

# Climate resilient technologies, adaptation, mitigation and their influence on farm income in Telangana State of India

## ABSTRACT

Climate change is a challenge for developing countries like India due to climate variability. The study area Telangana is also prone to frequent droughts, resulting in distress among farming communities, and witnessed crop failures leading to farmer's suicides. The State Action Plan on Climate Change (APCC) reported these issues ~~on~~ drought and heat waves in agriculture. Therefore, the present study was undertaken in 2017-18 by using ex-post facto research design to assess the climate resilient technologies, mitigation strategies adopted and their influence on farm income ~~in~~ already ascertained most vulnerable Mahabubnagar District and least vulnerable Khammam District farmers of Telanagana State. A total of 480 respondents, 240 from each district were selected randomly. Technology adoption index was constructed to ascertain the extent of adoption of climate resilient technologies and further study analyzed the factors influencing the adaptation of climate resilient technologies such as technology adoption index on household farm income along with other factors. The results of the study indicated that different strategies adopted by farmers in mitigating ~~the~~ climate change, use of drought tolerant varieties and ~~use of~~ life saving irrigations had a positive influence on adaptation to climate change. Further the study reported that Technology Adoption Index (TAI) showed a positive non-significant impact on ~~the~~ farm income in both scenarios considered i.e. Mahabubnagar and Khammam which implies that there ~~is~~ need ~~for~~ adopting more technologies intensively and timely, to ~~have~~ significant influence on farm income.

**Keywords:** Climate resilience, Agriculture, Technology Adoption Index, Climate-resilient technologies, Telangana.

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31 **INTRODUCTION**

32 Climate change can be understood as a long-term phenomenon indicating the statistical  
33 distribution of weather patterns over a period of time ranging from decades to millions of years  
34 (IPCC, 2011). Climate change is an important issue for the 21st century requiring renewed  
35 attention by all the stakeholders to address its adverse impact on agricultural productivity, the  
36 environment, and its effect on food security (Fischer *et al.*, 2001). Livelihoods can be defined as  
37 adequate stock and flow of food and cash with individual or a family to meet its basic needs  
38 (Acharya, 2006). Agriculture provides such a livelihood to more than half of the Telangana  
39 state's workforce, which is crucial for restoring sustainable growth in the rural economy.  
40 According to Rehana, *et al.* (2018), the frequency of severe and widespread multi-year droughts  
41 is due to erratic summer monsoon and an increase in air temperature, creating huge damage to  
42 crops and society. Crop failure due to drought has resulted in 342 farmers committing suicides in  
43 2015 as reported by the Ministry of Agriculture, Government of India. In 2016 about 14 lakh  
44 people from Mahabubnagar, Ranga reddy, Medak, and Nizamabad migrated to Hyderabad and  
45 other cities like Pune, Mumbai, and Ahmedabad as mentioned in the report of farmers  
46 organizations (Hindustan times, 2016). Hence, climate extremes pose a serious threat to crop  
47 yields, food security and farm income [Kalli and Jena, (2022, 2023)]. Effectively addressing  
48 climate change in agriculture requires a comprehensive strategy, with the focal point being a  
49 transition toward agricultural practices resilient to climate variations. Theoretically, farmers can  
50 adopt climate-resilient practices through a combination of external and internal factors. External  
51 factors play a role in rebuilding farmers' capacity to enhance their adaptive skills. Access to  
52 extension services, such as training [Tanti *et al.* (2023), Zakaria *et al.* (2020)], farm field schools  
53 (Osumba *et al.*, 2021), and demonstrations, make farmers aware and knowledgeable about the  
54 Climate-Smart Agricultural (CSA) practices [Mgendi *et al.* (2021), Makate *et al.* (2019)].  
55 Farmers who receive credit from public banks, private banks, and cooperative societies are better  
56 equipped to adopt climate-resilient practices (Kongogo *et al.* 2021).

57 Based on the above background it can be taken that there is a low level of awareness  
58 about climate change and knowledge on the factors influencing the decision regarding the  
59 suitable choices of adaptation strategies and the extent of adoption of those strategies by the  
60 farmers. Coping up and mitigating to adverse effects of climate change depends on the behavior

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61 of climatic variables, accordingly the present study has been taken up at district level in  
62 Telangana.

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## 64 METHODOLOGY

65 The present study was undertaken in 10 erstwhile districts of Telangana state. Where,  
66 paddy, maize and cotton are the three major crops widely grown in Telangana which constitutes  
67 a major part of the total cropped area. The climate-resilient technologies for all the above said  
68 crops were identified and further primary data pertaining to the information on qualitative factors  
69 vis-a-vis climate change, adaptation strategies and coping mechanisms adopted by the farmers  
70 was collected purposively from the already, selected villages of the most vulnerable  
71 (Mahabubnagar) and least vulnerable (Khammam) districts of Telangana state after ranking all  
72 the districts based on the estimated vulnerability indices.

