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Assessing the Impact of Climate Resilient Technologies in Minimizing Drought Impacts on Farm Incomes in Drylands

Josily Samuel *, Chitiprolu Anantha Rama Rao, Bellapukonda Murali Krishna Raju, Anugu Amarender Reddy, Pushpanjali , Ardha Gopala Krishna Reddy, Ramaraju Nagarjuna Kumar, Mohammed Osman , Vinod Kumar Singh and Jasti Venkata Naga Satya Prasad

ICAR—Central Research Institute for Dryland Agriculture (CRIDA), Hyderabad 500059, India; Car.Rao@icar.gov.in (C.A.R.R.); bmk.raju@icar.gov.in (B.M.K.R.); amarender.reddy@icar.gov.in (A.A.R.); anjali.scientist@gmail.com (P.); agkrishna27@gmail.com (A.G.K.R.); rn.kumar@icar.gov.in (R.N.K.); Md.Osman@icar.gov.in (M.O.); director.crida@icar.gov.in (V.K.S.); vn.jasti@icar.gov.in (J.V.N.S.P.)
* Correspondence: josilysamuel@gmail.com

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Abstract: Asia is the region most vulnerable to climate change and India is ranked as one of the most climate vulnerable countries in the world, frequently affected by natural disasters. In this study, we investigated the impact of drought on crop productivity, farmer's employment and income. The difference-in-difference model (DID) and stepwise multiple linear regression (MLR) were employed to quantify the impact of adopting climate resilient technologies (CRTs) on farm household income during a drought. The factors influencing farm incomes were analyzed using MLR. The study used survey data collected from the drought prone district of Telangana, India. Sixty farmers each from a village adopted under the National Innovations in Climate Resilient Agriculture (NICRA) program and a control village were interviewed. Primary data on the socio-economic characteristic of farmers, cropping pattern, income composition, productivity of major crops, employment and climate resilient interventions adopted by farmers were collected using a well-structured schedule. The results reveal that income crop cultivation was the major contributor to household income (60%) followed by livestock rearing. Farmers reported that droughts decreased the income from crops by 54 per cent and income from livestock rearing by 40 per cent. The farmers belonging to the climate resilient village had 35 per cent higher incomes compared to those in the control village and it was estimated to be Rs. 31,877/farm household/year during droughts using the DID estimate. Farm size, livestock possession, adoption of CRTs and investment in agriculture were the determining factors influencing farm income. Thus, farmers especially in drought prone regions need to be encouraged and supported to adopt cost effective, location specific climate resilient technologies.

Keywords: drought; farm income; climate resilient technologies; difference-in-difference estimate

1. Introduction

Dryland agriculture is a complex and vulnerable system with components of crops (grains), vegetables, livestock and horticultural trees. They are affected by persistent water scarcity, high climatic variability and frequent droughts. India is one of the most drought prone countries in the world and about 53% of the country's geographical area is arid and semi-arid. The drylands of semi-arid areas of central India are more drought prone compared to the other parts. The country's 45 percent of agriculture production comes from these drylands, wherein droughts have been causing a devasting loss. It was reported that about 330 million people were affected by drought during 2015–2016 [1–4]. India's agriculture system is dependent on the south–west monsoon with 68% of India's cropped area receiving rainfall between 750–2000 mm per annum. The productivity of crops grown here is heavily dependent on the climate and monsoon rainfall. Over the years, the irregularities in the monsoon such as late onset, prolonged breaks with short and intense rainfall spells and early withdrawal has made the drylands more vulnerable to droughts. The frequency and intensity of droughts are also increasing [5–12], posing challenges to the productivity of drylands of India. Studies irrespective of methodology indicate an increasing trend in severity and frequency of drought in the coming decades [11,13,14]. The Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) reports that extreme climate events such as drought are high risk and that they will have increasing impacts on livelihoods and poverty, exacerbating rural poverty in parts of Asia [15].

Droughts are the major constraint for crop productivity, particularly as India has shown higher yield reductions. Though impacts are evident in many ways, decline in crop productivity is prominent with more households reporting it. Studies also report declining farm incomes and increasing debt and unemployment [6,7,16–20]. The changes in climate and weather affect the natural resources, causing negative impacts on livelihoods [21–23]. Droughts and changes in seasonal rainfall patterns make agriculture less sustainable. In India, the estimated loss in agriculture by 2030 would be more than US$7 billion, and the annual losses from droughts are reported to increase, but this loss could be reduced by 80% if climate resilient technologies and adaptation measures were implemented [24,25].

Climate risk is usually manifested in drylands as an incidence of droughts and high-intra season variability in rainfall. A dryland farm household must manage different types of risks which affect the productivity of crops they grow and incomes, leading to food insecurity. Studies reveal that farmers' perceived production risk due to drought is the most important risk they frequently faced [12,26–28]. Managing the risk and enhancing productivity through the adoption of resilient technologies and sustainable intensification is critical for securing income and improving the livelihoods of these vulnerable regions. The climate resilient agriculture (CRA) practices will address risk and how droughts can be effectively addressed by building the resilience of the agroecosystem as a whole through climate resilient agriculture. In India, there have been changes in the developmental policies to make the capacity of systems to manage climate risks more mainstream.

