

Statistical Evidence on the Adoption of Climate Smart Agriculture Across Diverse Farming Systems

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Abstract – The study focuses on the determinants of CRATs (Climate-Resilient Agricultural Technologies) adoption in 7 ecologically diverse districts, namely, Munger, Nalanda, Nawada, Katihar, Purnea, Vaishali, and Samastipur. A stratified random sample study was able to find distinctions between small, marginal and medium sized farmers of rice-based and mixed cropping. Data on technologies such as zero/minimum tillage, crop diversification, timely sowing, crop calendar, site-specific nutrient control, laser land leveling, direct-seeded rice, and climate-resilient varieties was collected using surveys, interviews and field observations. The socio-economic and environmental variables on the adoption were measured using logistic regression, correlation analysis, and descriptive statistics. Results have shown that CRV/CSV was adopted the most with DSR and LLL becoming the least adopted initiatives. The favorable effects on adoption were observed with education, climate awareness, landholding size, residue management and investment although most of the effects were not significant.

Keywords – Climate-Resilient Agricultural Technologies, Direct Seeded Rice, Climate-Smart Varieties, Laser Land Levelling, Zero Tillage, Logistic Regression, Adoption Determinants, Smallholder Farmers, Mixed Cropping Systems, Agricultural Innovation.

I. INTRODUCTION

By 2050, an estimated 2.4 billion people are projected to live in emerging nations, mostly in sub-Saharan Africa and South Asia. In these areas, agriculture is a fundamental source of employment and economic driver. Nevertheless, over 20% of the population experiences food uncertainty on average. Approximately 75% of the global impoverished population resides in rural regions, with agriculture serving as their major income source. Boosting agricultural incomes and productivity within the small-holder industry is fundamental for attaining food security and alleviating poverty, serving as a fundamental component and catalyst for economic change and progress, within the wider framework of modernization and the growth of the non-farm sector.

It is projected by worldwide communities that agricultural production will have to increase by 60 percent by the year 2050 in order to meet the increasing demand and most of this increase will require increased productivity [1]. The agricultural growth is already suffering due to climate change. The IPCC (Intergovernmental Panel on Climate Change) also point to the fact that climate change has negative impacts on food production in most places in the world and the negative effects are more prevalent than the positive, especially in poor countries which are more vulnerable to other adverse effects of climate change. The frequency and intensity of the negative events such as high maximum temperatures, floods, heavy rainfalls and droughts are increasing and are expected to escalate in various locations. Seasonal and average high temperatures are anticipated to continue in their cycle, integrated with an overall rise in average precipitation.

These impacts will not be uniformly distributed. The scarcity of water in urban areas and drought in arid areas is expected to escalate by the century's conclusion. The idea of Climate-Smart Agriculture (CSA) is increasingly gaining prominence in agricultural planning to address the difficulties caused by climate change at both international and national levels. Farmers' inclination towards CSA technology and uses differs based on socio-economic attributes and precipitation zones.

- “CSA is a methodology that directs essential measures to reform and reorganize agricultural frameworks to adequately facilitate growth in climate and guarantee food security” [2].
- “CSA is a unified management strategy, which mitigates interrelated climate change and food security challenges, encompassing fisheries, forests, livestock, croplands, and landscapes” [3].
- CSA denotes an amalgamation of methodologies used in agriculture, climate change, conservation, and historical environmental ecology.

Therefore, when above mentioned criteria are evaluated together, it emerges that CSA may be identified as a method that directs the essential measures to raise the production of crops and preserve food privacy to adapt to a shift in climatic circumstances [4].

In recent years, CSA has been recognized as a distinctive possibility to concurrently attain food security and objectives related to climate change mitigation and adaptation. The notion is under investigation, however several agricultural methods supporting CSA have been documented and evaluated. Over the last 8 years, the CGIAR Research Program on CCAFS (climate change, agriculture and food security) has been tackling the necessity for validated and efficient CSA alternatives via its CSV (climate-smart village) methodology.

The CSV method allows significant research on agricultural practices and technology to identify their ability to deliver on the food security, mitigation, and adaptation objectives of CSA. The CSV strategy, which is based on the principles of participatory action research, also allows farmers to select practices and technology that best fit their local needs, and extracting insights on the agricultural practices and technologies in order to make policy decisions at both the global and local levels [5].

We are seeking to discuss the institutional, socio-economic, and environmental conditions that affect the application of climate-resilient agricultural initiatives in the heterogeneous agro-ecological regions. In particular, the research will measure the behavior of farmers in terms of adoption with descriptive, correlational and logistic regression analysis, to determine key drivers and limitations that determine technology adoption in vulnerable farming systems to climate.

The remainder of this study has been segmented as follows: Section II provides the background analysis of climate-resilient farming technologies. This adoption behavior of these technologies, as well as a critical definition of technology diffusion have been described in Section III. Section IV describes (i) field of study and sample, (ii) data collection methods, and (iii) statistical models’ analysis, which were utilized in this research. Section V will provide a detailed description of the findings that combine factors that affect the adoption of ZTMT, LLL, and CRV. Lastly, Section VI concludes the study highlighting the critical aspects determining the application of agro-technologies.

II. CLIMATE-RESILIENT AGRICULTURAL TECHNOLOGIES

Mba and Ogonnaya [6] concentrate their research on Climate-Resilient Varietal Selection (CRVS) technology. The creation and recognition of climate-resilient cultivars with enhanced tolerance to cold, floods, drought, heat, and salt stressors are crucial for sustaining and enhancing agricultural products while addressing the difficulties caused change in climate. Enhancing the productivity and profitability of the farming community is crucial for avoiding agricultural risks and enhancing the lifestyles of individuals reliant on agriculture. Abiotic stressors, including cold, heat, or drought may elicit a number of reactions in plants, including alterations in gene expression, signal transduction routes, and molecular/metabolic processes, along with cumulative effects on source and sink relationships for adaptation. The principal biotic and abiotic stressors constraining agricultural yield are shown in the following image. Drought, heat, salt, cold, and floods are significant abiotic stressors that negatively impact plant development and production.



A) After Harvesting Rice.



B) Potato Seeds Covered with Manure and Mulch of Rice Straw.

Fig 1. On-Farm Demonstration Potato Growing, Patna District, Bihar, India.

Yang and Huang [7] assert the need to stimulate, enable, and extend PZTM throughout Asia via collaboration with NGOs, research institutions, the commercial sector, and governmental bodies. These initiatives must take into account four essential factors to attain agronomic improvement. Upon obtaining accessibility to clean seeds of suitable genotypes (salt-tolerant and precocious), smallholder agriculturalists will require straightforward methods to adopt PZTM initiative. This

aspect is fundamental to the new agriculturalists in potato farming. Audiovisual materials created by farmers (so-called community videos) could be used as a good tool in sharing the PZTM.

