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Exploring the determinants of farm mechanization among farmers in midhill zone of Himachal Pradesh, India

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Abstract

The present study sought to assess economic analysis of agricultural mechanization in mid hill zone of Himachal Pradesh was conducted in Mandi district of Himachal Pradesh. A random sample of 120 farmers was chosen from 10 villages in the Mandi district's Gopalpur (31.64N, 76.74E) and Balh (31.89N, 76.94E) blocks. The findings showed that the literacy rate, occupation, literacy index, family type, land holding, and crop yield index were among the factors that affected farm mechanisation. While literacy rate, occupation, and crop yield index were found to have a positive relationship with farm mechanisation, they were not found to be statistically significant. In contrast, the literacy index, land holdings, and family type were found to be statistically significant. Farm mechanisation can rise by 0.016 and 0.009 percentage points, respectively, at the overall farm level for every percentage point increase in the occupation and literacy index. Each one percentage point increase in the nuclear type of family can increase 0.03 percentage point at overall level. Further, one percentage point increase in land holding and crop yield index can increase farm mechanization by 0.01 and 0.00012 percentage point at overall farm level respectively.

Keywords: Farm mechanization, socio-economic determinants, economic analysis, multiple linear regression, mechanization index.

Introduction

Agriculture continues to serve as the cornerstone of the Indian economy, providing livelihoods to approximately 58% of the country's rural population and ensuring food security for over 1.3 billion people (World Bank, 2021; Ministry of Agriculture & Farmers Welfare, 2020) ^[21, 13]. Since independence in 1947, India has witnessed transformative changes in its agricultural sector, driven by substantial government investment in infrastructure development, research and technology adoption, and policy support aimed at enhancing productivity and empowering farmers (Pingali, 2012; Singh and Sahni, 2019) ^[15, 18]. These sustained efforts have propelled food grain production from a modest 52 million tons in 1950-51 to an impressive 291.95 million tons by 2019-2020 (Government of India, 2020) ^[7]. However, despite this growth, the contribution of agriculture to the national Gross Domestic Product (GDP) has declined significantly from nearly 50% in the early 1950s to about 16.5% in 2019-2020, reflecting the rapid expansion of industrial and service sectors (Kumar & Mishra, 2019) ^[11]. Over the last 72 years, significant investments have been made by the government in the agriculture sector, in particular to generate strong infrastructure, improve science and technology in agriculture, introduce certain needs-based schemes and empower farmers to adopt the new agricultural technologies. Through concerted efforts by the government and some other stakeholders, the country's food grain production increased from 52 million tons in 1950-51 to

291.95 million tons in 2019-2020. At the same time, the share of agriculture in India's Gross Domestic Product (GDP) steadily declined from around 50 per cent in 1950-51 to 16.5 per cent in 2019-2020. Despite the small contribution to GDP, 43.21 per cent of the country's total population remains working and contributes to the manufacturing sector through raw materials and foreign exchange earnings through agricultural exports.

Nevertheless, agriculture remains the primary source of employment for about 43.21% of India's workforce, underscoring its critical role in socio-economic stability and rural development (Census of India, 2011; NSSO, 2018) ^[4, 14]. The sector also supports ancillary industries by providing raw materials to the manufacturing sector and contributes substantially to foreign exchange earnings through exports of agricultural commodities (Rao & Chand, 2020) ^[16].

This dual role highlights the agriculture's strategic importance beyond direct economic output.

The pivot of agricultural growth and modernization in India has been farm mechanization. The evolution of agricultural tools and machinery reflects the humanity's historical journey from manual subsistence farming to more efficient and technology-driven production systems (Zhou *et al.*, 2020) ^[22]. Early agricultural societies depended primarily on human and animal labor but advent of mechanization revolutionized the farming practices by introducing tractors, harvesters, irrigation pumps, and the other equipment that

significantly enhance productivity and reduce drudgery (Bhat *et al.*, 2018) ^[3]. In developing countries like India, the mechanical power sources contribute to more than 80% of total power utilized in agricultural production activities, replacing traditional animal and human labor to large extent (FAO, 2019) ^[6]. The extent to which the different power source like mechanical, animal, and human are used is largely influenced by factors such as resource availability, farm size and socio-economic status of farmers, and policy frameworks (Chauhan & Singh, 2021) ^[5].

