Dichotomous outcomes and drivers of drought resilience mechanisms of smallholder farmers in semiarid India

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Abstract:

Frequent droughts affect agriculture and livelihoods of millions of farm households in Semiarid India. Here we attempt to answer the question why some farm households are able to better cope with drought and bounce back quickly as compared to many others. The analysis considered 256 households-data from 2006 to 2014 from three semi-arid regions in India. Households were categorized using crop income and composite crop productivity index of pre-drought and post-drought years. The principal component analysis was applied to construct a composite vulnerability and resilience index. Study analyzes determinants of drought-impacts and risk choices through rigorous statistical process. It is revealed that cultivated area was more impacted then crop yields; adopting cash crops was an important driver of household's resilience. Crop income drives not only high drought impacts but also the ability of households to bounce back. Higher operated-area, off-farm and livestock income in pre-drought years and cash crop area and cropping intensity post-drought enabled households to stay highly resilient. We conclude that drought impacts and resilience ability of different farm households in a region is not uniform. There is need to consider this heterogeneity to devise robust policy to derive effective resilience enhancing strategies targeting vulnerable households.

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Abstract

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Key Words: Drought impacts, Rural households, Determinants, Resilience, Composite crop productivity index

Introduction

Drought is a complex phenomenon that imposes multiple impacts on global agricultural, environmental and socio-economical systems. In both developed and developing countries, drought is a major threat to livelihoods and economic development. As part of its Fourth Assessment Report, the Intergovernmental Panel on Climate Change (IPCC) in 2007 confirmed that our atmosphere is warming and with climate change, drought is projected to increase in extent, severity and frequency.

The semi-arid and arid regions of the tropics, which cover more than one third of the land surface are amongst the most vulnerable regions that are prone to drought disasters. However, the vulnerability associated with such drought disasters and the resilience capacity to effectively prepare for and respond to the effects of drought may vary not only at different social, geographical and temporal scales but also at household level. The causes of such vulnerability in the dryland tropics are multi-dimensional and are primarily due to widespread poverty, food insecurity, land degradation, inequitable land distribution and overdependence on rain-fed agriculture (Notenbaert et al. 2013; Lo´pez-Carr et al. 2014). Research on the impact of climate change and vulnerability on agriculture is a high priority in these regions, as the impact, if it follows the predictions, is expected to be widespread and severe (Khan et al. 2009).

Most of the research on climate change impacts revolve around assessing qualitatively and/or quantitatively - vulnerability, with a very few studies centered on resilience research. Vulnerability and resilience are two complexly interrelated concepts. While vulnerability focuses on exposure, sensitivity and adaptive capacity pre-shock, resilience focuses on the dynamics of social systems to respond and recover post-shock. There are many definitions that explain the concept of resilience, with two distinctive characteristics standing out: (1) the capacity to withstand a shock and (2) the capacity to bounce back after a shock (Tesso et al., 2012). The first characteristic implies essentially an absence of vulnerability. The second is the ability of individuals to recover to their original or an improved level of well-being after the experience of a shock.

A number of studies have been conducted to determine household level and regional level vulnerability in India. To our knowledge, there was no study focusing on inter-relation of both vulnerability and the resilience of farmers to dry spells and droughts in India. Although farm households are exposed to similar drought conditions, the sensitivity to the impacts of drought, their vulnerability and their resilience and adaptive capacity vary considerably. The present study tries to determine and analyze resource factors that differentiate farm households in terms of both their vulnerability to drought events and their capacity to adjust and transform to changing climate. Analyzing such relationships between vulnerability and resilience at household level is a crucial aspect that informs development actors, policy planners and governments, to derive effective mitigation plans and preparedness measures to reduce drought impacts.

Evidence

Understanding the drought impacts and resilience levels of the farm households is important for devising robust policy to derive effective resilience enhancing strategies targeting vulnerable households. Drought which is one of the common impact of climatic change, in simple word can be describe as scarcity of rainfall which leads to scarcity of water access both for agriculture and human need (there are three widely accepted drought classification documented; mild drought, moderate drought and severe drought as per the deviation of current rainfall from normal rainfall in a specific cropping year). Drought is a complex, slow processes of ecological challenge that affects people than any other natural hazard by causing serious economic, social and environmental losses in both developing and developed countries (Sonawane, 2016). The occurrence of drought directly affects production, lives, health, livelihoods, assets and infrastructure causing food insecurity and poverty. However, the indirect effects of drought on environmental degradation and reduced household welfare through its impact on crop and livestock prices could be larger than its direct effects (Zimmerman and Carter, 2003; Holden and Shiferaw, 2004). The semi-arid tropics (SAT) in India which are constrained due to poor soil fertility, rainfall variability, water scarcity, and poor development in rural infrastructure, institutions and markets is likely face an additional burden due to increased frequency of droughts because to climate change (Shiferaw and Bantilan, 2004). , The impacts of drought at households' level can be both ex-post and ex-ante

(Hansen et.al. 2012). Ex-post impacts refer to the losses that follow a climate shock while the opportunity costs associated with conservative strategies that risk-averse decision makers employ in advance to protect themselves against the possibility of climate shocks can be describe as ex ante impacts of drought. Study by Udmale et, al. 2015, on impacts of 2012 drought in Maharashtra state of India and found that it impacted domestic water supply, caused about 86% reduction in production of major crops. In addition crop failure subsequently affected livestock rearing and rural employment activities, resulting in high reductions in on-farm unskilled employment opportunities and an increase in unskilled labor in off-farm rural employment activities.