To address the effects of extreme weather events such as drought and to have sustainable adaptation strategies at farm level and demonstrate the same, the government of India (GoI) took up the concept of a climate resilient village (CRV) through the network program of the National Initiative on Climate Resilient Agriculture (NICRA), which is considered the largest outreach program ever in climate change. The project was initiated by the Indian Council of Agriculture (ICAR) and the Ministry of Agriculture and Farmers' Welfare (MoAFW) during 2011, and the second phase (which commenced in 2017) is called National Innovations in Climate Resilient Agriculture (NICRA). The program aims to enhance the resilience of Indian agriculture to climate change through strategic research and technology demonstration. The CRV was initiated under the technology demonstration component (TDC) in the 151 climatically vulnerable districts of the country by Krishi Vigyan Kendra (KVKs), constituting over one lakh farm families across the country. The TDC component addresses climatic vulnerabilities such as droughts, floods, heatwaves, cold waves and the like. The four intervention modules being implemented are (1) natural resource management; (2) crop production module; (3) livestock and fisheries interventions; (4) consisting of village level institutions and collective marketing groups, the introduction of weather-based insurance and climate literacy though the establishment of automated weather stations. The aim is to improve the resilience of Indian agriculture to climate change by demonstrating technologies or adaptation of crop and livestock and thereby up-scaling technologies [3,29].

Developmental programs are designed to bring measurable outcomes such as increasing incomes, skill development or learning and livelihood security and the policy question could be whether the program achieved the outcomes. Impact assessment has an important part in a program or project performance and is useful when the findings are used for replication elsewhere or to know if it can be spread to wider locations. There has been an increase in the impact of evaluation research over time, and the impact assessment methodology originates from the theory of causal inference and answers questions related to cause and effect. The causal inference (causality between a program and an outcome) and the counterfactuals (which outlines what the outcome would have been for a participant in the absence of the program) are the two integral concepts in impact evaluation [30]. There are important methods such as the randomized assignment, instrumental variables (IV) and regression discontinuity design (RDD), which estimates the counterfactuals while the method of difference-in-difference (DID) provides added methods for evaluation. Impact studies of technologies aimed at quantifying the expected change in the outcome, as well as estimate the outcome in the absence of the intervention and DID method, require a control group whose evolution over time reflects what the treatment group would have experienced in the absence of any intervention. DID helps in resolving the problem of unobserved differences in the characteristics of the comparison groups and it compares trends between the treatment and comparison groups. It has been used in a number of studies regardless of the type of intervention, program or technology adopted [31,32]. However, impact analysis brings out the effects of droughts on farm income as well as the benefits of adopting climate resilient technologies. The results could also be based on the socio-economic characteristics of the respondents. Exogenous characteristics such as age, gender, number of years of labor, market experience, land, livestock, credit facilities, participation in developmental programs, location, target group, etc., differ regardless of the evaluated intervention and the methodology used [31,33,34].

The role and impact of production technologies and practices on risk-reduction, stabilizing production and income and poverty have been perceived to be positive and are well documented [35,36]. The climate smart practices were found to improve household incomes by 83 per cent and the increased incomes were invested in livestock rearing, which acted as a better resilience measure during climate risks. The adaptation strategies through climate smart villages helped the farm households diversify crops and grow resilient livestock breeds and protect themselves from drought risks. Climate resilience not only increases farm income and net returns, but also contributes to food security and poverty reduction [34,37–39]. Reviews of the effect of documented climate risk management interventions found them to be effective in improving farm incomes, crop production and helping mitigate the impacts of droughts on farm households and their assets [9]. Climate resilient technologies were found to be a viable solution for the problem of water scarcity in the rainfed district of Himachal Pradesh, which showed a positive and significant impact in rice yields and net income in Karnataka under drought conditions [9,40,41]. More than 30 per cent income benefits were observed when farmers adopted drought and stress tolerant crops in India [36,42].

The importance and impact of promising resilient practices identified under the NICRA program to cope with weather aberrations in India are well documented [43,44]. A literature review of impact studies under the program is given below.

A comparative study on the climate interventions and farmers' practices indicated better net return and benefit cost ratio compared to farmer's practices. Significant increase was also found in irrigated land area and irrigation frequency, employment generation, land area (leased in), savings of farmers, crop productivity and expenditure patterns in the states of India, where climate resilient technologies were adopted. The improved technologies of pulses production adopted under the NICRA project in the villages of Hamirpur and the Jhansi district of Bundelkhand region of Uttar Pradesh gave higher net returns compared to farmers' practices [45]. We also see that the beneficiaries of the project in the Anantapur district of Andhra Pradesh were able to bring more areas under irrigation and increase the productivity of crops, with cropping intensity leading to an increase in their annual incomes after project implementation. Analysis of these impact variables was found to be statistically significant and the impact levels of more than 50 percent of beneficiaries were medium. Impact studies in the states of Andhra Pradesh, Telangana and Tamil Nadu found an increase in crop yields and profitability. The livestock and poultry interventions also gave small and marginal farmers additional incomes [40,46,47]. Location specific resilient practices implemented in the climate resilient villages of Bihar, Jharkhand and West Bengal states gave better economic returns to farmers. Another study in Uttarakhand and Karnataka helped more than 70 percent of the farmers in the villages to adopt short duration varieties and better soil and water conservation technologies, and the natural resources management strategies adopted by farmers of the Rewa District in Madhya Pradesh made them resilient to climate change. With the adoption of drought tolerant and short duration varieties, resilient intercropping systems and in-situ soil moisture conservation practices at the time of sowing also effectively helped in the mitigation of droughts. Socio-economic characteristics such as education, land holding, farm experience, resources and change proneness were found to influence the use of climate resilient adaptation strategies [48–51].