Despite notable advancements, the farm mechanization in India faces challenges related to affordability, uneven access, suitability for diverse cropping systems, especially in the smallholder farms that dominate agricultural landscape (Sharma *et al.*, 2017) ^[17]. Addressing the challenges through innovative technologies policies and capacity building remains essential for sustaining agricultural productivity and rural livelihoods in the face of growing population pressures and climate change (Joshi *et al.*, 2020) ^[9]. This research focuses on assessing current state of farm mechanization in India, examining trends, challenges and the future prospects to guide stakeholders in policy and practice.

Farm mechanization is the main reasons for country's agricultural development and overall growth. Initially, the

role of tools and equipment's in agriculture became very important as people were interested in growing crops. As civilization developed, styles of instruments and other equipment's used in cultivation have also been modified. Through the development of new technology, there has been a continuous change in design of farm machinery and equipment in order to maximize the efficiency and thus decrease farm labour. On the other hand, more than 80 per cent of the overall usage of power in agricultural production activities in developing countries comes from mechanical power sources. The usage of power between different sources to a larger degree is often controlled by the magnitude of resources accessible from different sources.

2. Material and Methods

2.1 Selection of the study area: Himachal Pradesh has a wide variation of topography, elevations, agro-climatic condition, socio-economic and cultural factors etc., which directly or indirectly affects the extent of farm mechanization. This study was conducted in the mid hill zone of Himachal Pradesh and district Mandi was selected purposively having wide range of variation in cultivation pattern. A random sample was chosen from 2 blocks in Mandi district's from Gopalpur (31.64N, 76.74E) and Balh (31.89N, 76.94E).