Resilience to climate change specially drought shocks is not homogeneous and varies from region to region and household to household. Crop failure is one of the direct impacts of drought. Many earlier studies documented adaptation and resilience to drought impacts at macro as well as micro level. Greater diversity in crops through intercropping and mixed cropping can reduce the risk of crop failure in the fragile SAT region (Jodha, 1980). Study by Sahu & Mishra, 2013, in Odisha, India, identifies climate change effects on rural agricultural dependent households have direct impact on the total income. Various studies have found that the adaptation to drought related adverse climatic constraints could be greatly enhanced through improved access to irrigation, credit, adapted production practices as well as effective agricultural extension programs and non-farm activities at the local level. (Hansen et al., 2012; World Bank, 2005b; Pandey and Bhandari, 2009). Several studies (Turvey et.al, 1988; Turvey, 1991; Veljanoska, 2014; Khanal & Mishra, 2017) found that choice of crop portfolio can have direct link to reduce the risk of crop failure and considered as one of the important resilience strategy to tackle the adverse consequences of drought on the households.

Data

Study location:

This study uses micro-level data surveys for 2006–2014 collected from rural farm households in semi-arid tropical regions of India by the International Crops Research Institute for the Semi-arid Tropic (ICRISAT) under the Village Dynamics Studies in South Asia (VDSA) program. It collects information on different socio-economic variables including farm inputs and outputs, price, markets, climate and farm households' characteristics in typical villages across India (for details data collection procedure follow Walker and Ryan, 1990 & Rao et.al,. 2009). The region's comparatively limited potential for agricultural growth and rapidly rising human population makes it complex for an agricultural-based strategy of rural development. The rainfall exceeds potential evaporation for 4 to 6 months of the year and mean annual rainfall in the SAT ranges from about 400 to 1,200 mm which leads to an unstable production environment. In the present study we considered six VDSA traditional villages located in three different regions namely Aurepalle and Dokur villages in Mahbubnagar region, Kanzara and Kinkhed villages in Akola region and Kalman and Shirapur villages in Solapur region. Availability of such high frequency household panel data provides the best platform to draw insights on the relationship between climate shocks and household-level variables. All the three regions selected for this study considerably vary in terms of their agricultural, socio-economic and environmental conditions.

The study households are from six different villages from three different agro-climatic regions. We have considered only those households for the study which were present during the entire study periods of 2006-2014. Total 256 households were selected from three study locations; 62 households from Mahbubnagar villages, 76 from Akola villages and 118 from Solapur villages. The selected households represent different class, caste, farm groups and socio-economic characteristics.

Rainfall distribution and identification of drought years:

We classify the study years as per Indian Meteorological Department's definition of a drought year: a normal year is when the seasonal rainfall is 75% or more of its long term average, moderate drought is when the rainfall deficit is between 26-50% of the long term average rainfall and severe drought is when the deficit exceeds 50% of the long term average rainfall for that particular year. Historically, households who were exposed to a number of climatic shocks especially droughts could have developed a better adaptive capacity. To study if this presumption holds true, we considered rainfall distribution data for the past 24 years beginning 1990 to 2013, and mapped the frequency of drought occurrences in each of the study villages (Table 1). The rainfall observations for a village were taken from the nearest weather station located at mandal (sub-districts) level. Deverkandra and Madgul mandals that belong to Mahbubnagar district have the highest frequency of droughts as compared to the Akola and Solapur regions. The drought occurrence was highest in Madgul mandal (about 60 percent time out of which 43 percent time moderate drought and 17 percent time severe drought) followed by Madgul, Mohol and North Solapur mandal. Occurrences of drought in Akola and Solapur regions mandals are quite low compared to Mahbubnagar region mandal and its varies from only about 4% to 30% percent times of the entire 24 years period. It is to be mentioned that Murtizapur mandal have not experience any severe drought occurrence in the considering time periods.

