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RELEVANCE AND DETERMINANTS OF FARM MECHANIZATION IN THE DIVERSE GEOGRAPHIC CONTEXT OF NEPAL

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ABSTRACT

This study assessed the overall scenario of mechanization in different ecological zones of Nepal and identified determinants of mechanization. A perception-based semi-structured questionnaire survey was conducted in four districts, each in Terai and Hills of Lumbini province, Nepal. Index ranking method and descriptive statistics were used to rank farmers' perceptions of factors affecting adoption, problems, and the impact of mechanization. A multiple linear regression model (OLS) was used to analyze determinants of farm mechanization, and the model was tested for normality, multicollinearity, and heteroscedasticity. The average machinery used per household in the study area was 1.68, and 58% of the machinery purchased was in grant support from the government. Extension service is a major source of information for adoption, and cost reduction is a major reason for using machines in farming. Most surveyed farmers responded that cost has decreased and production has increased with the use of machinery. Pollution, repair and maintenance, fuel supply, and lack of training are the few problems associated with mechanization. The study showed that the provision of subsidy, ecological zone (Terai region), total land, economically active members in the household, and distance from extension service were positively significant. In contrast, family size and membership in groups and cooperatives were negatively significant with the adoption of farm machinery. Effective extension service, Grant support program, establishment of custom hiring center, distribution of woman-friendly machines, and establishment of service centers in remote areas along with distributing machines recommended by the research center are important recommendations for enhancing the adoption of mechanization.

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INTRODUCTION

Agricultural mechanization is a process where human labour is replaced by other sources of energy (Daum and Birner, 2020). The application of tools, implements, and machinery to achieve agricultural production is farm mechanization (Sims and Kienzle, 2017). Farms with higher levels of mechanization are technically more efficient than those with no or low levels of mechanization (Huan et al., 2022; Vortia et al., 2021). Mechanization should not be considered only as an increase in mechanical power; the selection of systems is a key choice because certain mechanization has resulted in allocative inefficiency (Hormozi et al., 2012). Mechanization aims to strategically employ

technological advancements to enhance the overall efficiency of farming operations by boosting labor and land productivity (Amare and Endalew, 2016).

Nepal is an agrarian country with more than 50% of the economically active population engaged in Agriculture, Forestry, and fishery occupations (NSO, 2021). The agriculture sector's contribution to GDP was 24.1% in the fiscal year 2022/23 (MoF, 2023). Cereal crops, horticulture, and other cash crops dominate agriculture in Nepal. Among cereals, rice is the major crop in area, production, and productivity (MoALD, 2022). Fundamentally, Nepal follows a conventional agriculture practice (Chaudhary, 2018). Topographically, Nepal is divided into three ecological regions- Mountain (High Hills), Hill, and Terai covering 24%, 56%, and 20%, respectively. Land fragmentation, out-migration, and high production costs are a few issues in Nepalese agriculture. The average land holding is 0.55 ha, and the average parcel size is 0.19 ha (NSO, 2021).

In the past, most Nepalese farmers typically employed traditional farming tools like plows and hoes (Kapri and Ghimire, 2020). Animate power is the main power source in Nepal's agriculture, followed by human power, and the least is mechanical power, which constitutes 40.5%, 36.3%, and 23%, respectively (Shrestha, 2012). Mechanization in Nepal was low until 1990, but significant development in mechanization started only after 1990 (Takeshima & Justice, 2020). With the restoration of democracy, Nepal adopted a liberal economic policy, and the private sector started engaging in mechanization in import and distribution. Institutional development for agricultural mechanization in Nepal started in 1953 with establishing the Agricultural Engineering unit at Singhdurbar, Kathmandu. Mechanization was further expedited by establishing the Agricultural Implement Research Unit at Ranighat, Birgunj. With support from the Union of the Soviet Socialist Republic (USSR), the Agricultural Tools Factory (ATF) was established in 1964 and contributed significantly to the mechanization of agriculture. The establishment of the Nepal Agricultural Research Council (NARC) in 1991 has provided a clear role of agricultural mechanization research to the Agricultural Engineering Division (AED), Khumaltar, to ensure the utilization of quality machinery (Shrestha, 2022). AED was recently renamed the National Agricultural Engineering Research Centre (NAERC) under NARC. The extension of agricultural mechanization technologies was formally initiated by the Department of Agriculture only in 2004 after the establishment of the Directorate of Agricultural Engineering (DoAE), Hariharbhawan. Major institutions responsible for research, extension, and education related to mechanization in Nepal are the National Agricultural Engineering Research Center under NARC, agriculture offices of all 3-tier government and Purbanchal Campus, and the Institute of Engineering under Tribhuvan University, respectively.