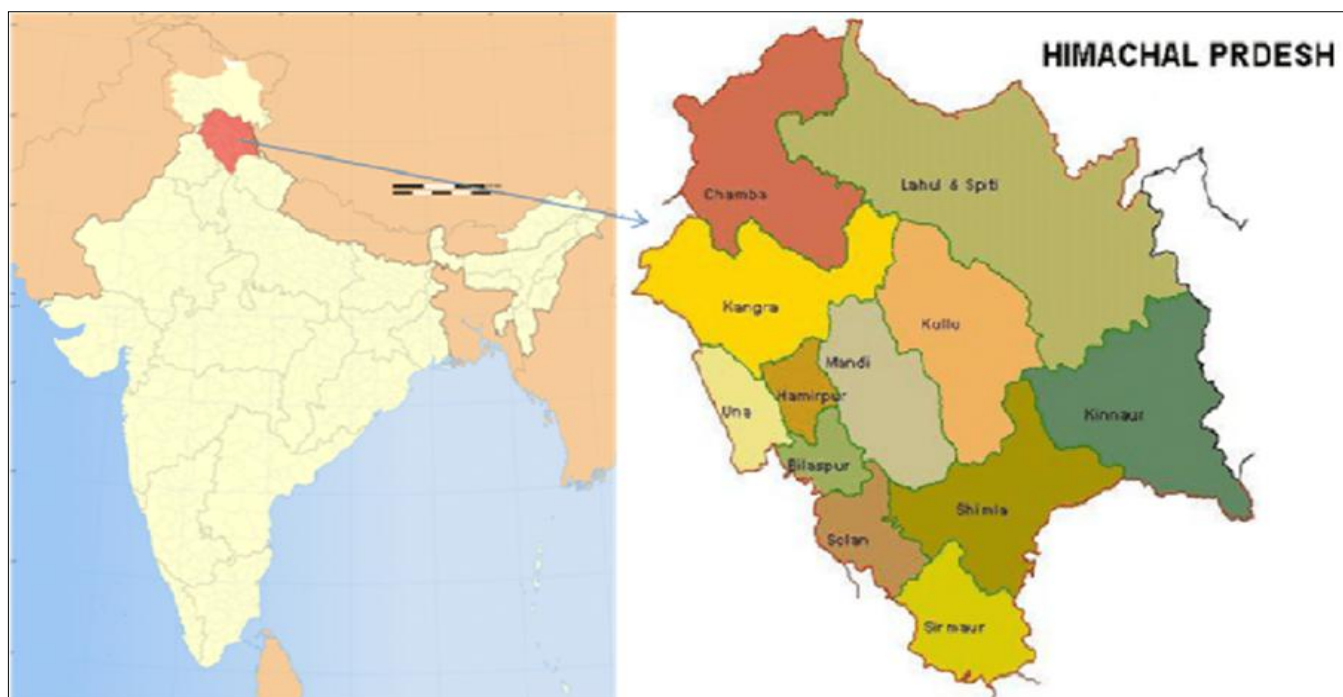


Fig 1: Map showing study area Himachal Pradesh

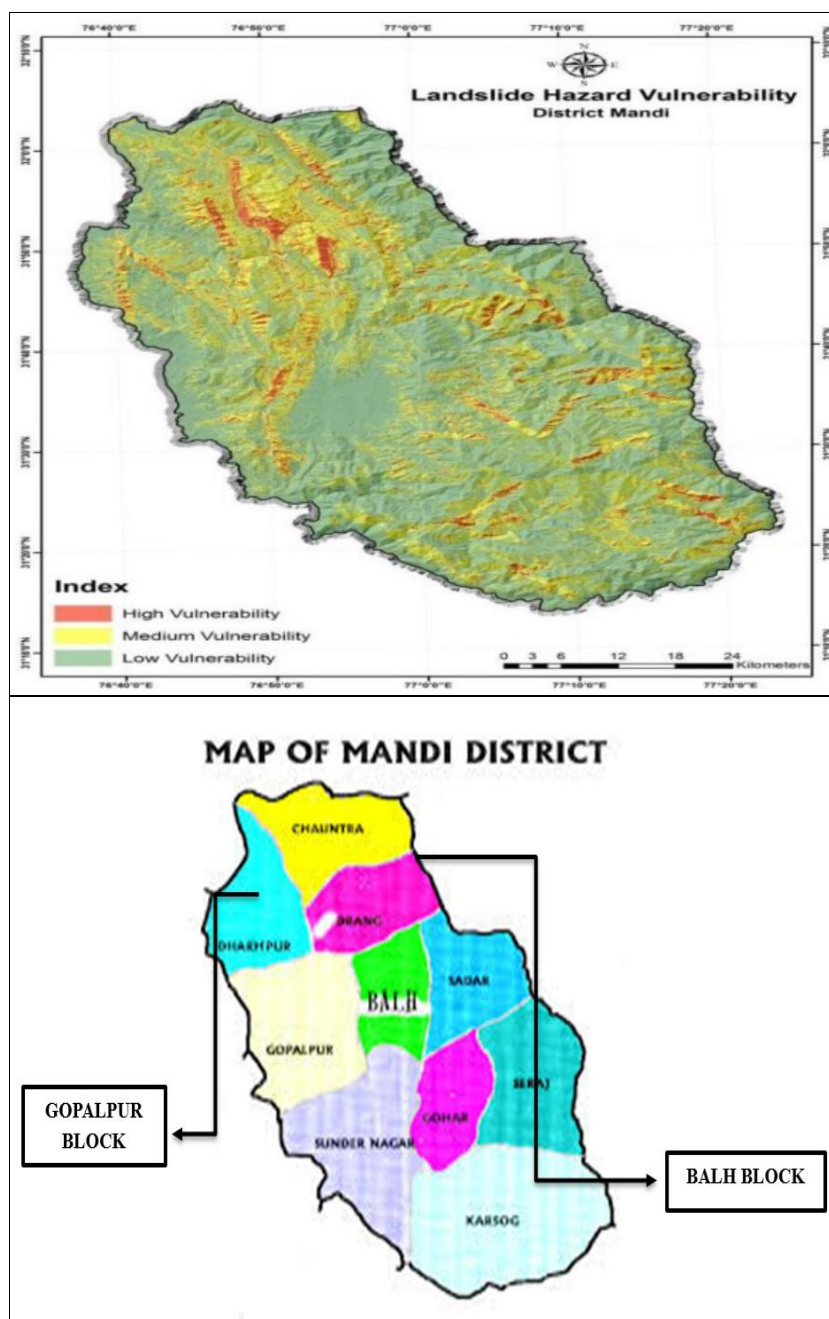


Fig 2: Map showing study area of two blocks Gopalpur and Balh of Mandi district

2.2 Sampling design

Multi-stage random sampling design was used to select 60 farmers. A sample of 10 villages selected from two blocks namely Gopalpur and Balh and a total of 60 farmers were drawn randomly representing 3 farmers from each selected village.

2.3 Data collection

Primary data were collected on suitably designed and pre-tested survey proforma through personal interview from selected farmers. The secondary data was collected from the selected developmental blocks, viz., Gopalpur (31.64°N, 76.74°E) and Balh (31.89°N, 76.94°E) of Mandi district.

2.4 Analytical framework

2.4.1 Tabular analysis

The total households were divided into three classes

according to the size of their land holding. The classes in which farmers are divided were marginal, small and medium. This analysis was carried out to estimate the socio-economic profile of the study area. The literacy index was calculated (Basu & Foster, 1998) [2] as follows

$$\text{Literacy index} = \frac{\sum W_i X_i}{\sum X_i}$$

Where W_i = weights (0, 1, 2, 3, 4 and 5) for illiterate, primary, middle, matric, senior secondary and graduate respectively. X_i = Number of persons in respective category.

$$\text{Literacy Rate} = \frac{\text{Total number of literate persons}}{\text{Total population} - \text{Population below 5 years}} \times 100$$

2.4.2 Factors affecting Farm mechanization

The factors affecting farm mechanization at micro level were calculated at household levels by regressing mechanization indices on different explanatory variables using multiple linear regression analysis. Mechanization index was taken as a dependent variable and socio-economic characteristics of the farm were taken as independent variables. (Kumar and Tripathi., 2018) ^[10]