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73 1. Technology Adoption Index (TAI): An adoption index was constructed to quantify the  
74 adoption of such technologies:

$$75 \quad \text{TAI} = A/P * 100$$

76 where,

77 A = Number of practices adopted by respondents, and

78 P = Total number of practices recommended.

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79 2. Multiple linear regression

$$80 \quad Y_i = B_0 + B_1 X_1 + B_2 X_2 + \dots + B_n X_n + e$$

81 Where, for i=1 to n observations

82  $Y_i$  = dependent variable

83  $X_i$  = explanatory variables

84  $B_0$  = Intercept

85  $B_i$  = slope coefficient

86 e = error term

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87 3. Tobit model

88 Adoption of agricultural technology generally involves a two-part decision-making process:  
89 whether to adopt and then how much to adopt. The Tobit model can be used in analyzing  
90 adaptation when the two decisions are made jointly.

## 91 RESULTS AND DISCUSSION

### 92 1.1 Adaptation to climate change by sample farmers

93 The data on various adaptation strategies being used by the farmers against the changing  
94 climate was collected and presented in Table 1. A dialogue with the respondents on adaptation of  
95 technologies against climate aberrations ~~on what~~ is followed ~~with~~ the respondents in both  
96 scenarios ~~considered~~ i.e. most and least vulnerable districts. The results revealed that  
97 Mahabubnagar and Khammam districts were practicing improved irrigation related to micro  
98 irrigation technologies as adaptation measures to ~~combat~~ continuous occurrence of drought. In  
99 addition, to cope ~~up~~ with ~~the~~ climate variability, the study found that farmers adopted a wide  
100 range of management ~~practices~~ such as adapting drought tolerant / resistant varieties, changing  
101 the variety in use and selecting a resistant variety (96.25%), change in cropping ~~pattern~~ and  
102 delayed sowing (99.58%). The most vulnerable conditions prevailing in Mahabubnagar district  
103 due to frequent droughts might have been the reason for adapting drought tolerant varieties. As  
104 the farmers are comparatively ~~well-to-do and were~~ earning better in Khammam, they have the  
105 ability to change cropping ~~pattern~~ which might attract new investment or bear the risk of delay in  
106 sowing. ~~Apart from these~~ use of trap crops, use of bio pesticides, staggered planting, delay in  
107 sowing, moisture retention by making deep furrows, mulching, adoption of contingent crops,  
108 leaving one season and going ~~for~~ next season and providing one life saving irrigation *etc* were  
109 considered and ranked in the order of ~~the~~ usage by ~~more~~ number of farmers. Most of the farmers  
110 in both the districts were leaving the existing crop and going for next season for cultivation in  
111 ~~ease~~ of ~~un-favourable~~ climatic conditions. Due to recurring ~~drought~~ under rainfed conditions  
112 farmers in the study area preferred drought tolerant crop varieties. Information on adaptation to  
113 climate change utilizing these technologies was used to develop a technology adoption ~~index and~~  
114 results are furnished in Table 1. Developing the adoption of technology ~~indicator~~ is difficult and  
115 complicated to ~~calculate~~ ~~as~~ majority of the farmers cannot distinguish which measures they  
116 practice can be called ~~as~~ technology and which they practice ~~are~~ from indigenous knowledge or  
117 experience. But the practices followed by respondents which clearly have a bearing ~~with~~ climate  
118 ~~resilience~~ were considered carefully. A technology adoption index has been worked out for each

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119 sample farmer and found that technology adoption index ranged from 51 to 70 **per-cent** in both  
 120 **the** districts.

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121 **Table 1 Adoptions of technology to climate variability by respondents in Khammam and**  
 122 **Mahabubnagar districts (n1=240 and n2=240)**

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Adaptation	Khammam		Mahabubnagar	
	Number	Rank as per priority	Number	Rank as per priority
Change in variety such as Drought tolerance / resistant varieties	235 (97.91)	2	231 (96.25)	1
Change in cropping pattern and delayed sowing	239 (99.58)	1	227 (94.58)	2
Staggered planting	114 (47.50)	5	122 (50.83)	5
Leaving <b>existing</b> crop and growing another crop	108 (45.00)	9	112 (46.67)	8
<b>Leaving existing</b> crop and growing next season	125 (52.08)	3	130 (54.17)	3
Moisture retention by making deep furrows etc	109 (45.42)	8	125 (52.08)	4
Mulching	106 (44.17)	10	113 (47.08)	7
One life saving <b>irrigating</b>	115 (47.92)	4	111 (46.25)	9
Use of trap <b>crops</b>	110 (45.83)	7	122 (50.83)	5
Use of pesticides	111 (46.25)	6	116 (48.33)	6