The Government of Nepal formulated the Agriculture Mechanization Promotion Policy (AMPP) to promote mechanization in 2006. Responding to labor shortages and increasing fallow lands in the countryside, MoAD launched the AMPP (MoALD, 2014). One of the most significant initiatives to implement the AMPP is the launch of the Prime Minister's Agricultural Modernization Project (PMAMP), which is in line with the Agriculture Development Strategy (ADS) (Devkota et al., 2020). ADS is the current policy guiding document of Nepalese agriculture. It has envisaged higher productivity based on mechanization with awareness creation, demand stimulation, concessionary financing arrangements, capacity building, and appropriate taxation (MoALD, 2014). PMAMP was implemented in the year 2073/74, with mechanization of agriculture being one of the strategies (PMAMP, 2020). This program has distributed around ten thousand small farm machinery equipment and 3000 medium and large farm machinery equipment (PMAMP, 2023). The government has also prioritized farm mechanization in every periodic plan and policy.

The average power consumption of Nepal is 0.8 kw/ha. In contrast, the average power consumption of neighboring country India is 3 kw/ha, and that of a highly mechanized country is up to 10 kw/ha (PMAMP, 2023). The national level of mechanization is 60%, but mechanization in mid-hills and high hills is 15% and 2%, respectively (PMAMP, 2023). Major machinery used in Nepalese agriculture are 4-wheeled tractors, cultivators, disk harrows, rotavators, 2-wheeled tractors/power tillers, mini tillers, rice transplanters, irrigation pumps, sprayers, threshers, corn sellers, etc. The majority of mechanization is concentrated in Terai districts adjoining the Indian border. With increasing road connectivity, tractors, mini tillers, and threshers are increasing in rural mid-hills and high hills (Gauchan & Shrestha, 2017). According to NSO (2023), tractor users

in 2011-12 were 845,000, and users increased to 1,000,639 in 2021/22. Within 10 years, the number of tractor users increased by almost 100%.

Migration has been a global trend, and agricultural households from rural agrarian countries have become the major source of this mobile population (Bhandari and Ghimire, 2016). Migration has adversely affected agriculture yield by inducing labor shortages, and remittance-receiving households are not investing such incomes in productivity-enhancing agricultural capital goods and inputs (Tuladhar et al., 2014). Currently, migration plays a central role in the livelihood decisions of most households, with nearly half of all Nepalese households having at least one member either working abroad or having returned from migration (Tiwari and Bhattarai, 2011). This has caused labor scarcity in Nepalese agriculture (Pingali, 2007). On the other hand, the use of manual labor in agriculture has increased the cost of production. Thus, mechanization is necessary for solving labor scarcity and reducing the cost of production. Realizing this fact, all three-tier governments have prioritized mechanization programs without prior cost-benefit and feasibility studies. In the name of mechanization, the use of farm machinery has increased haphazardly. This has further negatively impacted agriculture. Despite government priority, adoption of farm machinery has not been satisfactory. In this context, this study assesses the overall scenario of mechanization in different ecological zones and figures out issues associated with it. This study aims to find determinants of farm mechanization adoption and develop recommendations to enhance mechanization rationally in Nepalese agriculture.

