

IMPACT OF CLIMATE RESILIENT TECHNOLOGIES AT FARM AND HOUSEHOLD LEVEL ACROSS AGRO-ECOLOGICAL REGIONS IN INDIA

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ABSTRACT

The study evaluates the micro-level impact of Climate Resilient Technologies (CRTs) demonstrated under the project “National Innovations in Climate Resilient Agriculture (NICRA) project across 30 select Krishi Vigyan Kendras (KVKs) representing diverse agro-ecological zones in India. Primary data collected during years of climatic stress was analyzed to quantify the effect of Climate Resilient Technologies (CRTs) on productivity and income in crop, horticulture and livestock production systems. A resilience indicator (R) was used to assess the extent of yield and income loss avoided due to interventions. Results revealed significant resilience achieved across crop and NRM modules, with R values ranging from 0.37 to 0.98 in productivity and up to 0.89 in income. Highest resilience was observed in wheat with supplemental irrigation, drought-tolerant crop varieties, and interventions like zero tillage and crop diversification. At the household level, CRTs enhanced incomes across agriculture, horticulture, and livestock sectors showing increases up to 1309 percent and improved savings and labor efficiency through mechanization. The findings confirm that CRTs significantly strengthen adaptive capacity, improve resource use efficiency, and enhance livelihood resilience under climate variability, providing evidence for wider scaling in climate-vulnerable farming systems.

Keywords: resilience, productivity, income and adaptive capacity

INTRODUCTION

Climate variability and extreme weather events have emerged as critical challenges for Indian agriculture, impacting crop yields, livestock productivity, and rural livelihoods (Vinaya et al., 2023; Vinaya et al., 2025). Frequent occurrences of droughts, floods, hailstorms, and heatwaves have led to considerable losses, particularly in vulnerable agro-ecological zones (IPCC 2022; World Bank 2010). In response to these growing concerns, the Indian Council of Agricultural Research (ICAR) launched the National Innovations in Climate Resilient Agriculture (NICRA) project in the year 2010-11 (Tajpara et al., 2020), aimed at enhancing the adaptive capacity of farming systems through the development and dissemination of Climate Resilient Technologies (CRTs) (Singh et al., 2021; Vinaya and Tapan 2023; Vinaya and Shivamurthy, 2021). These include drought and flood-tolerant crop varieties, improved natural resource management (NRM) practices, water-saving irrigation technologies, weather-informed agricultural decisions, and risk-reducing livestock interventions (Vinaya and Shivamurthy, 2018).

This study assesses the micro-level impacts of CRTs implemented across 30 NICRA project KVKs by analysing

primary data collected during years of climatic stress. The impact was measured using a scientifically derived metric, the Resilience Indicator (R), developed by Rama (2018), which quantifies the avoided loss in productivity and income due to CRT adoption. The analysis covers multiple CRT modules such as crop production, NRM, livestock and mechanization. Comparative assessments were made between farm performance with and without CRTs during stress years, offering empirical insights into their effectiveness. Additionally, the study presents evidence on how CRTs have enhanced resource use efficiency, optimized input costs, and improved economic returns for farmers under adverse climatic conditions.

Beyond farm productivity, the study explores the broader household and village-level impacts of CRT adoption. Findings indicate substantial improvements in annual income and savings across agriculture, horticulture, and livestock sectors. Mechanization interventions, such as drum seeding, significantly reduced labour requirements while enhancing productivity. In many regions, households experienced improved quality of life through increased income, better food security, and enhanced capacity to invest in education, health, and livelihoods. Overall, the results underscore the potential of CRTs as vital tools for building

climate resilience in Indian agriculture and offer a strong case for their mainstreaming into national adaptation strategies and sustainable agricultural development programs.

OBJECTIVE

To assess the micro-level impact of climate-resilient technologies at farm and household level in terms of enhancing the resilience in productivity and income

METHODOLOGY

The study employed a mixed-method approach to post-facto assess the micro-level impact of Climate Resilient Technologies (CRTs) implemented under the NICRA project across 30 KVKs (sample) out of 121 KVKs in the project representing diverse agro-ecological regions (Table 1). Primary data collection was conducted through structured and pre-tested questionnaires (schedules) administered to beneficiary farmers in NICRA-adopted villages to assess the quantitative impact of CRTs at farm and household level. The data focused on quantifying changes in productivity, income, resource use efficiency, household-level income, savings, and labour hours before and after the implementation of CRTs, especially during years of climatic stress (droughts, floods, heat waves, etc.).