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123  
 124 Based on the calculation of technology adoption index (TAI) for all the respondents were  
 125 classified as low adopters (0-25), medium adopters (26-50), **Semi** medium adopters (51-75) and  
 126 **High** adopters (75 -100) and presented in Table 2. The technology adoption index ranged from 0-  
 127 100. **Evidently** it was found that only 7.5 % and 2.92 % of the erstwhile Khammam and  
 128 Mahabubnagar **district** were low **adopters as** so it can be understood **that** lowest level of  
 129 technology adoption was observed in Mahabubnagar farmers compared to Khammam. This  
 130 might be due to the least loss **incurred** so they might **not adopted** many measures to **combat**  
 131 drought in Mahabubnagar district. Mean Technology adoption index for Khammam sample  
 132 farmers is **48.2** while that of Mahabubnagar **was** 57.54.

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133 Technology adoption index in case of medium adopters among Khammam sample  
 134 farmers about 57.5% were there when compared to 39.18% of farmers of Mahabubnagar. But  
 135 when the semi medium level of adaptation was among these districts is compared to 42.08% of  
 136 Mahabubnagar farmers were found to have adopted more technologies over 31.67% of farmers  
 137 in Khammam. It can be concluded that the vulnerability scenarios both do not show a  
 138 differentiated effect on technology adoption index it is the income, resource endowment,  
 139 awareness, affordability, knowledge gained from media and their fellow farmers might have  
 140 helped them to decide which set of adaptation measures to follow.

141 **Table 2 Technology adoption index among the sample farmers**

Distribution of TAI (%)	Number of Farmers	
	Khammam	Mahabubnagar
Low Adopters TAI (0-25)	18 (7.50)	7 (2.92)
Medium Adopters TAI (26-50)	138 (57.50)	94 (39.18)
Semi Medium TAI (51-75)	76 (31.67)	101 (42.08)
High adopters TAI (>75)	8 (3.33)	38 (15.82)
Mean Technology Adaptation Index	48.2	57.54

142  
 143 **1.2 Determinants of the level of adaptation to climate change in agriculture**

144 From the results, it is inferred that the coefficient of farm income has positive influence on  
 145 adaptation to climate change in Khammam and but negative in Mahabubnagar district, implying  
 146 that higher the farm income, higher the willingness and level of climate adaptation technologies  
 147 and vice versa in Mahabubnagar as it is most vulnerable district. Unlike other limited dependent  
 148 models, the coefficients in Tobit model can be interpreted directly with magnitudes of  
 149 influencing the level of adaptation to climate change. It could be interpreted as one unit increases  
 150 in the farm income, will be producing a chance of 3.05 percent increase in adaptation to climate  
 151 change. Farm size was negatively associated with level of adaptation to climate change in both

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152 the districts and coefficient -1.806\* was statistically significant in Khammam, implying that  
 153 lower the farm size, higher the intensity of adaptation to climate change which may be probably  
 154 the cost to be incurred for following adaptation technologies might increase as farm size  
 155 increases. If one unit increases in the farm size, there will be a chance of decreasing 1.8 percent  
 156 in adaptation of climate change among the Khammam district respondents. Similarly, the  
 157 coefficient of access to credit was negative but highly significant, implying that higher the access  
 158 to credit, lower will be the level of adaptation. If one unit increases in the credit access will give  
 159 chance of decreasing 4.95 percent in adaptation of climate change in agriculture because farmers  
 160 might not come forward for utilizing their credit money towards climate adaptation technologies  
 161 due their risk averse attitude.

162 **Table 3 Determinants of climate change adaptation**

Variables	Khammam			Mahabubnagar		
	Coefficient	Standard error	Pr(> z )	Coefficient	Standard error	Pr(> z )
Intercept	2.719	4.568	2.00E-16	2.714	4.568	2.00E-16
Age	5.927	1.669	0.7225	1.779	1.338	0.1838
Farming experience	1.41	1.679	0.401	<b>5.361***</b>	2.102	0.0108
Education	2.884	1.962	0.1415	2.007	2.116	0.343
Farm income	<b>3.053*</b>	1.761	0.83	-1.457	1.696	0.948
Farm size	<b>-1.806*</b>	9.804	0.0655	-3.425	1.019	0.8863
Extension contact	2.21	2.077	0.9153	<b>3.425*</b>	2.007	0.0879
Access to credit	<b>-4.95***</b>	2.016	0.0141	2.02	1.995	0.3113
Membership in farmers associations	2.7	2.027	0.1829	2.215	2.038	0.2771
Climate change awareness	2.641	2.687	0.9217	3.533	2.024	0.8614
Depth of ground water levels	-1.27	1.635	0.4374	-2.514	1.719	0.1437
Log-likelihood	-993.193			-986.17		

