

Determinants and Barriers of Crop Diversification: A Case Study of Water User Associations Group in Jalpaiguri district, West Bengal

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Abstract: *This study examines the determinants, and barriers to crop diversification among marginal farmers in Jalpaiguri, West Bengal, associated with Water User Associations (WUA). Conducted in 2024 in Kranti block, the research assesses how irrigation expansion influences diversification, a key strategy for food security and climate resilience. A multinomial logistic regression using household level data (N= 120) was estimated to identify drivers of crop diversification. The result of the study revealed that livestock-rearing households diversify less, and instead rely on livestock for income. The barriers to household crop diversification include limited credit access and inefficient public irrigation systems. The findings emphasize the urgency of improving irrigation systems, introducing targeted credit schemes, and adopting subsidy policies that incentivize diversification. Such measures could significantly enhance climate resilience and livelihoods for marginal farmers. This study provides policy insights to promote sustainable crop diversification in vulnerable regions.*

Keywords: Crop diversification, Vulnerable regions, Climate resilience, Multinomial logistic regression, Irrigation

INTRODUCTION

In West Bengal, India, the Accelerated Development of Minor Irrigation (ADMI) project was launched in 2012 to support small and marginal farmers in rainfed areas by providing subsidized irrigation and strengthening community-based institutions such as Water User Associations (WUAs). In the Jalpaiguri district, smallholders had previously relied primarily on canal irrigation or monsoon rainfall, with limited access to minor irrigation facilities. The ADMI project, through the formation of WUAs, aims to expand minor irrigation schemes and enhance water accessibility for smallholders, which could help them diversify their crops and improve their well-being.

Numerous studies have already shown that minor irrigation contributes positively and significantly to crop diversification (Pattanayak, 2022; De and Chattopadhyay, 2010). Crop diversification is a sustainable adaptation strategy that minimises economic and environmental risks (Akber et al., 2022). The extent of crop diversification plays a crucial role in managing income risk, with higher diversification intensity recommended in areas with high climate variability (Peidraet al., 2020). Therefore, it is generally expected that households participating in WUAs and accessing ADMI project facilities would diversify their crops. However, this is not always the case. While minor irrigation may provide households with the opportunity to diversify, the actual extent of diversification often varies due to other socio-economic factors.

Keeping this issue in mind, the present study aims (i) to estimate the extent of crop diversification at the household level. (ii) to identify the factors influencing the degree of crop diversification and, (iii) to explore the barriers that hinder diversification.

REVIEW OF LITERATURE

Crop diversification is widely recognized as an important adaptation strategy due to its multiple environmental and economic benefits. Environmentally, it can improve soil fertility and reduce pest populations, while for farmers, it contributes to enhanced well-being (Zou et al., 2024). However, several factors influence both the choice and extent of crop diversification.

Labeyrie et al. (2021) found that small-scale farmers often tend to adopt water-demanding crops, even in areas where reduced rainfall is predicted to lower yields. This suggests that farmers' knowledge plays a crucial role in shaping their diversification strategies. In addition to knowledge, barriers such as insufficient agricultural credit,

poor transportation infrastructure, and lack of storage facilities for agricultural products can hinder crop diversification even in regions with high potential for it (Kumar et al., 2022).

Singh et al. (2022), in their study of the Indo-Gangetic plains of India, revealed that farm size and proximity to markets positively influenced crop diversification, while irrigation intensity and household net income had a negative effect. These factors not only affect the choice to diversify but also influence the extent of diversification. Similarly, Aheibam et al. (2017), in their study in Manipur, found that the education level of the household head, access to ploughs, and training programs positively impacted the degree of crop diversification.

The above literature highlights that while crop diversification offers significant environmental and economic advantages, farmers often face socio-economic challenges that limit its adoption. Therefore, studying the factors that influence the extent of crop diversification, along with the associated barriers, is essential for formulating context-specific and effective agricultural policies.

METHODOLOGY

Primary data was collected in the year 2024 from 120 household members of the five WUA at Chapadanga, Moulani, Chak Moulani, Bidurerdanga and Dakshin Matiyali in the Kranti block of Jalpaiguri district.