To objectively measure the impact of CRTs, a Resilience Indicator (R) was used, which was conceptualized and developed by Rama Rao, C. A. (2018). The indicator quantifies the proportion of yield or income loss avoided due to CRT adoption and is calculated using the formula, $R = 1 - (\text{Normal Yield} - \text{Yield with Intervention}) / (\text{Normal Yield} - \text{Yield without Intervention})$. This indicator was applied to assess resilience across various modules, including crop production, natural resource management (NRM), livestock systems, and mechanization. Comparative analysis was conducted between farms adopting CRTs and those following conventional practices during the same climatic stress years.

For household-level assessment, income and savings data were collected for three production systems (agriculture, horticulture, and livestock) before and after NICRA implementation. A paired t-test was used to determine the statistical significance of changes in income and savings. Additionally, man-hour savings due to mechanization were computed by comparing labor requirements before and after CRT adoption. The data were aggregated and analysed using descriptive statistics and tabular comparisons, allowing for regional and module-wise insights into the resilience benefits of CRTs across different vulnerability zones.

Table 1: Study area of project the project - 30 KVKs (23 states and 1 UT)

Sr. No.	Zone	State	Name of KVK	Vulnerability	Agro-ecological region represented (NBSSLUP 2015)
1	I	Punjab	Faridkot	High Temperature	Western Plains
2		H. P	Kullu	Drought and cold wave	Western Himalayas
3		Uttarakhand	Uttarkashi	Drought	Western Himalayas
4	II	Rajasthan	Jhunjhunu	Frost and heat stress	Western Plains
5		Haryana	Sirsa	Salinity and heat wave	Western Plains
6	III	UP	Gonda	Floods	Eastern Plains
7			Hamirpur	Drought and heat wave	Northern Plain and Central Highlands
8	IV	Jharkhand	Gumla	Drought and heat wave	Eastern plateau (Chhattisgarh)
9			Godda	Drought	Eastern (Chhotanagpur) Plateau and Eastern Ghats
10		Bihar	Aurangabad	Drought	Northern plain
11	V	West Bengal	Coochbehar	Heavy rainfall	Bengal and Assam Plain
12		Odisha	Kendrapara	Flood and cyclone	Eastern Coastal Plain
13		A & N	Andamans	Cyclone	Islands of A & N
14	VI	Assam	Dhubri	Flash floods and terminal drought	Bengal & Assam plain
15		Sikkim	East Sikkim	Hailstorm, frost and long dry spells	Eastern Himalayas
16	VII	Mizoram	Lunglei	Water stress	North-eastern Hills (Purvachal)
17		Nagaland	Mon	Water scarcity	North-eastern Hills (Purvachal)
18	VIII	Maharashtra	Jalna -I	Drought	Deccan Plateau
19			Nandurbar	Drought and soil erosion	Deccan Plateau

Sr. No.	Zone	State	Name of KVK	Vulnerability	Agro-ecological region represented (NBSSLUP 2015)
20		Gujarath	Banaskantha-I	Drought	Western Plain. Kachchh and part of Kathia war Peninsula
21	IX	Chattishgarh	Bhatapara	Drought	Eastern Plateau
22		M.P	Datia	Drought	Northern Plain and Central Highlands
23		M.P	Tikamgarh	Drought	Central Highlands (Malwa. Bundelkhand & Eastern Satpura
24		M.P	Jhabua	Drought	Central (Malwa) Highlands. Gujarat Plains & Kathiawar Peninsula
25	X	A. P	Srikakulam	Floods	East Coast Plain
26		A. P	Kurnool	Drought	Deccan plateau and Eastern Ghats
27		Telangana	Khammam-I	Drought	Deccan (Telangana) Plateau and Eastern Ghats
28		Tamilnadu	Namakkal	Drought and heat stress	Eastern Ghats. TN uplands and Deccan (Karnataka) Plateau
29	XI	Karnataka	Tumkur	Drought	Deccan Plateau (hot arid region)
30		Kerala	Alaphuza	Water logging / salinity	Western Ghats & Coastal Plain

RESULTS AND DISCUSSION

Primary data collected from 30 project KVKs employing a structured questionnaire were used for quantifying the impact of CRTs on productivity and income of crop and livestock production systems at farm level during the years of climatic stress. This was done for all successfully demonstrated CRTs in crop, NRM and livestock modules. A comparison of productivity and income with and without intervention during a stress year was made using a derived variable R (Resilience Indicator).