163 Note:\* and \*\*\* indicate .1 and .001 level of significance

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164 **1.3. Performance of various factors influencing ~~on~~ farm household income in different**  
 165 **scenario**

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166 In order to study if there is any significant influence of level of technology adaptation on  
 167 farm income along with other factors such as age, education, farm size, seed, cropping intensity,  
 168 fertilizer use, plant protection chemicals, experience, number of members available for farm  
 169 work, human ~~labour~~, credit ~~availability~~ and cropping intensity were considered and multiple  
 170 linear regression analysis and Tobit analysis were carried ~~out~~ and the results were presented in  
 171 Table 4

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172 **Table 4 Factors influencing ~~the~~ farm household income in most and least vulnerable**  
 173 **scenario**

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Variables	Khammam			Mahabubnagar		
	Coefficients	Standard Error	P-value	Coefficients	Standard Error	P-value
Intercept	4857.623	10274.161	0.637	7822.869**	5197.420	0.001
Age	393.100**	141.514	0.006	39.884	67.332	0.554
Education	26.102	188.828	0.890	171.269	115.932	0.141
Size of land holding	88.644	787.708	0.910	3703.311***	989.606	0.000
Experience	117.451	131.977	0.374	100.284	135.368	0.460
Technology adoption index (TAI)	8.318	61.382	0.892	15.451	36.540	0.673
No. of members available for farm work	458.833	430.202	0.309	2.000	669.998	0.555
Credit availability	0.372**	0.125	0.003	-0.023	0.024	0.334
Human labour	-0.081	0.290	0.781	-0.107	0.198	0.589
Machine labour	-0.999	0.787	0.206	-0.256	0.566	0.652
Cropping intensity	0.127	0.079	0.110	0.010	0.018	0.998
Irrigation	2.900	2.454	0.239	-2.345	1.262	0.064
Seeds	- 0.985**	0.289	0.001	- 0.724***	0.163	0.000
Fertilizer and manures	1.888***	0.424	0.000	0.384	0.285	0.179
Plant protection	-3.213**	1.003	0.002	-0.274	0.439	0.533
R square	31.330			36.510		

174 **Note: \*\* and \*\*\* indicate .01 and .001 level of significance**

175 The results presented in Table 4, indicated that technology adoption index (TAI) showed a  
176 positive non significant impact on the farm household income in both scenarios considered i.e.  
177 Mahabubnagar and Khammam, which implied that they can adopt more technologies intensively  
178 and timely; to have significant influence on farm income. This calls for intensification of  
179 research in the direction of developing more crop specific strategies, technologies including the  
180 drought tolerant and disease-tolerant/resistant and popularizing the same information using all  
181 the digital tools to ensure faster implementation of those technologies at field level. Among the  
182 other variables considered, seeds and plant protection chemicals showed negative correlation  
183 with farm income indicating the excessive use in both the districts. However, fertilizers (1.888)  
184 and credit availability (0.372) have significantly influenced farm income in Khammam district.  
185 In Mahbubnagar size of holding has significantly influenced the farm income implying that there  
186 is a need to consolidate the holdings to realize economies of scale.

187 The results are in line with the study conducted by Jena *et al.* (2023) where findings show  
188 that both paddy crop yield and net agricultural income have been higher for the adopters of crop  
189 rotation and integrated soil management while, adoption of technologies resulted in an increase  
190 of 42–45% in farm income. Further, adoption of these practices led to a yield improvement of  
191 about 2.5 quintals per acre of paddy crop for the adopters. The major drivers that jointly  
192 influenced farmers to adopt these practices were found to be access to extension service, access  
193 to credit, subsidies for seed and electricity use in agriculture.

## 194 Conclusion

195 It can be concluded that among all districts of Telangana there was a general trend of  
196 narrowing crop diversification which has to be widened. The decline in crop diversification  
197 resulted crop failures followed by market failures and subsequently reduced farm income. The  
198 climate resilient technologies which are proved successful must be promoted. Providing  
199 subsidies for cultivation of millets and creating market linkages might help in bringing crop  
200 diversity in the districts with high vulnerability. There is a need to reorient the extension  
201 approach in promoting climate adaptation technologies and necessary measure have to be taken  
202 to increase the purchasing power of the farmer as the climate adaptation technology index  
203 produced a non significant positive impact on the farm income.

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