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Farmers' Vulnerability to Rainfall Variability and Technology Adoption in Rain-fed Tank Irrigated Agriculture

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Abstract

Increasing temperature and variability in precipitation in the semi-arid regions have reduced crop yields and increased vulnerability of the farmers. This paper has estimated the vulnerability of both farmers and irrigation tanks to rainfall variability in a rain-fed area. It has also looked into the adoption of technologies to cope up with rainfall variability and the determinants of technology adoption in the rain-fed tank irrigated agriculture. Tank performance has been evaluated through adjusted tank performance measure, vulnerability has been estimated through livelihood vulnerability index and technology adoption has been studied through a logit model. The data were collected through multistage sampling technique in two areas with below normal rainfall and above normal rainfall. The study has revealed that tank performance and livelihood vulnerability are marginally higher in below normal rainfall area. The adoption of technologies was significantly influenced by the extension services and land tenure. This implies the need for effective policies for the transfer of climate adaptation technologies in agriculture.

Key words: Agriculture, vulnerability, rainfall variability, climate adaptation, adaptation technologies

JEL Classification: Q10, Q54, Q16

Introduction

Some of the most profound and direct impacts of climate change over the next few decades will be on agricultural and food systems of the world (Brown and Funk, 2008). Agriculture is a part of both the problem and solution in the sense that agriculture is a source of three major green house gases (carbon dioxide, methane and nitrous oxide) and it is also a sink for carbon dioxide through carbon sequestration into biomass products and soil organic matter (Johnson *et al*., 2007). Some scientific evidences claim that climate change is already negatively affecting agriculture in the developing countries and this situation is likely to worsen (IPCC, 2007). The recent estimates of greenhouse emissions reveal that agriculture accounts for 17 per cent of the total emissions in India, while land-use change and forestry are the sink of carbon emissions (GoI, 2010). Increasing temperatures and declining precipitation over the semi-arid regions are likely to reduce yields of corn, wheat, rice, and other primary crops in the next two decades (Lobell *et al*., 2008). Saseendran *et al*., (2000) have reported a decrease in rice yield by 3 to 15 per cent under a climate change scenario of 1.5 °C rise in temperature and an increase of 2 mm per day in precipitation. A large part of the arable land in India being rain-fed, the productivity of agriculture depends on the rainfall and its distribution. In the semi-arid and sub-humid areas, the rainfall deficits can dramatically reduce crop yields and livestock numbers and productivity (Bruinsma, 2003). The fluctuations in yearly rainfall as well as within a monsoon season govern the yield of crops (Chinchorkar, 2011). In this background, the present

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study was undertaken with the overall objective of understanding the vulnerability of farmers to rainfall variability and identifying the determinants of adoption of technologies to reduce the vulnerability in the rain-fed tank irrigated agricultural production environment.

Methodology

This micro level study was conducted in the Pudukkottai district of Tamil Nadu where nearly 40 per cent of the net sown area is under rain-fed agriculture. There are more than 400 rainfed tanks in the district which depend on the rainfall. A multistage sampling technique was followed to select the sample farmers from the study area. In proportion to the number of blocks having above and below normal rainfall, two blocks with below normal rainfall and one block with above normal rainfall were selected for the study based on the deficit or excess rainfall received in 2009-10 compared to the normal rainfall. In the next stage, ten rain-fed tanks were selected at random from each block and from each tank command, five farmers were selected at random. Thus, 50 farmers were selected from each block, making the total sample of 150 farmers. The data collected related to the year 2009-10.

Rainfall Variability and Tank Performance

The tank performance is generally measured as the ratio of actual area irrigated by a tank to the total command area. This definition, however, does not purely reflect the actual tank performance since the wells in the tank command also contribute for tank performance both as a supplementary source in the wet season and as a sole source of irrigation during the dry season. Also, higher number of wells reflect the uncertainty in tank water supply and the farmers' ability to cope with the deficit supply compared to tanks with adequate water supply whose dependence on wells will be comparatively less. Hence, Adjusted Tank Performance (ATP) was estimated following Palanisami and Balasubramanian (1998):

$$\text{ATP} = [\text{Area irrigated by tank} - \text{Area irrigated by wells above the threshold level}] / [\text{Total command area of the tank}] \qquad \ldots(1)$$

if the well density was higher than the sample mean well density (threshold level),

and,

$$\text{ATP} = \frac{\text{Actual area irrigated by the tank}}{\text{Total command area of the tank}} \qquad \ldots(2)$$

if the well density was less than the sample mean well density.