Statistical analysis: The Herfindahl-Hirschman index (HHI) is a statistical measure of concentration (Rhoades 1993).

$$HHI = \sum_{i=1}^n \left(\frac{q_i}{Q} \right)^2$$

Where:

q_i represents the area or production share of each crop type i in the total cropped area Q .

n is the number of different crop types being considered.

In this context q_i could represent the percentage of land area or production dedicated to each crop type, and Q would be the total land area or production of all crops combined. The HHI calculated this way provides a measure of crop concentration or diversification within the agricultural system or region, with higher values indicating less diversified and more concentrated crop production, and lower values indicating greater crop diversification.

The multinomial logit regression technique is employed when the choice of strategy serves as the dependent variable. The analysis employs multinomial logit because of its superior ability to yield comprehensive and precise test results compared to the more restricted and intricate needs of multinomial probit (Hausman and Mcfadden, 1984). A multinomial logistic regression model can be used to analyse a dependent variable with several categories.

The dependent variable can assume any discrete values, which we can identify as numbers 1, 2, 3, ..., m, for categorisation. Regarding the level of crop diversification, households have the option of low crop diversification (0), moderately diversify (1), or highly diversify (2). In this study, following Sendhil et al. (2018), the crop diversification index obtained is grouped into three categories.

For a dependent variable with categories, we define the j th crop diversification choice made by the i -th household as having a value of 1 for moderate diversification and 2 for high diversification. If the i th household does not choose the j th crop diversification, the value is 0. The chance of a

household with attributes X choosing crop diversification j , is described as,

$$\pi_{ij} = \frac{e^{\alpha_j + \beta_1 X_{i1} + \dots + \beta_k X_{ik}}}{1 + e^{\alpha_j + \beta_1 X_{i1} + \dots + \beta_k X_{ik}} + \dots + e^{\alpha_m + \beta_1 X_{i1} + \dots + \beta_k X_{ik}}}; j = 2, \dots, m$$

Where $\pi_{i1} = 1 - \sum_{j=2}^m \pi_{ij}$ and $\sum_{j=0}^1 \pi_{ij} = 1$

After obtaining the fitted α and β values, they may be utilised to evaluate the log odds of households selecting each crop diversification option, compared to the reference option. It is estimated that there is a probability that the household will choose a different level of crop diversification instead of choosing low crop diversification. The computation of log odds is performed as follows:

$$\log \left(\frac{\pi_{ij}}{\pi_{i1}} \right) = \alpha_j + \beta_1 X_{i1} + \dots + \beta_k X_{ik}; \text{ where } j=2, \dots, m.$$

Therefore, using the model, we can predict the likelihood of a particular form of crop diversification compared to the base outcome. The regression coefficients determine the logarithm of the likelihood of choosing a certain form of crop diversification compared to the standard category. In general, the j subscript on both the intercept, α_j , and slope β_j , shows an intercept and a slope for comparing each category to the reference category. The α represents the intercept of the category, β represents the slope of the category, represents each category, and represents the predictor variables of the study. Below in Table 1 the description of variables and their measurements are given.

Table 1. List of variables and their description

Variables	Variable Type	Definition and unit of measurement
Dependent variables		
Y=1, Low level of crop diversification	nominal	when HHI is between 0.63 to 1
Y=2, Moderate level of crop diversification	nominal	when HHI is between 0.37 to 0.63
Y=3, High level of crop diversification	nominal	when HHI is between 0.02 to 0.37
Sex	dummy	Sex was assigned as 1 if the head of the household was male or 0 if female
Age	continuous	Age of the head of the household
Education	continuous	number of years of schooling
working members	continuous	total number of members in the family who are working
land holdings	continuous	total agriculture land holdings in acres
Access to credit	dummy	1, if a household has access, and 0, otherwise

Source: Authors own work

Table 2: Summary statistics of the dependent variable

Diversification	Frequency	Percentage
Low	26	21.67
Moderate	51	42.50
High	43	35.83