Assessing the impact of droughts on economic outcomes is limited and has not used comparable data for farmers when not experiencing drought. Studies on the impacts of climate change are still inadequate for many areas, particularly in Asia. Supporting conclusions on observed and projected impacts of climate change on poverty, livelihood and economic valuation are relatively sufficient, but the knowledge gaps need to addressed, especially in south Asia. Reviews of various research on climate change impacts also reveal gaps in the evidence about the effectiveness of CRTs in helping smallholder farmers overcome climate related risks [9,22]. Better assessment and quantification of the impacts of climate extremes such as drought are needed to know the impact and after effects of drought. A detailed analysis will help develop a better understanding of the socio-economic changes as a consequence of drought and will also help us to be proactive in facing drought in the future. It is important to look into the local impacts, specifically on agriculture and livestock productivity, food security, drinking water supplies, migration and importantly on primary family income, which comes from agriculture [52]. The impacts of these climate resilient interventions need to be quantified in the form of changes in farm productivity, farm income and employment at household level, especially during times of climatic extremes such as droughts. Consequently, the broad objective of this study was to understand the socio-economic characteristics and income composition of dryland farm households. Furthermore, the specific objective was to quantify drought impacts on the crop productivity, income and employment of farm households. The study emphasises the importance of adopting climate resilient technologies (CRTs) in minimising drought impacts through the DID estimate. Further, the paper investigates the impact of various socio-economic factors influencing farm incomes during droughts.

2. Method and Data

2.1. Study Area

The present study was conducted in the Nandyalagudem, Boringthanda and Kasarabad villages of Atmakoor Mandal in the Nalgonda district of Telangana state in the south-central region of India during the period 2019–2020. The map of the study area is given in Figure 1. More than 80 percent of the state is vulnerable to agricultural drought in the changing climate scenario and the study district is one of the extreme drought prone districts of the state. The study location was selected due to its vulnerability to frequent droughts, and the district identified on a scientific analysis based on exposure, sensitivity and adaptive capacity in relation to climate change under the NICRA program, to implement the TDC component for establishing the climate resilient village (CRV). The major vulnerability addressed in the study villages was drought and erratic rainfall [43,53,54]. The district comes under the NARP zone—southern Telangana Zone (AP_4) (Figure 1) and the average rainfall of the study area is 750–850 mm, wherein interventions against drought and prolonged dry spells were witnessed. Out of the total cropped area of 300 ha, 80% is under rainfed crops and the major crops grown are cotton, pigeon pea and rice.

Figure 1. Map showing the study area in south-central India.

2.2. Sample and Data Collection

Both household surveys and key informant interviews were adopted to collect information from 120 randomly selected households with 60 farm households each from the treatment and control villages. A pre-tested questionnaire was used to collect data from both the villages during the years 2019–2020. The questionnaire was designed to collect information on demographics and economic profile, land endowments, age, education, cropping pattern, composition of household income, crop and livestock production data, climate resilient interventions adopted and constraints faced by farmers. As the impacts of CRTs are multiple, the farmers benefit in a number of ways; the impact is measured by the indicator household gross income or farm household income (during a normal and drought year) and it is calculated as the sum of income from agricultural activities, i.e., income from crops cultivated, livestock reared, off-farm income (labor), and non-farm income (including small businesses etc.). At the same time, the impact of drought on the income composition and employment and productivity of major crops was collected.

3. Methodology

The socio-economic characteristics of the sample farmers, land holding particulars, crops grown, farm incomes obtained and employment status of the respondents were analyzed through descriptive statistics. There are several impact assessment methodologies for the evaluation of technological interventions. However, the major challenge is using a more reliable methodology for better evaluation. Comparative study between the treated and non-treated groups is one technical way, while before and after intervention comparison is another way. Impact evaluations rely on control or comparison groups, as well as other econometric techniques. Without a comparison group that yields an accurate estimate of the counterfactual, the true impact of a program cannot be established.

3.1. The Method of Difference-in-Difference (DID)

One tool, which controls for factors or events known as confounders that are correlated with the outcomes but are not caused by the project, is the DID estimate. The DID method is depicted in the Table 1 and it is one of the recent improvements in development studies and in many economic evaluation studies [55–57].

Table 1. The method of difference-in-difference in impact assessment of CRTs.

Particulars	Treatment Farmers	Control Farmers	Difference Across Groups
After	T1	C1	T1-C1
Before	T0	C0	T0-C0
Difference across time	T1-T0	C1-C0	Double difference (T1-C1)-(T0-C0)

The difference-in-difference model.

The methodology in estimating causal relationships was widely used since the study by Ashenfelter and Card (1985). The data are collected for two groups for two periods and one of them is the treatment group while the other is the control group. The treatment group receives treatment in one period while the control group receives no treatment during both periods. The average gain over time in the control group is extracted from the gain over time in the treatment group. This double differencing method removes biases arising from permanent differences between these groups, as well as time differences in the treatment group, which can be due to time trends [55–59]. Here, the change in the farm income of the treatment group compared to the income in the control group measures the treatment effect. The difference in the impact of the NICRA program can be computed from income before the treatment. This difference is called the "first difference." The same difference in outcomes between the treatment and control groups after the conclusion of the project is called the "second difference". The DID estimate for the present study has been modified and given below [60].

Basic DID Regression Framework.

The basic DID regression with two groups, treatment (j = 1) and control (j = 0), and two time periods, representing pre- (t = 0) and post-treatment (t = 1) is as follows:

$$Y_{ijt} = \beta_0 + \beta_1 E_j + \beta_2 Post_t + \beta_3 E_j \times Post_t + \beta_4 X_{ijt} + \varepsilon_{ijt} \quad (1)$$

where Y_{ijt} is the outcome for individual i in group j at time t, E_j is an indicator for the treatment group j, $Post_t$ is an indicator variable for time t being after the intervention change, X_{ijt} are individual level covariates and ε_{ijt} is the error term. E_j is equal to one if the data is for the treatment village, regardless of the value of t, and equal to zero in a control village. $Post_t$ is equal to one if the observation occurs after the intervention, regardless of the value of j. The interaction term therefore equals one only for observations that are in the treatment group after the intervention. The details of the regression coefficients are given in the Table 2. The estimated coefficient β_3 reveals any change in outcome Y from the pre-intervention time to the intervention time that occurs in the treatment group and not in the control group.