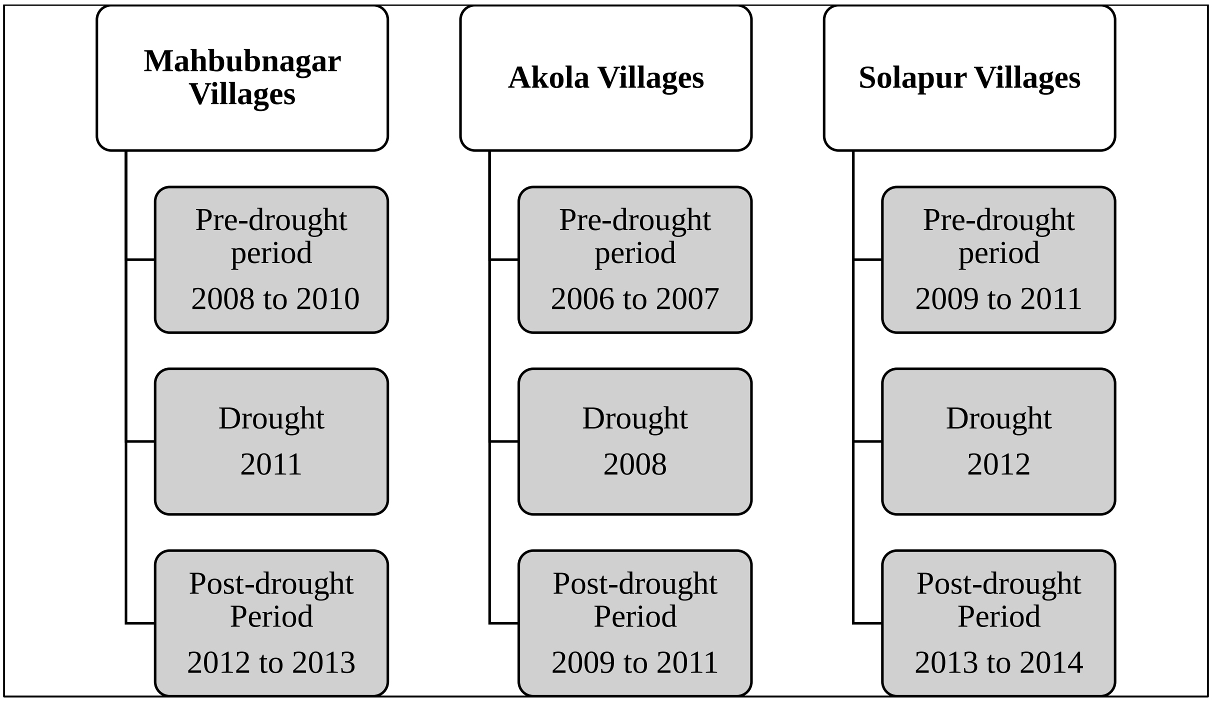
Table 1: Drought frequency distribution across study mandals during year 1990 to 2013

Region	Mandal	Corresponding study Village	Normal Rainfall	Moderate Drought	Severe Drought	Rainfall Variability (CV %)
Mahbubnagar Region	Deverkandra	Dokur	56.52	39.13	4.35	28
	Madgul	Aurepalle	39.13	43.48	17.39	33
Akola Region	Murtizapur	Kanzara & Kinkhed	95.83	4.17	0.00	24
Solapur Region	Mohol	Shirapur	70.83	16.67	12.50	35
	North Solapur	Kalman	79.17	16.67	4.17	30

Source: Collected from respective mandal office

As the central focus of this paper is to understand household resilience as a concept that encompasses both the capacity to withstand a shock and the capacity to rebound to pre-shock position or higher, we consider both the socio-economic and biophysical indicators namely crop income and crop productivity for 3 years pre-drought and post-drought with the drought year as a reference to estimate the level of households resilience. The following table summarizes the drought years identified in each of the study regions and also indicates the pre and post drought years we consider for our analysis

Figure 1: Identifying drought, pre-drought and post drought years in different study locations



Source: ICRISAT VLS-VDSA database

Methodology

1. Assessing and Categorizing Resilience: An integrated approach

Studies such as Mishra et. al., 2015; Biswas 2017, have measured the impacts of drought on farm households either considering change in crop income or change in crop productivity. However the crop income or productivity alone may not be able to capture the impact of drought realistically. The higher market prices of agricultural commodities in case of constrained supplies due to drought might envelop its impact on income even if the crop productivity has been impacted significantly. In our dataset also, we have observed such phenomena. Hence we have considered both per hectare crop income as well as crop productivity to measure the impact of drought on the farm households. The drought impact on crop production for a household will depend not only its impact on absolute productivity levels but also on the cropped area of a particular crop. Hence we have used a more robust method constructing the composite crop productivity index (CCPI) for each household and comparing its magnitude across households and periods.

Crop productivity of any household may be seen as the overall capacity of its farming system. It is the manifestation of complex inter-play of various factors of the farm environment. Physical factors (such as climate, soil, etc.) and human-induced factors (viz. level of farm mechanization and use of various inputs like skill and knowledge of the farmers, institutional assistance, etc.), as well as market factors like demand and crop selection, together constitute the farm environment of any region (Biswas 2017). Every crop has a different yield rate and shares different amounts of cropland and therefore makes a definite contribution to overall productivity of any region. It is difficult to compare different crop productivity with their absolute values due to high variation in their physical quantity, i.e. we cannot compare the productivity of any pulse crop with sugarcane productivity. Hence we have considered a more robust and comparable Composite Crop Productivity Index (CCPI) using the method by Biswas, 2017. The CCPI considered both the absolute yield and area under the particular crop. In order to measure crop productivity, an index of hectare yield (kg/ha) of various crops grown in the sub-area unit has been pre-meditated by dividing the hectare-yield of various crops by maximum hectare-yield of the respective crops in the entire region. This simple ratio provides the index of yield achievement of each crop in the sub-area units. In this method, the highest hectare-yield of a crop throughout all the sub-area units of the region has been considered as the maximum achievable yield limit of each crop. Thus, the ratio of actual hectare-yield of each crop to its maximum hectare-yield reflects the yield achievement (efficiency) level with respect to the highest hectare-yield of each crop in the region. This may be expressed as;

$$I_{Y\,av.a} = {}^{Y_a}/_{Y_{a.max}} \qquad \text{(i)}$$

Where, $I_{Y\,av.a}$ is the yield achievement index of crop *a* for the household, Y_a the hectare-yield of crop *a* for the household and $Y_{a.max}$ is the highest hectare yield of crop *a* in the selected village. As a result the maximum value of yield achievement index ($I_{Y\,av}$) would range between 0 and 1.