Table 3: Summary statistics of categorical variables

Variables	Frequency	Percentage
Sex		
Female	28	23.33
Male	92	76.67
Credit taken		
No	79	65.83
Yes	41	34.17
Livestock		
No	72	60
Yes	48	40
Irrigation type		
Private	59	49.17
Public	61	50.83

RESULTS AND DISCUSSION

Socio-economic characteristics of the households:

The study covered five Water User Associations (WUAs) and surveyed 120 households. The findings reveal varied levels of crop diversification across households, with a significant proportion falling into moderate and high diversification categories (Table 2). The primary crops cultivated included boro, jute, mustard, tea, and a range of vegetables such as tomato, lady's finger, brinjal, chili, and bitter gourd. Gender-wise, male-headed households were predominant (Table 3). Livestock rearing was practiced by less than half of the surveyed households. Access to credit was common, with loans obtained mainly from Self Help Groups (SHGs), Bandhan Bank, and rural banks. While loans from rural banks were primarily invested in agriculture, those from SHGs and Bandhan Bank were more often used for education, marriage, and household assets. Despite universal access to WUA-provided irrigation, there were clear differences in private irrigation ownership, with nearly 40 percent of households possessing their own facilities. To ascertain the rationale behind private irrigation, we found two important factors contributing to this phenomenon. First, several households possessed private irrigation equipment before joining the WUA. Second, it is important to highlight that certain households possessed land units of comparatively larger dimensions than others. Therefore, the inability of public facilities to adequately cover the entire area necessitated the use of private irrigation facilities.

Table 4: Estimates from multinomial logit regression model

Low crop vs moderate crop diversification					Low crop vs high crop diversification				
Variable	Coeff	SE	z-value	p-value	Variable	Coeff	SE	z-value	p-value
Sex					Sex				
Male	0.82	0.67	0.12	0.90	Male	0.21	0.73	0.30	0.76
Age	0.02	0.02	0.87	0.38	Age	0.01	0.02	0.65	0.51
Educ level	0.03	.07	0.40	0.68	Educ level	0.04	0.07	0.60	0.55
Livestock owned					Livestock owned				
Yes	-1.91	.59	-3.24	0.001***	Farm	-1.61	0.61	-2.62	0.009**
Access to credit					Access to credit				
Yes	-0.99	0.59	-1.69	0.09*	Yes	-0.82	0.59	-1.41	0.88
Irrigation type					Irrigation type				
Public	-1.08	0.59	-1.82	0.06*	Public	-1.09	0.61	-1.79	0.07*
Log annual income of Household	0.02	0.79	0.04	0.97	Log annual income	0.09	0.78	0.12	0.90
Land size in acres	0.05	0.29	0.18	0.86	Land size in acres	0.43	0.29	1.49	0.13
Working members	0.14	0.35	0.40	0.68	Working members	0.36	0.35	1.02	0.30
Constant	0.52	7.55	0.07	0.94	Constant	-1.91	7.52	-0.25	0.80

Determinants of crop diversification:

Crop diversification enhances agrobiodiversity, which improves natural resource management and boosts household income, consumption, nutrition, and overall health (Vernooy, 2022). To explore the factors influencing the extent of crop diversification, this study uses a Multinomial Logistic Regression model to examine the relationship between various independent factors and the level of diversification (Table 4). Therefore, this section provides an overview of

the findings derived from the multinomial logit model, highlighting the influential elements that impact the degree of crop diversification. Before proceeding with the model, the results of the multi-collinearity test ($VIF = 1.54$) indicated the absence of any significant issues among the explanatory variables. Hence, this study presents significant conclusions regarding the factors that have influenced the extent of crop diversity across households. The variables under investigation in this study encompass gender, sex, education level, livestock owned, access to credit, irrigation type, log annual income from farms, and land area measured in acres. The findings from the multinomial logit analysis suggest that the independent factors, namely livestock holdings, credit taken, and irrigation types significantly influence crop diversification.