The linear "difference-in-differences" estimate is therefore:

Table 2. Difference-in-difference in regression coefficients.

	Pre	Post
No change	β_0	$\beta_0 + \beta_2$
Change in intervention	$\beta_0 + \beta_1$	$\beta_0 + \beta_1 + \beta_2 + \beta_3$

$$(T1\text{-}C1)\text{-}(T0\text{-}C0) = [(\beta_0 + \beta_1 + \beta_2 + \beta_3) - (\beta_0 + \beta_2)] - [(\beta_0 + \beta_1) - \beta_0] = \beta_3$$

3.2. Stepwise Multiple Linear Regression

Studies have shown a number of factors influence farm incomes; here, we investigate the importance and influence of the socio-economic variables of farmers, adoption status, etc., on the income of a farm household during droughts. Regression analysis is important and reliable in determining the factors influencing the dependent variable we are concerned with. It is used in this study to model multiple independent variables, both continuous and categorical. Multiple linear regression models the relationship between a dependent variable (i.e., farm income) and explanatory variables (Table 3) by fitting a linear equation using observed data. The first step in multiple regression is to examine pairwise relationships among all variables; the stepwise multiple regression performs the multiple regression a number of times, each time removing the weakest correlated variable.

Table 3. Description of the variables used in the MLR model.

Variables	Description	Measurement
Dependent variable		
Farm income	Income of household from crops, livestock, off-farm and non-farm activities	Rupees/farm/year
Independent variables		
Age	Age of the respondent	Years
Education	Educational status of the respondent	Number of years
Family size	No. of members in the family	Numbers
Investment	Whether investment in agriculture influences the farm income	Rupees/acre/year
Type of farming	Rainfed or otherwise	1 = Yes; 0 = No
Farm size	Land holding of farmer influences the income	Hectares
Adoption status	Whether climate resilient technologies influence farm incomes	1 = Yes; 0 = No
Livestock rearing	Whether rearing livestock influences the farm income	1 = Yes; 0 = No

4. Results and Discussion

4.1. Demographic and Farm Profiles of the Farmers

The socio-economic characteristics, land holding and crop details of the respondents are outlined in Table 4. Most of the respondents were middle age, with the average age ranging from 44–46 years with 50 percent of them literate. Though the average land holding of farmers was 2.27 hectares, more than 50% of respondents were small farmers with less than 2 ha land. In both study villages, the primary occupation of more than 80 percent of respondents was agriculture (crops and livestock). More farmers in the treatment village went for livestock rearing compared to the control village (60.74%). The farmers of the treatment villages were able to grow diversified crops such as rice, cotton, red gram, mulberry and vegetables and opted for livestock rearing when they were trained and provided with the needed interventions. The average income of the respondents was

Rs. 2,14,327/farm household/year. The particulars of land holding and farm size are detailed in the Table 5a,b. The operational land was higher in the treatment village and the increase could be attributed to the leasing in of land. The average leased in land was about 1.87 ha in the treatment village. More than 80% of the farmers in the study area were small and medium farmers and more than 50 percent of farms had land less than 2 hectares.

Table 4. Farm profiles and socio-economic characteristics of respondents.

Characteristic and Categories	Control	Treatment	All
Age (years)	44	46	45
	Social Class (%)		
SC	17	0	9
ST	7	66	35
OBC	75	34	56
	Education (%)		
Illiterate	35	52	43
literate	65	48	57
	Primary Occupation (%)		
Agriculture (crops)	42	56	50
Agriculture + livestock	53	40	46
Others (business)	5	4	4
	Livestock possession (%)		
Yes	41.67	60.71	47
No	58.33	39.29	53
Major Crops Grown	cotton, rice	rice, cotton, red gram, mulberry, chilli	
Investment in agriculture (Rs/acre/Year)	22,600	34,303	20,672
	Group membership		
Yes	29	45	
No	61	55	
Land holding (hectares)	2.15	2.40	2.27
Average income per farm /year (Rs)	193,916	236,197	214,327

Table 5. Details of the land and farm sizes in the study villages.

(a)

Land (Ha)	Treatment	Control
Owned	3.27	3.19
Leased out	0.94	0.07
Leased in	1.87	0.71
Fallow	0.39	0.03
Total Operational land	5.14	3.93

(b)

Farm size	Treatment (%)	Control (%)
Small (<2 ha)	54	72
Medium (2–4 ha)	36	23
large (>4 ha)	10	5

4.2. Cropping Pattern and Income of the Respondent Farmers

The major crops grown in both villages are cotton and rice followed by red gram, which are the important crops of the drylands. However, in the treatment village other high value crops and vegetables were also grown, which increased the cropping intensity by 5.9 percent in the treatment village. Improving farm incomes under the limited land available is possible by increasing the number of crops grown, and thereby increasing the sown area. An increase in the cropping intensity helps to increase farm incomes within the available land and other resources (Table 6).

Table 6. Description of cropping pattern in the study villages.