Impact of NRM intervention at farm level

Table 2 shows that the productivity and income

resilience achieved through adoption NRM related CRTs in different districts. Resilience in the range of 0.43 to 0.96 was achieved both in productivity and income. Maximum resilience value of 0.96 both in productivity and income was achieved in the district of Banaskantha in Gujarath with the adoption of deep summer ploughing with micro-irrigation system in castor crop and minimum resilience value of 0.43 in productivity, 0.44 in net income was achieved in Tumkur district of Karnataka with the adoption of Trench cum bunding in Ground nut crop with K-6 variety. The findings are similar to that of findings of Mani (2016); Tajpara et al., (2018); Devojee et al. (2025); Bhabhor et al. (2024); Ghasura et al. (2024) and Parikh et al. (2024).

Table 2: Impact of NRM intervention at farm level

Sr. No.	Name of the KVK	Crop	Variety	Name of the intervention	Mean Resilience (R) in yield / ha	Mean Resilience (R) net income
1	Banaskantha	Castor	GCH -7	Deep ploughing in summer	0.47	0.50
2	Banaskantha	Castor	GCH-7	Deep Summer Ploughing with micro irrigation system	0.96	0.96
3	Coochbehar	Garlic	343	Straw mulching	0.75	0.71
4	Faridkot	Basmati Rice	PUSA 1718	Spray with potassium nitrate	0.69	0.65
5	Faridkot	Rice	PR 114	Spray with potassium nitrate	0.57	0.64
6	Faridkot	Wheat	HD 3086	Spray with potassium nitrate	0.66	0.58
7	Khammam	Cotton	Raasi 65	Broad bed Furrow	0.73	0.63
8	Tikamgarh	Blackgram	PU-1	Broad bed Furrow	0.78	0.73
9	Tumkur	Groundnut	K-6	Trench cum bunding	0.43	0.44
10	Tumkur	Brinjal	Arka Sirish	Critical irrigation with harvested pond water	0.75	0.69

Impact of crop production interventions at farm level

Table 3: Impact of crop production interventions at farm level

Sr. No.	Name of the KVK	Crop	Variety	Name of the intervention	Mean Resilience (R) in yield / ha	Mean Resilience (R) net income
1	Coochbehar	Rice	SS-1	Submergence tolerant variety	0.54	0.63
2	Coochbehar	Maize	DKC 908	Zero Tillage	0.65	0.64
3	Coochbehar	Mustard	Jhumka	Straw mulching after seeding	0.47	0.60
4	Gumla	Lentil	PL-08	Drought tolerant variety	0.37	0.42
5	Khammam	Chillies	LCA-625	Virus tolerant variety	0.57	0.53
6	Kullu	Maize	Bajuara makka	Short duration HYV	0.74	0.74
7	Kullu	Wheat	HPW-368	Drought tolerant variety	0.78	0.72
8	Nandurbar	Soybean	JS-9305	Short duration variety	0.67	0.81
9	Nadurbar	Chickpea	Digvijay	Drought tolerant variety	0.55	0.58
10	Tikamgarh	Chickpea	JG-12	Wilt tolerant variety	0.74	0.66
11	Tikamgarh	wheat	GW-3288	Zero tillage	0.77	0.71
12	Tikamgarh	Mustard	Giriraj	Crop diversification with mustard	0.73	0.62

Table 3 shows the resilience achieved both in productivity and income through the adoption of crop related CRTs in different NICRA villages of project KVKs. The resilience value (R) ranged from 0.37 to 0.78 in productivity and 0.42 to 0.81 in case of net income for the cases that are presented here. The highest resilience value of 0.78 was achieved with the adoption of drought tolerant variety HPW 368 in wheat in Kullu district and lowest resilience value 0.37 was achieved with the adoption of drought tolerant variety of Lentil (PL-08) in Gumla district. Similarly, a maximum resilience value of 0.81 was achieved in income with the adoption of the short duration variety JS 9305 in Soybean in Nandurbar district and minimum resilience value of 0.42 was achieved with the adoption of drought tolerant variety

of Lentil (PL-08) in Gumla district. Similar finding has been reported by Sasanka et al. (2016); Pokiya et al. (2024); Tiwari et al. (2024); Anusha and Vinaya (2022) and Vinaya et al. (2018).