Further in order to capture the relative area of a particular crop into the index, the weighted yield indices of various crops were constructed by multiplying the yield achievement index with the ratio of cropland under a particular crop to the total cropped area for the household. Cross-section area (a simple ratio of crop-land under specific crop to total cropland) was used to give weightage. Then all the weighted yield achievement indices were added to obtain the composite crop productivity index (CCPI) for a household. Thus, the weighted yield achievement index indicates the contribution of various crops to CCPI. This is expressed as

$$I_{WY\,av.a} = I_{Y\,av.a} \times \frac{C_a}{C} \qquad \text{(ii)}$$

Where $I_{WY\,av.a}$ is the weighted yield achievement index (WYAI) of crop *a* for the household, $I_{Y\,av.a}$ the yield achievement index of crop *a*, C_a is the area under crop *a*, and *C* is the total cropland under all the selected crops for the household. Theoretically if weighted yield achievement index is more than 0.50 considered as very high and if the value is less than 0.05 is considered very low and values in-between considered moderate to high. Therefore the composite Crop Productivity Index (CCPI) define as;

$$CCPI = \sum_{i=1}^{n} WYAI_i \quad \text{, where i indicate crop 1 to crop n} \qquad \text{(iii)}$$

CCPI is used to categories the sample household to find out the degree of impact and level of resilience due to drought and after drought shock.

Vulnerable Households: As we noted above, drought or any climatic shock impacts farm households both in terms of their crop productivity and subsequently their income. To understand if the households are vulnerable to such climatic shocks we compare average per-hectare crop income and Composite Crop Productivity Index (CCPI) of pre-drought years with reference to drought year estimates to evaluate the impacts of such climatic shocks on farm households. Households could be identified as vulnerable if deviation of income and crop-productivity values of pre-drought year from that of drought year were positive, and not impacted when the deviation was negative. We further divide the sample households in terms of the level of vulnerability they face in case of a climatic shock in to three groups.

1. Not Impacted
2. Moderately Impacted
3. Highly Impacted

The impacted households whose deviation values are less than the median are classified into moderately impacted households group and the remaining are classified as highly impacted households group.

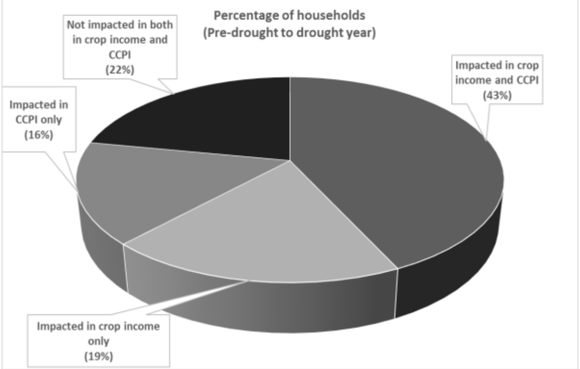
Resilient Households: We define resilience as the ability to bounce back from the after-effects of a climatic shock to bounce back to their pre-shock levels of livelihoods. Following similar quantitative approach used above to measure and classify level of vulnerability, we measure the level of resilience to bounce back from the climatic shock in the sample households using the average value of per hectare crop income and CCPI. Resilient households were those whose deviation of crop income and CCPI in post-drought period was significantly positive in reference to the drought year. The households are also categorized based on the magnitude of their bounce back post-shock into moderately resilient and highly resilient groups. Therefore we have the following three groups of households categorized in terms of their magnitude of resilience:

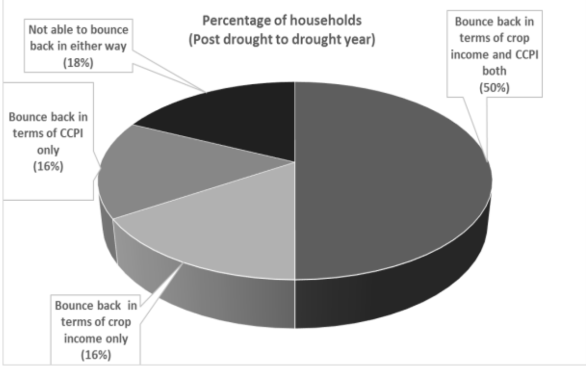
1. Not resilient
2. Moderately resilient
3. Highly resilient

The households whose positive deviation values are less than the median are classified as moderately resilient households and the remaining as highly resilient households.

Vulnerability and Resilience matrix: The level of vulnerability and the magnitude of resilience varied across the sample households. We constructed a matrix with the categorized groups of vulnerable and resilient households to evaluate each household's vulnerability and resilience level (Fig 2). We noticed that more than 43% households were impacted in terms of both the crop income and crop productivity, 16% were impacted only in terms of their crop productivity and 19% in terms of their crop income. About 22% of the sample households were able to withstand the shock in terms of both the indicators. Fifty percent of the households were resilient in terms of bouncing back from the drought-shock in respect of both the crop income and crop productivity, while 18% of the households not able to bounce back.

Figure 2:Vulnerability and Resilience matrices in terms of crop income and CCPI





Source: ICRISAT VLS-VDSA database

Therefore to evaluate the households' vulnerability and resilience to drought, only crop income or crop productivity alone does not reflect the total effects of a climatic shock. In order to integrate both the variables we used principal component analysis to construct a composite vulnerability and resilience index.