	Particulars	Treatment	Control
I (A)	Kharif Crops		
1.	Paddy	71.23	103.04
2.	Cotton	21.15	26.32
3.	Red gram	10.83	2.02
	Total	103.22	131.38
II (B)	Rabi crops		
1.	Paddy	13.77	31.78
2.	Chilli	4.66	
3.	Mulberry	14.37	
4.	Maize	0.91	
5.	Vegetables	1.21	
	Total	34.92	31.78
II	Gross Cropped Area	138.14	163.56
III	Net Cultivable Area	103.22	129.35
IV	Cropping Intensity (%)	134	126.45
	Per cent change	5.84	

A farm household receives income from major sources such as crop cultivation, livestock rearing, labor and other non-farm activities such as business, tailoring, shops, etc. A typical dryland farm family receives its income from activities such as crops, livestock, non-farm labor and off-farm income. Sources of income from crops include cultivation of cereals, pulses, oilseeds, fibers, sugarcane, commercial crops, fruits, vegetables, etc.; non-farm includes wages received from working on other fields in the village or nearby village; livestock includes income from dairy, poultry, sheep and goats; non-farm income includes income from small businesses, shops, construction works, tailoring, automobile repair shops, etc. The major share of income for a farm household (Figure 2) was by crops cultivated in both the treatment (74%) and control village (64%), followed by income from off-farm activities (12% and 13%) and livestock rearing (11% and 8%). When we compare the treatment and control villages, it is evident that income from agricultural activities had a major share in total farm incomes where climate resilient strategies were adopted. The respondents in the control village received about 15% of their income from other non-farm activities. The average income of the treatment village was Rs. 236,191/year while in the control village the income was Rs. 193,916/year, with a percentage increase of 21.8 percent over the farm households in the control village.

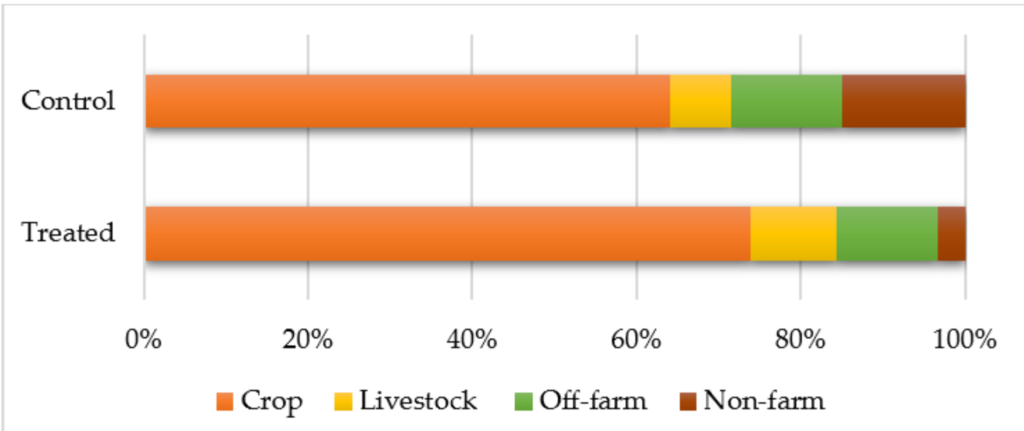

Figure 2. Income composition of farmer respondents.

4.3. Impact of Drought on Crop Productivity, Income and Employment

The data on the productivity of crops, employment days and income of farmers during drought and normal years are presented in Figures 3–5. The changes in crop production and productivity are one of the most evident impacts of extreme weather events [7,19,27,61,62]. The data on the productivity of crops, employment days and income of farmers during drought and normal years are presented in Figures 3–5. Irrespective of the crops grown, the effect of drought was evident in the reduction in yield especially in the control village. The percentage reduction in yield was highest for chilli (44.35), followed by maize (41.67), mulberry (32.32), red gram (34.70), cotton (30.41) and rice (28.81) in the treatment village. The reduction in yields of cotton and rice was below 40 percent with the highest reduction reported for red gram (58.46) in the control village. The results of the study also found that the employment days of a farmer reduce during a drought compared to a normal year. While looking into the days of employment, farmers reported that employment from crop and livestock activities during droughts reduced by 29 and 23 percent. However, there was an increase in employment days from off-farm activities, which would be because farmers, especially the small and marginal farmers, tend to go as laborers to other farms and nearby villages having access to irrigation. The data from the control village also showed a notable reduction in employment days, including the employment from off-farm activities.

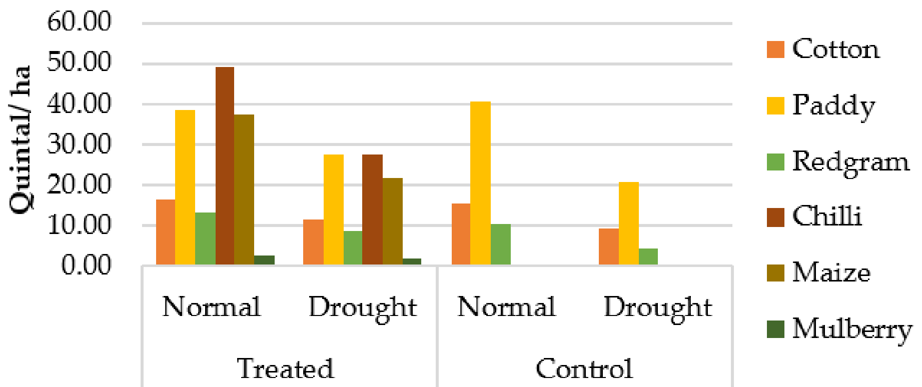

Figure 3. Drought impacts on the productivity of major crops.

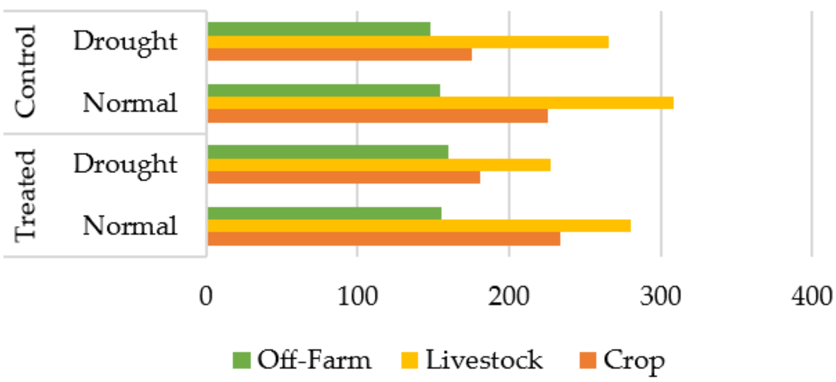

Figure 4. Impact of drought on employment days.