Determinants of Adjusted Tank Performance

The exact relationship between tank performance and various parameters affecting the performance is complex in nature; hence regression analysis was used to capture these inter-relationships. A linear multiple regression equation [Equation (3)] was estimated to identify the factors influencing the tank performance:

$$\text{ATP} = a + b_1\,\text{FPART} + b_2\,\text{OME} + b_3\,\text{REV} + b_4\,\text{ENC} + b_5\,\text{WELL} + b_6\,\text{RFALL} \qquad \ldots(3)$$

where,

ATP = Adjusted tank performance (in per cent),

FPART = Farmers' participation in tank maintenance works (five years' mean in humandays / ha/year)

OME = O&M expenditure (five years' mean in ₹/ ha),

REV = Resource mobilized for tank maintenance (five years' mean in ₹/ha),

ENC = Encroachment in tank water spread (%),

WELL = Number of wells per ha of command area, and

RFALL = Dummy, if below normal rainfall = 1; above normal rainfall = 0.

Rainfall Variability and Livelihood Vulnerability

Livelihood Vulnerability Index (LVI) and Intergovernmental Panel on Climate Change (IPCC) framework approach of Hahn *et al*. (2009) were adopted to assess the vulnerability of the study blocks.

Livelihood Vulnerability Index

The LVI of Hahn *et al*. (2009) is a composite index comprised of seven major components to assess the exposure to natural disasters and climate variability, social and economic characteristics of households that affect their adaptive capacity, and current health, food, and water resource characteristics that determine their sensitivity to climate change impacts. In this study, an additional major component, irrigation, was also included since irrigation has a significant influence on the livelihood vulnerability of rain-fed agriculture. Each major component was comprised of several sub-components or indicators as defined in Annexure 1.

Each of the sub-components was measured on different scales and hence these components were standardized following UNDP (2007):

$$Index_{sb} = \frac{S_b - S_{min}}{S_{max} - S_{min}} \quad \ldots(4)$$

where, sb is the sub-component value for the block, S_{min} and S_{max} are the minimum and maximum values for each sub-component in the blocks under study. If there was a negative relationship between the variable and vulnerability, the inverse values of the components were taken. The major component was calculated by averaging the standardized sub-components as per Equation (5):

$$M_b = \frac{\sum_{1}^{n} index_{sb} i}{n} \quad \ldots(5)$$

where, M_b is one of the seven major components for block b and n is the number of sub-components in each major component. Then, LVI is the weighted average of the seven major sub-components as given in Equation (6).

$$LVI_b = \frac{\sum_{i-1}^{8} w_{Mi} M_{bi}}{\sum_{i-1}^{8} w_{Mi}} \quad \ldots(6)$$

Equation (6) can also be expressed as Equation (7) :

$$LVI_b = \frac{w_{SDP} SDP_b + w_{LS} LS_b + w_{SN} SN_b + w_H H_b + w_F F_b + w_W W_b + w_I I_b + w_{NDCV} NDSV_b}{w_{SDP} + w_{LS} + w_H + w_{SN} + w_F + w_{W+wI} + w_{NDCV}} \quad \ldots(7)$$

The weights of each major component, W_{Mi} are the number of sub-components that make up each major component. The LVI is scaled from 0 (least vulnerable) to 0.5 (most vulnerable).

IPCC Framework for Calculating LVI

The alternative method for calculating LVI incorporated the IPCC vulnerability definition by grouping the eight major components under exposure, adaptive capacity and sensitivity (Table 1).

