless	0	0	3	0	0	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	2	9
Marginal	0	8	4	8	1	1	1	1	0	0	1	0	2	0	0	0	1	0	0	1	2	31
Small	10	7	8	2	5	5	2	1	2	3	1	2	2	3	1	3	2	2	1	1	11	74
Medium	8	3	4	0	5	2	1	5	2	2	2	1	0	0	3	1	1	2	2	1	24	69
Large	5	3	1	4	3	1	3	1	3	1	2	3	1	2	1	1	1	1	2	2	26	67
Total	23	21	20	14	14	12	8	8	7	6	6	6	5	5	5	5	5	5	5	5	65	250

* Notations are similar to Table 11

Table 17. Most profitable adaptation strategies for farmers in Karnataka.

Symbol	Adaptation Technology
B1	Additional Skill Development Activities
B2	Additional Skill Development Activities + Following Improved Crop Production Practices
B3	Livestock + Additional Skill Development Activities
B4	Livestock + Change in Cropping Pattern
B5	Livestock + Additional Skill Development Activities + Change in Cropping Pattern
B6	Livestock + Additional Skill Development Activities + Following Improved Crop Production Practices
B7	Livestock + Additional Skill Development Activities + Change In Planting Date
B8	Livestock + Additional Skill Development Activities + Change in Cropping Pattern + Following Improved Crop Production Practices
B9	Livestock + Additional Skill Development Activities + Change in Cropping Pattern + Change in Planting Date
B10	Livestock + Additional Skill Development Activities + Change in Cropping Pattern + Farm Mechanization

The four poverty transitions in Karnataka were analyzed with respect to the different adaptation strategies, and the results are presented in Table 18.

Table 18. Distribution of poverty transitions in Karnataka with different adaptation strategies for an income of ₹ 36,500 per year.

Adaptation Strategies	Vulnerable to vulnerable	Less vulnerable to less vulnerable	Vulnerable to less vulnerable	Less vulnerable to vulnerable	Total
Cfaig + Cfccp + Cfcpd	17	4	0	2	23
Cfaig + Cfccp	18	3	0	0	21
Cfaig	17	3	0	0	20
Cfaig + Cfcpd	10	4	0	0	14
Livestock + Cfaig + Cfccp	5	0	3	6	14
Livestock + Cfaig	6	4	0	2	12
Livestock + Cfaig + Cfcpd	6	1	0	1	8
Livestock + Cfaig + Cfccp + Cfcpd	3	0	2	3	8
Livestock + Cfaig + Cfccp + Fmech	2	0	1	4	7
Cfccp	4	1	0	1	6
Cfaig + Cfccp + Cfic	3	1	0	2	6
Livestock + Cfaig + Cfccp + Cfic	0	0	1	5	6
Cfccp + Cfcpd	5	0	0	0	5
Cfaig + Fmech	3	2	0	0	5
Cfaig + Cfic	3	2	0	0	5

Table 18. continued

Adaptation Strategies	Vulnerable to vulnerable	Less vulnerable to less vulnerable	Vulnerable to less vulnerable	Less vulnerable to vulnerable	Total
Cfaig + CFcpd + Fmech	2	2	1	0	5
Cfaig + CFccp + Fmech	2	2	1	0	5
Livestock + CFccp	4	0	0	1	5
Livestock + Cfaig + Cfic	1	1	1	2	5
Livestock + Cfaig + CFcpd + Fmech	3	1	0	1	5
Others	18	13	13	21	65
Total	132	44	23	51	250

Analysis was done to know the distribution of each of the four poverty transitions across different landholding groups. The results are presented in Table 2 of Appendix-B. It shows that there is no change in poverty levels with the adaptation strategies for marginal farmers due to their less per-capita income, farm size and socio-economic conditions. In the case of small farmers, the adaptation strategies such as livestock, additional skill development activities, changing cropping pattern, changing planting date, farm mechanization and their combinations are helpful to shift the vulnerable farmers to the less vulnerable conditions. The combinations of additional skill development activities, changing cropping pattern, changing planting date, livestock, and farm mechanization help the less vulnerable farmers to remain less vulnerable. The other adaptation strategies also show significant differences in the livelihoods of marginal and large farmers.

However, some of the farmers may move from less vulnerable to vulnerable category in the next year if they adopt certain practices that can increase the income as well as decrease the marginal income. For example, the probability of large farmers moving from less vulnerable to vulnerable is more in Karnataka due to the higher variability in the per-capita income compared to the other two states (Table 7).

The determinants of vulnerability for Karnataka state was also assessed against the consumption level with the household characteristics and adaptation strategies (Table 19).

Table 19. Determinants of consumption level-Karnataka.

Variable	Coefficient	SE	p-value
Constant	2.7335	0.6922	0.0001
Farm size	0.183	0.0329	0
Household size	−0.0399	0.0129	0.001
Distance to market for sales	0.011	0.0088	0.2102
Household gender	2.994	0.6125	0
Education level	0.2743	0.1428	0.056
Age	0.0302	0.0271	0.2656
Marital status	0.4678	0.8652	0.5893
Married years	−0.041	0.0249	0.1019
Number of male earning members	0.4753	0.2642	0.0733
Number of female earning members	−0.4046	0.2438	0.0985

continued

Table 19. continued

Variable	Coefficient	SE	p-value
Health status	−0.291	0.3075	0.3449
Experience in farming	−0.001	0.0149	0.9472
SC1B	0.1883	0.3638	0.6053
SC2B	−1.3525	0.4392	0.0023
SC3B	0.1402	0.4438	0.7524
Livestock ownership	0.9136	0.3104	0.0036
CFaig	0.6543	0.4346	0.1335
CFccp	0.9679	0.2925	0.0011
CFcpd	0.0625	0.2865	0.8276
CFfic	0.8962	0.3215	0.0058
Fmech	0.9398	0.323	0.004
R-square	0.821		

Dependent variable: logarithm of per-capital consumption
For explanation of the symbols, refer to Table 8.

The results show that farm size has a positive effect on consumption level. The household education level and number of male earning members are also found to be significant in reducing the vulnerability. The coefficient of household size is significant and negative, implying that the higher the household size, the lesser will be the per-capita consumption level, resulting in an increase in vulnerability. This might be due to the non-employment of the female members of the family who rely on their rain-fed farms only. It is also negative in the case of number of female earning members, indicating the possibilities of vulnerability with female income that are normally less compared to income earned by male family members. In another study, Jha et al. (2012) reported that having more number of female numbers tended to decrease the per-capita consumption. The climate change shocks encountered by the farmers have significant negative effect on households' consumption, thus, increasing the vulnerability. The livestock possession has a significant positive effect on per-capita consumption due to the additional income generated by the livestock. Other farm-specific variables that have a positive effect on per-capita consumption are farm mechanization and change in cropping pattern.

4.2.3. Vulnerability mapping of households in Rajasthan

In Rajasthan, the net income from farm and livestock for each farmer were computed, and the per-capita income was derived. Among those farmers who owned land, 54 farmers incurred loss from crop production. The results of the three-stage FGLS procedure for two levels of annual income, viz., ₹ 36,500 and ₹ 20,060, are shown graphically in Figure 13 and Figure 14.

The average per-capita income from farming activities including livestock was ₹ 20,060 (₹ 54.96 per day). The analysis of vulnerability to poverty revealed that about 86% and 70% of the farmers are vulnerable to poverty when the per-capita income is fixed at ₹ 36,500 and ₹ 20,060 respectively (See, Fig. 13, Fig. 14 and Table 20).

Table 20. Possible poverty transitions for study households in Rajasthan.