Rahman and Routray [8] have highlighted how this technology has affected the involvement of the women, which is made easy due to the reduction in labour (removal of ploughing, digging or digging; see Fig. 1). In addition, visual data, language and inclusion of female images in the training material can be augmented, thus increasing the participation of women. Finally, in order to prepare the future carbonated market and recompences sufficiently, it is essential to analyze the reduction in the carbon footprint attained through the implementation of PZTM relative to conventional tillage. Simple and easy to use calculators such as CFT (Cool Farm Tool) [9] and CCAFS-MOT [10] can be used to calculate carbon footprints and prove to be effective in potato farming.

The concept of zero-tillage is introduced by Friedrich [11]. Zero-tillage refers to agricultural practices that limit soil disturbance to solely sowing operations and vehicular traffic, necessitating chemical methods for weed control. Zero-tillage has shown to be beneficial in maize cultivation on sloped, structurally unstable soils, in double cropping systems including cereal and feed crops, and in pasture rehabilitation. It preserves agricultural remains on the soil surface and safeguards the earth against water and wind erosion. Zero-tillage results in increased moisture levels in the upper soil layer, diminished soil aeration, enhanced mechanical resistance to root penetration, decreased temperature fluctuations within the soil, and altered nutrient distribution patterns across the soil profile.

Singh et al. [12] defined DSR (direct-seeded rice) as an approach of cultivating rice by directly spreading seeds in the field instead of seedling relocation. Direct seeding is the most ancient way of rice cultivation used by humans for centuries, although it has been progressively supplanted by puddled transplanting for several causes. Numerous Asian nations, including as Philippines, Cambodia, Thailand, Sri Lanka, Vietnam, and Malaysia, have engaged in direct seeding activities for years. India has used DSR for an extended period and has progressively escalated over the past few years. Indian states characterized by predicted variable soil moisture and rainfall distribution constraints, such as eastern Uttar Pradesh, Karnataka, Odisha, part of Bihar, Chhattisgarh, Jharkhand, and Tamil Nadu, have significant DSR agriculture potential.

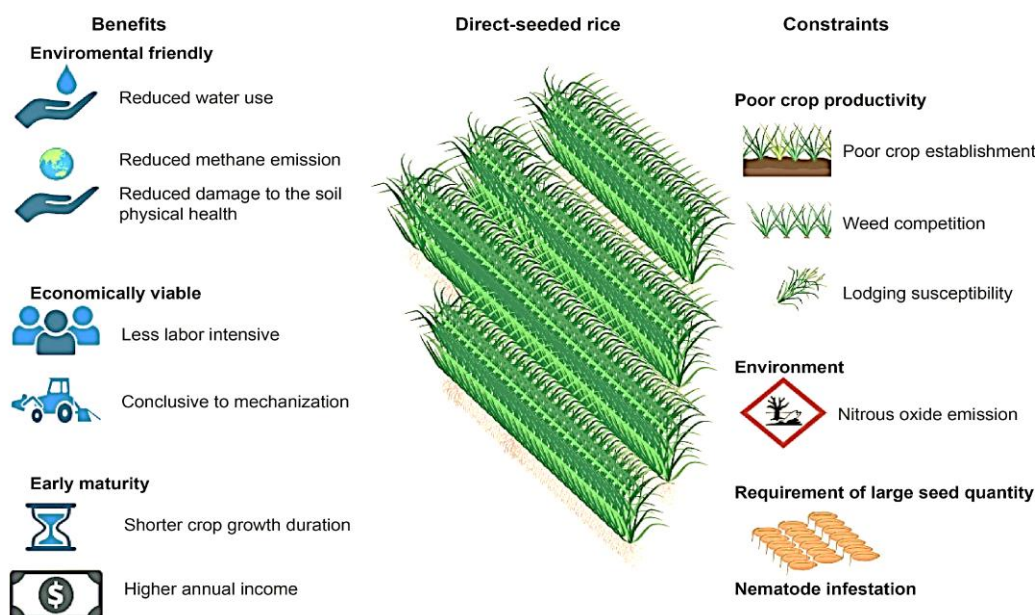


Fig 2. Important Advantages and Limitations of Direct-Seeded Rice Technology.

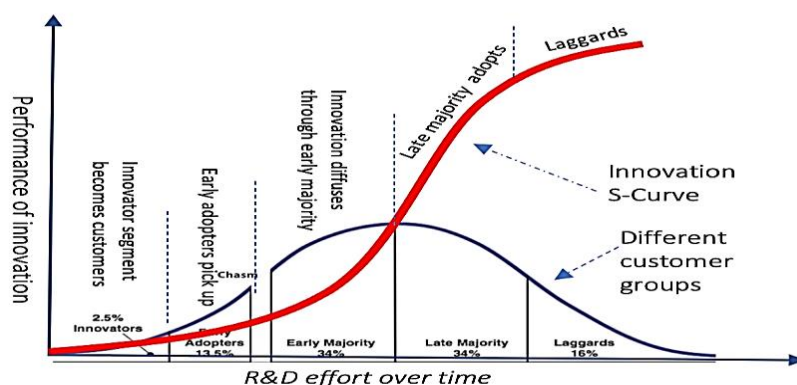


Fig 3. S-Shaped Acceptance Curve for Innovations.

DSR has lately been endorsed as the primary environmentally sustainable rice farming technology by several international and national organizations involved in climate mitigation strategies and standards. It indicates a favorable tendency to decrease reliance on labor and water in rice farming (see **Fig. 2**).

III. ADOPTION BEHAVIOR AND TECHNOLOGY DIFFUSION

Various forms of innovation are inherent in several processes associated with agricultural operations [13]. These include both the implementation of conventional improvements and intricate technological advancements. Numerous innovations impact various sectors and sub-sectors of the value chain essential for agricultural development, including the adoption of agricultural technologies and inputs, as well as structural innovations like new organizational and cooperative models. Diffusion and acceptance of inventions are often used in conjunction, despite being distinct ideas. Diffusion of innovations is the procedure by which an invention is disseminated via certain systems over a designated period among the constituents of a social framework.

Hameed, Counsell, and Swift [14] elucidates the adoption behavior of individuals and organizations about innovation. It examines the method by which knowledge on new technology is distributed to members of a community or social system via particular channels throughout time.

The idea delineates this process by identifying numerous phases that an individual must traverse prior to the adoption of a revolutionary technology. The steps included are “understanding, persuasion, decision, implementation, and confirmation.” Kucharavy and De Guio [15] has delineated an S-shaped curve for the adoption of innovation in this process. According to Martinez, Polo, and Flavián [16], this procedure also enables the adopters to be subdivided into 5 clusters: “laggards, late majority, early majority, early adopters, and innovators.” **Fig. 3** illustrates the S-shaped curve.