Each major component was comprised of several sub-components or indicators, same as in LVI and defined in Annexure 1. Similarly, Equations (4)–(6) were used to calculate the LVI–IPCC. Instead of one weighted average as in the LVI approach, in this method three weighted averages of the major sub-components were calculated according to the three contributing factors explained in Table 1 using Equation (8):

$$CF_b = \frac{\sum_{i-1}^{n} w_{Mi} M_{bi}}{\sum_{i-1}^{n} w_{Mi}} \quad \ldots(8)$$

where, CF_b denotes the contributing factors (exposure, sensitivity, or adaptive capacity) for the blocks b; M_{bi} are the major components for blocks b indexed by i; w_{Mi} is the weight of each major component; and n is the number of major components in each contributing factor. The three contributing factors were combined using Equation (9):

$$LVI\_IPCC_b = (e_b - a_b) * s_b \quad \ldots(9)$$

where, $LVI\text{–}IPCC_b$ is the LVI for block b expressed using the IPCC vulnerability framework; e is the exposure score for block b; a is the adaptive capacity score for block b; and s is the sensitivity score for block b. The LVI–IPCC was scaled from 0 (least vulnerable) to 1 (most vulnerable).

Table 1. Contributing factors to LVI as per IPCC approach

Contributing factor	Major components
I. Exposure	1. Natural disasters and climate variability
II. Adaptive capacity	1. Socio- demographic profile 2. Livelihood strategies 3. Social networks 4. Irrigation
III. Sensitivity	1. Health 2. Food 3. Water

Technology Adoption for Reducing Vulnerability

Rainfall variability, especially deficit rainfall, increases the vulnerability of rain-fed agriculture. There are several strategies to reduce vulnerability and technology adoption is one of the important strategies to reduce vulnerability. But, one of the important issues with regard to these technologies is their adoption. And since the State Agricultural Universities (SAUs) generate these technologies, adoption of these technologies was specifically studied. When such a technology is followed more or less permanently or over a long period in response to recurring water stress or deficit rainfall, it becomes technology adaptation. Adaptation is the response to reduce vulnerability by moderating the potential damages.

An adoption index was constructed to quantify the adoption of such technologies:

Adoption Index = [a/p]* 100,

where, a = Number of practices adopted by respondents, and p = Total number of practices recommended. The respondents were classified as adopters if the adoption index was 50 or above. The recommended practices for crop production are given in the 'Package of Practices' approved by the State Department of Agriculture in consultation with the Tamil Nadu Agricultural University. From this package of practices technologies recommended for rainfall variability/water stress were identified to quantify adoption. The recommended technologies considered in the present study were puddling and levelling, planting of tolerant varieties, direct sowing, irrigation management practices and spraying of chemicals.

A logistic model was specified to study the determinants of technology adoption of farmers to rainfall variability. The value of Pi was taken as 1 if the farmer was an adopter and 0 if non-adopter. The model was estimated through maximum likelihood method.

$$L_i = ln\left[\frac{P_i}{1-P_i}\right] = \beta_0 + \beta_1 x_1 + \dots \dots + \beta_7 x_7 + u_i$$

where,

$P_i / (1-P_i)$ = The odds ratio in favour of becoming an adopter,

X_1 = Age of household-head in years,

X_2 = Household size in numbers,

X_3 = Education in years,

X_4 = Farming experience in years,

X_5 = Availing extension services (Yes=1; No=0),

X_6 = Access to climate information (Yes=1; No=0), and

X_7 = Land tenure (owned =1; otherwise=0)

Results and Discussion

Rainfall Variability and Tank Performance

The agriculture in study area is dependent on rain-fed tanks and hence rainfall is one of the important determinants of tank performance. Better tank performance (measured by the ratio of actual area irrigated by the tank to the total command area) ensures higher productivity of agriculture in the command area. The adjusted tank performance in the study area is given in Table 2. It was observed that the average tank performance was higher in the below normal rainfall block. This could be due to the fact that the area irrigated by the wells in the tank command in BNRB (Below Normal Rainfall Blocks) was less than that of ANRB (Above Normal Rainfall Blocks).

Tank performance was modelled including six explanatory variables, namely farmers' participation, O&M expenditure, resources mobilized, encroachment, well density and rainfall, to capture the important determinants of tank performance. The coefficients of different factors that influenced the tank performance are given in Table 3. The value of R^2 implied that 65 per cent of variation in tank performance could be explained by the variables specified in the model.