The index values were divided in three quintiles both for drought impacts and bouncing back situation. For impact situation the three quintile described as not impacted, moderately impacted and highly impacted as per the composite index value. Similarly for post-drought period the three groups of households were classified as not able to bounce back, moderately bounce back and highly bounce back. Further the households were again grouped into four categories combining both pre-drought and post drought situations. Households considered in the first category who were not impacted, second category describes as impacted but not able to bounce back, third category as moderately impacted and moderately bounce back and lastly the fourth category is described as highly impacted and highly bounce back.

Region wise distribution of sample households in terms of four composite categories:

In all 66% of the households were impacted due to drought and among them 52 percent households were able to bounce back to their previous or near to previous conditions (Table 2). In Mahbubnagar region highest number of households (44%) fall in the category of highly impacted and highly bounce back followed by Solapur and Akola. The share of households impacted but not able to bounce back was highest in Solapur (17%) followed by Akola (13%) and Mahbubnagar (8%) region . About one third of the households might have better adaptation mechanism and were not impacted due to drought.

Table 2: Region wise percentage distribution of different categories of households

Household categories	**Mahbubnagar**	**Akola**	**Solapur**	**overall**
Not impacted	29	30	38	34
Impacted but not bounce back	8	13	17	14
Moderately impacted and moderately bounce back	19	34	17	22
Highly impacted and highly bounce back	44	22	28	30

Source: ICRISAT VLS-VDSA database

2. Econometric methods

We performed a multinomial logistic regression to determine the factors responsible for the households' level of vulnerability and resilience. We use the composite vulnerability and resilience matrix approach to categorize the sample households into the following groups, which become our dependent variable.

1. Vulnerable and not resilient
2. Moderately vulnerable and moderately resilient
3. Highly vulnerable and highly resilient

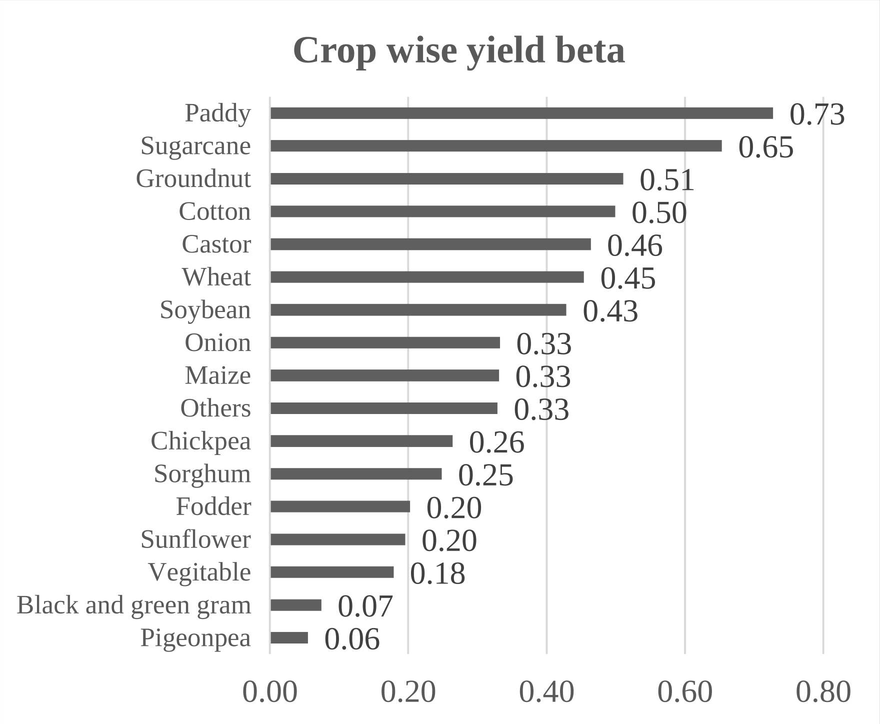
Family size, including availability of family labour, operated total area, ratio of irrigated to operated area, proportion of cash crops in the total cropped area, cropping intensity, income from livestock and off-farm sources, and crop diversity index are used as explanatory variables to understand what helps households to withstand a shock and be resilient. We also consider the risk profile of individual household in terms of their crop portfolio as indicated by the crop yield beta to evaluate if it contributes to households resilience.

Estimating crop yield-beta: Many earlier studies (such as Turvey, 1991; Bezabih & Falco, 2012; Veljanoska, 2014) estimated crop-portfolio in terms of crop beta either based on crop revenue or crop area using single index model. Study by Turvey (1991) had measured individual crop risk and portfolio risk using the Single Index Model. Many other studies have measured risk of rainfall variability or household's food security by estimating beta for crops and households crop portfolio in different locations (Bezabih & Falco, 2012; Veljanoska, 2014; Khanal & Mishra, 2017). In the present estimation we also use the Single Index Model as describe by Turvey (1991). Here the individual crop weighted yield achievement index (WYAI) have been regress on composite crop productivity index (CCPI) for the year 2006 to 2014 and the coefficient of beta of each crop considered in the model indicated specific crop's riskiness. Higher the beta value higher the riskiness of the particular crop in terms of climatic shock specifically drought. The regression equation is of the form as mentioned here;

$WYAI_i = \alpha + \beta(CCPI) + e_i$, i= crop 1 to crop n (iv)

The value of 'β (beta)' represents individual crop's riskiness in terms of yield, higher the value of beta represents higher climatic riskiness. In a multi cropping portfolio, the riskiness of a households is calculated using the average of yield beta of all crops cultivated in a particular year. Among all the major crops cultivated in the study regions paddy (β=0.73) was found most riskiest crops in terms of yield, followed by sugarcane (β=0.65), groundnut (β=0.51), cotton (β=0.50), castor (β=0.46), wheat (β=0.45), soybean (β=0.43), onion (β=0.33) etc., and pigeonpea (β=0.06) was the least risky crop in terms of impacts on crop yield due to drought (Figure 3).