The origins of the contemporary idea of diffusion of innovations are traced to studies mostly conducted in American rural sociology from the 1940s to the 1970s. The scientific study domain of innovation diffusion, particularly in rural regions and agriculture, became a primary focus of early American rural sociology, evolving to address practical requirements. Sociological study on the dissemination of innovation mostly originated from anthropology, owing to its qualitative technique. Nonetheless, as Greenhalgh et al. [17], the establishment of the paradigm was contingent upon the rural sociology tradition, which exhibits the greatest involvement rate in diffusion of innovations research.

Kosarek, Garcia, and Morris [18] identify the seminal research conducted by Asprooth, Norton, and Galt [19] on the transmission of hybrid maize among North American farmers as a pivotal study in the field of innovation diffusion. This research resulted in the formation of a “research paradigm” in the examination of innovation dissemination, particularly in the United States. Prins, Verhoef, and Franses [20] presents empirical data indicating that the timing of adoption within a specific sample allows for the categorization of adoption patterns, resulting in a cumulative curve that exhibits the well-known S-shape, while the analysis of adoption frequency reveals a bell-shaped curve.

IV. MATERIALS AND METHODS

Study Field and Sample

Our research was conducted in 7 locations: Munger, Nalanda, Nawada, Katihar, Purnea, Vaishali, and Samastipur, which are all agricultural areas in the region with different types of ecosystems (see **Fig. 4**). The soil texture, water availability in these districts, frequency of flood and drought, and intensity of cropping in these districts vary, and thus, they are suitable to the analysis of various adoption patterns of CRATs. We have used a stratified random sample technique to ensure that there is representation of small, marginal, and medium-scale farmers. The key sample respondents were rice and other crop farmers. The sampling technique ensured that the adoption behavior with regard to different socio-economic groups was objectively and statistically assessed.

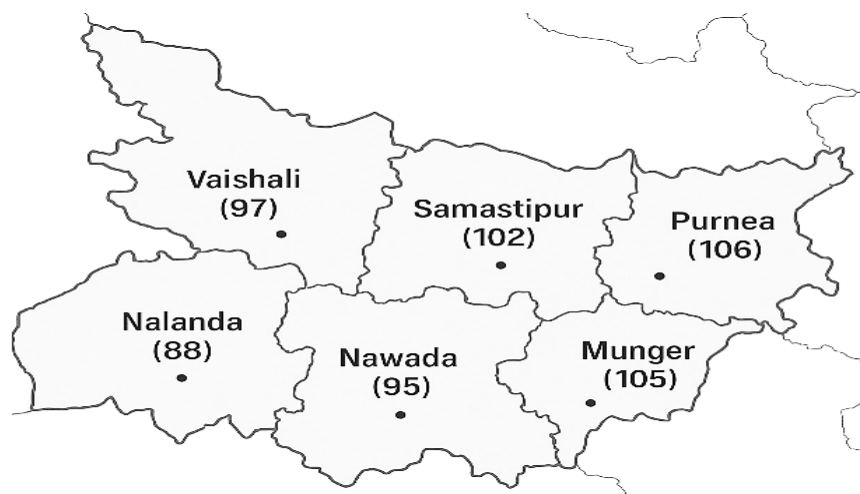


Fig 4. Map Showing the Area of Study and Sample Distribution.

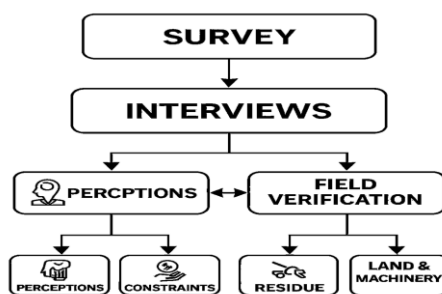


Fig 5. Data Collection Framework.

Data Collection Procedures

The mode of data collection was of a mixed method involving structured surveys, semi structured interviews with the farmers, and direct field observations (see Fig. 5). The survey tool gathered information about the climate change awareness, understanding of the soil health, land features, the availability of machinery, availability of inputs, and application of the technologies, including ZTMT (zero tillage/minimum tillage), LLL (laser land leveling), CRV/CSV (climate-resilient varieties), DSR (direct seeded rice), SSNM (site-specific nutrient management), CCTS (crop calendar and timely sowing), CD (crop diversification). Interviews provided additional information to what farmers believed concerning the risk of low yield, the issues of making investments, issues of handling residues, and the assistance received by institutions. The data to support the self-reported data was based on field observations, to verify actual on-farm practices, to assess residue management practices, and to document the physical condition of land and equipment.

Statistical Analysis Techniques

Descriptive statistics, correlation analysis, and logistic regression model were used to examine the dynamics of CRAT uptake as part of the investigation (see Fig. 6). We used descriptive statistics to define the demographical traits, level of awareness, landholdings and frequency of adoption of the research sites. Correlation matrices were developed to identify initial relationships among social, economic and environmental factors. Then, the probability of each CRAT adoption under the influence of significant aspects such as awareness, land features, initial investment needs, access to extension services, and distance to agricultural institutions was estimated with the help of logistic regression models. We applied pseudo-R² values, regression coefficients, and level of significant to determine the effectiveness of the model. All the statistical calculations were performed with the help of standard tools that were supposed to ensure that the results were correct and replicable.

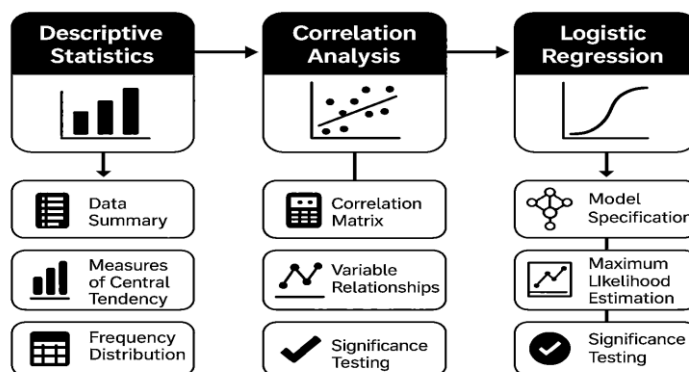


Fig 6. Statistical Analysis Workflow.

V. RESULTS AND ANALYSIS

Fig. 7 indicates that the data percentages for different CRATs were biased against users. CRVS is used by 18% of the population, making it the most prevalent strategy. LLL is at 5%, while DSR is at 5.5%. Merely 4.5% of individuals use CD, while an equivalent 4.5 percent implement CCTS. SSNM and Zero tillage had the least adoption rates at 2% and 2.5%, correspondingly. Fig. 7 illustrates that among the climate-resilient agricultural practices, Climate Resilient Variety (CRVS/CSV) was the most prevalent at 43%, followed by DSR at 13%, and Low-Land Legumes (LLL) at 12%. Eleven percent were classified as CCTS, whereas ten percent were categorized as CD. Despite SSNM exhibiting the least rate of adoption at approximately 5%, the overall sample has inherited behaviors associated with ZTMT at 6%.