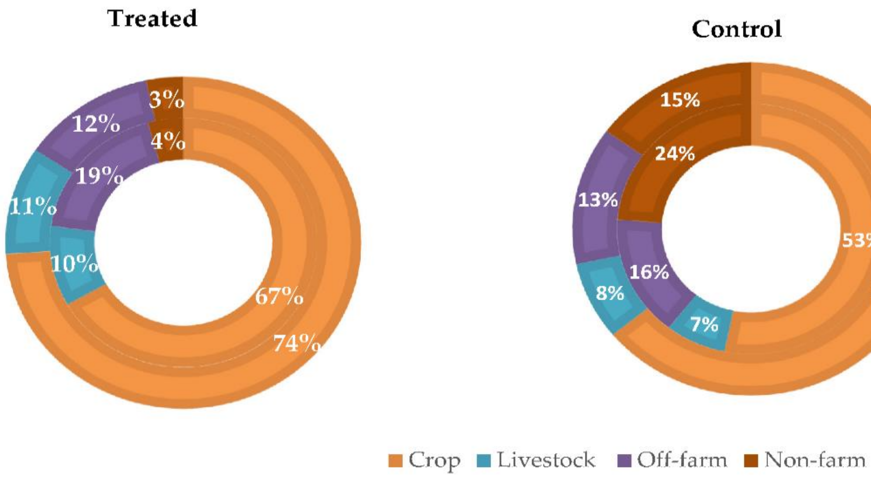

Figure 5. Income composition of farmers during drought and normal years.

It is also interesting to see the changes in the composition of income of a farm household during droughts (Figure 5). The farmers who benefited from climate interventions had higher incomes compared to those who did not. The inner doughnut chart (Figure 5) represents the composition of income during droughts and outer during normal years. There is an evident reduction in income from crop cultivation in both villages, while livestock income reduced by only 1%. However, in the village where there were interventions on climate resilient technologies and support, there was a reduction in crop income; they received income from off-farm activities [63] but in the control villages they had to depend more on non-farm sources of income. A number of climate risk management strategies are implemented in the NICRA villages related to in-situ moisture conservation, bio-mass mulching, residue incorporation, water harvesting and water saving irrigation methods as well as other institutional interventions, which enhances climate literacy and works towards overall resilience of the village. As such, farmers were able to cope with extreme climatic events such as droughts. The impacts of droughts can be direct and indirect, and the severity of drought impact differs depending on vulnerability and adaptability to droughts in each location. Some of the evident drought impacts have lowered crop diversity, causing a significant reduction in the yield of crops due to which the prices of crops increased, and these ultimately led to loss of income in farm families. A study of the drought impacts revealed a significant reduction (more than 50%) in the overall income at household level and 48% of farmers reported irregular income during droughts, especially agricultural income. Climatic factors have a significant influence on the variability of major crop yields, seen as a reduction of harvest (15–28%) or total failure of crops. The studies also report the impact of droughts on production, employment, wages and farm income in the states of Gujarat, Rajasthan and Telangana [7,61,64,65]. The paired t-test results are set out in Table 7. The results show a significant reduction in the income from crops and livestock compared to off-farm and non-farm sources. Drought affected crops and livestock similarly but with varying intensity; few resource poor farmers had completely lost their crop, while livestock was affected due to a shortage in fodder availability.

Table 7. The change in composition of farm income.

Income (Rs/Farm Household/Year)	Normal Year	Drought Year	*t*-Test
Crop	174,607	113,929	7.959 ***
Livestock	24,804	17,768	0.797 **
Off-Farm	28,857	31,727	−1.018
Non-Farm	7929	7286	1.000
Total	236,196	170,153	7.210 ***

Asterisks *** indicate statistical significance at the 1% level and ** at 5%.

4.4. Income of Farmers across Different Farm Sizes

The respondents were grouped based on their farm sizes as small (<2 ha), medium (2–4 ha) and large (>4 ha) farmers to examine whether the income of farmers differed across land sizes during droughts (Figure 6). It is known that farm income increases with farm size [61] and we found that the riskiness of farm incomes declines with farm size. As income from crops and livestock contributes more to the large farmer's total incomes, in absolute terms they experienced the most decline (>30 per cent) followed by medium and small farmers. The small and medium farmers were most affected with a reduction in income by 45.93 and 50.70 per cent while the large farmers were less affected with only 1.70 per cent reduction in income, as the large farmer operates with different constraints and diversifies the crops to reduce the risk of income loss. Climate extremes are the major source of risk to smallholder farmers, particularly in dryland regions. Livelihood potential becomes eroded through distress sale and loss of productive assets, because of their less resilient mechanisms, etc. Small and marginal farmers specifically in the drylands are the most affected [9,50,66] and the agricultural income of these farmers is also less, making them most vulnerable to droughts. The large farmers were less affected with only 1.70 per cent reduction in income as the large farmers operate with different constraints and diversify the crops to reduce the risk of income loss. Increased frequency of droughts affects livestock, due to mortality and poorer reproductive performance, and for sustenance the farmer goes for off-farm and non-farm work. As a long-term strategy its reported that farmers go for farm diversification and equip themselves for receiving income from non-agricultural sources. Community based preparedness and mitigation planning, drought prediction and monitoring mechanisms are needed for timely and better mitigation of droughts [9,63,67,68].