Table 2. Adjusted tank performance in the study area

Adjusted tank performance (%)	Percentage of tanks in	
	Above normal rainfall blocks	Below normal rainfall blocks
< 50	20	0
50-75	50	30
75-100	30	70
Mean adjusted tank performance (%)	70	78

Table 3. Determinants of adjusted tank performance

S.No	Independent variable	Mean values	Regression coefficient	t-value
1	Farmers' participation (humandays/ha/year)	0.37	0.157	0.08
2	O&M expenditure (₹/ha/year)	1558.51	0.185*	1.72
3	Resourced mobilized (₹/ha/year)	14.81	-0.051	-0.10
4	Encroachment (%)	13.17	-0.473	-1.28
5	Well density (No. of wells/ha)	0.25	-0.136***	-3.89
6	Rainfall (1 if above normal rainfall block and 0 otherwise)	-	0.227**	2.18
	R^2	-	-	0.65

Note: ***, ** and * denote significance at one per cent, five per cent and ten per cent levels, respectively.

The determinants of tank performance were studied by fitting a linear regression model with ATP as the dependant variable. The results revealed that the farmers' participation in tank maintenance by way of contributing humandays did not have significant influence on tank performance. Operation and maintenance investment significantly influenced the performance of the tank. The average O&M expenditure on the sample tanks was ₹ 1559 /ha/year. Resources were mobilized for tank maintenance from tank usufructs such as sale of fishes, trees grown on the tank bunds, collection of fees/rents from duck-growers and cattle growers but it did not influence tank performance significantly. The coefficient of well density was significant and negative, indicating that well density could reduce the tank performance. The increasing number of wells could pose a threat to the sustainability of tanks as a direct source of irrigation. The coefficient of variable rainfall was positive and significant, indicating better tank performance in below normal rainfall blocks. This could be due to higher number of wells in the above normal rainfall tank command area.

Rainfall Variability and Livelihood Vulnerability

A Livelihood Vulnerability Index (LVI) was constructed to measure the overall vulnerability of the farm households in below normal rainfall blocks and above normal rainfall blocks with 8 major components and 29 sub-components of vulnerability. Each of the sub-components was measured on different scales (Appendix 1) and hence these component values were indexed as described in the methodology. The indexed values have been presented in Table 4.

Socio-Demographic Profile — Indices of sub-components like dependency ratio and female-headed households were relatively high in below normal rainfall blocks but index of illiteracy was more in the above normal rainfall block. The overall major component value for the socio-demographic profile did not show much difference between the two categories.

Livelihood Strategies — The overall major component value for livelihood strategies was higher in below normal rainfall blocks, which showed higher vulnerability. But, values for two sub-components, 'households depend solely on agriculture' and 'livelihood diversification' were relatively low in the below normal rainfall blocks, thus reducing the overall vulnerability.

Social Networks — The households in below normal rainfall blocks reported frequent borrowings of money and receipt of assistance in-kind from family, friends, and relatives in the past one month than above normal rainfall block. Similarly, a higher number of households in below normal rainfall blocks had approached the local government for financial assistance during the past 12 months and hence had lower vulnerability index value. Overall, the vulnerability index on account of social network did not show much difference.

Health — The three sub-components of the vulnerability due to health included time to travel to health facility, chronic illness, and missing of work/ school due to illness. The aggregated overall health vulnerability index for above normal rainfall block was higher than that for below normal rainfall block.

Food — The index of vulnerability on account of food comprised five sub-components in which three sub-