Figure 3: Distribution of crop yield beta of major cultivated crops



Source: Estimated based on ICRISAT VLS-VDSA database

A tobit regression approach has been applied to estimate the determinants of yield beta at the household level (Table 3). The regression coefficients of selected variables show that, household specific factors such as dependency ratio, years of education of head, head's age, access to irrigation, cropping intensity, crop diversity and greater options for off-farm income have negative impact on a household's average crop yield-beta portfolio. However the yield-beta for the moderately impacted households was lower than that of not impacted households. Access to credit played a major role in households' ability to choose more risky crop portfolios in terms of yield.

Table 3: The determinants of yield beta – A Tobit regression analysis

Variables	Coefficients
Family size	-0.00129
Dependency ratio	-0.02187[S]
Head years of education	-0.00684 [S]
Head age	-0.00228 [S]
Operate area (Ha)	0.00100
Irrigated to operated area	-0.06418 [S]
Cropping intensity	-0.06691 [S]
Crop diversity index	-0.35126 [S]
Log borrowing	0.01416 [S]
Off-farm income to total income ratio	-0.10227 [S]
Livestock income to total income ratio	0.00403
Pre-drought year dummy (Drought year is reference)	0.03356 [S]

Post-drought year dummy (Drought year is reference)	0.01796
Impacted but not bounce back (reference=not impacted)	0.00553
Moderately impacted and moderately bounce back (reference=not impacted)	-0.02818 S
Highly impacted and highly bounce back (reference=not impacted)	0.04090 S
Constant	0.58393 S

Note: S indicates coefficients are statistically significant

Source: ICRISAT VLS-VDSA database

Results:

Intra-category and inter-period comparison of some basic characteristics:

The intra household category and inter time periods comparisons of some important socioeconomic variables which are relevant in terms of drought impacts are presented in Table 4. Land holding among not impacted and impacted but not able to bounce back category households are little higher than that of other two categories in all the three study periods. The cropping intensity during the drought year for all four categories of households was less than 100% which means their gross cropped area was lower than that of net operated area. It indicates the direct impact of drought on households' crop cultivation due to limited option of irrigation facility in the study regions (SAT region). The adoption of cash crop appeared to be an driver for drought impacts as well as farmers ability to quickly bounce back to their earlier status. Households who were impacted but not able to bounce back have less options for irrigation, less operated area in post-drought period mainly due to due to less leased-in area and low cropping intensity in the post drought .

Table 4: Category wise some basic characteristics of the sample households

Category of households	Particulars	Pre-drought years	Drought year	Post-drought years
Not impacted	Average operated area (Ha)	3.26	3.38	3.17
	Irrigated area to operated area (%)	47.99	43.86	36.48
	Leased in area to operated area (%)	13.79	15.20	14.88
	Gross crop area (Ha)	3.18	2.99	3.45
	Cropping intensity (%)	107	0.95	1.19
	Cash crop area to total crop area (%)	55.42	48.18	54.58
	Crop diversity index	0.45	0.42	0.45
Impacted but not bounce back	Average operated area (Ha)	3.66	3.55	3.48
	Irrigated area to operated area (%)	37.35	31.55	30.38
	Leased in area to operated area (%)	9.51	10.10	8.78
	Gross crop area (Ha)	4.28	3.45	3.56
	Cropping intensity (%)	119	0.97	1.06
	Cash crop area to total crop area (%)	45.15	43.81	49.77
	Crop diversity index	0.52	0.42	0.47
Moderately impacted and moderately bounce back	Average operated area (Ha)	2.83	3.07	3.09
	Irrigated area to operated area (%)	43.91	38.07	40.38
	Leased in area to operated area (%)	8.98	15.37	17.69

	Gross crop area (Ha)	3.59	3.05	3.32
	Cropping intensity (%)	127	0.97	1.12
	Cash crop area to total crop area (%)	45.58	43.86	56.48
	Crop diversity index	0.47	0.40	0.47
Highly impacted and highly bounce back	Average operated area (Ha)	2.69	2.58	2.36
	Irrigated area to operated area (%)	51.16	45.17	42.30
	Leased in area to operated area (%)	11.91	11.27	10.85
	Gross crop area (Ha)	2.78	2.12	2.54
	Cropping intensity (%)	120	0.92	1.18
	Cash crop area to total crop area (%)	56.74	38.39	67.88
	Crop diversity index	0.41	0.31	0.38

Source: ICRISAT VLS-VDSA database

Impacts on area and yield due to drought:

The impacts of drought in terms of area cultivated and yields among major cultivated crops in the study area is presented in Table 5. Drought impacts on four pre-defined household categories in terms of area cultivated and crop yields have been measureds in terms of weighted yield achievement index (WYAI) in the stipulated periods. we considered three different scenarios as defined here: scenario-1 indicates the impacts of droughts indicating proportion of pre-drought to drought year, scenaruio-2 indicate level of bounce back (Proportion of post-drought to drought year) and scenario-3 defines whether a household is able to regain their previous pre-drought status. Among the two extreme categories- 'not impacted' and 'highly impacted and highly bounce back' it was found that in terms of overall area cultivated among major crops was higher in both pre-drought and post-drought year compared to drought year for the first category, but drought impacted in terms of yields achievements . The 'not impacted' category of households were better off in post-drought year than that of pre-drought year in respects to both area cultivated and yield achievements (proportion was 1.42 for area and 1.29 for WYAI). Highly impacted and highly resilient households were more impacted in terms of area (6.45) compared to yield achievements (5.49); their level of bouncing back from drought shock was higher compared to other three categories. These households were not able to reach to their previous pre-drought status in terms of area but able to gain in terms of overall yield achievements. Also it is to be mentioned that on an average wheat was the most impacted crops due to drought in respect to area cultivated and yield achievement compared to other major cultivated crops.