Factors Influencing Adoption of ZTMT

Data indicated that the implementation of ZTMT provides several insights derived from logistic regression and correlation studies (see Tables 1-4). Descriptive data revealed modest closeness and awareness to essential farming organizations, with average values of 2.701 for soil fertility education, a distance of 29.312 km from KVKs, and 2.631 for CD. No characteristic

had a substantial link with the adoption of ZTMT, with the greatest correlations recorded at 0.301 for yield loss concerns. The other parameters, like average production of rice and wheat and non-agricultural sources of income, are not relevant to implementation of ZTMT methods. Regression logistic results confirmed the importance of yield losses fears with a 0.3 coefficient (where p is 0.488) revealing a significant but not significant connection with ZTMT implementation.

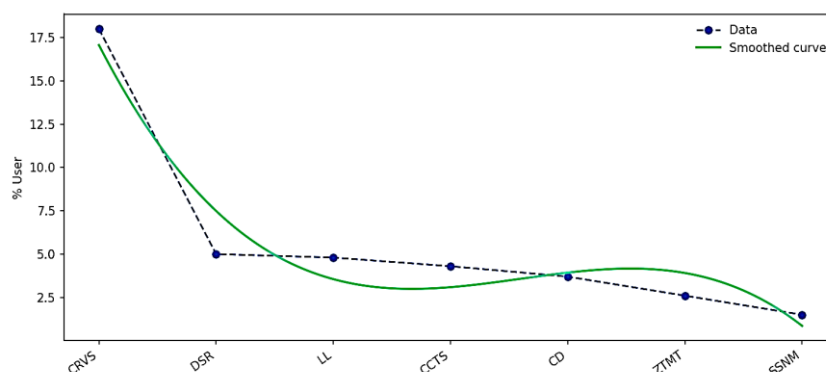


Fig 7. Seven Project Sites Adopting and Distributing Crats.

A major factor was the residue control, its coefficient (0.29) is 0.459 which means that the existence of residue (no animal feed was used or burned) may positively impact the application of ZTMT. Even though it was the main aspect, edaphic education had a coefficient of 0.365 (where p is 0.345) indicating its relevance in facilitating the adoption of ZTMT. The knowledge of global warming had a significant correlation with a 0.273 coefficient (where p is 0.471), however this finding lacked statistical significance. The analysis included the proximity to the KVKs, which exhibited a -0.168 non-significant coefficient (where p is 0.625), indicating that increased proximity may impede implementation. Promotional actions in fields (with a 0.217 coefficient, and a p value of 0.567) and instructions completed (with a 0.243 coefficient, and p value of 0.496) shown favorable although negative effects (see Fig. 9).

Various CRATs comprehension (with a p value of 0.526 and a 0.239 coefficient), initial ZTMT/LLL investment (with a p value of 0.575 and a 0.211 coefficient), reluctance because of elevated machinery costs (p value of 0.417, and 0.297 coefficient), and ZTMT device accessibility (p value of 0.393, and 0.323 coefficient) were additional elements affecting implementation, though statistically nonsignificant. The goodness-of-fit measure was 0.251, showing that the system accounted for approximately 25% of ZTMT adoption and its variations.

The system groups variable quantities into independent, mediating, and dependent variables. Such grouping offers an overall perspective on the interchange of a number of factors in CRATs implementation paths. The regression analysis highlights the direct effects whereas the grouping shows the great role of the intermediating factors, including technical knowledge, access to financing, labor supply, those that influence outcomes indirectly.

The role of these mediators is to facilitate or hinder the association of the independent variables (e.g., determinants of CRATs implementation) and the dependent variables (e.g., economic returns and productivity), and therefore influence the net effect. Notwithstanding the absence of significant numerical correlations, the positive dynamics in various parameters, especially the fear of control over residues and the decrease in yield provide certain opportunities of focused interferences in the future. Improvement of these parameters would lead to improved uptake of ZTMT. Fig 8 shows CRATs.

Table 1. Outcome Variables

Category	Variable	ZTMT	LL	CRV	CD	SSMN	CCTS	DSR
Outcome	% Shift out of Hunger	3.49 ± 1.20	3.49 ± 1.20	3.49 ± 1.20	3.49 ± 1.20	3.49 ± 1.20	3.49 ± 1.20	3.49 ± 1.20
Outcome	Income from Daily Plot Tasks (‘000 USD)	1200 ± 100	1200 ± 100	1200 ± 100	1200 ± 100	1200 ± 100	1200 ± 100	1200 ± 100
Outcome	Avg. Annual Income from Beans (‘000 USD)	2.00 ± 1.00	2.00 ± 1.00	2.00 ± 1.00	2.00 ± 1.00	2.00 ± 1.00	2.00 ± 1.00	2.00 ± 1.00
Outcome	Avg. Annual Productivity (tons/acre)	29.8 ± 4.4	29.8 ± 4.4	29.8 ± 4.4	29.8 ± 4.4	29.8 ± 4.4	29.8 ± 4.4	29.8 ± 4.4
Outcome	Avg. Plot Productivity (kg/m ²)	29.8 ± 4.4	29.8 ± 4.4	29.8 ± 4.4	29.8 ± 4.4	29.8 ± 4.4	29.8 ± 4.4	29.8 ± 4.4

Table 2. Facilitating Variables

Category	Variable	ZTMT	LL	CRV	CD	SSMN	CCTS	DSR
Facilitating	Technology Adoption (1–5)	3.1 ± 1.1	3.1 ± 1.1	3.1 ± 1.1	3.1 ± 1.1	3.1 ± 1.1	3.1 ± 1.1	3.1 ± 1.1
Facilitating	Risk Management Index (1–5)	3.0 ± 1.2	3.0 ± 1.2	3.0 ± 1.2	3.0 ± 1.2	3.0 ± 1.2	3.0 ± 1.2	3.0 ± 1.2
Facilitating	Climate Change Awareness (1–5)	3.2 ± 1.0	3.2 ± 1.0	3.2 ± 1.0	3.2 ± 1.0	3.2 ± 1.0	3.2 ± 1.0	3.2 ± 1.0

Table 3. Input Variables

Category	Variable	ZTMT	LL	CRV	CD	SSMN	CCTS	DSR
Input	Membership (yes)	2.8 ± 1.5	2.8 ± 1.5	2.8 ± 1.5	2.8 ± 1.5	2.8 ± 1.5	2.8 ± 1.5	2.8 ± 1.5
Input	Education (years)	4.8 ± 2.3	4.8 ± 2.3	4.8 ± 2.3	4.8 ± 2.3	4.8 ± 2.3	4.8 ± 2.3	4.8 ± 2.3
Input	Land Bearing (ha)	2.5 ± 1.3	2.5 ± 1.3	2.5 ± 1.3	2.5 ± 1.3	2.5 ± 1.3	2.5 ± 1.3	2.5 ± 1.3
Input	Age (years)	34.7 ± 9.8	34.7 ± 9.8	34.7 ± 9.8	34.7 ± 9.8	34.7 ± 9.8	34.7 ± 9.8	34.7 ± 9.8