A comparison of resilience achieved in the productivity of paddy in Godda district of Jharkhand through adoption of various crop related CRTs in a stress year is depicted in the following graph. Highest productivity resilience of 0.64 was achieved with the adoption of the drought tolerant variety Naveen alone or in combination with summer ploughing and lowest productivity resilience of 0.44 was achieved with the adoption of SRI (System of rice intensification). Similar finding has been reported by Thakor and Joshi (2024).

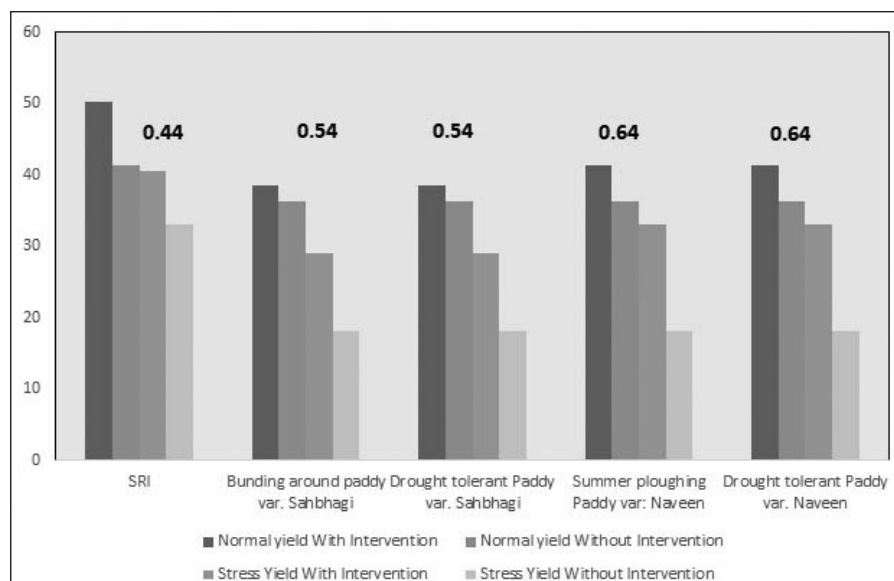


Fig.1: Productivity resilience achieved in paddy due to adaption of CRTs (KVK, Godda)

The following below graph shows the resilience achieved in income through adoption of various crop related CRTs in paddy along with diversification with groundnut. Highest R value of 0.89 was achieved through diversification, which is one of the efficient strategies in crop production

module for building resilience in income. Another similar example is of diversification of desi cotton with foxtail millet in Kurnool that was successfully demonstrated to have the potential for achieving higher income resilience during a drought year.

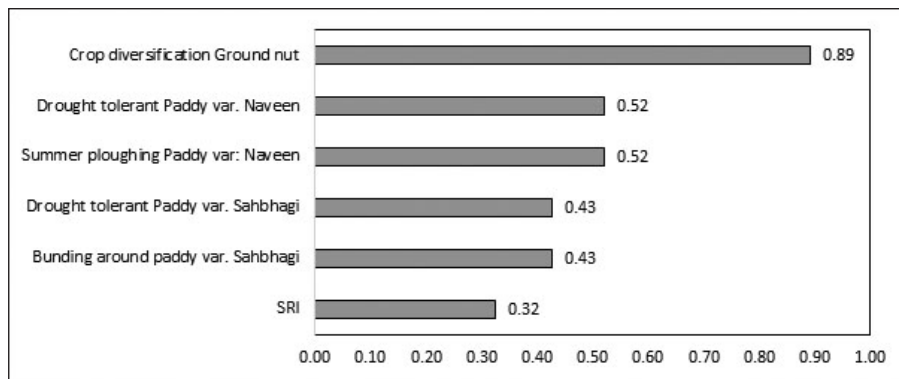


Fig. 2 : Income resilience achieved in paddy due to adaption of CRTs in a drought year in KVK, Godda, Jharkhand

Productivity of different crops with and without adaption of Intervention in stress year, Gumla, Jharkhand

year in Gumla district of Jharkhand is depicted in the following graph. Here a comparison of resilience indicator R was made across interventions and across crops. Highest R value was achieved in black gram with the adoption of variety PU-31 followed by 0.89 in SRI method of paddy cultivation.