Table 5: Proportion of cultivated area and weighted yield achievement index (WYAI) of major crops under three different scenarios

Crop, area and WYAI		Not impacted (1)			Impacted but not bounce back (2)			Moderately impacted and moderately bounce back (3)			Highly impacted and highly bounce back (4)		
		Scenario			Scenario			Scenario			Scenario		
		1	2	3	1	2	3	1	2	3	1	2	3
Cotton	Area	1.65	0.97	0.58	2.99	1.79	0.60	1.85	1.26	0.68	1.25	1.23	0.98
	WYAI	0.58	0.85	1.47	0.78	0.91	0.97	0.94	1.26	1.34	0.88	1.85	2.10
Groundnut	Area	0.73	1.45	1.97	1.87	0.91	0.49	1.04	1.03	0.98	16.83	7.75	0.46

	WYAI	0.21	0.44	2.05	0.51	0.13	0.25	0.83	0.59	0.71	29.21	13.46	0.46
Paddy	Area	0.75	0.87	1.15	1.01	0.51	0.51	0.80	0.99	1.24	1.52	1.01	0.67
	WYAI	0.77	0.85	1.09	0.98	1.28	1.31	0.93	0.84	0.90	1.87	2.33	1.25
Sorghum	Area	1.06	0.83	0.78	1.01	1.18	1.16	1.28	1.17	0.91	1.12	0.58	0.52
	WYAI	0.56	0.57	1.02	0.85	0.48	0.56	0.78	0.65	0.83	1.08	0.80	0.74
Soybean	Area	0.44	1.34	3.06	0.50	0.94	1.90	0.38	0.89	2.36	0.48	0.81	1.70
	WYAI	0.56	0.84	1.50	0.57	0.66	1.16	0.69	1.01	1.46	0.51	1.24	2.43
Sugarcane	Area	0.85	1.22	1.44	0.90	0.78	0.86	0.88	1.29	1.47	1.24	1.80	1.46
	WYAI	1.12	1.09	0.97	1.36	0.80	0.59	1.42	0.96	0.67	2.80	2.73	0.98
Wheat	Area	18.82	17.34	0.92	14.49	5.38	0.37	28.68	11.51	0.40	22.75	12.22	0.54
	WYAI	1.42	1.74	0.97	3.78	2.57	0.68	3.08	1.73	0.56	2.10	2.69	1.28
Overall	Area	3.47	3.43	1.42	3.25	1.64	0.84	4.99	2.59	1.15	6.45	3.63	0.90
	WYAI	0.75	0.91	1.29	1.26	0.98	0.79	1.24	1.00	0.93	5.49	3.58	1.32

Note: *Scenario-1 = Proportion of pre-drought to drought year; Scenario-2 = Proportion of post-drought to drought year; and Scenario-3 = Proportion of post-drought to pre-drought year*

Source: Estimated based ICRISAT VLS-VDSA database

Drought impacts on household Income:

The income of ‘impacted but not bounce back’ households was highest in all the three time periods Rs. 267166, Rs. 254620 and Rs. 194726 in the pre-drought, drought and post-drought period respectively Table 6). The household income was lowest among highly impacted and highly bounce back category. The crop income of highly impacted and highly bounce back households in drought year was about half (Rs. 28712) as compared to pre-drought year crop income (Rs. 57166) but overall income reduce only about 8% due to increase in off-farm income during drought year. These households were able to quickly bounce back in the post-drought year due to significant increase (about 2.2 times) in crop income. Thus the crop income which is highly impacted due to drought shock could work as an important driver of resilience.

Table 6: Category wise household income from different sources (in Rs.)

Year	Income category	Not impacted	Impacted but not bounce back	Moderately impacted and moderately bounce back	Highly impacted and highly bounce back
Pre-drought year	Crop income	50877 (32.13)	147920 (55.37)	74290 (44.72)	57166 (36)
	Livestock income	27968 (17.66)	36756 (13.76)	26968 (16.23)	31388 (19.77)
	Off-farm income	79482 (50.2)	82490 (30.88)	64870 (39.05)	70221 (44.23)
	Total income	158327 (100)	267166 (100)	166128 (100)	158774 (100)
Drought year	Crop income	83347 (43.37)	114270 (44.88)	50713 (32.29)	28712 (19.54)
	Livestock income	25375 (13.2)	36557 (14.36)	28438 (18.11)	29824 (20.3)
	Off-farm income	83444 (43.42)	103793 (40.76)	77897 (49.6)	88385 (60.16)
	Total income	192165 (100)	254620 (100)	157049 (100)	146921 (100)
Post-drought year	Crop income	66005 (41.01)	80421 (41.3)	67428 (42.1)	63580 (40.1)
	Livestock income	22775 (14.15)	36114 (18.55)	28380 (17.72)	27148 (17.12)
	Off-farm income	72179 (44.84)	78190 (40.15)	64340 (40.18)	67810 (42.77)