The model results are presented using the low level of crop diversification as the reference category. The model results indicated that households that owned livestock had a negative and significant effect on moderate and high levels of diversification at a 1 percent significant level. The negative association between households with livestock and moderate or high levels of crop diversification is that the chance to diversify high or moderately decreases with the increase in livestock. It was observed from the field survey that households with low crop diversification relied more on livestock as their main source of income. Accessibility of credit has shown a significant negative association with a moderate level of diversification at a 10 per cent significant level. This indicates that as credit accessibility increases the probability of households moving from low crop diversification to moderate diversification declines. It was found from the study that households who moderately diversify their crops use credit money for purposes such as education of their children, marriages, and buying assets for personal consumption, and they hardly utilise credit to invest in diversifying their crops. This result was correlation with the result of Kemboi et al. (2020). Lastly, it was observed that the households, which used public irrigation facilities had a negative association with moderate and high crop diversification compared to low crop diversification at a 10 per cent significant level. It shows that poor public irrigation facilities in the village have become a barrier to higher diversification of crops.

Barriers to crop diversification:

To examine the barriers to crop diversification, a qualitative approach was adopted. Information was collected through semi-structured interviews with selected farmers. The interviews revealed that agriculture has suffered due to low crop yields, excessive use of chemicals, and the prevalence of small landholdings. Crop diversification has emerged as a key strategy to address this issue. In the study area, there is a noticeable increase in the variety of crops grown and land allotted to them. Farmers are now cultivating a variety of vegetables during the rabi season, including brinjal, lady's finger, leafy greens, onions, pumpkins, ridge gourds, bitter gourds, cucumbers, and sesame. These changes, alongside a notable increase in the productivity of Boro and other crops, highlight how farmers are adapting to evolving climate conditions.

However, not all crops have benefited from these changes. Jute production, in particular, has declined sharply due to rising temperatures and insufficient rainfall. This is concerning because jute plays a vital role in climate change adaptation, offering significant environmental benefits and

upporting farmers' livelihoods (Rahman and Rahman 2024). While the changing climate has favoured certain crops, jute's specific temperature requirements have made it increasingly vulnerable.

Discussions with farmers revealed several challenges, even though irrigation facilities have helped promote crop diversification. One major issue is the limited number of shallow tube wells provided by the government, which benefits only farmers with land nearby. However, even for these farmers, the wells often fail to cover their entire farming area, forcing them to invest in additional irrigation solutions. The problem is compounded when these tube wells break down. Government assistance for repairs is frequently delayed or unavailable, leaving farmers to shoulder the repair costs themselves. This lack of reliable support contributes to what Vermillion and Sagardoy (1999) describe as "system deterioration," a condition that widens the gap between the actual and potential performance of irrigation systems.

In addition, farmers are facing numerous challenges in their farming activities, primarily due to low market prices for their produce (Kumar et al., 2019). This situation was also observed in the study area where most farmers tend to concentrate on cultivating only a few crops, which provides them with a more predictable income.

CONCLUSION

Based on the findings from this study, it is evident that crop diversification is an important strategy for addressing the challenges posed by climate change in Jalpaiguri district. In the study factors like livestock holdings, access to credit, and irrigation types were found to influence the extent of crop diversification significantly. Generally, an increase in livestock tends to reduce the likelihood of choosing moderate or low diversification. Similarly, increased credit accessibility does not necessarily translate into higher crop diversification, as the funds are often allocated to non-agricultural uses. Moreover, as public irrigation facilities increase, the chance to opt for moderate or high crop diversification decreases because of its inefficiency and low service. Despite the potential benefits of diversification, several barriers persist. These include poor services for irrigation infrastructure, insufficient government support, limited market access, and absence of crop insurance. These challenges hinder farmers' ability to diversify effectively and reduce their vulnerability to climate risks. To enhance the resilience of agriculture in this region, it is essential to address these barriers by improving irrigation facilities, providing better market access, and offering crop insurance programs. In addition, policies that encourage the productive use of credit and income towards agricultural investment are crucial for promoting sustainable crop diversification.

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