	Transition from				
	Vulnerable to		Less vulnerable to		
Per-capita income level	Vulnerable	Less vulnerable	Vulnerable	Less vulnerable	Total
₹ 36,500 (₹ 100 per day)	219	3	0	34	256
₹ 20,060 (₹ 54.96/day)	165	6	13	72	256

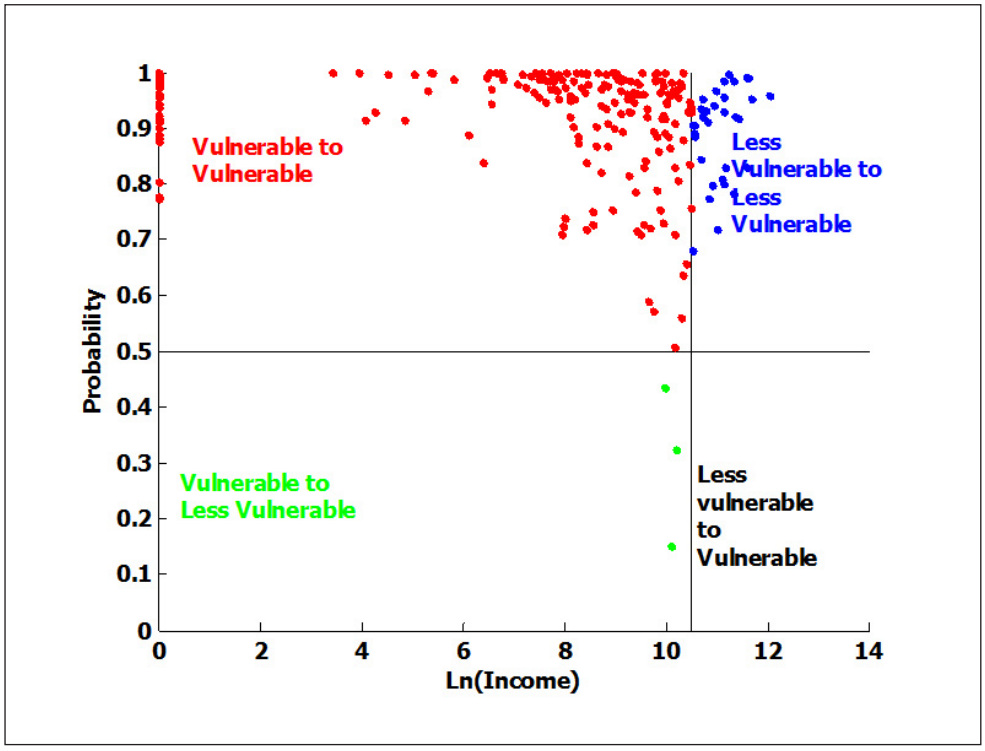

Figure 13. Household vulnerability in Rajasthan (income at ₹ 36,500 per year) plotted against Ln (income).

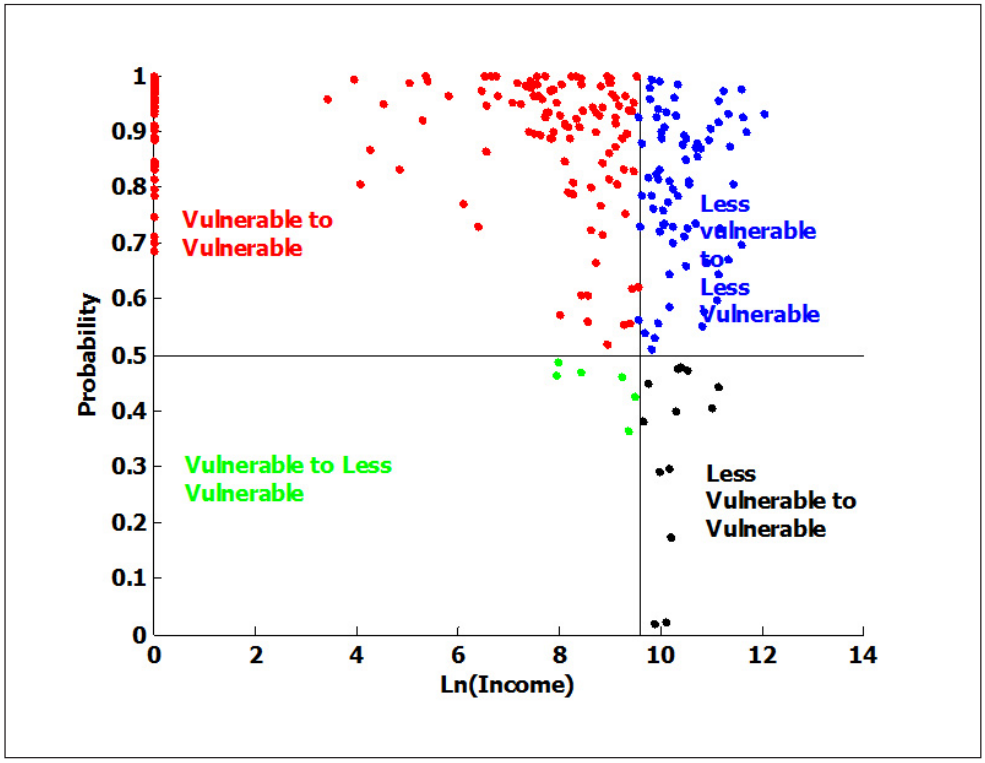

Figure 14. Household vulnerability in Rajasthan (income at ₹ 20,060 per year) plotted against Ln (income).

The poverty transitions mentioned above were analyzed with respect to the landholdings of the farmers (Table 21). The trends are more or less similar to that of Andhra Pradesh and Karnataka. The analysis showed that vulnerable to vulnerable transition percentage decreases when the landholding size increases from small to large. The transition is 100% for landless and marginal farmers while it is 68% for large farmers. Similarly, the percentage of transition from less vulnerable to less vulnerable category increases across categories. It is nil for landless and marginal category farmers while it is 32% for large farmers, which indicates that they are less vulnerable currently and will continue to be less vulnerable in the next year also, with a probability of more than 0.5.

Table 21. Distribution of percentage of transitions across different category of farmers of Rajasthan for an income of ₹ 36,500 per year.

	Transition			
Category of farmer	Vulnerable to vulnerable	Less vulnerable to less vulnerable	Vulnerable to less vulnerable	Less vulnerable to vulnerable
Landless	100.0	0.0	0.0	0.0
Marginal	100.0	0.0	0.0	0.0
Small	86.4	10.2	0.0	3.4
Medium	82.8	15.6	1.6	0.0
Large	68.0	32.0	0.0	0.0
Total	86.3	12.5	0.4	0.8

Effects of different adaptation strategies on study farm households' vulnerability (by farm category)

Different adaptation strategies may help minimize the vulnerability of the households. Hence, the influence of adaptation strategies on the vulnerability grouping of households should be examined. The distribution of farmers among the different categories ranged from 13% (landless) to 25% (medium). Table 20 presents the farm categories distribution across different adaptation strategies.

Livestock is the major strategy followed by farmers, as is evident from Table 22. Out of the 256 farmers, 254 owned livestock and only two farmers were purely rain-fed. Appendix-A3 presents the household income and marginal income for switching to the next profitable adaptation strategy across landholding categories.

Rain-fed farmers have incurred losses whereas for others, in general, the income had increased with land holdings for most of the adaptation strategies. Figure 15 presents four most suitable adaptation strategies for each category of farmers based on landholdings. Owning livestock and farm mechanization (R2) seems to be the most suitable strategy for marginal farmers. They can realize a maximum of ₹ 49,541 per household by following this strategy with a marginal income of ₹ 22,841. For maximum revenue, small farmers should own livestock, maintain poultry and goats apart from farm mechanization (R4). This combination can fetch an income of ₹ 191,384 per household with a marginal income of ₹ 71,172. The next suitable strategy for this farm category is to own livestock and providing supplementary irrigation (R5), which can earn an income of ₹ 120,212 and a marginal income of ₹ 13,417. Medium-sized landholding farmers can derive a maximum income of ₹ 238,045 with a marginal income of ₹ 32,867 if they use livestock, own farm ponds and adopt farm mechanization (R6). If the large farmers use the same strategy, they can get a maximum income of ₹ 365,510 whose marginal income will be ₹ 214,273. The next

suitable strategy for them is livestock, maintaining poultry and goats and farm mechanization (R4) that can provide an income of ₹ 151,237 with a marginal income of ₹ 18,357.

The four poverty transitions for Rajasthan were analyzed with respect to the different strategies, and the results are presented in Table 23. The vulnerable to vulnerable level is similar to that of Andhra Pradesh and Karnataka. The probability of shifting from vulnerable to less vulnerable category by improving the per-capita income with the adaptation strategies alone will be less due to the small farm size and comparatively lesser net income from some of these adaptation strategies.

Table 22. Distribution of farmers in Rajasthan according to adaptation strategies.