$$Y = a_0 + b_1X_1 + b_2X_2 + \dots + b_nX_n + u$$

Where,

Y = Farm Mechanization index

a_0 = Intercept

b_1 = Regression Coefficients

X_1 = Literacy rate

X_2 = Occupation

X_3 = Literacy index

X_4 = Joint/Nuclear family

X_5 = Family size

X_6 = Land holding

X_7 = Crop yield index

u = Error term

3. Results and Discussion

3.1 Factors affecting farm mechanization in the study area:

The factors influencing agricultural mechanisation in the study region were examined using multiple linear regression. The investigation took into account variables such as the agricultural yield index, land holdings, family type, occupation, literacy rate, and literacy index.

The descriptive statistics of the variables used to examine the factors influencing farm mechanisation in the study area are shown in Table 1. Farmers' degrees of mechanisation varied significantly, as evidenced by the average mechanisation index of 0.26 and the coefficient of variation (CV) of 46.15%. At 88.24%, the literacy rate was relatively high and had very low variability (CV = 13%). With a CV of 27.40% and an average of 2.81, the literacy index, which measures educational quality, indicated that respondents' educational backgrounds varied moderately. Small to medium-sized farms predominated, as seen by the average land holdings of 1.27 hectares and the average family size of 5.9 people, which is typical of rural household structures. With a low variance (CV = 10.12%) and a comparatively high crop production index of 128.51, the region's agricultural productivity was frequently significant.

Table 1: Descriptive statistics of the variables used in the multiple linear regression analysis:

Variable	Mean	Std.	CV
Mechanization index	0.26	0.12	46.15
Literacy rate (%)	88.24	11.47	13
Agriculture occupation	0.28	0.45	160.71
Literacy Index	2.81	0.77	27.4
Type of family	0.53	0.5	94.33
Family Size (No.)	5.9	2.08	35.26
Land holding (ha)	1.27	0.71	55.95
Crop Yield Index	128.51	13.01	10.12