The resilience in Productivity of different crops achieved with the adaption of CRT Interventions in a stress

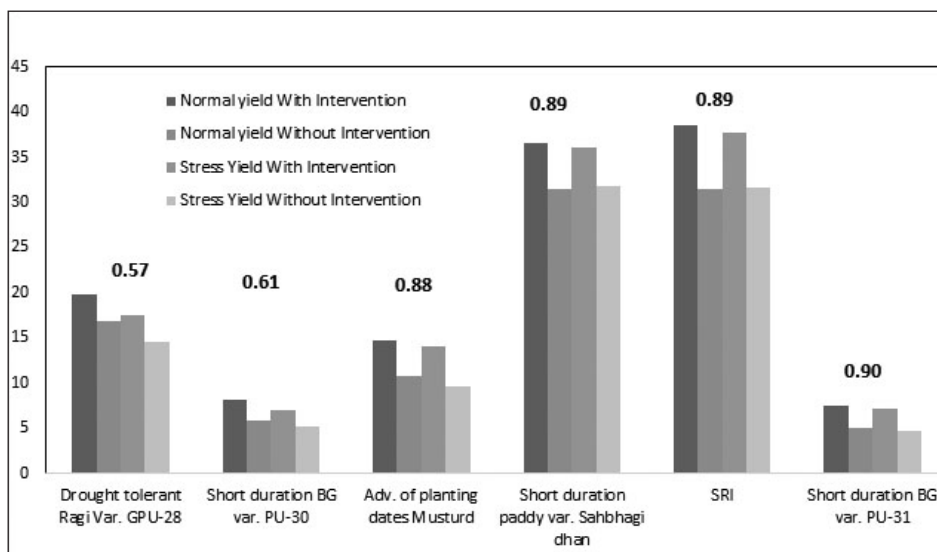


Fig. 3 : Productivity of different crops with and without adaption of intervention in stress year, Gumla, Jharkhand

Resilience achieved in net income through different interventions in a drought year at gumla

that in the same district of Gumla, advancing planting dates of bottle gourd achieved highest value of R in income followed by adoption of short duration black gram variety PU-31.

When resilience in income was considered for comparison of impact of CRTs at farm level, it was noticed



Fig.4. Resilience achieved in net income through different interventions in drought year, Gumla.

Productivity resilience achieved with adoption of CRTs in a drought year (Banaskantha)

In the district of Banaskantha in Gujarat when Resilience Indicator R was compared among different crops

and interventions, it was noticed that highest measure of resilience was recorded in the intervention “Advancing planting dates in mustard crop with the variety GDM -4 followed by crop diversification with Cumin. Varying levels of R were recorded in other interventions.

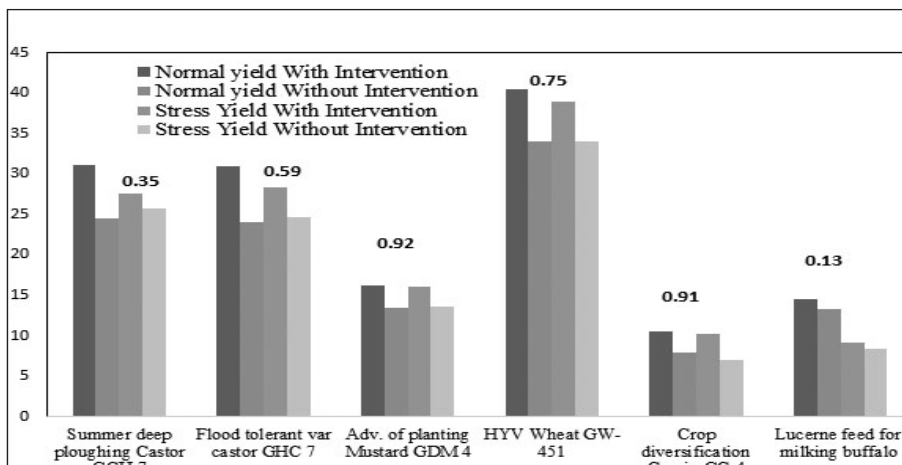


Fig.5. Productivity resilience achieved with adoption of CRTs in a drought year (Banaskantha)