Category of farmer	Livestock only (R1)	Livestock + Fmech (R2)	Livestock + Poultry and Goats (R3)	Livestock + Poultry and Goats + Fmech (R4)	Livestock + Cpsi + Fmech (R5)	Livestock + IFPonds + Fmech (R6)	Rain-fed only (R7)	Others (R8)	Total
Landless	25	0	5	1	0	0	1	1	33
Marginal	27	14	3	5	0	0	1	0	50
Small	27	17	5	1	5	1	0	3	59
Medium	33	15	9	4	1	1	0	1	64
Large	23	15	3	4	2	2	0	1	50
Total	135	61	25	15	8	4	2	6	256

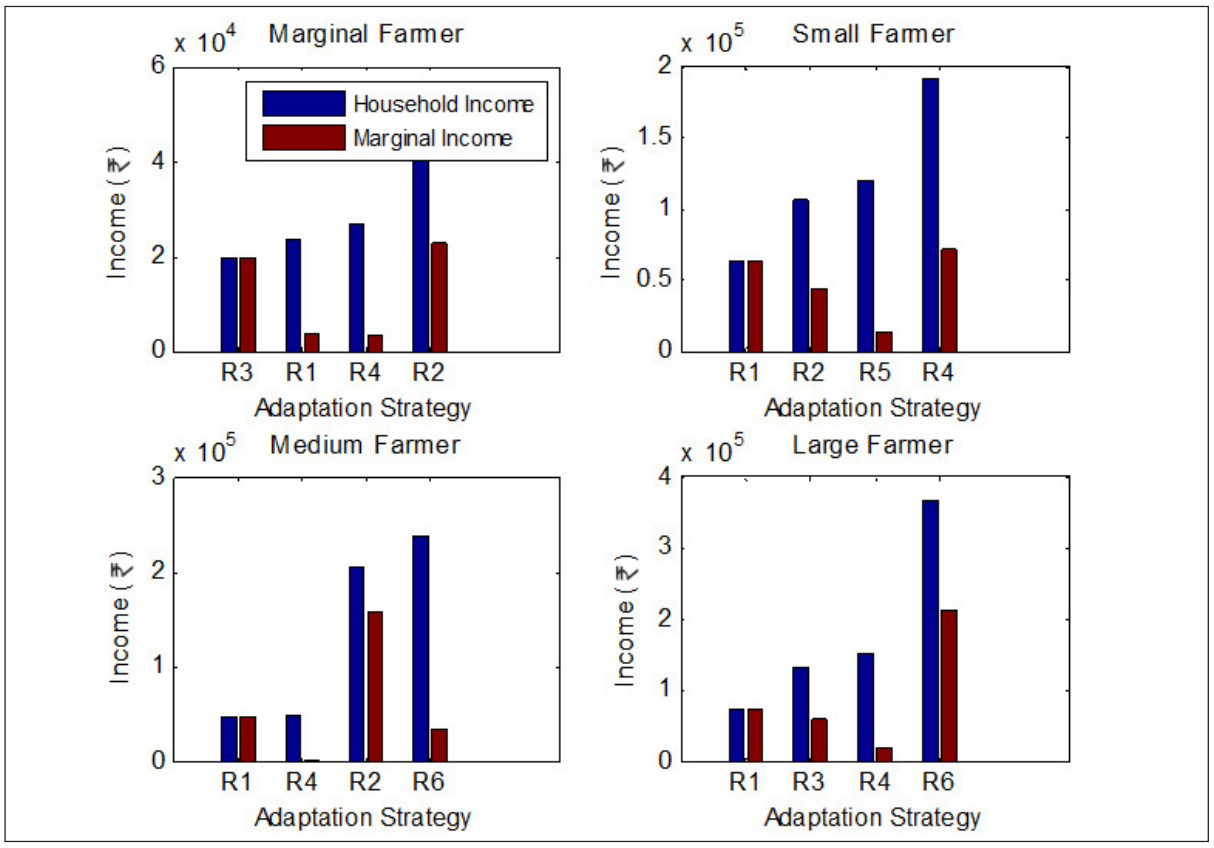

Figure 15. Adaptation strategies followed by farmers of Rajasthan.

Table 23. Distribution of poverty transitions at Rajasthan across different strategies for an income at ₹ 36,500 per year.

Adaptation strategy	Vulnerable to vulnerable	Less vulnerable to less vulnerable	Vulnerable to less vulnerable	Less vulnerable to vulnerable	Total
Livestock only	122	13	0	0	135
Livestock + Fmech	47	14	0	0	61
Livestock + Poultry and Goats	24	1	0	0	25
Livestock + Poultry and Goats + Fmech	14	1	0	0	15
Livestock + Cpsi + Fmech	5	0	1	2	8
Livestock + IFPonds + Fmech	2	2	0	0	4
Rain-fed only	2	0	0	0	2
Others	5	1	0	0	6
Total	221	32	1	2	256

Similarly, analysis was done to know the distribution of each of the four poverty transition among the landholdings of the farmers and different adaptation strategies. The results are presented in Table 3 of Appendix-B. The probability of marginal farmers to remain vulnerable for all combination of adaptation strategies seems to be high due to their low per-capita income, small farm size, and socio-economic factors. However, in the case of large, medium, and small farmers, the transition of less vulnerable to less vulnerable seems to be viable due to the adaptation of livestock, farm mechanization, and poultry and goats combinations.

Further, the determinants of vulnerability for Rajasthan were assessed against the consumption level with the household characteristics and adaptation strategies (Table 24).

Table 24. Determinants of consumption level - Rajasthan.

	Coefficient	SE	p-value
Constant	0.1973	0.4431	0.6566
Farm size	0.178	0.0125	<0.01
Household size	−0.0319	0.00965	0.0005
Distance to market for sales	0.0139	0.0208	0.5056
Household gender	1.3823	0.9042	0.1277
Education level	1.0129	0.2679	0.0002
Age	−0.0153	0.0244	0.5307
Marital status	−0.7303	0.6504	0.2627
Married years	−0.0001	0.0202	0.9973
Number of male earning members	0.0425	0.2645	0.8725
Number of female earning members	−0.4627	0.2586	0.0749
Health status	−0.5508	0.1335	0.0001
Experience in farming	0.052	0.022	0.0189

continued

Table 24. continued

	Coefficient	SE	p-value
SC1R	−0.0079	0.5088	0.9876
SC2R	0.0362	0.5479	0.9473
SC3R	−0.6535	0.2510	0.005
Livestock ownership	6.5652	1.1689	0
CFlf	−1.2195	0.8315	0.2271
CFsls	0.9473	0.3826	0.014
Cfmpoultry	−0.7232	0.7138	0.3121
CNFbm	−1.3748	0.4415	0.0021
CNFsnfe	−0.1531	0.4191	0.7153
CNFrag	0.5611	0.3742	0.1351
CNFlfc	−0.6749	0.6254	0.2817
Fmech	1.1905	0.3627	0.0012
R-square	0.9405		

Dependent variable: logarithm of per-capital consumption
For explanation of the symbols, refer to Table 8.

The above results show that farm size has a positive effect on the consumption level, thus, reducing the vulnerability to poverty. The educational levels of the households also help in reducing the vulnerability. As noticed in the other two states, the coefficient of household size is significant and negative, which implies that the higher the household size, the lesser will be the per-capita consumption level which in turn will increase the vulnerability. Other socio-economic variables that have a negative effect on vulnerability are number of female earning members and health status, which generates less calorie intake and increase mortality (Brooks et al., 2005). The climate change shocks encountered by the farmers have a significant negative effect on households' consumption, thus, increasing the vulnerability. The livestock possession has a strong significant positive effect on per-capita consumption. Other farm-specific variables that have a positive effect on the per-capita consumption are farm mechanization and selling livestock. These results could help in identifying the appropriate adaptation strategies for addressing the household vulnerability.

4.3. Simulation analysis

A simulation analysis was carried out to determine the trend in the number of households falling under the four transitions by increasing the poverty line and household income (Table 25). The scenarios included three poverty lines as explained in section 3, viz., i) using the current average household income from the selected states; ii) World Bank estimate of US$1.25 adjusted to US$1.5 due to inflation, which is equivalent to ₹ 100/day and close to the current NREGA wage rate (2010-2011 prices); and iii) ₹ 200/day in view of the increased demand for higher wages in the rural areas. The actual household income and increased income with the adaptation strategies were also considered for the analysis. In the case of increased income of the households, the increase in income through the adaptation of different adaptation strategies was examined. Accordingly, those adaptation strategies that could provide higher income were considered to derive the increased income. Thus, the increase in income of the households will be 21% in Andhra Pradesh region, 24% in Karnataka region, and 19% for Rajasthan region.

