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Determination of the Factors Influencing Adaptation Strategies of Tank-irrigated Farmers: Empirical Evidence from Tamil Nadu

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ABSTRACT

Background: Tank-irrigated farmers using tank irrigation systems are implementing adaptation strategies to enhance the sustainability of the agricultural ecosystem. In this particular context, The current research aims to thoroughly examine the various adaptation strategies employed by tank-irrigated cultivators, along with the crucial factors that impact the choice and execution of these strategies.

Methods: The data was gathered from 300 tank-irrigated cultivators using a multistage random sampling procedure in ten tank intensive districts' of Tamil Nadu. The Heckman two-stage procedure was employed to identify the factors affecting tank-irrigated cultivators adaptation decisions.

Result: This research found that 83.00 per cent of tank-irrigated cultivators are aware of climate change and 72.33 per cent of them have implemented adaptation strategies. Soil and water management practices (SWP), changing sowing dates and crop insurance were the popular adaptation methods of the tank-irrigated cultivators in the study locale. The model results indicate that adaptation strategies of tank-irrigated farmers are positively influenced by various variables, including age, gender, level of education, access to climate information, availability of credit and ownership of livestock. Moreover, variables such as age, level of education, number of contacts with extension agents and credit access exhibit a substantial and positive impact on the farmers' level of awareness.

Key words: Adaptation, Climate change, Heckman model, Tank irrigation.

INTRODUCTION

Climate change primarily affects crucial industries such as agriculture and its associated sectors, consequently impacting the food security needs (Muchuru and Nhamo, 2019; Senthil Kumar, 2022; Arivelarasan *et al*., 2023). With its tropical and subtropical climate and more than 50% of its population engaged in agriculture, India is projected to face significant repercussions from climate change (Malhi *et al*., 2021; Shukla *et al*., 2023). Additionally, it is estimated that the annual crop losses solely due to climate change have incurred a cost equivalent to approximately 0.25% of India's Gross Domestic Product (Singh, 2020). Adaptation plays a vital part in effectively reducing the negative consequences of climate change (Holland *et al*., 2017). Cultivators who implement adaptive measures to cope with changing climatic conditions are more likely to attain enhanced livelihood security (Gebre, 2023). It is imperative to comprehend the practices and determinants that influence farmers' choice of suitable adaptation measures in order to minimize their vulnerability to change in climate (Musafiri *et al*., 2021).

Droughts are common in the semi-arid areas of South India (Srivastava and Chinnasamy, 2021). In these regions, tank cascade systems are widely used communal resources crucial in providing irrigation (Narayanamoorthy *et al*., 2021). The first water bodies census in India reported a total of 43,837 irrigation tanks in Tamil Nadu (Ministry of Jal Shakti, 2023). Unfortunately, the effectiveness of these irrigation tanks has been declining due to changing climatic conditions. This decline is especially concerning for smallholder farmers and marginalized cultivators in the resource-constrained semi-arid areas of Tamil Nadu, as they heavily rely on these tanks for irrigation. Therefore, it is imperative for farmers in the region to implement adaptation strategies to sustain their agricultural activities

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and livelihoods. Several studies conducted in India (Banerjee, 2015; Jain *et al*., 2015; Dhanya and Ramachandran, 2015; Swami and Parthasarathy, 2020; Singh, 2020) have investigated the factors that affect farmers' adaptation strategies. Nevertheless, little research has been done to look at the determinants of adaptation methods specifically in tank-intensive regions, where farmers are particularly susceptible to climate vagaries. It is crucial to comprehend the adaptation decisions made by tank irrigated farmers in order to protect them through an appropriate policy framework. Against this background, this research aims to document the various adaptation measures utilized by tank irrigated cultivators and to analyze the factors that influence the adoption of these strategies among tank-irrigated cultivators in Tamil Nadu.

MATERIALS AND METHODS

Study locale

The state of Tamil Nadu is located with coordinates between 11.1271°N and 78.6569°E. The state experiences a tropical climate, with consistently high temperatures throughout the year, except during the monsoon season. However, it receives a substantial amount of annual rainfall, averaging 945 mm. One of the State's primary irrigation sources is tanks, which irrigates about 1.67 million hectares (m.ha) primarily supporting rice cultivation. There are an estimated 40,000 irrigation tanks in Tamil Nadu, mostly in the form of cascades.