Table 4. Indexed sub-components, major components and overall LVI

Major component	Sub-component	BNRB*	ANRB*	BNRB	ANRB
Socio-demographic profile	Dependency ratio	0.214	0.184	0.225	0.228
	Percentage of female household	0.140	0.120		
	Percentage of households where household-head has not attended school	0.320	0.380		
Livelihood strategies	Percentage of households with family members working in a different community/place	0.380	0.340	0.418	0.415
	Percentage of households depending solely on agriculture for income	0.640	0.660		
	Average agricultural livelihood diversification index	0.235	0.246		
Social networks	Average receive: give ratio	0.323	0.204	0.391	0.388
	Average borrow : lend money ratio	0.470	0.440		
	Percentage of households that have not gone to their local government for assistance in the past 12 months	0.380	0.520		
Health	Average time to get health facility	0.427	0.416	0.389	0.409
	Percentage of households with chronic illness in family	0.480	0.360		
	Percentage of households where a family member had to miss work or school in the past 2 weeks due to illness	0.260	0.450		
Food	Percentage of households dependent solely on family farm for food	0.620	0.520	0.341	0.310
	Percentage of households struggling to find food	0.120	0.140		
	Average crop diversity index	0.347	0.349		
	Percentage of households that do not stock crop produce	0.340	0.300		
	Percentage of households that do not save seeds	0.280	0.240		
Water	Percentage of households reporting water conflicts	0.560	0.360	0.306	0.253
	Percentage of households that utilize a natural water source	0.260	0.300		
	Average time spent to get water source	0.376	0.340		
	Percentage of households without consistent water supply	0.320	0.240		
	Inverse of the average No. of litres of water stored/ household	0.016	0.017		
Irrigation	Percentage of households with well irrigation	0.540	0.520	0.553	0.547
	Percentage of irrigated area	0.500	0.480		
	Percentage of households buying well water	0.620	0.640		
Natural disasters & climate variability	Average number of flood, drought events in the past 6 years	0.465	0.430	0.453	0.469
	Percentage of households that did not receive early warning about the natural disasters	0.430	0.440		
	Percentage of households with loss due to recent natural disasters	0.520	0.480		
	Mean standard deviation of monthly average rainfall (2005- 10)	0.398	0.524		
Overall LVI	Below Normal Rainfall Blocks	0.378			
	Below Normal Rainfall Blocks	0.367			

*BNRB=Below Normal Rainfall Blocks; ANRB=Above Normal Rainfall Block components had higher vulnerability score in below normal rainfall blocks. Vulnerability indices of sub-components like households relying solely on farms for food, households storing crops and saving seeds were high in below normal rainfall blocks. The overall food vulnerability score for below normal rainfall blocks (0.341) was higher than that for above normal rainfall block (0.310), indicating high vulnerability in below normal rainfall blocks.

Water — Vulnerability due to water is directly related to rainfall variability. The index of vulnerability to water had five sub-components. The sub-component indices for water conflicts, households without consistent water supply and the time spent to fetch water were high in the above normal rainfall blocks. The overall vulnerability index value for the major component water was higher in below normal rainfall blocks.

Irrigation — Irrigation is another important variable directly related to rainfall variability, especially in the rain-fed tank irrigated areas. The three sub-components of the index for irrigation were households with well irrigation, percentage of irrigated area, and the extent of water markets. The vulnerability score was higher in the below normal rainfall blocks for the first two sub-components. But, when all the sub-components were aggregated, the overall irrigation vulnerability index was marginally higher in the below normal rainfall blocks.

Natural Disasters and Climate Variability — Vulnerability to natural disasters and climate variability were quantified based on four sub-components which accounted for the average number of floods and drought in the past 6 years, early warnings, and loss due to natural disasters and past five-year rainfall variability. The overall index for the major component, natural disasters and climate variability, was higher in the above normal rainfall blocks mainly due to the higher sub-component value for 'mean standard deviation of monthly average rainfall'.

Overall, the Livelihood Vulnerability Index aggregating all the above eight major components was marginally higher for the below normal rainfall blocks.

LVI- IPCC Approach

An alternative method for calculating LVI is the LVI-IPCC approach, which incorporates the IPCC definition of vulnerability. According to IPCC, the contributing factors to vulnerability are exposure, adaptive capacity and sensitivity to climate impacts and these contributing factors were aggregated into LVI-IPCC as given in the methodology. Accordingly, the eight major components discussed under the LVI approach were aggregated under the three contributing factors, namely exposure, adaptive capacity and sensitivity as presented in Table 5. The contributing factor, exposure was measured by the major component 'natural disasters and climate variability'. Similarly, the adaptive capacity was measured by the major components socio-demographic profile, livelihood strategies, social networks and irrigation. Sensitivity was measured for major components — health, food and water. The LVI-IPCC index was 0.061 for below normal rainfall blocks and 0.051 for the above normal rainfall block (Table 5), indicating marginally higher vulnerability of the households in below normal rainfall blocks.