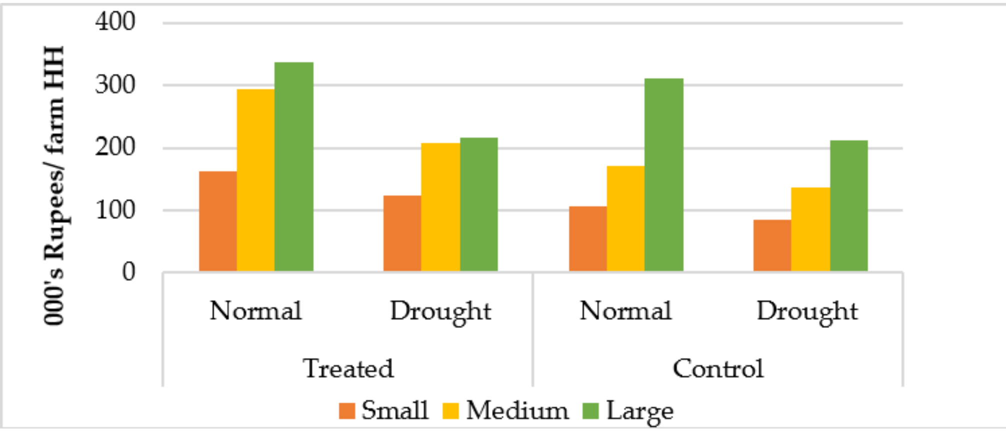

Figure 6. The impact of drought across farm sizes.

4.5. Impact of Climate Resilient Interventions on the Income: The Difference-in-Difference (DID) Estimate

The DID estimation was used to quantify and understand the income changes due to drought as well as to understand whether adoption of CRTs can cushion yield, employment and income loss of farmers. The estimate obtained in the first differences showed the difference of income of farmers in the treatment and control village during a normal year (Rs. 42,280) and in a drought year (Rs. 10,403) (Figure 7) and the DID estimates are shown in Table 8.

Therefore, the double difference/impact of programs is the difference in the above first differences estimated by the DID model (Table 8) which was Rs. 31,877/Farm household/Year. A farm household, when adopting climate resilient technologies, has saved an average income of Rs. 31,877/Farm household/year (Tables 1 and 2). It is evident that during a drought year the control village farmer had a loss of his investment in agriculture and his family income reduced significantly. Any intervention in the agricultural systems through research, training and development is done by introduction and upscaling of technology, which certainly has a positive effect on the crop production and productivity, leading to an increase in the income of farmers. The agricultural adaptions are intended to increase adaptive capacity by modifying farming practices, improving crops and livestock through investing in new technologies and infrastructure [38,46,47,69]. The study results support other findings on the direct effects of technology adoption on the increase in crop productivity, enhancing income, poverty reduction and the productivity induced indirect effects such as lower price, higher consumption, increased demand for labor, etc., which translates into better incomes and food security for the small and marginal dryland farmers [33,47,70,71].

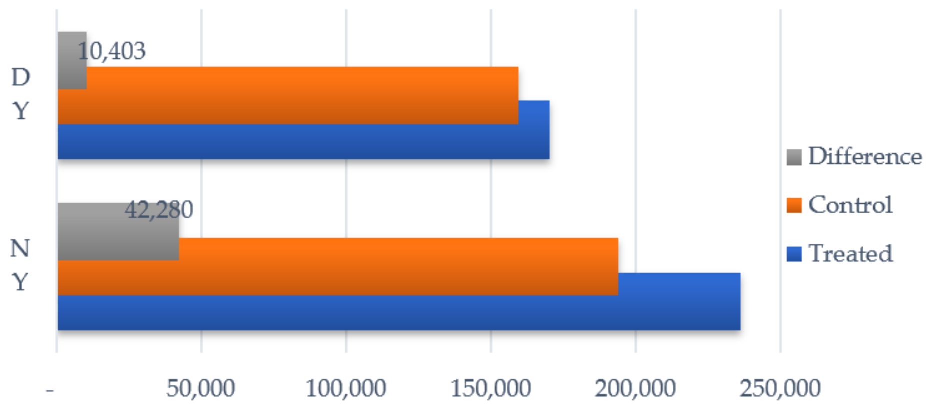

Figure 7. The first differences obtained are depicted in the above figure. Note: DY= drought year, NY = normal year.

Table 8. DID model estimation.

DID Model	Coefficients
CRT Treatment	42,279 **
CRT year	−34,166 *
CRT year × CRT treatment	−31,887
Constant	193,916 ***

* Figures are significant at: 10%. ** Figures are significant at: 5%. *** Figures are significant at: 1%.

Determinants of Farm Income of Farmers during a Drought Year

The results of the stepwise multiple regression ascertain the importance of other socio-economic factors and technology adoption on the income farm households during droughts. All variables included in the analysis are given in the methodology and the results are given in Table 9. The analysis eliminates insignificant variables until all variables are significant. The eliminated variables included the education, age of the farmers, rainfed or otherwise, and off-farm income. The farm size, livestock possession, adoption of CRTs and investment in agriculture were found to significantly determine the income of farmers. Among the four models, the farm size is the first factor to be retained and the results indicate that a unit increase in the farm size increases the income by Rs. 15,986. Land holding of the farmers is the most important assets of a farm household and risks such as drought vary with land size. The success of any technology and adaptation interventions depends on the major resource base, i.e., land. The land size of the farmer influences the adaptive capacity of farmers. It is also known that the small and marginal farmers of India are the most vulnerable to climate change and that farm income was positively and significantly associated with land holding size [34,50,72].

Table 9. Determinants of farm income during a drought year (stepwise regression).