Table 25. Scenarios for the simulation of different poverty line (PL) and household income (HI) (with and without adaptation strategies).

Scenario 1	PL = ₹ 42.4/day for Andhra Pradesh, ₹ 179.3/day for Karnataka and ₹ 54.9/day for Rajasthan. HI: no change in current household income
Scenario 2	PL = ₹ 42.4/day for Andhra Pradesh, ₹ 179.3/day for Karnataka and ₹ 54.9/day for Rajasthan. HI: increased income of the household (21% for Andhra Pradesh, 24% for Karnataka and 19% for Rajasthan due to adaption of improved strategies)
Scenario 3	PL = ₹ 100/day HI: no change in current household income
Scenario 4	PL = ₹ 100/day HI: increased income of the household (21% for Andhra Pradesh, 24% for Karnataka and 19% for Rajasthan due to adaption of improved strategies)
Scenario 5	PL = ₹ 200/day HI: no change in current household income
Scenario 6	PL = ₹ 200/day. HI: increased income of the household (21% for Andhra Pradesh, 24% for Karnataka and 19% for Rajasthan due to adaption of improved strategies)

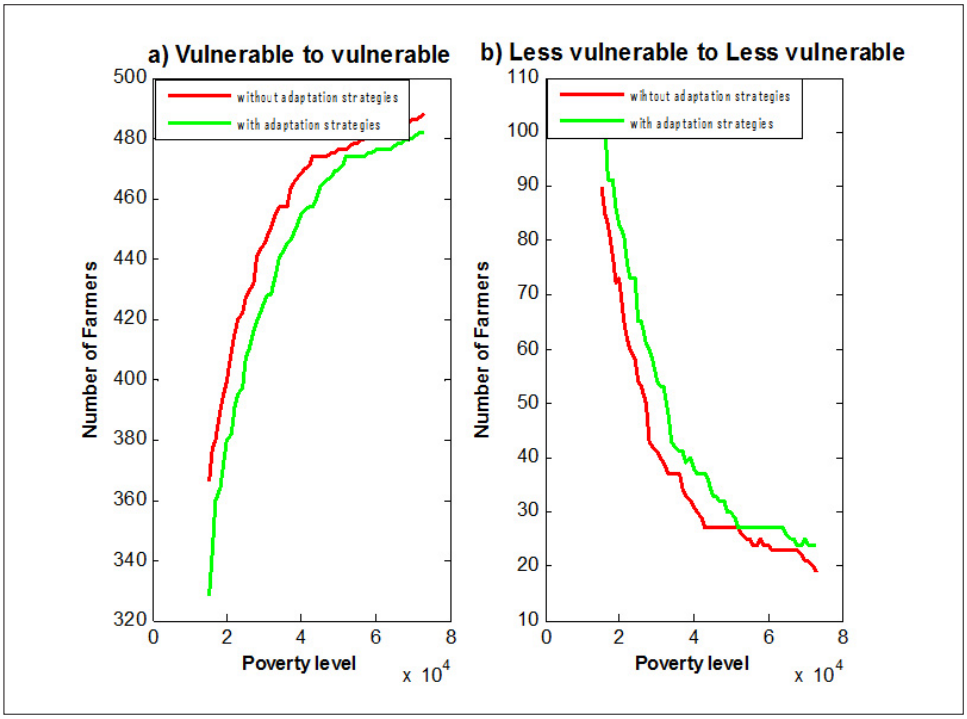

Figure 16. Simulation of poverty transitions for farmers of Andhra Pradesh.

The first graph in Figure 16 indicates that as poverty level increases, more farmers will come under the vulnerable category. In the first graph, the curve corresponding to 'with adaptation strategies' is below the curve 'without adaptation strategies', indicating that these adaptation strategies could help to decrease the transition from vulnerable to vulnerable. In the second graph, the curve corresponding to 'with adaptation strategies' is above the curve 'without

adaptation strategies' implying that the transition 'less vulnerable to less vulnerable' will be more when adaptation strategies are followed. Thus, there is a need to improve the livelihood of farmers by creating more awareness of the adaptation strategies as well as capacitating farms to adopt those strategies that could provide comparatively more income than others.

In the case of Karnataka, the average household income level is higher compared to Andhra Pradesh (Fig. 17). When the adaptation strategies are followed, the transition from vulnerable to vulnerable will be lower compared to the situation when no adaptation strategies are followed.

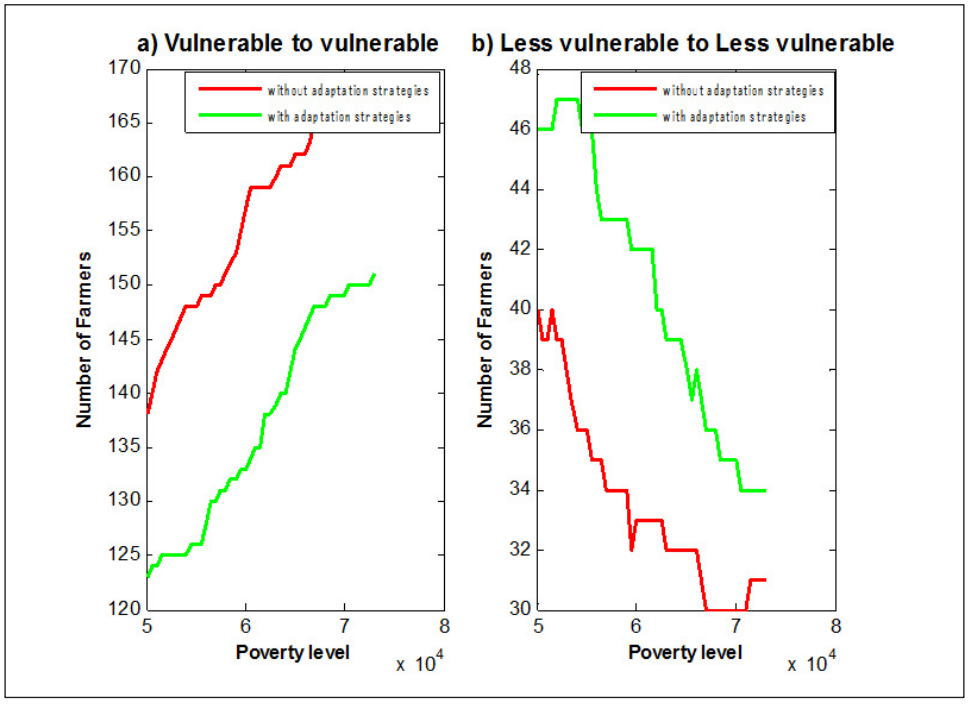

Figure 17. Simulation of poverty transitions for farmers of Karnataka.

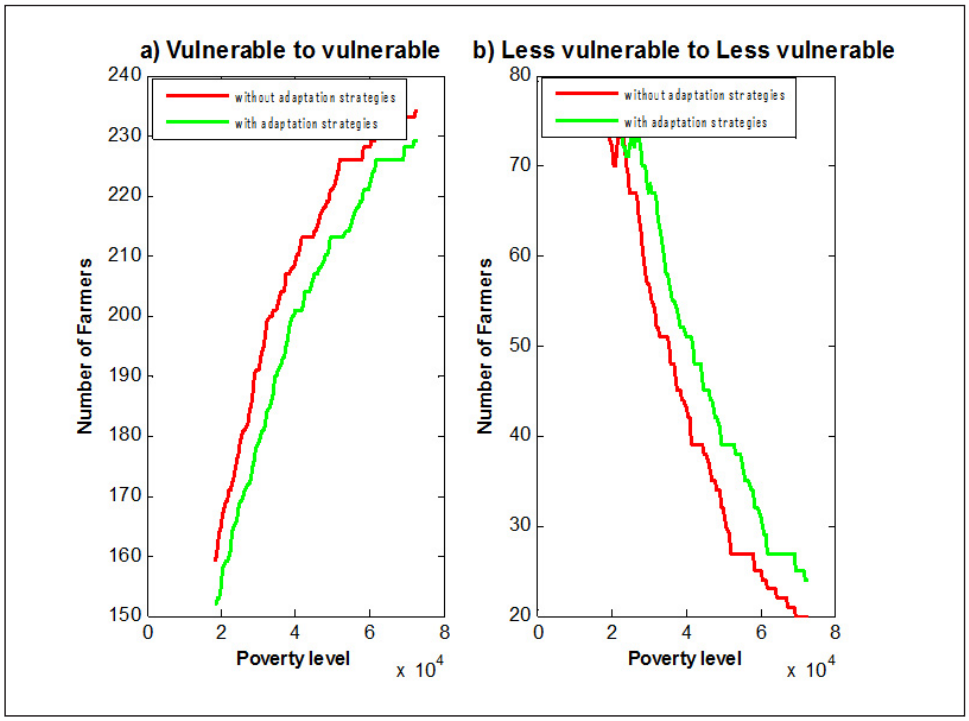

Figure 18. Simulation of poverty transitions for farmers of Rajasthan.