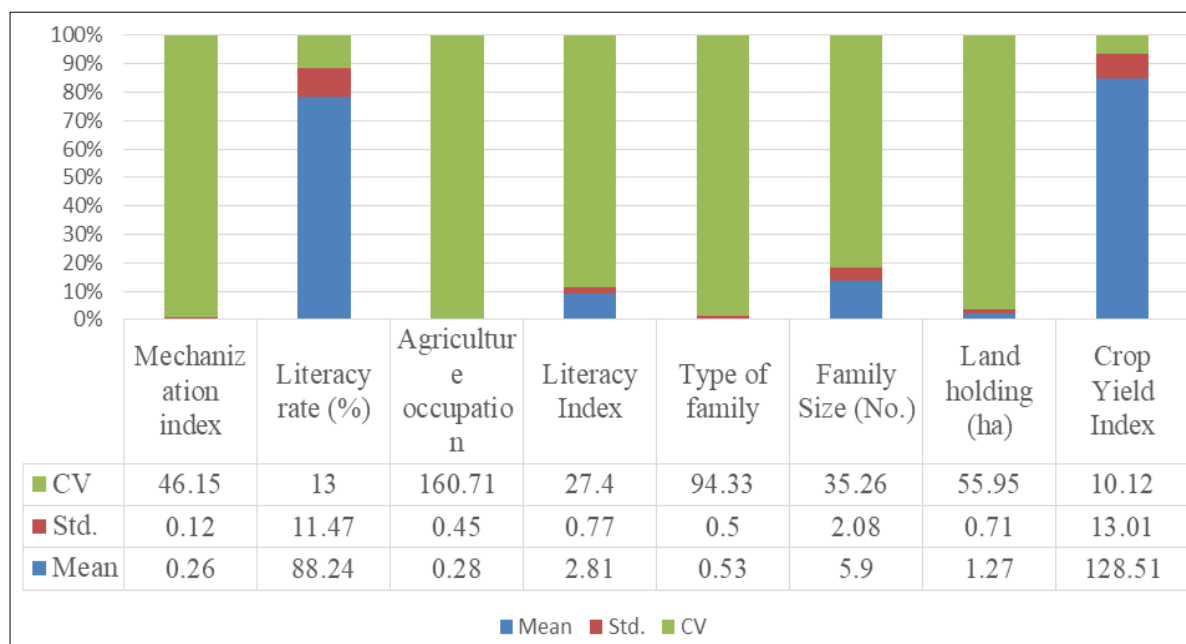


Fig 2: Graph showing descriptive statistics of various variables

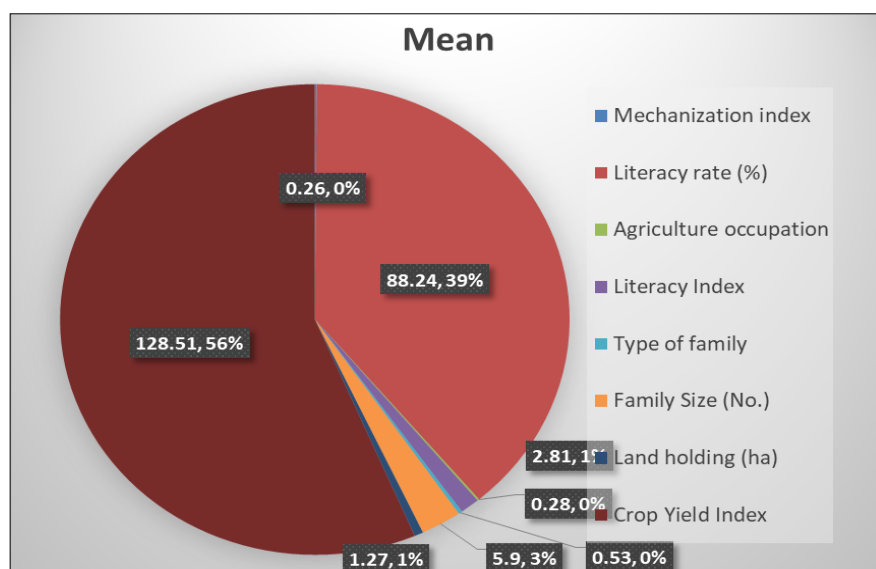


Fig 3: Pie Chart showing different mean values of various variables influencing farm mechanization

The pie chart (figure 3) illustrates the mean values of the numerous variables affecting rural and agricultural development. The Crop Yield Index is the most significant of these factors, accounting for 56% of the overall mean value, with an average of 128.51. This indicates that one of the most significant variables in the dataset is agricultural productivity.