S.No	Variable	Notation	R	Standard Error	Coefficient	t-Value	F-Value	R2
1	Constant	Intercept	-	26,399.48	13,075.44	0.50		
2	Farm Size	X1	0.439 [a]	3741.58	15,986.40	4.27 ***		
3	Livestock Possession	X2	0.533 [b]	16,658.31	55,083.33	3.31 ***	14.31 ***	0.32
4	Adoption status	X3	0.563 [c]	16,579.78	46,086.95	2.78 **		
5	Investment in agriculture	X4	0.583 [d]	1.07	2.13	2.00 *		

* Significance at 10%, ** Significance at 5%, *** Significance at 1%. [a] = Predictors: (Constant), farm size. [b] = Predictors: (Constant), farm size, livestock possession (1 = Yes). [c] = Predictors: (Constant), farm size, livestock possession (1 = Yes). [d] = Predictors: (Constant), farm size, livestock possession (1 = Yes), Treatment (1 = Yes), Investment agriculture (Rs/acre/year).

$$\text{Model: } Y = 13{,}075.44 + 15{,}986.40\ X_1 + 55{,}083.33\ X_2 + 46{,}087\ X_3 + 2.13\ X_4$$

Y = Dependent Variable: Farm income
a = Predictors: (Constant), farm size
b = Predictors: (Constant), farm size, livestock possession (1 = Yes)
c = Predictors: (Constant), farm size, livestock possession (1 = Yes),
d = Predictors: (Constant), farm size, livestock possession (1 = Yes), Treatment (1 = Yes),
Investment agriculture (Rs/acre/year)

The result indicates that those who are rearing livestock will receive an income benefit of Rs. 55,083, compared to those who depend on crops for their income. Of course, livestock rearing is more drought resistant than crop cultivation; livestock also provides a safety net against drought, and the risks due to crop failure would be minimized. Farmers benefit from livestock more in drought years and in order to have a more secure and sustainable system, we need to go for biomass intensification, promotion of fodder crops and fodder banks and encourage agri-livestock systems especially in drylands. With interventions in livestock, such as improved drought tolerant breeds, improved husbandry and management practices through advisory services, this helps to increase the fodder availability, etc. And also the farm household gets access to animal source foods, and by selling livestock and its food, their income security is enhanced [6,36,37,73].

With regards to adoption status, adoption of climate resilient technologies significantly and positively influences the income of farmers. It further strengthens the impact of technology adoption on farm income; the coefficient indicates a benefit Rs. 46.086/farm household over farmers in the control village. The findings are consistent with studies specifically in an Indian context [34,36,74–76], which quantified the incremental benefits of climate smart technologies and study in Telangana (Nalgonda, Mahbubnagar and Warangal districts), which concluded that these technologies sustainably increase incomes and improve livelihoods [35,77]. Investment in agriculture was positively and significantly associated with farm incomes and a rupee investment in agriculture, increases the farm income by Rs. 2.13.

5. Conclusions and Policy Implications

This study examined the impact of drought on farm incomes in drylands, quantified the economic impact of adopting climate resilient technologies in reducing the effect of climate extremes such as droughts and identified the significant factors which influence income of farm households during droughts. In this study, a methodological framework to examine and quantify the impacts of climate extremes and the benefits of adopting CRTs through the NICRA project have been developed and used to analyze the primary data collected from drought a prone district of Telangana state, India.

The study results indicated significant reduction in crop productivity in drought years and the reduction in productivity was reported to be more than 40% for rice, cotton, chilli, maize and red gram. The study indicated a reduction in days of employment from agriculture by 26 per cent. The impact of droughts on the income composition of farm households, as well as across different farm sizes, were analyzed. The income from crops was reduced by 54 per cent, livestock by 40 per cent and the small and medium farmers were most affected. The difference-in-difference (DID) estimate revealed a dryland farm household can receive income benefits of Rs. 31,877 when they adopt climate resilient technologies during droughts. Factors such as land holding, adoption of climate resilient technologies and livestock rearing and investment in agriculture had positive and significant impacts on farm incomes. The limitations of questionnaire surveys also apply to this study and their scope is limited to the location and randomly selected farm households; however, the results and data of this study could be used for comparison of drought impacts as well as the benefits of adopting appropriate technologies in future studies.

The results illustrate that there are visible impacts of drought that cannot be ignored, and at the same time they can be avoided or reduced by adopting better technologies. There is a need for every dryland village to have institutions which help in guiding farmers in risk management as well as build up social capital within farmers, micro-financing, insurance, community preparedness and planning to cope with extreme events, ecosystem-based adaptation measures, diversification, ground referenced online databases using remote sensing and geographical information systems, etc. Mainstreaming adaptation programs into development planning and administration will help monitor drought impacts. Integration of physical, biophysical, and social sciences into a comprehensive understanding of climate–agriculture interactions is also needed [11,29,78–80]. Climate resilient technologies primarily help in stabilizing production and incomes. Interventions through programs such as the National Innovations in Climate Resilient Agriculture, by implementing the concept of a climate resilient village (CRV), have the potential of minimizing effects of drought and enhancing farm incomes. Future research may focus on studies understanding the measures taken by drought affected farmers to recover and further comprehensive assessments and evidence of adaptation interventions specifically to droughts at different locations.

As resource poor farmers can have both social and economic limitations, such as lack of information on better technologies, poor access to markets, weak social capital, less access to farm machinery, etc., it is important to target these interventions, especially to small and marginal farmers of drylands. Although in recent times we have seen more investment in climate risk management, the increasing population and fragmentation of farms, reducing farm sizes and climate change are making agriculture more risk prone. Nonetheless, a sustainable intervention and longer involvement of farm communities in adopting resilient technologies will lead to more defined outcomes.

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