The difference between the LV1 for households of BNRB and ANRB is not found to be significant. It is due to the fact that LVI is a composite vulnerability index comprising climatic/climate-related components and other socio-economic components. Most of the values for climate-related components have shown higher differences between BNRB and ANRB, but the component values related to other socioeconomic variables have not shown a similar trend and hence the larger difference in climate-related components was even out in the overall index. Similar results with marginal difference in the indices were reported by Hahn *et al*. (2009).

Technology Adoption to Cope up with Rainfall Variability/Water Stress

The State Department of Agriculture and the Tamil Nadu Agricultural University have released a package of practices for crop production. These practices include among other recommendations, technologies to cope up with deficit rainfall or water stress. Examples of such technologies are: puddling and levelling, use of stress tolerant varieties, direct sowing, irrigation practices, spraying of chemicals, etc. Adoption of these technologies was quantified by constructing a technology adoption index, calculated as the ratio of number of practices adopted by respondents to the total number of practices recommended (Table 6).

Table 5. LVI-IPCC contributing factors calculation for below and above normal rainfall blocks

Category	IPCC contributing factors to vulnerability	Major components	Major component values	Number of sub-components per major component	Contributing factor values	LVI-IPCC value
Below Normal Rainfall Blocks	Exposure	Natural disasters and climate variability	0.453	4	0.453	0.061
	Adaptive capacity*	Socio–demographic profile	0.295	3	0.272	
		Livelihood strategies	0.299	3		
		Social networks	0.475	3		
		Irrigation	0.018	3		
	Sensitivity	Health	0.389	3	0.338	
		Food	0.341	5		
		Water	0.306	5		
Above Normal Rainfall Block	Exposure	Natural disasters and climate variability	0.469	4	0.469	0.051
	Adaptive capacity*	Socio–demographic profile	0.334	3	0.305	
		Livelihood strategies	0.292	3		
		Social networks	0.576	3		
		Irrigation	0.019	3		
	Sensitivity	Health	0.409	3	0.311	
		Food	0.310	5		
		Water	0.253	5		

Note: * Taking the inverse of the adaptive capacity sub-components indicators: Socio-demographic profile, Livelihood strategies, Social networks and irrigation.

Table 6. Distribution of technology adoption index (TAI)

Distribution of TAI (%)	Number of farmers	
	BNRB*	ANRB
< 50	38(38)	15(30)
51-70	47(47)	21(42)
>71	15(15)	14(28)
Average TAI (%)	70	65

*Note:**BNRB = Below normal rainfall blocks and ANRB=Above normal rainfall blocks; Figures within the parentheses indicate percentage to total number of farmers.

Table 7. Factors influencing technology adoption in below normal rainfall blocks

Variable	Estimated logit	't'-value	Odds ratio	Probability
Intercept	-1.738	-0.83	0.176	0.406
Age	0.005	0.07	1.005	0.941
Education	0.047	0.74	1.048	0.458
Household size	0.065	0.50	1.067	0.618
Farming experience	0.006	0.08	1.006	0.933
Extension services	1.011**	1.99	2.750	0.047
Climate information	0.158	0.28	1.172	0.778
Ownership of land	1.250**	2.01	3.489	0.045

Note: LR statistic (7df) = 13.29; Mc Fadden $R^2 = 0.35$; ** - Significant at 5 per cent level

The adoption of water stress related technologies was 70 per cent in below normal rainfall blocks and 65 per cent in above normal rainfall blocks. A logit model was estimated to identify the determinants of adoption of these technologies in below normal rainfall blocks and the results are presented in Table 7.

The expected signs of regression coefficients and their statistical significance are most important in the binary regressand models like logit. The results of the logit model indicated that 'extension services' and 'ownership of land' had positive significant influence in adoption of technologies to cope with rainfall variability. The estimated logit value of extension services showed a significant positive relationship with adoption. This implies that farmers with access to extension services are more likely to adopt than the farmers without access to extension services. In terms of odds ratio, it could be inferred that the farmers with access to extension services were 2.7-times more likely to adopt the technologies than the farmers without access to extension services, other things remaining the same. It was also found that the farmers who owned land were more than 3-times likely to adopt than the farmers who did not own land. The other variables specified in the model like age, education, household size, farming experience and capital formation did not significantly influence adoption of water stress-related technologies.