Productivity of crops with and without adaption of intervention in East Sikkim

The following graph depicts a measure of resilience R achieved in different climate resilient interventions at farm level across crops in east Sikkim where hailstorms, frost and

long spells define the vulnerability of the district. Among the interventions demonstrated, highest resilience of 0.93 was achieved in case of the intervention “Early cold tolerant cabbage variety ‘rare ball’ followed by early cold tolerant cauliflower variety ‘Suhasini’.

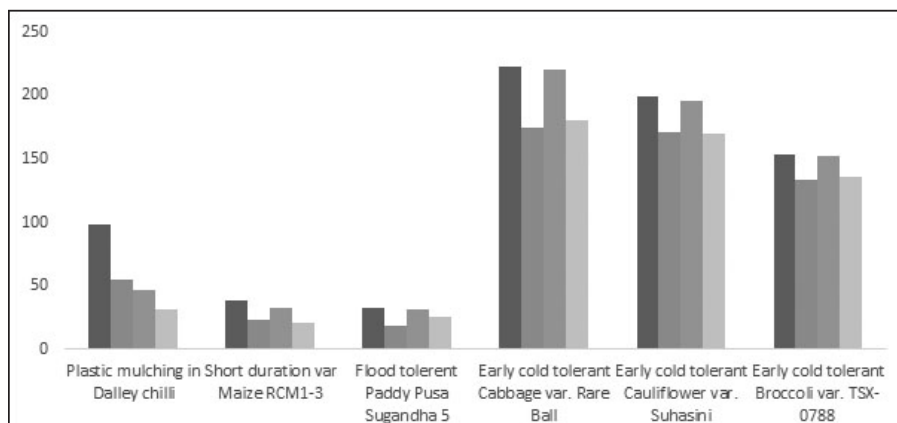


Fig.6. Productivity of crops with and without adaption of intervention in East Sikkim

Other evidences of significant resilience impacted by CRTs to productivity at farm level

Some more evidences of significant resilience imparted by CRTs to productivity of crops at farm level across KVKs are presented in the following table. A range of interventions are included here from crop and NRM modules. Among the interventions mentioned here the highest resilience measure of 0.98 was recorded in 'water harvesting and supplemental irrigation in wheat' in Datia

district followed by Low water requiring *rabi* Mustard variety RVM2 (0.94) in Tikamgarh district.

From all the results obtained at farm level, it is noticed that all the successfully demonstrated CRT interventions across the modules either singly or in combination built significant levels of resilience both into productivity and income (depends on the market price of the commodity) with a wide variation among them in all the ago-ecological situations studied.

Table 4: Evidences of significant resilience impacted by CRTs to productivity at farm level

KVK	Intervention	Yield in Normal year (q)	Yield in stress year with Intervention (q)	Yield in stress year without intervention (q)	Resilience indicator (R)
KVK, Dhubri	Flood tolerant rice variety Ranjit Sub 1	42.30	41.60	38.40	0.82
KVK, Dhubri	Staggered planting of rice during kharif	42.30	41.50	30.00	0.93
KVK, Gonda	Wheat variety HD-2967	46.25	44.50	38.50	0.77
KVK, Jhunjhunu	Heat tolerant Wheat variety Raj. 4238	45.70	43.85	36.92	0.79
KVK, Coochbehar	Flood tolerant Jute variety JBO 2003H	24.00	22.50	21.00	0.50
KVK, Datia	Advancement of planting dates of Mustard for terminal heat stress	16.98	15.89	10.66	0.83
KVK, Datia	Water harvesting and supplemental irrigation in wheat	45.10	44.89	35.20	0.98
KVK, Jalna	BBF in soybean	15.25	14.80	12.87	0.81
KVK, Nandurbar	Drought tolerant chickpea variety JAKI-9218	14.52	14.07	11.24	0.86
KVK, East Sikkim	Early cold tolerant Cauliflower var. White Excel	199.50	196.10	156.30	0.92
KVK, Tikamgarh	Low water requirement <i>rabi</i> Mustard variety RVM2	15.40	15.20	12.10	0.94