With a value of 88.24, or 39% of the mean, the Literacy Rate is the second-largest contributor. This implies that the surveyed population has a comparatively high level of education, which may favorably affect the adoption of technology and the general development of rural areas.

The mean value of land holding is 1.27 hectares, representing 1% of the total. Given this low percentage, it is likely that most families run small farms, which could

restrict economies of scale. Other factors that contribute less than 1% to the overall mean include the Mechanisation Index (0.26), Agriculture Occupation, Literacy Index, Family Type, and Family Size. In comparison to crop yield and literacy rate, their smaller amounts show that, although still important, these factors have a less significant quantitative impact.

All things considered, the data emphasizes the significant roles of literacy and crop productivity play in the rural landscape, but it also indicates low levels of mechanisation and small land holdings that may impede agricultural development.

Standard Deviation

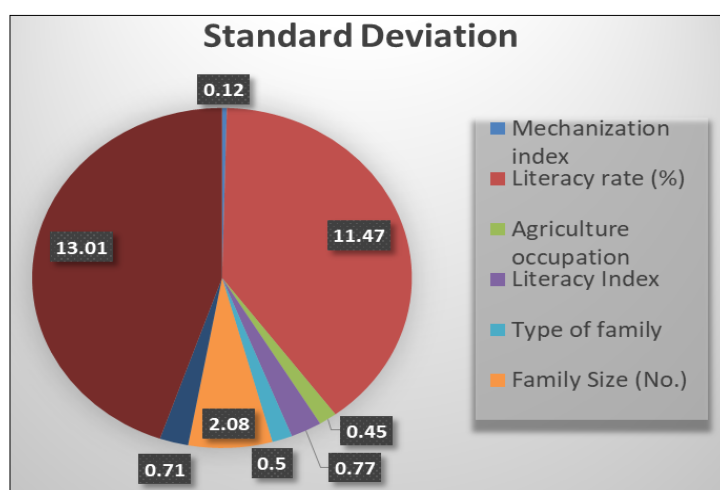


Fig 4: Pie Chart showing standard deviation of various variables influencing farm mechanization

This pie chart (figure 4) illustrates the degree of variability in the dataset by showing the standard deviation of several socioeconomic and agricultural parameters. The two variables with the biggest fluctuations are the Crop Yield Index (13.01) and the Literacy Rate (11.47), which demonstrate notable variations in the population's production and educational attainment.

Conversely, indicators like the Literacy Index (0.50), Agriculture Occupation (0.45), and Mechanization Index (0.12) show little fluctuation, indicating a fairly consistent distribution among respondents. Land Holding (0.77 ha), Family Type (0.71), and Family Size (2.08) all showed moderate variability.

These results imply that although certain socioeconomic

elements, including agricultural productivity and educational opportunities, vary greatly, structural features mostly stay the same. These trends highlight the

significance of determined attempts to improve fairness and lessen inequities in rural development programs.

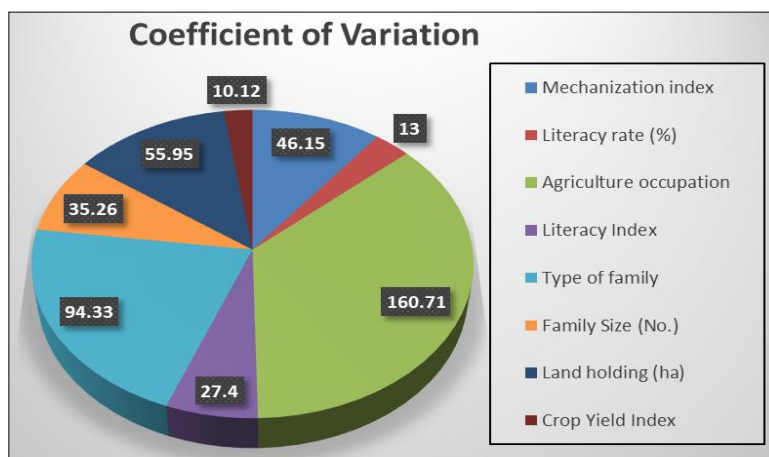


Fig 5: Pie Chart showing coefficient of variation of various variables influencing farm mechanization