Data and Sampling

The research work was conducted in Tamil Nadu state, India, with a specific focus on tank-irrigated areas. The study encompasses the entire state but excludes two agro-climatic zones, namely the High Rainfall Zone and the High Altitude and Hilly Zone, due to their extreme climate conditions (Fig 1). The study utilized a multi-stage random sampling method to select sample farmers. In the first stage, two districts were purposively chosen from each agro-climatic zone, specifically those with the highest variation in temperature and rainfall. In the second stage, blocks (administrative units in India) were selected, with the first two blocks in each district that had the largest tank irrigated area being included. The third stage involved the selection of tanks, with one non-system tank chosen in each block. Priority was given to tanks that were closest to an Automatic Weather Station (AWS). Finally, in the fourth stage, sample farmers were selected. Fifteen rice farmers, who all relied on the tank for their farming, were randomly chosen from each tank. Thus, a total of 300 tank farmers were surveyed using a scientifically designed pre-tested questionnaire for this study. The survey was conducted between December 2022 and January 2024.

Heckman's two-step procedure

The present study utilized the Heckman two-stage model, as the process of adapting to changing climatic conditions entails two stages, similar to the adoption of agricultural innovations (Asrat and Simane, 2018). The first step involved determining whether or not tank-irrigated cultivators were aware of the change in the climate. Whether farmers adapted to climatic change after becoming aware of it was the subject of the second stage (Maddison, 2006; Tripathi and Mishra, 2016). The first stage, referred to as the "selection" stage, was thought to be the sub-set of the second stage, known as the "outcome" stage. This implies that there is a bias in sample selection, as it is probable that the second stage sub-set, consisting of

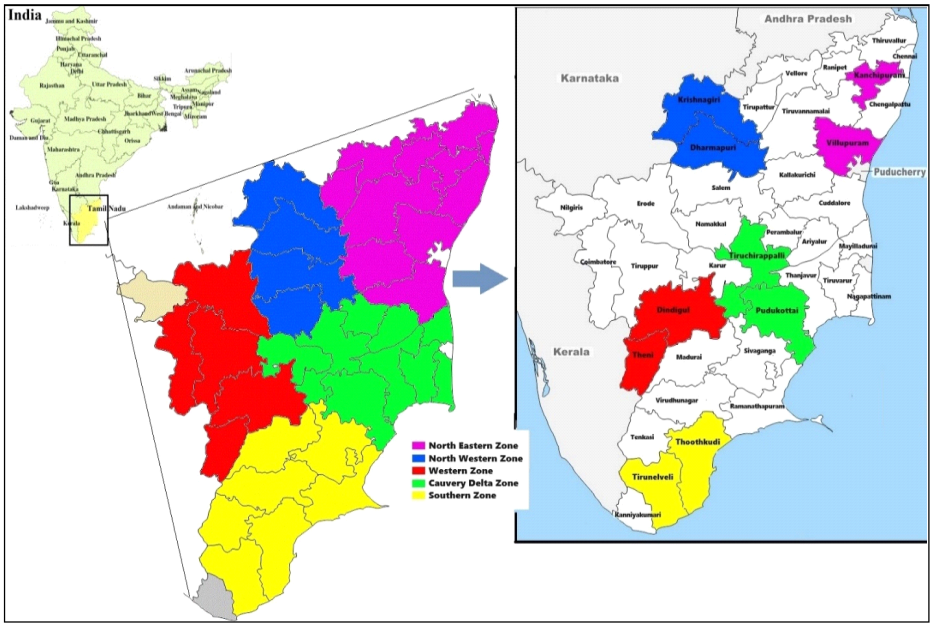


Fig 1: Study area.

individuals who reacted to the changing climate, is non-random and inherently distinct from the first-stage sub-sample, which consists of individuals who were unaware of climatic changes. Furthermore, alternative regression models, such as the nominal probit regression model, binomial logit model and binomial probit model, are inadequate in addressing selection bias appropriately. To mitigate this concern, Heckman's two-step procedure was utilized.

Heckman's two-step process depends on the notion that there is a deeper association, which is represented by the latent function:

$$Y^*_j = X_j\beta + U_{1j} \quad (1)$$

In the above equation, Y^*_j is the latent variable (the tendency of the tank-irrigated farmers to implement adaptation tactics against changing climate), X is a k-vector of explanatory variables, comprising various determinants assumed to affect the adaptation of tank-irrigated households, β is the coefficient or parameter coefficient and U_{1j} is the remainder term. As a result, only the binary result that the probit model predicted is seen as:

$$Y_j^{probit} = (y^*_j > 0) \quad (2)$$

The dependent variable is seen only if observation j is seen in the selection equation:

$$Y_j^{select} = (Z^{\delta}_j + U_{2j} > 0) \quad (3)$$
$$U_1 \sim N(0,1)$$
$$U_2 \sim N(0,1)$$
$$\text{corr}\,(U_1 \sim U_2) = \rho$$

In the equation above, Y_j^{select} represents the awareness of a tank-irrigated farmer regarding climatic changes, Z = An m vector of regressors, that comprise various factors assumed to influence awareness of tank irrigated farmers; δ is the parameter estimate, U_{2j} is an error term U_1 and U_2 are error terms. Thus, the first step of Heckman's two-step procedure is the selection model (equation 3), which constitute the awareness of climate change. The second step is the outcome model (equation 1), that represents whether the tank-irrigated farmer implemented adaptation strategies to the change in climate and depends upon awareness about climate change.