Table 4. Results of Logistical Planning for CRAT Adoption

Variable	DSR coef (p)	CCTS coef (p)	SSMN coef (p)	CD coef (p)	CRV coef (p)	LL coef (p)	ZTMT coef (p)
Topography	–	–	–	–	–	-0.044 (0.004) *	–
Drainage Conditions	0.023 (0.006) *	–	–	–	–	–	–
Age	0.024 (0.007) *	–	–	–	–	–	–
Different CSA Practice Understanding	0.027 (0.007) *	–	–	–	–	–	–
Soil Test Awareness	–	–	–	–	–	–	–
Saving Time Without Additional Costs	–	0.034 (0.006) *	–	–	–	–	–
Social Availability	0.023 (0.004) *	–	0.028 (0.012) *	0.020 (0.004) *	–	–	–
Education	0.029 (0.003) *	–	–	–	–	0.037 (0.003) *	–
ZT Machine Availability	–	–	–	–	–	–	0.019 (0.001) *
Cost-Related Reluctance	–	–	–	–	–	–	-0.015 (0.003) *
Initial Investment on Zero Tillage TL.	–	–	–	0.016 (0.004) *	-0.022 (0.008) *	-0.027 (0.003) *	-0.010 (0.004) *
Training Received	–	0.026 (0.005) *	–	0.020 (0.003) *	0.020 (0.008) *	–	0.010 (0.005) *
Promotional Activities in the Village	–	0.027 (0.003) *	–	0.020 (0.004) *	0.020 (0.005) *	–	0.012 (0.004) *
Distance from KVK	–	–	–	–	–	–	-0.011 (0.004) *
CD	-0.0242 (0.004) *	-0.0271 (0.003) *	0.0270 (0.004) *	-0.015 (0.004) *	-0.030 (0.005) *	-0.020 (0.002) *	-0.011 (0.003) *
Soil/Edaphic Education	0.0231 (0.003) *	–	–	0.0221 (0.004) *	0.029 (0.005) *	–	0.021 (0.001) *
Residual control	–	–	–	–	–	–	0.013 (0.002) *
Yield Loss Fear	0.0201 (0.002) *	–	–	0.008 (0.002) *	–	–	0.006 (0.001) *

Determinants of LLL Adoption

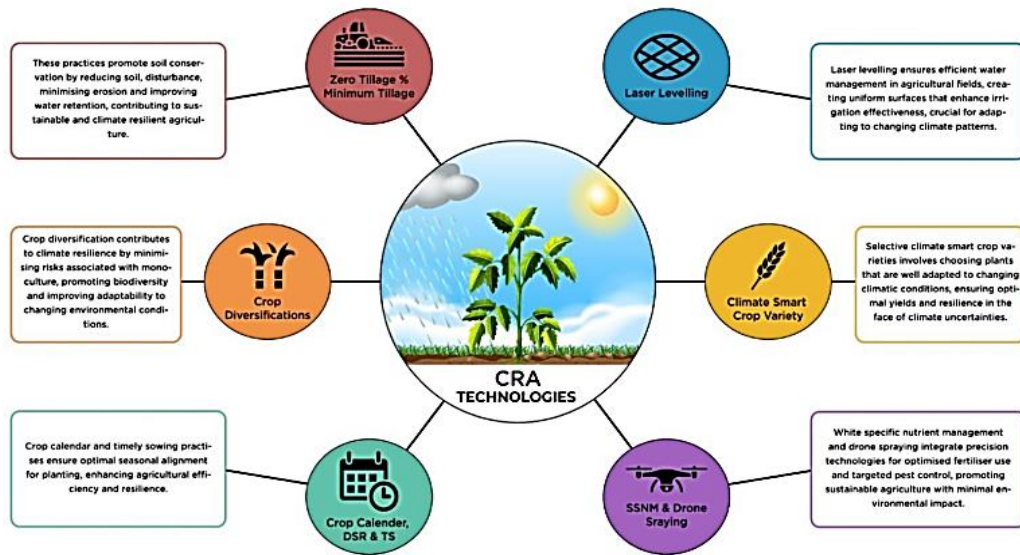


Fig 8. CRATs.



Fig 9. Zero Tilling Seed Drill.



Fig 10. LLL.



Fig 11. CRV.

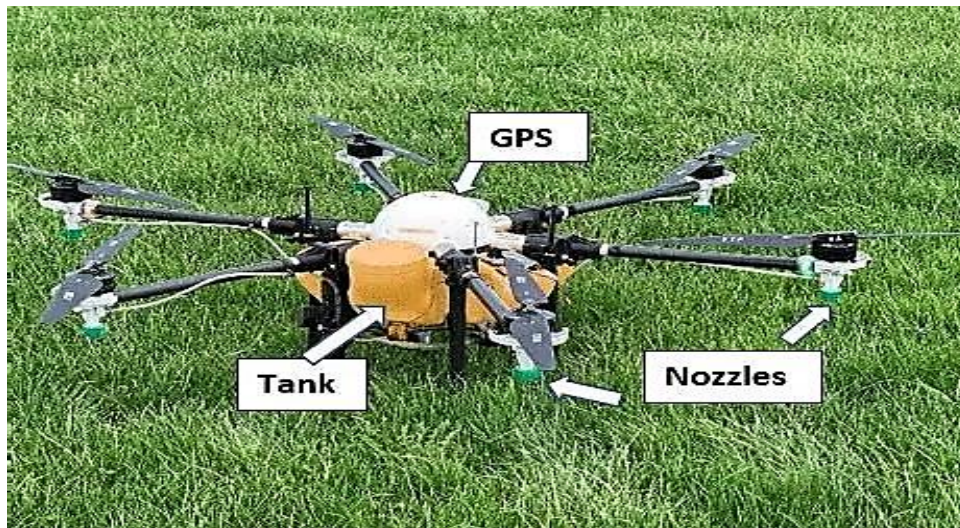


Fig 12. Application of Spray Drones.



Fig 13. Mass Interview and Farmer Meetings.



Fig 14. Crop Diversifications.



Fig 15. Greenseaker Application Under SSNM.



Fig 16. DSR Technology.

Descriptive statistics demonstrated that high start-up costs of LLL are a critical adoption problem, as high costs discourage many farmers. association studies showed that the Internet slight amount of Start-up Investments in LLL had the most considerable association with LLL adoption (see **Tables 1-4**). This was supported by the results of the logistic regression, as a 0.400 coefficient (where p is 0.253) showed a significant negative, but not significant connection with LL adoptions. The variable land bearing came out as a significant variable and the coefficient of land bearing was 0.350 (p value of 0.331) meaning that the agriculturalists with larger land bearings tend to pursue land leveling.