	Total income	160959 (100)	194726 (100)	160148 (100)	158537 (100)

Note: Values in the parenthesis indicating percentage to total income
Source: ICRISAT VLS-VDSA database

Determinants of drought impacts and resilience of farm households:

There are multiple factors responsible for a households to be in either of the pre-defined categories in relation to drought impact. The present study apply multinomial logistic regression method to describe the role of different important factors in a household's behavior during and after harsh climatic shock-drought (Table 7). Instead of actual regression coefficients we considered the marginal values (dy/dx) in the present analysis to interpret the results in simpler way. Pre and post drought situation of the selected indicators were taken as explanatory variables and we tried to find out their roles resulting a farm households as 'impacted but not bounce back', 'moderately impacted and moderately bounce back' or 'highly impacted and highly bounce back'. Proportion of cash crop area, percentage crop diversity index and square of percentage of crop yield beta in post-drought period and proportion of off-farm and livestock income of pre-drought period indicate a households significantly less likely to be in the category of 'impacted but not bounce back' and more likely to be in the same category due to the factors as ' crop diversity ', ' off-farm and livestock income and ' crop yield beta in the post-drought period. The households less likely to be in the group of 'moderately impacted and moderately bounce back' due to the factors like total operated area, ' crop diversity of pre-drought time and crop diversity, crop yield beta in post-drought period, whereas operated area, crop diversity, crop yield beta in post-drought years have significant positive role likely to keep the households in this category. The 'highly impacted and highly bounce back' group of households have been more likely to be in the same category as a results of total operated area, off-farm and livestock income in pre-drought year and cash crop area, cropping intensity of post-drought periods and less likely to be here due to post-drought operated area and post-drought off-farm and livestock income.

Table 7: Determinants of drought impacts and resilience of farm households– a multinomial logistic regression analysis

Variables		Impacted but not bounce back	Moderately impacted and moderately bounce back	Highly impacted and highly bounce back
Family Size	Average	0.01395	-0.01229	-0.00166
Total operated area (ha)	Pre-drought	-0.00136	-0.06887 ^{S}	0.07023 ^{S}
	Post-drought	0.01111	0.08680 ^{S}	-0.09791 ^{S}
Ratio of irrigated area to total area	Pre-drought	-0.20565	-0.00188	0.20753
	Post-drought	0.13047	-0.12825	-0.00222
Ratio of cash crop to total crop area	Pre-drought	-0.13520	0.05029	0.08491
	Post-drought	-0.23881 ^{S}	-0.13899	0.37780 ^{S}

Cropping intensity	Pre-drought	-0.02877	-0.03482	0.06359
	Post-drought	-0.12990	-0.05047	0.18037 S
Crop diversity index in percentage	Pre-drought	0.00722	-0.01017 S	0.00295
	Post-drought	-0.01155 S	0.01724 S	-0.00569
Square of percentage of crop diversity index	Pre-drought	-0.00005	0.00011	-0.00006
	Post-drought	0.00012 S	-0.00020 S	0.00008
Ratio of off-farm income to total income	Pre-drought	-0.61992 S	0.20651	0.41340 S
	Post-drought	0.52647 S	-0.14901	-0.37747 S
Ratio of livestock income to total income	Pre-drought	-0.79754 S	-0.03333	0.83087 S
	Post-drought	0.67056 S	0.06564	-0.73621 S
Crop yield beta in percentage	Pre-drought	-0.00322	-0.00290	0.00612
	Post-drought	0.01082 S	-0.01664 S	0.00582
Square of percentage crop yield beta	Pre-drought	0.00008	-0.00003	-0.00005
	Post-drought	-0.00018 S	0.00023 S	-0.00006

Note: S indicates coefficients are statistically significant

Source: ICRISAT VLS-VDSA database

Discussion and Conclusions:

The study try to understand and document the impacts of drought on the farm households in semi-arid tropics villages of India and hypothesized based on the argument that drought does not impact all the households homogeneously. Therefore here we have divided the sample households in four categories based on their impacts in respect to crop income and composite crop productivity (CCPI). The analysis found that the direction of drought impacts on crop income and CCPI always not in the same direction and therefore the households were grouped combining both the impacts on crop income and crop productivity. As per crop yield beta which is considered an indicator of crop riskiness due to drought was found that paddy is the most risky crop followed by sugarcane, groundnut cotton etc. in respect to impact on crop yield due to drought in the study regions. In terms of impacts on area and crop yield achievement index it was found that among the major cultivated crops the impacts of drought on average cultivated area was higher compare to that of average yield achievement index and wheat crop was the most impacted crops both in area and yield achievements due to drought. The regression analysis found that the household groups who were highly impacted and highly bounce back are more likely to be in the same category as a results of total operated area, off-farm and livestock income in pre-drought year and cash crop area, cropping intensity of post-drought periods and less likely to be due to post-drought operated area and post-drought proportion of off-farm and livestock income. Also it was found that household cropping intensity and more focus on food crops cultivation are some important factors for increased resilience level of a households due to climatic shock like drought in the region. Therefore the study conclude that impacts of climatic shock like drought does not impact rural households in same manner and also the resilience capacity of the households is not homogeneous. Hence there is need to consider this heterogeneity to devise robust policy to derive effective resilience enhancing strategies targeting vulnerable households.

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