The Coefficient of Variation pie chart (figure 5) illustrates the relative variability of numerous significant agricultural and socioeconomic factors, offering information on the consistency that each variable is in relation to its mean. With a coefficient of variation of 160.71, the Agriculture Occupation variable had the largest relative variability, showing notable variations in the degree of agricultural activity among the population examined. Type of Family (94.33) and Family Size (55.95) follow, indicating a significant range in household size and structure. Moderate variability is shown by the Mechanisation Index (46.15),

Land Holding Index (35.26), and Literacy Index (27.4), suggesting some variation among respondents in these areas. Conversely, the literacy rate^[13] and the crop yield index (10.12) have the lowest CV values, indicating that they are comparatively constant across the population.

Overall, the wide range of family dynamics and agricultural occupations emphasizes how diverse rural livelihoods are, whereas crop yield and literacy rates seem to be more stable. These findings highlight the necessity of adaptable and regional policy strategies to deal with the various socioeconomic realities found in rural regions.

Table 2: Estimated coefficients of multiple linear regression model for factors influencing farm mechanization in study area

Variables	Coefficients	Std Error	p value
Literacy rate	0.0005	(0.0012)	0.64
Occupation	0.016	(0.023)	0.49
literacy index	0.009***	(0.005)	0.07
Type of family	0.03**	(0.015)	0.05
Land holding	0.01*	(0.0016)	0.000
Crop yield index	0.00012	(0.0008)	0.88
Intercept	0.02	(0.13)	0.86
F value	9.60*		
R-square	0.52		
Adjusted R-square	0.46		
Root MSE	0.86		

Note: Figures in parentheses indicate standard errors to total in each category *, ** and *** significant at 1, 5 and 10 per cent level

The findings of multiple linear regression for the variables influencing farmers' levels of agricultural mechanisation are displayed in Table No. 2. The fitted model explained 46% of the variation in farm mechanisation and was deemed significant. Farm mechanisation in the research area was found to be significantly impacted by the literacy index, family type, and land holdings. It was discovered that for every unit increase in the literacy index, the agricultural mechanisation index would rise by 0.009 units as educational quality improved. Likewise, the farm mechanisation index will rise by 0.03 units for nuclear family structures.

Overall, it became apparent that there was a clear

correlation between land holding size and farm mechanisation; that is, as land holding size increased, so would farm mechanisation. Given that the coefficient of multiple determination (R^2) was only 0.46, it may be further deduced that there might be additional factors influencing farm mechanisation. Although they were not deemed statistically significant, the literacy rate, occupation, and crop yield index were also found to have a positive link with farm mechanisation. Therefore, the analysis came to the conclusion that as education improves and land holding size increases, agricultural mechanisation in the study area will rise. Farm mechanisation was also found to be directly related to the dominance of the nuclear family system.