Drainage status had a strong impact on the result with a coefficient value of 0.300 (p value = 0.378) implying that agriculturalists whose soils are not fully exploited are leveling the land surface to improve the edaphic quality. The terrain especially the humpy topography had a value of 0.25 (where p is 0.449) which is positive but negative effect on implementation. The positive patterns were found in the Android use (0.200 coefficient and 0.519 p value) and soil adaptability to different farming models (p value of 0.548, and 0.180 coefficient) but were not significant. The nearness of the KVKs had a coefficient of -0.150 value (with a value of 0.605), indicating that the closer the support centers, the slower the process of implementation can be. The market distance, the number of cars and farmers' age were established to be having a trivial effect on LL adoption (**Fig. 10**, and **Fig. 17-23**).

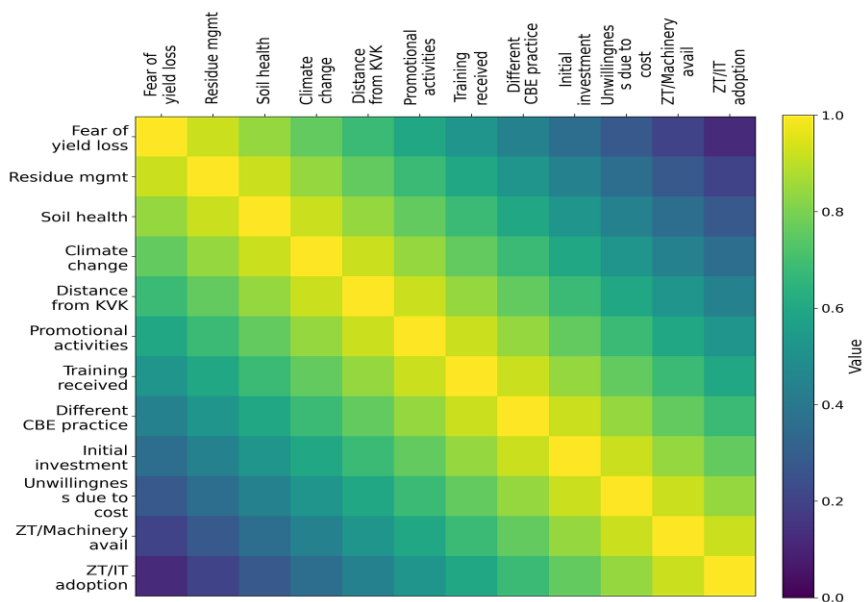


Fig 17. Variables Versus CRATs.

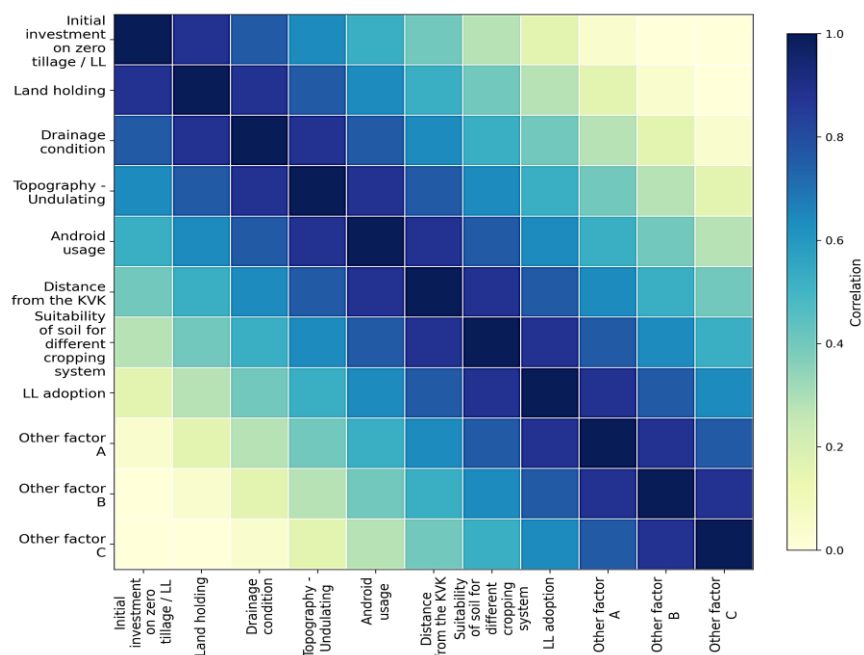


Fig 18. LLL.

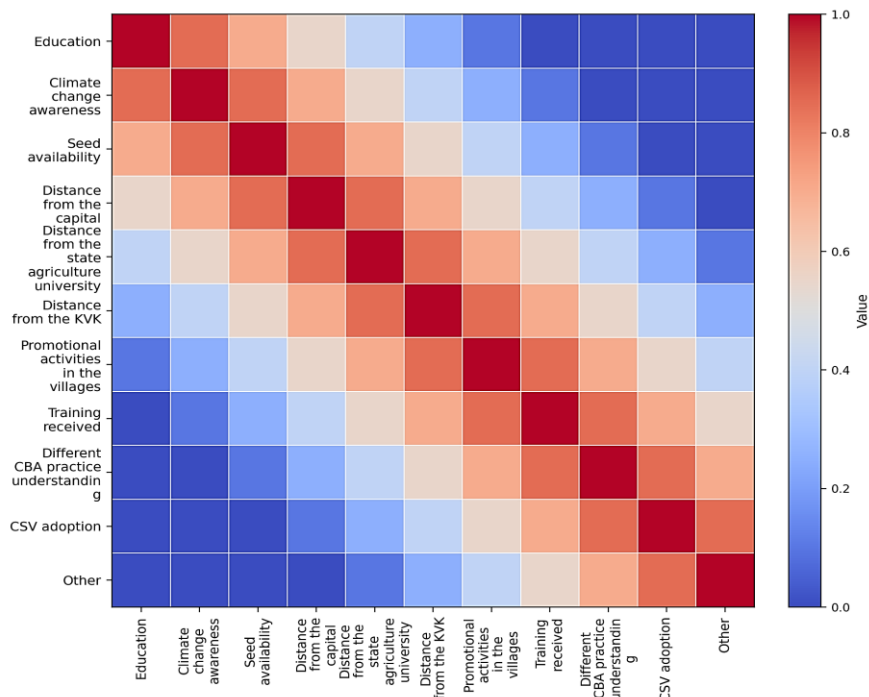


Fig 19. CSV.