Standard probit techniques produce biased results when there is a correlation ($\rho \neq 0$) between the error terms from the selection and outcome equations (Asrat and Simane, 2018). As a result, for every parameter in such a model, the Heckman probit offers reliable and asymptotically efficient estimates. The variables considered in the study are described in Table 1.

RESULTS AND DISCUSSION

Socio-economic characteristics of the tank-irrigated farmers

A significant percentage of the farmers surveyed were middle-aged individuals, with an average age of approximately 46. The younger generation has shown a lack of interest in agriculture, increasing the average age of Indian farmers, which now stands at 50. It was found that 82.0% of households were headed by males, which can be attributed to the prevalence of patriarchal family structures in Southern India. On average, the families in the study had four members, ranging from two to eight. The tradition of joint families has disintegrated in the study

Table 1: Description of variables.

Variables	Description	Mean	S.D
Dependent variables			
Adaptation to climate change	Dummy variable: 1 if the tank-irrigated farmer has adapted to climatic changes and 0 otherwise	0.72	0.026
Awareness of climate change	Dummy variable: 1 if the tank-irrigated farmer had awareness about climate change and 0 otherwise	0.83	0.028
Independent variables			
Age	Continuous variable: The age of the tank-irrigated farmer in years.	46.69	11.73
Gender	Dummy variable: 1 if the tank irrigated farmer is male; 0 otherwise	0.82	0.385
Education	Continuous variable: Years of education of the household head utilizing tank irrigation.	8.97	3.463
Family size	Continuous variable: The number of family members in the household using tank irrigation.	4.33	0.789
Farm size	Continuous variable: Total landholding in hectares	0.948	0.725
Gross income	Continuous variable: Estimated annual income in Indian rupees (INR)	74380	37524.4
Extension contact	Continuous variable: The annual number of contacts with extension personnel	5.61	3.44
Access to Climate information	Dummy variable: 1 if the tank-irrigated farmer had access to climate information; 0 otherwise	0.76	0.026
Credit access	Dummy variable: 1 tank irrigated farmer had access to credit;0 otherwise	0.73	0.025
Livestock ownership	Dummy variable: tank irrigated farmer had ownership of livestock; 0 otherwise	0.75	11.73

*Based on the authors' compilation.

area due to villagers relocating to urban centers in search of better economic opportunities. The head of an average household has completed secondary school, while less than 1% of households have received a college education. Most of the sample farmers (96.67%) were small farmers, who owned land holdings between 1 and 2 hectares, practiced rice cultivation and had an average annual income of INR 74,380.

Adaptation strategies of the tank-irrigated farmers and their determinants

The analysis revealed that the vast majority of farmers (83.00 %) who utilized tank irrigation were aware of climatic changes and the remaining 17.00% were not aware of the change in climatic conditions. Tank-irrigated farmers who reported observing changes in climate were later questioned about their plans to adapt to changing climate conditions. It was found that 72.33% of the sample farmers have implemented numerous adaptation practices to mitigate the impacts of climatic changes. These practices are detailed in Table 2. These include Soil and water management practices, changing sowing dates, crop insurance, mixed farming, System of Rice Intensification (SRI), fallowing, off-farm employment and selling of assets (Fig 2).

The most commonly implemented adaptation measure to climatic variability was Soil and Water management practices (SWC), which was practiced by 72.33% of the sample farmers. The results align with the findings of Belay *et al*., (2022), who reported that one of the most commonly employed climate-smart agricultural practices by farmers was soil and water conservation techniques. In Tamil Nadu's semi-arid regions, farmers used water conservation techniques, according to Mohanraj *et al*. (2024).

Besides, one-third of the farmers (59.00%) adjusted their crop planting schedules strategically, taking into account the varying lengths of growing seasons, as well as the corresponding fluctuations in heat and moisture levels. Tripathi and Mishra (2016) and Bahinipati *et al*. (2021) have also reported that farmers commonly employ crop calendar changes as an adaptation strategy. It was discovered that 47.67% of farmers were enrolled in crop insurance schemes as an adaptation technique. This finding corroborates the earlier studies conducted by Madaki *et al*. (2023) and Jha and Gupta (2021). Mixed farming (41.00%) was another adaptation strategy of the Tank irrigated farmers. In line with this, previous study conducted by Marie *et al*. (2020) also proved that mixed farming was a prevalent practice.