The trends found in Rajasthan are also similar to that of Andhra Pradesh and Karnataka. This indicates that the adaptation strategies can help to reduce transition from 'vulnerable to vulnerable' and could increase the transition from 'less vulnerable' to 'less vulnerable'. As the poverty level increases, more farmers will come under vulnerable category, and the number of farmers in other less vulnerable categories will decrease with an increase in poverty level (Fig. 18).

It was observed that more number of households came under the vulnerable category when the poverty level increases without any increase in household income. Moreover, when the household income increases with the adoption of the proposed adaptation strategies, the number of vulnerable households decreases to 68% in Andhra Pradesh, 92% in Karnataka and 96% in Rajasthan (Table 26). In the case of Karnataka and Rajasthan, the same trend was observed, indicating that the poverty level is a key factor in deciding the vulnerability grouping of the households.

Interestingly, even though the household income could increase from 19 to 24% in the study regions due to the adaptation strategies, the percentage of vulnerable households moving out of the vulnerability category will be limited due to higher poverty level in the rain-fed regions except in Karnataka. The higher household income in Karnataka resulted in 7 to 8% reduction in the number of households in the vulnerable category (Table 27). This highlights the importance of increasing the household income beyond 24% to move the households out of the vulnerability category.

The above results indicate that the adaptation strategies are important to move the farmers from the vulnerable to less vulnerable category. Adaptation is increasingly seen as an inevitable answer to the challenges posed by climate change. The farmers are also compelled to adopt the resilient measures to decrease the vulnerability due to climate variability. However, small

Table 26. Results of the simulation analysis of household vulnerability.

	State		
	Andhra Pradesh	Karnataka	Rajasthan
Scenario	Households vulnerable (%)		
Scenario 1	76	72	67
Scenario 2	68	67	64
Scenario 3	94	62	86.7
Scenario 4	92	57	83.6
Scenario 5	96.5	82	96.1
Scenario 6	96.1	76	93.8

Note: Descriptions of the scenarios are given above.

Table 27. Changing scenarios and reduction in the households under vulnerable category.

	Percentage reduction in vulnerable households		
Scenario*	Andhra Pradesh	Karnataka	Rajasthan
Move from S1 to S2	10.53	6.94	4.48
Move from S3 to S4	2.13	8.06	3.58
Move from S5 to S6	0.41	7.32	2.39

* description of scenarios as explained above in Table 26.

farmers are still vulnerable to future climate change, and the large and commercial farmers have to deal with the conditions in the region possessing a greater adaptive capacity (Muller and Shackleton, 2014). Lack of knowledge and information, shortage of labor, lack of inputs and extension services, and inappropriate policies are the barriers to the adaptation (Gbetibouo, 2009). Researchers and policy makers should think of up-scaling the initiatives that could trigger income through different interventions and increase the number of households above the vulnerability levels. In this context, it is important to examine the profitable adaptation strategies that are being derived from the study.

5. Conclusions and recommendations

Conclusions

Rain-fed farmers are more vulnerable to climate variability. Given the current crop production systems in three regions of South Asia, viz., Andhra Pradesh (mixed crop-livestock, red soils), Karnataka (mixed crop-livestock, black soils) and Rajasthan (rangeland, agro-pastoral), the household vulnerability measured in terms of expected poverty was analyzed by considering the per-capita income of farmers and various socio-economic factors. About 94% of the households in Andhra Pradesh, 62% in Karnataka and 87% in Rajasthan fall under vulnerable category, and the rest fall under the less vulnerable category. The per-capita income of the farmers varies greatly across the three locations. In all the regions, the probability of vulnerable households to become less vulnerable increases when the farm size increases. However, the results indicated that the currently vulnerable households have a higher probability to remain vulnerable due to their low per-capita income. This is particularly important in rain-fed regions of Andhra Pradesh and Rajasthan. The results of the simulation analysis indicated that more farmers would continue to be vulnerable, implicating that household income should be increased to move them out of the vulnerable category.

In this context, different farm level adaptation strategies that will enhance the household income under different farm groups (viz., marginal, small, medium and large) in the rain-fed regions have been examined.

In Andhra Pradesh, the suitable strategy for small farmers is a combination of livestock, additional skill development activities, change in cropping pattern and planting date, and farm mechanization that can fetch a net income of ₹ 111,616 per household over the current marginal income of ₹ 63,136. The combination of livestock, additional skill development activities, change in cropping pattern and providing supplemental irrigation with farm mechanization is suitable for large farmers to realize a net income of ₹ 534,370 per household and a marginal income of ₹ 252,284 over the existing practice.

In Karnataka, the possession of livestock will be remunerative for landless farmers as it can fetch a net income of ₹ 37,519 per household. For marginal farmers, a combination of livestock, additional skill development activities and change in cropping pattern seems to be a better adaptation strategy as it can fetch a household net income of ₹ 60,388 with a marginal income of ₹ 20,970. Small farmers will get a higher income when they adopt a package of livestock, additional skill development activities, change in cropping pattern, and improved crop production practices, which can fetch a household net income of ₹ 174,235 and a marginal income of ₹ 30,452. Medium farmers can opt for owning livestock, awareness of technology and follow improved crop production practices that can bring a net income of ₹ 3,55,868 per household with a marginal income of ₹ 54,817. Large farmers who own more than four hectares of land can obtain a maximum household income of ₹ 1,899,021 if they adopt livestock,

additional skill development activities, change in cropping pattern, and farm mechanization that can result in a marginal income of ₹ 429,657 over the existing practices.

In Rajasthan, owning livestock and farm mechanization seems to be the most suitable strategy for marginal farmers that can result in a maximum household net income of ₹ 49,541 and a marginal income of ₹ 22,841. For maximum revenue, small farmers should own livestock, maintain poultry and goats apart from mechanization that can fetch an income of ₹ 191,384 with a marginal income of ₹ 71,172. The next suitable strategy for them will be to own livestock and provide supplementary irrigation that can earn a net income of ₹ 120,212 per household and a marginal income of ₹ 13,417. Medium-size landholding farmers can derive a maximum income of ₹ 238,045 with a marginal income of ₹ 32,867 per household if they have livestock, own farm ponds (for supplementary irrigation) and mechanize their farm. If large farmers use the same strategy, they can get a maximum net income of ₹ 365,510 with a marginal income of ₹ 214,273. The next suitable strategy for them will be livestock production, maintaining poultry, mechanize their farm that can provide a net income of ₹ 151,237 per household with a marginal income of ₹ 18,357.

In all the three states, the combination of livestock production, additional skill development activities, change in cropping pattern and planting date, farm mechanization, supplemental irrigation and improved crop production practices were found to be important to move the farmers from the vulnerable to less vulnerable category. Specifically, livestock was found to be a universal entry point in all the three states. Hence, developing new technologies emphasizing high yielding breeds can be worked out.

Recommendations

The current level of adoption of various adaptation strategies ranged from 23% in Andhra Pradesh and Rajasthan to 26% in Karnataka. Farmers are reluctant to adopt the different adaptation strategies even though they yield comparatively higher income than the pure rain-fed situation because the risks associated with these adaptation strategies may be high due to the high variability in rainfall, lack of skills in adoption of the strategies, and lack of supplemental irrigation sources.