Drivers of CRV Adoption

The descriptive statistics indicated that the most significant variables affecting the adoption were education levels, climate change education and the presence of seeds; the link research indicated that awareness and significance were the most important with CRV implementation. The regression outcome created the fact that it possessed a 0.500 coefficient (p value 0.095) that was a positive non-significant correlation with CRV adoption. The climate change education was one of the most significant predictors with a coefficient of 0.450 (p value of 0.147; Fig. 11, and Fig. 19) indicating that the education growth is positively associated to the CRV adoption. There was positive albeit statistically insignificant correlations between distance and both the capital (0.351 coefficient and a 0.29 p value) and the centralized/state agricultural schools (a 0.3 coefficient, and 0.38 p value). The distance to agricultural support centers may boost adoption, shown by a 0.250 significant coefficient (with a p value of 0.46) regarding the distance from KVKs.

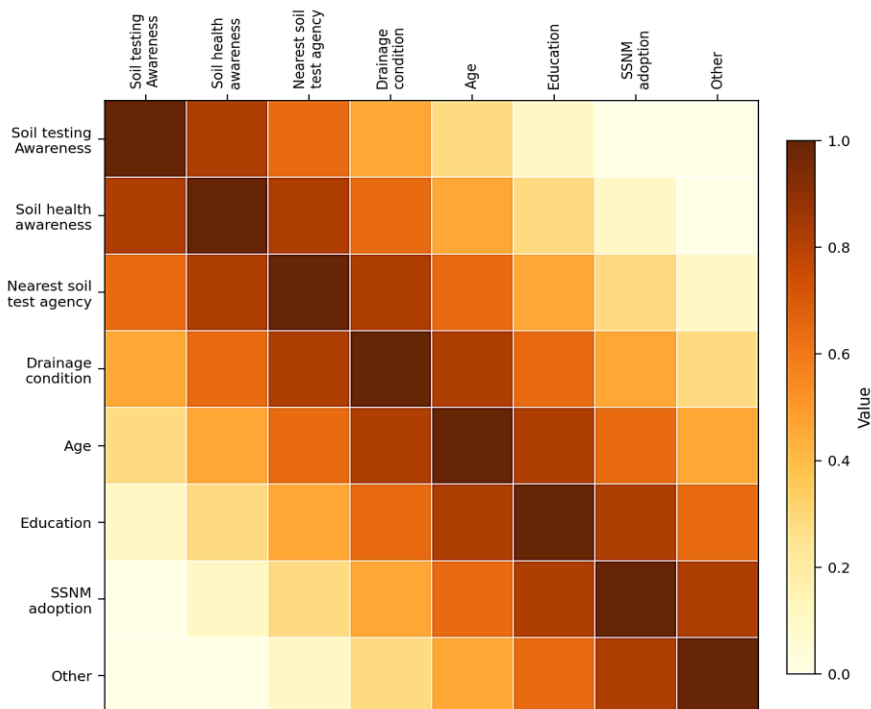


Fig 20. SSNM.

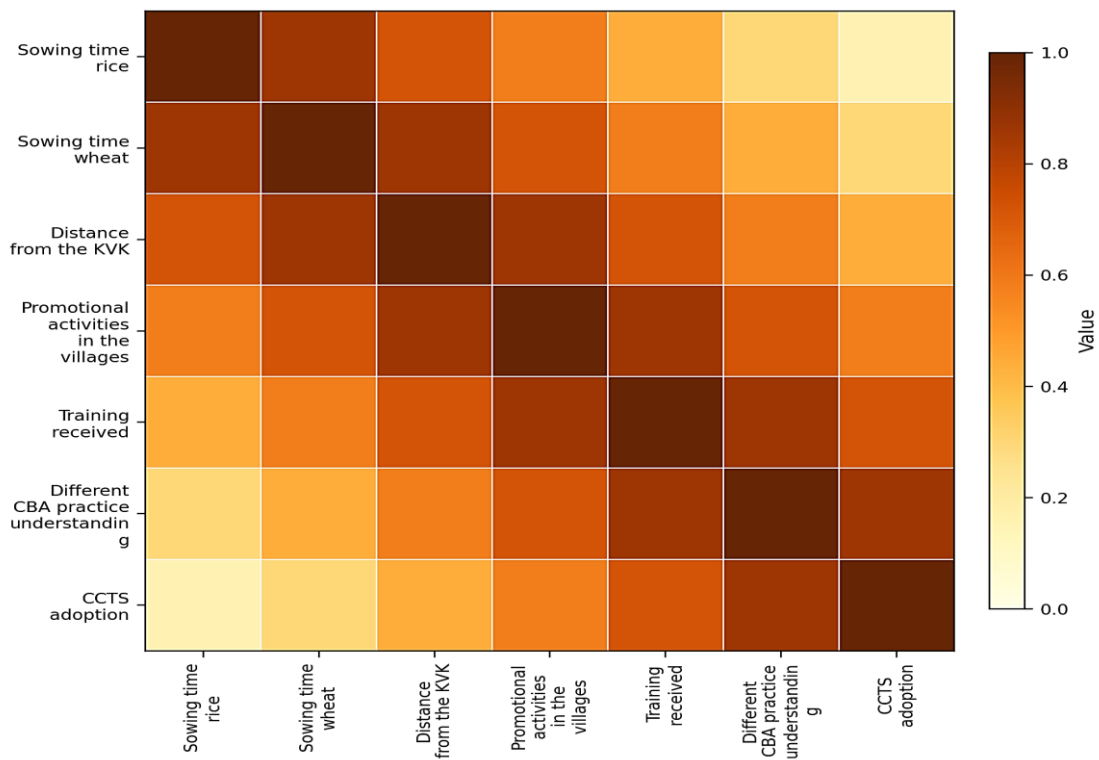


Fig 21. CCTS.