Farmers have begun utilizing the System of Rice Intensification as a response to the exacerbated water crisis caused by climate change. This method not only conserves water, but also requires less financial investment while yielding higher crop outputs. Additionally, 25% of the sample farmers have implemented fallowing as an adaptation strategy, aligning with the earlier research conducted by Atube (2021). Since agriculture was becoming less profitable in the area, a small percentage of farmers (16.33%) started seeking employment in non-agricultural industries. Some farmers (11.67%) had to sell their assets (land, livestock and gold jewelry) to alleviate financial stress attributed to climate change. Farmers used their household assets to reduce climate-attributed vulnerability against cropping and maintain family expenses, which confirmed the research evidences of Aryal *et al*. (2021). Notably, 28.00% of the tank-irrigated farmers did not implement any adaptation measures to address the unpredictable nature of climate.

The Heckman procedure was utilized to analyse the determinants of adaptation measures to climatic change among tank-irrigated farmers. Consequently, the sample selection problem has been identified, which underscores the justification for employing the Heckman probit model. The rho value (Wald χ^2 =9.09, with P<0.001) was significantly different from zero. Heckman probit model's strong explanatory power was further demonstrated by its significant likelihood function (Wald χ^2 = 77.37, with P<0.001). The dependent variable in the selection model is binary, representing the extent of awareness about climate change among tank-irrigated farmers. The dependent variable in the outcome equation is also binary and represents whether a tank-irrigated farmer has implemented adaptation strategies. The selection model examines the variables that impact awareness levels regarding climate change, whereas the outcome model analyzes the variables that affect the adaptation strategies among tank-irrigated farmers (Table 3).

The findings obtained from the outcome stage that assesses the variables influencing farmers' decision-making regarding adaptation strategies have revealed that the majority of explanatory variables have had the anticipated impact on the probability of adaptation practices. It has been established that several factors, including age, gender, education, climate information, credit access and ownership of livestock, have a beneficial effect on adaptation.

The age of the sample farmers, which denotes their level of experience in farming, has been identified as a statistically significant explanatory variable. Numerous

Table 2: Adaptation strategies of tank irrigated farmers.

Adaptation	Number	Per cent
Soil and water management practices	217	72.33
Changing sowing dates	177	59.00
Crop insurance	143	47.67
Mixed farming	123	41.00
System of Rice Intensification(SRI)	88	29.33
Fallowing	75	25.00
Off-farm employment	49	16.33
Selling of assets	35	11.67

*Based on the authors' compilation.

studies have demonstrated that farmers with extensive experience are more inclined to conceive changes in climate. The likelihood of implementing adaptation strategies increases by 6.64 % with each additional year in the age of the sample farmer. The influence of gender on adaptation practices was highly significant. The findings also indicate that in cases where the household head is male, there is a 41% higher likelihood of implementing adaptation strategies. Empirical evidence indicates that women experience a disproportionate impact of adverse effects resulting from climate change in comparison to men. This observation aligns with the research findings of Adzawla (2019). This could be attributed to the existing gender inequality, which hampers women's access to education, training and information, thus impeding women cultivators' capacity to adapt to climate change.

The findings indicate that each additional year of education is expected to lead to a 7.66% rise in the implementation of adaptation measures. The significant relationship between education and adaptation practices has been supported by earlier research by Swami and Parthasarathy (2020) and Melkamu (2023). The findings show that the use of adaptation practices was significantly impacted by the readily accessible climate information. The marginal effects reveal that climate information enhances the likelihood of implementing adaptation