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

The high risks in technology adoption among the small and marginal farmers should be quantified so that appropriate measures can be worked out.

Awareness should be created and the skill development activities should be enhanced through capacity-building programs. This is more relevant for strategies such as small farm mechanization, farm pond design and construction, provision of supplemental irrigation through sprinklers and maintenance of fodder plots and improved livestock rearing.

Most of the farmers face the risk of rainfall variability. Thus, investment in farm ponds for providing supplementary irrigation can be a viable option for them, but it requires a detailed examination. The investment in the construction of farm ponds and provision of supplemental irrigation through micro-sprinklers may be costlier for small and marginal farmers; therefore, the option for convergence of different government programs that can facilitate the construction of

farm ponds and other water harvesting structures need to be examined. This can minimize the transaction cost of farmers as well as project implementation by the government departments.

Furthermore, to expedite the process of adaptation, public private partnership (PPP) in small farm machinery development, micro-irrigation development, and weather-based crop insurance product should be developed to enhance the household income and reduce the vulnerability level. Successful business models should be developed for each region and should be made available to the interested partners and implementation agencies.

References

Amemiya T. (1977). The maximum likelihood and non-linear three stage least squares estimator in the general non-linear simultaneous equations model. Econometrica, 45: 955-968.

Adger WN. (1999). Social vulnerability to climate change and extremes in coastal Vietnam, World Development, 2: 249-269.

Brooks N, Adger WN and **Kelly PM.** (2005). The determinents of vulnerability and adaptive capacity at the national level and the implications for adaptations. Global Environmental change, Vol.15, pp:151-163.

Chaudhuri S, Jalan J and **Suryahadi A.** (2002). Assessing household vulnerability to poverty: A methodology and estimates for Indonesia. Department of Economics Discussion Paper No. 0102-52. New York. Columbia University.

Christiaensen J, and **Subba Rao K.** (2004). Towards an understanding of household vulnerability in rural Kenya. World Bank Policy Research Working Paper 3326. Washington DC. World Bank.

Deressa T, Hassan RM, and **Ringler C.** (2009). Assessing household vulnerability to climate change: the case of farmers in the Nile Basin of Ethiopia. International Food Policy Research Institute, Washington.

Gbetibouo GA. (2009). Understanding farmers perceptions and adaptations to climate change and variability: The case of Limpopo basin, South Africa. IFRI Discussion paper 00849. http://www.ifpri.org/sites/default/files/publications/ifpridp00849.pdf accessed on 15.05.2014.

Government of India, Planning Commission (2013). Press Note on Poverty Estimates,2011-12.

Jha R, Kang W, Nagarajan HK and **Pradha KC.** (2012). Vulnerability as expected poverty in rural India. ASARC working paper 2012/04. https://crawford.anu.edu.au/acde/asarc/pdf/papers/2012/WP2012_04.pdf accessed on 22/05/2014.

Kasperson JX, Kasperson RE, Turner BL, Hsieh W and **Schiller A.** (2000). Vulnerability to global environmental change, The Human Dimensions of Global Environmental Change, Cambridge, MIT Press.

Kavikumar KS. (2010). Climate sensitivity of Indian agriculture: Role of technological development and information diffusion, in Lead papers-National Symposium on Climate Change and Rainfed Agriculture, Indian Society of Dryland Agriculture, Central Research Institute for Dryland Agriculture, Hyderabad, February 18-20, 2010. pp. 1-18.

NREGA. (2014). State wise notified wages for MNREGA. http://nrega.nic.in/nerega_statewise.pdf accessed on 14.3.2014.

Mahendra Dev S. (2012). Small farmers in India: Challenges and Opportunities. Working Paper No.WP-2012-014. Indira Gandhi Institute of Development Research, Mumbai.

Muller C and **Shackleton S.** (2014). Perception of climate change and barriers to adaptation amongst commonage and commercial livestock farmers in the semi-arid Eastern Cape Karoo, African Journal of Range and Forage Science, Vol.13 (1): pp. 1-12.

Palanisami K, Ranganathan CR, Nagothu US and **Kakumanu KR.** (2014). Climate change and agriculture in India, studies from selected river basins. Routledge Taylor & Francis Group, New Delhi.

Singh NP, Bantilan MCS, Byjesh K and **Murty MVR.** (2012). Adapting to climate change in agriculture: Building resilience with an effective policy frame in SAT India, Policy Brief. 18. http://oar.icrisat.org/5936/1/Policy%20Brief%2018. pdf accessed on 15.05.2014.

Statistical abstract Andhra Pradesh (2008). Directorate of Economics and Statistics, Government of Andhra Pradesh, Hyderabad.

Statistical abstract Andhra Pradesh (2012). Directorate of Economics and Statistics, Government of Andhra Pradesh, Hyderabad.

Statistical abstract of Karnataka (2012). Directorate of Economics and Statistics, Government of Karnataka, Bangalore.

Venkateswarlu B and **Rama Rao CA.** (2010). Rainfed agriculture: Challenges of climate change, agriculture to-day year book 2010. pp. 43-45.

World Bank (2008). World Bank updates poverty estimates for the developing world. http://web.worldbank.org/wbsite/external/news/0,contentMDK:21882162~pagePK:34370~piPK:34424~theSitePK:4607,00.html accessed on 14.03.2014.

World Bank (2012). New estimates reveal drop in extreme poverty 2005-10. http://econ.worldbank.org/wbsite/external/extdec/0,contentMDK:23129612~pagePK:64165401~piPK:64-165026~theSitePK:469372,00.html.

Appendix

Appendix-A1

Household family income and marginal income of Andhra Pradesh farmers under different typologies and land holdings

Marginal Farmer	Rainfed only	CFcpd + Fmech	Livestock + CFcpd + Fmech	Livestock + Cpsi + Fmech	Livestock + CFccp + CFcpd + Fmech	Livestock + Cpsi	CFccp + Cfic + Fmech	Livestock + Cfic	Livestock + Cfic + Fmech	Livestock + CFccp + CFcpd + Cfic + Cpsi + Fmech	Livestock + Cfaig + Cfccp + Cpsi + Fmech	Livestock + Cfaig + CFccp + CFcpd + Cfic + Cpsi + Fmech	Cpsi + Fmech	Fmech only	Cfaig + Fmech	CFccp + Fmech	Livestock + Fmech	Cfaig + CFccp + Fmech	CFcpd only	Livestock only	Livestock + CFccp + Fmech	Livestock + Cfaig + CFccp + CFcpd + Fmech	Livestock + Cfaig + Fmech	Livestock + Cfaig + CFccp + Fmech
HH Income	−753	−588	0	0	0	0	0	0	0	0	0	0	263	1,893	4,702	7,208	10,602	10,615	12,197	18,127	32,505	44,464	52,180	111,616
Marginal Income		164	588	0	0	0	0	0	0	0	0	0	263	1,631	2,808	2,506	3,394	12	1,582	5,931	14,377	11,960	7,716	59,436

Small Farmer	Livestock + Cfccp + Cfcpd + Fmech	Livestock + Cfccp + Cfcpd + Cfic + Cpsi + Fmech	Cfaig + Cfccp + Fmech	Livestock only	Rainfed only	Livestock + Cfaig + Cfccp + Cpsi + Fmech	Livestock + Cfaig + Cfccp + Cfcpd + Cfic + Cpsi + Fmech	Cfcpd only	Cfaig + Fmech	Cfccp + Fmech	Livestock + Cfic	Fmech only	Cfcpd + Fmech	Livestock + Cpsi + Fmech	Livestock + Cfaig + Cfccp + Fmech	Livestock + Cfcpd + Fmech	Cfccp + Cfic + Fmech	Livestock + Cfaig + Fmech	Livestock + Cfaig + Cfccp + Cfcpd + Fmech	Livestock + Fmech	Livestock + Cfic + Fmech	Livestock only	Livestock + Cpsi	Livestock + Cfccp + Fmech	Cpsi + Fmech
HH Income	−8,345	−2,116	−1640	−115	0	0	3,000	4,751	8,186	13,842	18,027	19,054	24,975	27,473	28,217	32,419	32,842	34,281	37,390	39,737	47,731	47,961	48,480	63,738
Marginal Income		6,229	476	1,525	115	0	3,000	1,751	3,435	5,656	4,185	1,027	5,921	2,499	744	4,201	423	1,439	3,109	2,347	7,994	229	520	15,258