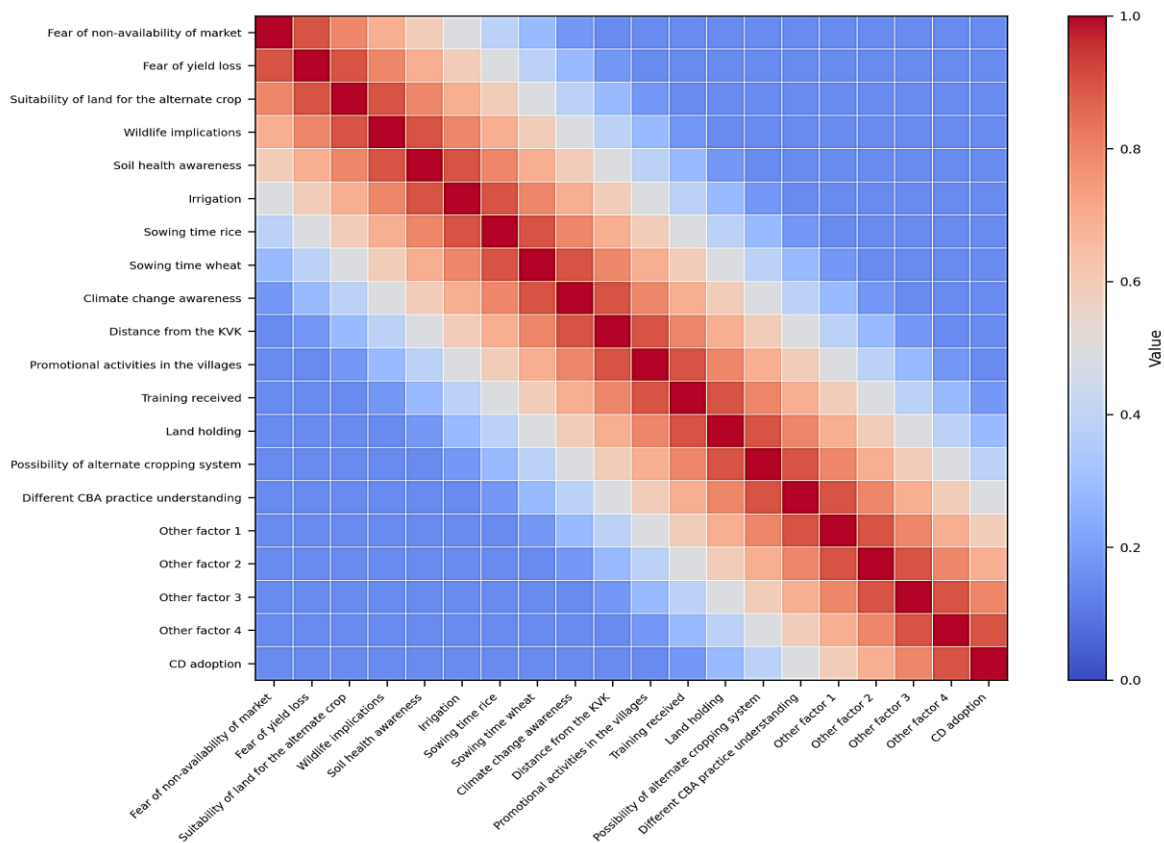


Fig 22. CD.

Village promotional activities and training had positive associations (0.202, $p = 0.578$ and 0.150, $p = 0.685$, respectively), although neither variable reached statistical significance. An understanding of various CRATs shown a

positive albeit statistically insignificant effect on CRV adoption (coefficient = 0.100, $p = 0.792$). A logistic regression model with a pseudo-R-squared value of 0.32 accounted for 32% of the variance in CRV uptake.

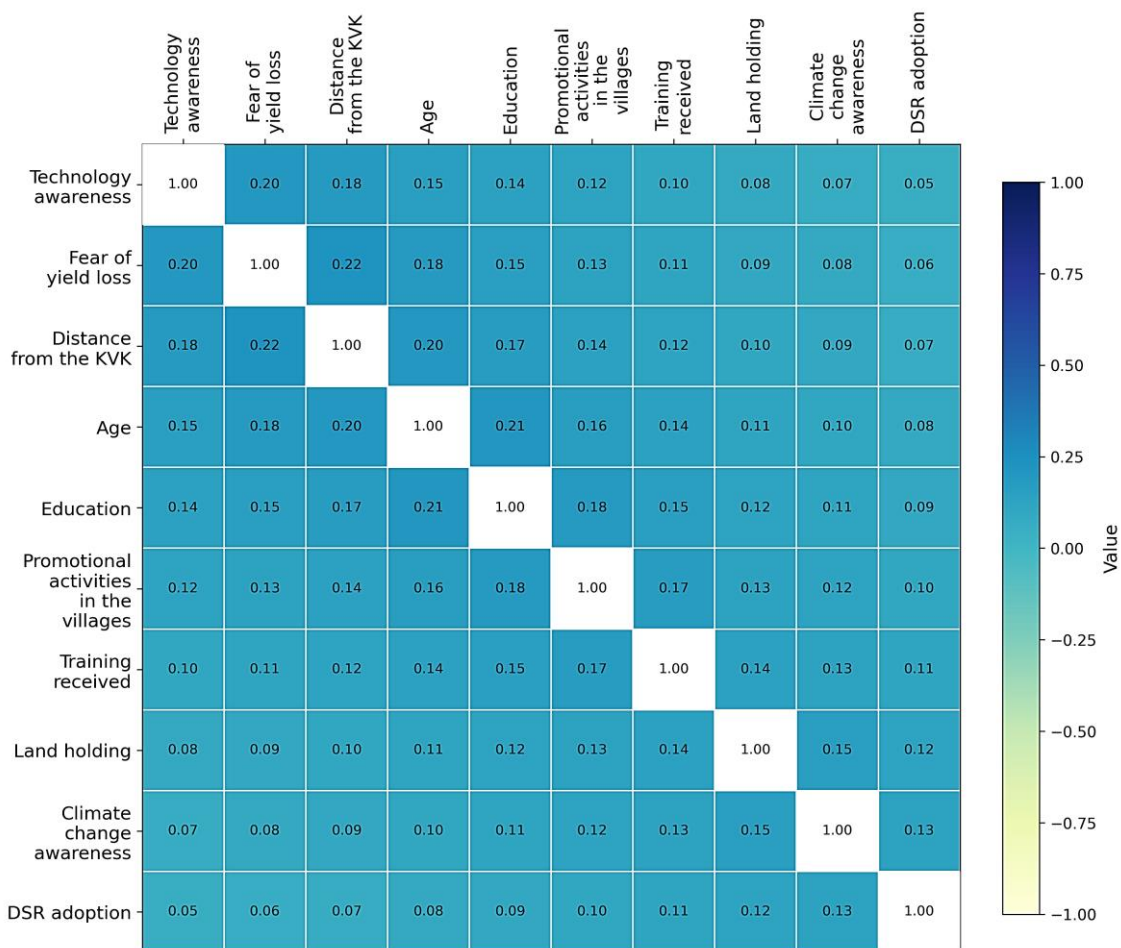


Fig 23. DSR.

VI. CONCLUSION

This study provides a comprehensive assessment of the factors determining the implementation of climate-resilient farming initiatives across seven diverse agricultural districts. Even though the general adoption rates have been high with most CRATs, the results indicate significant directional impacts of education, climate change awareness, landholding size, residue management, and initial investment requirements on adoption behavior. Although these factors were statistically insignificant in the logistic regression models, the general positive trends of the factors indicate its practical applicability in real-world decision-making among the smallholder farmers. The moderate pseudo-R² values suggest that implementation is affected by integration of direct and mediating elements (such as access to training, distance to agricultural universities or institutions, and availability of machinery) that collectively shape farmer decisions.

CRedit Author Statement

The author reviewed the results and approved the final version of the manuscript.

Data Availability

No data was used to support this study.

Conflicts of Interests

The authors declare no conflict of interest.

Funding

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Competing Interests

There are no competing interests.

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