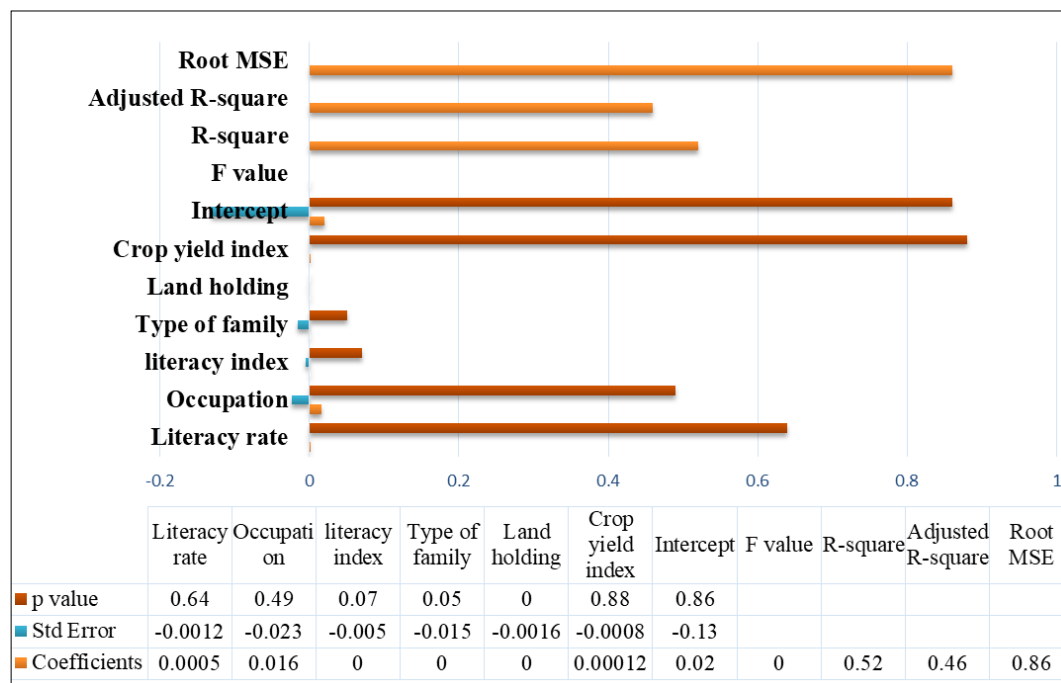


Fig 6: Graph showing estimated coefficient of various variables influencing farm mechanization in study area

Discussion and Implications of Results

Literacy Index: The positive relationship ($\beta = 0.009$, $p = 0.07$) implies that better quality of education positively promotes farm mechanization adoption. This is consistent with research by Singh *et al.* (2017) [20], which found that farmers with higher levels of education are more open to new agricultural technologies and mechanisation, which increases productivity and efficiency.

Family Type: There was a substantial positive correlation between mechanisation and nuclear family systems ($\beta = 0.03$, $p = 0.05$). According to Kumar and Sharma (2019) [12], this can be a reflection of decision-making efficiency and a greater demand for mechanised inputs in smaller family units with less labour available.

Land Holding: The most significant factor was farm size ($\beta = 0.01$, $p < 0.01$), supporting earlier research (Bairwa *et al.*, 2020) [1] showing that mechanisation investments are justified for bigger landholdings because of economies of scale and improved cost-effectiveness.

Non-significant Variables: Although they had a positive correlation, the crop yield index, literacy rate, and agricultural occupation were not statistically significant in this model. This might be the result of indirect impacts or mediation by other factors that were not examined in this study, like market proximity, extension services, or credit availability (Singh & Gupta, 2018) [19].

Over half of the variation in farm mechanisation cannot be explained by the model's adjusted R^2 of 0.46, suggesting that additional research is necessary to identify potential determinants such as the availability of machinery services, budgetary limitations, or sociocultural factors (Joshi *et al.*, 2021) [8].

The study emphasizes how important family structure, landholding size, and educational quality are to the advancement of farm mechanisation in rural areas. Farmers

can better understand and implement mechanised farming techniques with improved education, which increases productivity and operational efficiency (World Bank, 2020) [21]. Larger land holdings and a preference for nuclear families point to socioeconomic changes affecting availability of labour and the demand for mechanisation.

5. Conclusion

Farm mechanisation was influenced by a number of parameters, including land holdings, occupation, literacy rate, crop yield index, and family type. While the literacy rate, occupation, and crop yield index were shown to have a positive relationship with farm mechanisation, the literacy index, family type, and land holdings were determined to be statistically significant. At the general farm level, agricultural mechanisation can rise by 0.016 and 0.009 percentage points, respectively, for every percentage point increase in the occupation and literacy index. The overall level can rise by 0.03 percentage points for every percentage point increase in nuclear family types. Additionally, farm mechanisation can rise by 0.01 and 0.00012 percentage points at the total farm level for every percentage point increase in land holding and crop yield index, respectively.

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