Impact of climate resilient technologies in improving resource use efficiency, building resilience and adaptive capacity at household and village level

The impact of CRTs in improving resource use efficiency and building resilience at household and village level was quantified in terms of various impact parameters. The following table depicts impact of CRTs on household level income from three production systems (Agriculture, horticulture and livestock) in NICRA villages as a comparison of before and after NICRA project situations. Significant increase in household level income in one or the other production system was invariably recorded in NICRA

households of all the districts which is a major impact of CRTs at household level. The income from agriculture increased in all the districts after implementing the NICRA project, with the highest increase of 151.67 percent observed in Godda and the lowest increase of 2.38 percent in Banaskantha. Similarly, in horticulture, Lunglei saw a remarkable income increase of 1309.42 percent, while Khammam experienced a minimum increase of 26.21 percent. Banaskantha, Alleppey, and Faridkot did not focus on horticulture due to high flood and drought-prone areas. Regarding income from livestock, Tikamgarh showed the highest increase of 356.10 percent, and Banaskantha recorded the lowest increase of 43.53

Table 5: Household level Impact of CRTs in terms of income from different production systems

Sr. No.	Name of the KIVK	Income from different production systems (₹ / year before NICRA)			Income from different production systems (₹ / year after NICRA)		
		Ag.	Hort.	LS	Ag.	Hort.	LS
1	Alleppuzha	44423	---	24548	54064*	----	58612*
2	Aurangabad	34375	3993	6315	43500*	7260	17792*
3	Banaskantha	261397	--	73195	267621	--	105064*
4	Coochbehar	29775	19225	4814	45900	45375	20902 *
5	East Sikkim	15660	21602	42069	20914*	30677*	77298*
6	Faridkot	452100	--	13894	672575*	--	30609*
7	Godda	22425	49245	13491	56438*	107887*	25150*
8	Jalna	103025	30375	19100	217150*	63250*	83325*
9	Jhabua	142354	19116	28600	225830*	33402*	54746*
10	Khammam	145717	26507	40256	201748*	33457	79823*
11	Kullu	85342	88684	39131	159236*	226315*	79184*
12	Lunglei	5187	5359	48035	12250*	75531*	124482*
13	Namakkal	91875	48625	31575	151625*	96925*	47725*
14	Nandurbar	55452	6342	7216	87417*	16922*	25421*
15	Tikamgarh	208703	11477	55411	457000*	43830*	252735*

*Significant at $P < 0.01$ and **Significant at $P < 0.05$

percent. The increased income levels can be attributed to the rise in irrigated areas and yield levels among NICRA beneficiaries, resulting from the implementation of climate-resilient technologies, Kumar and Aggarwal (2013).

The higher diversification can be attributed to increased awareness of NICRA farmers on the protection offered by multiplicity of crops, in case any mishap occurs. Crop diversification was ranked four after ranking of various adaptation technologies in Indian agriculture based

on importance, urgency of action, no regret character, co-benefit, mitigation potential and economic benefit (Pathak et al. 2012). More diverse agro ecosystems with a broader range of traits and functions will be better able to perform under changing environmental conditions (Matson et al. 1997, Altieri 1999), which is important given the expected changes to biotic and abiotic conditions (Lin 2011). Crop diversity is critical not only in terms of production but also because it is an important determinant of the total biodiversity in the system (Matson et al. 1997).

Impact of CRTs on household income and savings

Table 6: Impact of CRTs on household income and savings

Sr. No.	Name of KVK	Mean household income (₹)		Mean household savings (₹)	
		Before NICRA	After NICRA	Before NICRA	After NICRA
1	Alaphuza	126913	184471*	105889	166684*
2	Srikakulam	125297	180241*	105889	166684*
3	Bhatapara	183933	374242*	11437	128998*
4	Coochbehar	71049	163252*	14047	100176*
5	Dhubri	86725	118500*	13097	20455*
6	East sikkim	95404	148706*	19186	45402*
7	Godda	85262	191979*	37302	114012*
8	Jalna	157473	418236*	42875	196500*
9	Jhabua	165139	288506*	53982	116742*
10	Jhunjhunu	148725	289750*	38812	117150*
11	Tikamgarh	287870	788877*	225838	639562*
12	Tumkur	51168	214241*	36548	153488*