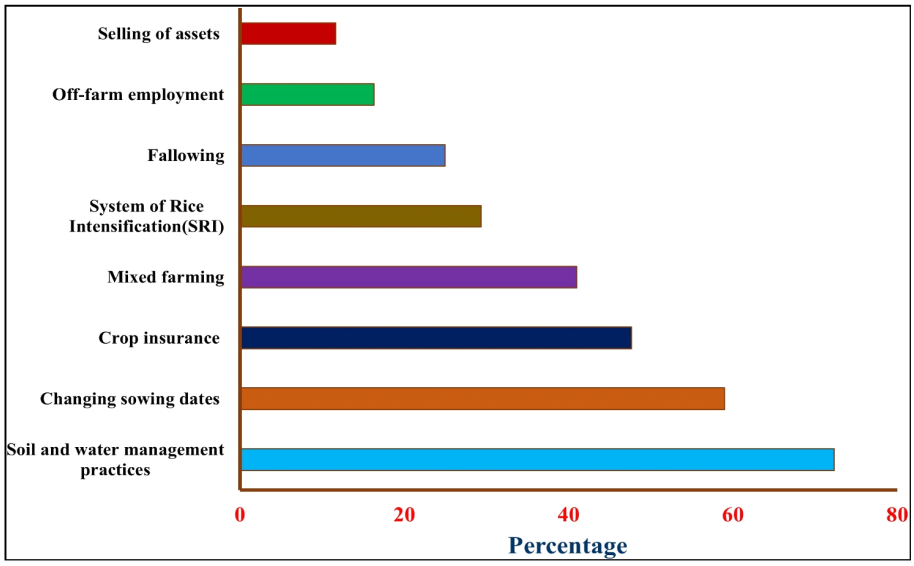


Fig 2: Level of adaption of climate change adaptation strategies among tank irrigated farmers.

Table 3: Results of the Heckman Probit Selection Model.

Explanatory variables	Outcome model				Selection model			
	Regression		Marginal values		Regression		Marginal values	
	Coefficient	Z value	Coefficient	Z value	Coefficient	Z value	Coefficient	Z value
Age	0.0033	3.158	0.0664	6.818	0.1371	3.948	0.0218	3.563
Gender	0.2265	2.429	0.4159	4.709				
Education	0.0085	2.938	0.0766	4.333	0.5037	3.336	0.0800	8.647
Family size	0.0170	1.404	0.0170	1.404				
Farm size	0.0235	0.480	-0.0588	-0.239	3.3991	0.000	0.0540	0.076
Gross income	0.0000	-0.707	-0.0176	3.759	0.0010	0.005	0.0016	0.018
Extension contact	0.0080	1.427	0.0530	0.213	2.5220	2.547	0.0601	3.085
Access to climate information	0.2074	3.261	0.1085	4.473	0.0472	2.951	0.2072	2.785
Credit access	0.3387	5.491	0.2578	2.608	3.3419	0.785	0.0053	0.001
Livestock ownership	0.3713	5.680	0.3713	5.680				
_cons	-0.4876	-4.303			-7.4108	0.000		
Wald Chi-square (Zero slopes) 77.37 p<0.001								
rho (Independent equation) 9.09 p<0.001								
Total observation = 300								
Censored observation= 249								
Uncensored observation= 51								

Source: Based on the authors' compilation.

practices by 10.85%. Similar findings have been reported in earlier research studies (Marie *et al*., 2020; Belay *et al*., 2022; Kumar *et al*., 2023). Access to credit was identified as a significant determinant of climate change adaptation, increasing the likelihood of adoption by 10.6%. This factor elucidates the financial circumstances of Indian farmers, who typically possess small and marginal land holdings and lack adequate income to undertake measures against climate change. Therefore, credit access plays a crucial role in the process of climate change adaptation, aligning with the findings of Loria and Bhardwaj (2016).

The findings of the selection model, which examined the variables affecting tank-irrigated farmers' awareness about changing climate conditions, indicate that age, educational level, contact with extension personnel and credit access have a positive impact on farmers' awareness.

CONCLUSION

Climate change substantially affects the agricultural production systems of developing countries. As a result, farmers in these nations must adopt adaptation techniques to protect their livelihoods. Among farmers using tank irrigation, the most commonly employed adaptation strategies were soil and water management practices (SWP), adjusting sowing dates and implementing crop insurance. The study also found that factors such as age and educational status, access to extension agents and credit availability positively influenced their awareness levels. Moreover, variables such as age, gender, educational status, access to climate information, credit availability and livestock ownership positively influenced the adaptation techniques of tank-irrigated farmers. The study also revealed that approximately one-fourth of farmers did not follow any adaptation practices. It is crucial for the government to identify factors that can enhance the adoption of these strategies. For example, the findings suggest that farmers with higher levels of education and experience are more likely to utilize adaptation techniques. Additionally, the presence of extension agents increases awareness of climate change. Therefore, policymakers should develop appropriate policies that promote higher education levels among farmers, implement training programs and improve extension services. Moreover, cultivators are most probably to implement adaptation measures if they have access to financial resources. Therefore, the state should provide credit to farmers to facilitate their adaptation to the changing climate. Introducing a new concept called adaptation credit could be beneficial.

Conflict of interest

The authors have no conflicts of interest to declare. All co-authors have seen and agree with the manuscript's contents and there is no financial interest to report. We certify that the submission is original work and is not under review at any other publication.

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