Conclusions

In the semi-arid and sub-humid areas, rainfall deficits reduce crop yields and increase vulnerability of the farmers. The rainfall variability influences the performance of tanks in the rain-fed areas, agricultural productivity and livelihood security. The study has revealed that the tank performance and livelihood vulnerability of farmers is higher in the below normal rainfall area. Adoption of technologies helps the farmers to achieve livelihood security in the face of changing climate. Technologies generated by the research systems can greatly contribute to this process. The study has revealed that adoption of technologies to cope with climate related stress is 70 per cent and the adoption is significantly influenced by extension services and land ownership. This implies the need for effective technology transfer policies for climate adaptation in agriculture.

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Appendix 1

Major components and sub-components of livelihood vulnerability index

Major component	Sub-components	Explanation of sub-components
Socio-demographic profile (SDP)	Dependency ratio	Ratio of the population under 15 and over 65 years of age to the population between 19 and 64 years of age.
	Percentage of households where the primary adult is a female.	If a male head is away from the home for more than 6 months in a year the female is counted as the head of the household.
	Percentage of households where head of the household has not attended school	Percentage of households where the head of the household has not attended school
Livelihood strategies (LS)	Percentage of households with family member working outside their primary work activity	Percentage of households that report at least 1 family member who works outside their primary work activity.
	Percentage of households dependent solely on agriculture as a source of income	Percentage of households that report only agriculture as a source of income.
	Average agricultural livelihood diversification index	The inverse of (the number of agricultural livelihood activities + 1) reported by a household.
Social networks (SN)	Average receive: give ratio	Ratio of (the number of types of help received by a household in the past month+1) to (the number of types of help given by a household to someone else in the past month+1).
	Average borrow : lend money ratio	Ratio of household borrowing money in the past month to household lending money in the past month.
	Percentage of households that have not availed assistance from local bodies/ Govt. in past 12 months	Percentage of households that reported that they have not approached local government for any assistance in the past 12 months.
Health (H)	Average time to get health facility	Average time taken to get to the nearest health facility.
	Percentage of households with family member with chronic illness	Percentage of households that report at least 1 family member with chronic illness.
	Percentage of households where a family member had to miss work/school in the last 2 weeks due to illness	Percentage of households that report at least 1 family member who had to miss school of work due to illness in the past 2 weeks.
Food (F)	Percentage of households dependent solely on family farm for food	Percentage of households that get their food primarily from their personal farms.
	Percentage of households struggle to find food	Percentage of households struggle to obtain food for their family.
	Average crop diversity index	The inverse of (the number of crops grown by a household+1).
	Percentage of households that do not stock crop produce	Percentage of households that do not save crops from each harvest.
	Percentage of households that do not save seeds	Percentage of households who do not store seeds from year to year.

Contd.

Appendix 1 contd...

Major component	Sub-components	Explanation of sub-components
Water (W)	Percentage of households reporting water conflicts	Percentage of households that report having heard about conflicts over water in their community.
	Percentage of households that utilize a natural water source	Percentage of households that report a river, lake, pool and tank as their primary water source.
	Average time spent to get water	Average time it takes to travel to their primary water source.
	Percentage of households that do not have a consistent water supply	Percentage of households that report that water is not available at their primary water source every day.
	Inverse of the average number of liters of water stored per household	The inverse of (the average number of liters of water stored by each household+1).
Irrigation (I)	Percentage of households with well irrigation	100 – [% of households used well irrigation for cultivation purpose]
	Percentage of irrigated area	100 – [% of irrigated area by well irrigation]
	Percentage of households buying well water	100 – [% households buying well water during non tank season]
Natural disasters and climate variability (NDCV)	Average number of flood and drought events in the past 6 years	Total number of floods and droughts that were reported by households in the past 6 years.
	Percentage of households that did not receive early warning about the natural disasters	Percentage of households that did not receive a warning about the most severe flood and drought event in the past 6 years.
	Percentage of households with loss as a result of recent natural disasters	Percentage of households with loss as a result of the most severe flood and drought in the past 6 years.
	Mean standard deviation of monthly average rainfall (years: 2005-2010)	Standard deviation of the average monthly rainfall between 2005-2010 was averaged for each block.