Medium Farmer	Livestock + Cfccp + Cfcpd + Cfic + Cpsi + Fmech	Livestock + Cfccp + Cfcpd + Fmech	Livestock + Cpsi	Cfcpd only	Cfccp + Cfic + Fmech	Livestock + Cfic	Rainfed only	Cfcpd + Fmech	Cfaig + Fmech	Livestock + Cfccp + Fmech	Livestock + Cfccp + Cfcpd + Fmech	Livestock + Cfaig + Fmech	Livestock +Cfic + Fmech	Livestock + Cfcpd + Fmech	Livestock + Cfaig + Cfccp + Cpsi + Fmech	Cfaig + Cfccp + Fmech	Livestock + Fmech	Cpsi + Fmech	Fmech only	Livestock only	Livestock + Cfaig + Cfccp + Fmech	Livestock + Cpsi + Fmech	Livestock + Cfaig + Cfccp + Cfcpd + Fmech	Livestock + Cfaig + Cfccp + Cfcpd + Cfic + Cpsi + Fmech
HH Income	-28,573	−680	0	0	0	0	3,836	11,388	19,029	24,094	29,471	29,850	33,280	37,725	39,337	40,800	41,164	46,818	64,536	84,928	90,424	103,800	116,502	460,323
Marginal Income		27,893	680	0	0	0	3,836	7,552	7,641	5,065	5,377	379	3,430	4,445	1,612	1,463	364	5,653	17,718	20,392	5,497	13,376	12,702	343,821

Large Farmer	Rainfed only	Cfcpd + Fmech	Cfccp + Fmech	Cfaig + Fmech	Livestock + Cfaig + Cfccp + Cfcpd + Fmech	Cfcpd only	Cfccp + Cfic + Fmech	Cfaig + Cfccp + Fmech	Livestock + Cfic + Fmech	Livestock + Cfccp + Cfcpd + Cfic + Cpsi + Fmech	Livestock + Cfaig + Cfccp + Cfcpd + Cfic + Cpsi + Fmech	Livestock + Cfaig + Cfccp + Fmech	Livestock + Cfaig + Fmech	Livestock + Fmech	Livestock only	Livestock + Cfccp + Cfcpd + Fmech	Livestock + Cfic	Livestock + Cfcpd + Fmech	Livestock + Cfccp + Fmech	Livestock + Cpsi + Fmech	Cpsi + Fmech	Livestock + Cpsi	Fmech only	Livestock + Cfaig + Cfccp + Cpsi + Fmech
HH Income	−11,595	−3,340	0	0	0	0	0	0	0	0	0	37,922	49,588	60,892	71,256	72,213	110,543	124,236	155,316	182,086	193,080	219,108	379,929	534,370
Marginal Income		8,255	3,340	0	0	0	0	0	0	0	0	37,922	11,666	11,304	10,364	957	38,330	13693	31,080	26,770	10,994	26,028	160,821	154,442

Appendix-A2

Household family income and marginal income of Karnataka farmers under different typologies and land holdings

Marginal Farmer	Cfaig + CFccp + CFcpd	Livestock + Cfaig + CFccp + Fmech	CFccp	Livestock + Cfaig + CFccp + Cffic	Cfaig + Fmech	Cfaig + Cffic	Cfaig + CFcpd + Fmech	Livestock + CFccp	Livestock + Cfaig + Cfic	Cfaig + CFcpd	Cfaig + CFccp + Cffic	CFccp + CFcpd	Cfaig + CFccp + Fmech	Cfaig + CFccp	Livestock + Cfaig + CFccp + CFcpd	Cfaig	Livestock + Cfaig + CFcpd	Livestock + Cfaig	Livestock + Cfaig + CFcpd + Fmech	Livestock + Cfaig + Cfccp
HH Income	0	0	0	0	0	0	0	0	0	5,831	7,776	12,738	16,220	22,787	28,955	30,897	34,874	38,677	39,418	60,388
Marginal Income		0	0	0	0	0	0	0	0	5,831	1,945	4,962	3,482	6,567	6,167	1,942	3,977	3,803	741	20,970

Small Farmer	Livestock + Cfaig + Cffic	Cfaig + CFccp + Cffic	Livestock + Cfaig + CFcpd + Fmech	Cfaig + Cfic	Cfaig + CFccp	Cfaig + CFcpd	Cfaig + CFccp + CFcpd	Cfaig + CFcpd + Fmech	CFccp + CFcpd	Livestock + CFccp	CFccp	Cfaig + CFccp + Fmech	Cfaig	Livestock + Cfaig + Cfccp	Livestock + Cfaig + CFccp + Fmech	Livestock + Cfaig + CFccp + CFcpd	Livestock + Cfaig	Cfaig + Fmech	Livestock + Cfaig + CFcpd	Livestock + Cfaig + CFccp + Cfic
HH Income	−4,345	19,208	44,970	52,664	54,051	64,302	70,549	75,099	81,841	86,202	87,428	89,237	93,254	101,599	102,784	116,734	143,784	163,784	169,433	174,235
Marginal Income		23,553	25,762	7,694	1,387	10,251	6,247	4,550	6,742	4,361	1,226	1,809	4,017	8,345	1,184	13,950	27,050	20,000	5,649	4,802

Medium Farmer	Cfaig + CFcpd	CFccp + CFcpd	Cfaig + Fmech	Livestock + Cfaig + CFcpd	Cfaig	Livestock + CFccp	Livestock + Cfaig + CFcpd + Fmech	CFccp	Cfaig + CFccp + CFcpd	Cfaig + CFccp	Cfaig + CFccp + Cfic	Livestock + Cfaig + Cfccp	Livestock + Cfaig + CFccp + Fmech	Cfaig + CFcpd + Fmech	Livestock + Cfaig + CFccp+Cfic	Cfaig + Cfic	Cfaig + CFccp + Fmech	Livestock + Cfaig + CFccp + CFcpd	Livestock + Cfaig + Cfic	Livestock + Cfaig
HH Income	0	0	0	60,771	68,678	93,883	120,583	131,062	136,499	164,620	187,359	187,925	215,372	231,363	248,751	260,241	298,795	301,050	355,868	750,237
Marginal Income		0	0	60,771	7,907	25,205	26,700	10,480	5,437	28,121	22,739	566	27,447	15,991	17,389	11,490	38,554	2,255	54,817	39,4369

Large Farmer	CFccp+CFcpd	Cfaig	Cfaig+CFccp	Livestock+Cfaig+CFcpd	Cfaig+CFcpd+Fmech	Cfaig+Cfic	Livestock+Cfaig+Cfic	Cfaig+CFcpd	Livestock+Cfaig+CFcpd+ Fmech	Cfaig+CFccp+CFcpd	Cfaig+CFccp+Cfic	Livestock+Cfaig	Cfaig+Fmech	Cfaig+CFccp+Fmech	Livestock+Cfaig+CFccp+ CFcpd	Livestock+Cfaig+CFccp+ Cfic	Livestock+Cfaig+Cfccp	CFccp	Livestock+CFccp	Livestock+Cfaig+CFccp+ Fmech
HH Income	150,100	204,018	246,360	256,161	303,616	306,558	372,745	425,638	455,046	526,857	632,880	675,214	731,054	852,324	863,957	876,257	985,476	1,296,617	1,469,365	1,899,021
Marginal Income		53,918	42,342	9,801	47,455	2,941	66,187	52,893	29,409	71,810	106,024	42,334	55,840	121,270	11,633	12,299	109,219	311,141	172,748	429,657

Appendix-A3

Household family income and marginal income of Rajasthan farmers under different adaptation strategies and land holdings

Marginal Farmers	Rain-fed only	Livestock + Cpsi + Fmech	Livestock + IFPonds + Fmech	Livestock + Poultry and Goats	Livestock only	Livestock + Poultry and Goats + Fmech	Livestock + Fmech
HH Income	−4,237	-	-	19,878	23,645	26,700	49,541
Marginal Income		4,237	-	19,878	3,767	3,055	22,841

Small Farmers	Rain-fed only	Livestock + Poultry and Goats	Livestock + IFPonds + Fmech	Livestock only	Livestock + Fmech	Livestock + Cpsi + Fmech	Livestock + Poultry and Goats + Fmech
HH Income	-	9,672	41,091	63,288	106,795	120,212	191,384
Marginal Income		9,672	31,419	22,197	43,507	13,417	71,172

Medium Farmer	Rain-fed only	Livestock + Poultry and Goats	Livestock only	Livestock + Poultry and Goats + Fmech	Livestock + Fmech	Livestock + Cpsi + Fmech	Livestock + IFPonds + Fmech
HH Income	-	22,031	46,284	48,098	205,178	235,668	238,045
Marginal Income		22,031	24,253	1,814	157,080	30,490	2,376

Large Farmer	Rain-fed only	Livestock only	Livestock + Poultry and Goats	Livestock + Poultry and Goats + Fmech	Livestock + Fmech	Livestock + Cpsi + Fmech	Livestock + IFPonds + Fmech
HH Income	0	72,941	132,880	151,237	199,642	291,883	365,510
Marginal Income		72,941	59,940	18,357	48,405	92,241	73,627

Appendix-B

Table 1. Distribution of farmers in Andhra Pradesh across different land holdings and typologies for each poverty transition.