*Significant at $P < 0.01$ and **Significant at $P < 0.05$

(a) Annual income

From the, table 6, it can be seen that, maximum annual income of 318.70 percent change was obtained in Tumkur district and minimum was in 36.63 per cent in Dhubri . The difference was statistically significant at less than five per cent level of significance which was tested using paired t-test. In Tumkur, maximum income was obtained due to additional area for agriculture and extending cultivation to new seasons due to adoption of resilient crop varieties and water management practices. Schrooten and Stephan (2005) reported that saving is positively influenced by per capita income. So, the findings can be positively attributed to an increased income coming from climate resilient farms.

(b) Annual saving

Table 6, revealed that the maximum annual savings, with a percentage change of 1027.90 per cent, was observed in the Bhatapra, while the minimum change of 56.18 per cent was recorded in the Dhubri. These savings were positively influenced following expenditures on various household items, education, and healthcare, at two distinct points in time. A paired t-test conducted on household income and savings before and after the implementation of the NICRA project in adopted villages indicated a significant increase in both parameters across all KVKs and vulnerability categories, underscoring the tangible impact of the CRTs in enhancing household-level quality of life. The study conducted by Ismail and Tendot (2012), implies that a majority of household expenditures are allocated to rental and loan payments and healthcare expenses when there is an increase in income

Household level Impact of CRTs related to mechanization

Table 7: Household level Impact of CRTs related to mechanization

Sr. No.	Name of the KVK	Man, hours saved in an year before NICRA	Man, hours saved in an year after NICRA
1	Alleppey	0.28	16.11*
2	Banaskantha	2.69	8.56*
3	Coochbehar	13.20	21.60*
4	Datia	25.85	34.61
5	Dubri	12.25	25.07*
6	East Sikkim	5.55	11.00*
7	Gonda	35.15	42.87*
8	Jalna	12.75	12.82
9	Jhabua	158.75	266.75*
10	Khammam	40.72	47.87*
11	Kullu	150.01	700.03*
12	Namakkal	3.85	12.39*

*Significant at P < 0.01 and **Significant at P < 0.05

Table 7, revealed that the maximum man hours saved, with a percentage change of 98.26 per cent, was observed in the Allppey , while the minimum percentage of 0.58 per cent was recorded in the Jalna . In Allppey, the primary technique contributing to the significant man hours saved was the use of the drum seeder for rice planting. This method allowed farmers to save considerably more man hours compared to the traditional manual planting method. Additionally, the adoption of drum seeding resulted in an average yield increase ranging from 9 per cent to 29 per cent, along with a benefit-cost ratio ranging from 1.9 to 2.9, when compared to the current practice of transplanting. These findings suggest that there is considerable potential for the wider adoption of drum seeding techniques in these states, especially under the National Mission on Sustainable Agriculture (Prasad et al. 2014).

CONCLUSION

The implementation of Climate Resilient Technologies (CRTs) across 30 NICRA KVKs has demonstrated significant impact in sustaining farm-level productivity and income during climate stress years. The resilience indicator (R) effectively quantified the avoided losses, with values ranging up to 0.98 in productivity and 0.89 in income. NRM and crop-based interventions showed promising results across diverse agro-ecological zones. CRTs also enhanced household income across agriculture, horticulture, and livestock sectors, with remarkable gains observed in Godda, Lunglei, and Tikamgarh. Mechanization interventions significantly saved labor time while improving yield efficiency. Increased household savings post-intervention confirmed CRTs’ role in improving rural livelihoods. Overall, CRTs have proven effective in building resilience, resource use efficiency, and adaptive capacity at both farm and household levels.

RECOMMENDATIONS

- (1) Area under diversified crops, contingency crop varieties, abiotic stress tolerant, short duration varieties identified through the project can be scaled up through inclusion in local seed chains and through participatory seed production (development of seed villages).
- (2) The impact of ex-situ water harvesting and efficient use, in-situ moisture conservation measures, resource conserving planting and irrigation methods can be scaled up through ongoing government schemes like MGNREGA, watershed projects and DPAP.

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CONFLICT OF INTEREST

All authors declare that they have no conflict of interest

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