	Marginal				Small				Medium				Large			
Adaptation Strategy	V-V	LV-LV	V-LV	LV-V	V-V	LV-LV	V-LV	LV-V	V-V	LV-LV	V-LV	LV-V	V-V	LV-LV	V-LV	LV-V
Livestock + Fmech	13	0	0	0	39	1	0	0	53	1	0	0	12	1	0	0
Fmech only	24	0	0	0	39	0	0	1	28	4	0	0	3	2	0	0
Rain-fed only	7	0	0	0	8	0	0	0	7	0	0	0	2	0	0	0
Livestock only	6	0	0	0	7	0	0	0	8	1	0	0	5	1	0	0
CFccp + Fmech	4	0	0	0	13	0	0	0	1	0	0	0	0	0	0	0
Livestock + Cfaig + Fmech	1	0	0	0	4	0	0	0	6	0	0	0	4	0	2	0
Cfaig + Fmech	7	0	0	0	4	0	0	0	4	0	0	0	0	0	0	0
Livestock + Cfaig + CFccp + Fmech	1	0	0	0	3	0	0	0	5	1	1	0	4	0	0	0
CFcpd + Fmech	5	0	0	0	7	0	0	0	1	0	0	0	1	0	0	0
Livestock + CFccp + Fmech	1	0	0	0	2	0	0	0	6	0	0	0	2	1	0	0
Livestock + CFcpd + Fmech	0	0	0	0	4	0	0	0	4	0	0	0	1	2	0	0
Livestock + Cpsi + Fmech	0	0	0	0	3	0	0	0	3	1	1	0	0	0	1	1
Cpsi + Fmech	3	0	0	0	3	0	0	0	1	0	0	0	0	1	0	0
Livestock + CFccp + CFcpd + Fmech	0	0	0	0	1	0	0	0	3	0	0	0	1	0	0	0
Livestock + Cfaig + CFccp + CFcpd + Fmech	3	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0
Livestock + Cpsi	0	0	0	0	2	0	0	0	0	0	0	0	1	1	0	0
CFcpd only	2	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
CFccp + Cfic + Fmech	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0
Cfaig + CFccp + Fmech	1	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0
Livestock + Cfic	0	0	0	0	2	0	0	0	0	0	0	0	1	0	0	0
Livestock + Cfic + Fmech	0	0	0	0	2	0	0	0	1	0	0	0	0	0	0	0
Livestock + CFccp + CFcpd + Cfic +Cpsi+Fmech	0	0	0	0	1	0	0	0	2	0	0	0	0	0	0	0
Livestock + Cfaig + Cfccp + Cpsi + Fmech	0	0	0	0	0	0	0	0	1	0	0	0	0	2	0	0
Livestock +Cfaig+CFccp+CFcpd+Cfic+Cpsi+Fmech	0	0	0	0	0	0	0	0	2	1	0	0	0	0	0	0
Others	6	0	0	0	17	1	0	0	12	2	1	0	9	3	1	2
Total	84	0	0	0	167	2	0	1	150	11	3	0	46	14	4	3

V = Vulnerable, LV = Less vulnerable

Table 2. Distribution of farmers in Karnataka across different land holdings and typologies for each poverty transition.

	Marginal				Small				Medium				Large			
Adaptation Strategy	V-V	LV-LV	V-LV	LV-V	V-V	LV-LV	V-LV	LV-V	V-V	LV-LV	V-LV	LV-V	V-V	LV-LV	V-LV	LV-V
Cfaig + CFccp + CFcpd	0	0	0	0	9	1	0	0	6	2	0	0	2	1	0	2
Cfaig + CFccp	8	0	0	0	7	0	0	0	2	1	0	0	1	2	0	0
Cfaig	4	0	0	0	7	1	0	0	3	1	0	0	0	1	0	0
Cfaig + CFcpd	8	0	0	0	2	0	0	0	0	0	0	0	0	4	0	0
Livestock + Cfaig + Cfccp	1	0	0	0	2	0	2	1	2	0	1	2	0	0	0	3
Livestock + Cfaig	1	0	0	0	3	2	0	0	0	1	0	1	0	0	0	1
Livestock + Cfaig + CFcpd	1	0	0	0	2	0	0	0	1	0	0	0	1	1	0	1
Livestock + Cfaig + CFccp + CFcpd	1	0	0	0	0	0	1	0	2	0	1	2	0	0	0	1
Livestock + Cfaig + CFccp + Fmech	0	0	0	0	1	0	1	0	1	0	0	1	0	0	0	3
CFccp	0	0	0	0	3	0	0	0	1	1	0	0	0	0	0	1
Cfaig + CFccp + Cfic	1	0	0	0	1	0	0	0	1	0	0	1	0	1	0	1
Livestock + Cfaig + CFccp + Cffic	0	0	0	0	0	0	1	1	0	0	0	1	0	0	0	3
CFccp + CFcpd	2	0	0	0	2	0	0	0	0	0	0	0	1	0	0	0
Cfaig + Fmech	0	0	0	0	2	1	0	0	0	0	0	0	1	1	0	0
Cfaig + Cfic	0	0	0	0	1	0	0	0	2	1	0	0	0	1	0	0
Cfaig + CFcpd + Fmech	0	0	0	0	1	1	1	0	0	1	0	0	1	0	0	0
Cfaig + CFccp + Fmech	1	0	0	0	1	0	1	0	0	1	0	0	0	1	0	0
Livestock + CFccp	0	0	0	0	2	0	0	0	2	0	0	0	0	0	0	1
Livestock + Cfaig + Cfic	0	0	0	0	0	0	1	0	0	1	0	1	1	0	0	1
Livestock + Cfaig + CFcpd + Fmech	1	0	0	0	1	0	0	0	1	0	0	0	0	1	0	1
Others	2	0	0	0	7	2	1	1	6	6	8	4	1	5	4	16
Total	31	0	0	0	54	8	9	3	30	16	10	13	9	19	4	35

Table 3. Distribution of farmers in Rajasthan across different land holdings and typologies for each poverty transition.

	Marginal				Small				Medium				Large			
Adaptation Strategy	V-V	LV-LV	V-LV	LV-V	V-V	LV-LV	V-LV	LV-V	V-V	LV-LV	V-LV	LV-V	V-V	LV-LV	V-LV	LV-V
Livestock only	27	0	0	0	23	4	0	0	29	4	0	0	18	5	0	
Livestock + Fmech	14	0	0	0	15	2	0	0	11	4	0	0	7	8	0	0
Livestock + Poultry and Goats	3	0	0	0	5	0	0	0	9	0	0	0	2	1	0	0
Livestock + Poultry and Goats + Fmech	5	0	0	0	1	0	0	0	4	0	0	0	3	1	0	0
Livestock + Cpsi + Fmech	0	0	0	0	3	0	2	2	0	0	1	0	2	0	0	0
Livestock + IFPonds + Fmech	0	0	0	0	1	0	0	0	0	1	0	0	1	1	0	0
Rain-fed only	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Others	0	0	0	0	3	0	0	0	0	1	0	0	1	0	0	0
Total	50	0	0	0	51	6	2	2	53	10	1	0	34	16	0	0