MATERIALS AND METHODS

Study area

Lumbini province is one of Nepal's seven provinces, which are comprised of terai and hill terrain. Geographically, Lumbini province expands from 27˚20' to 29˚ 0' north latitude and 81˚ 21' to 84˚ 02' east longitude. This province comprises 12 districts, of which 6 are terai districts, 5 are hilly districts, and 1 is a high hill district. The study was conducted in four districts of Lumbini province: two hilly districts, namely Palpa and Gulmi, and two terai districts, namely Kapilbastu and Banke. The contribution of Lumbini province to the national gross domestic product is 14.10%. The agricultural sector's contribution to the province's gross domestic product is 29.40%, while its contribution to the national gross product is 23.9 %. The average land holding per farming family is 0.7 hectares. 76.5% of the farming families share 50% of the total land in the province. This province has around 68000 ha of cultivable land, of which only 27% has been cultivated (DoAD, 2022).

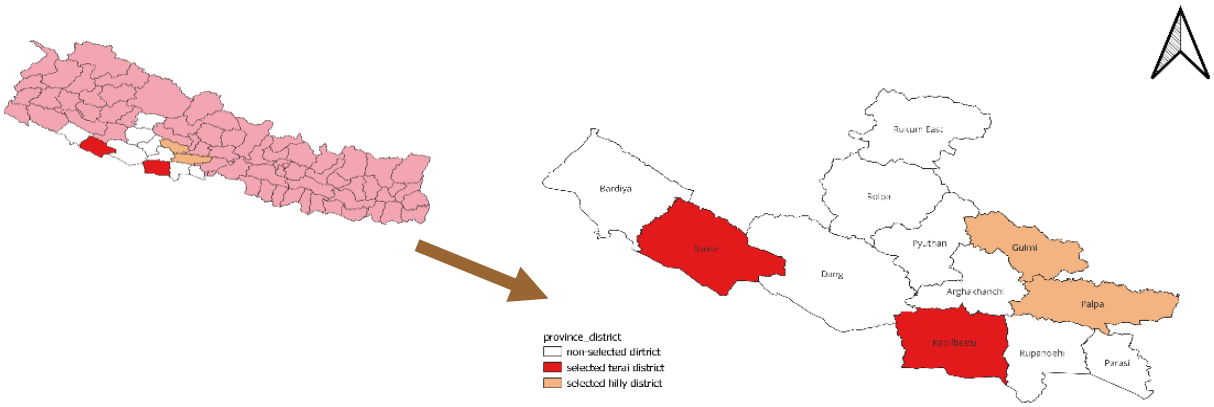

Figure 1. Map of Nepal and study area.

Rice, Wheat, and Maize are the major cereal crops cultivated in the province, while finger millet, buckwheat, and barley are minor. Citrus is the major fruit of the hills, whereas mango and banana are the

major fruit crops cultivated in the lower range. Vegetable farming is on a commercial scale both in hill and terai districts.

Sampling procedure and sample size

A multistage sampling technique was followed in this study. Twelve districts of Lumbini province were divided into two clusters: six hilly districts and six terai districts. In the first stage, two districts from each cluster were selected using simple random sampling. The study area was selected in such a way as to represent the whole province ecologically. Nature and Intensity of mechanization are different in different ecological zones. Farmers who received grant support from the provincial government comprise the population. The provincial government supported 1196 farmers with financial aid in the fiscal year 2022/23. Among them, 125 households were selected for the study, more than 10% (~120) of the population. The number of respondents from each ecological zone was purposively selected in proportion to the number of grantees in each zone.

Table 1. Population and sample size of respondents of different ecological zones.

Ecological zone	Grantee Farmers	Sample Size
Hill	562	59
Terai	634	66
Total	1196	125

Data and data collection technique

The study was carried out using both primary and secondary data. Primary data was collected via household survey using an interview schedule and Focus group discussion using a semi-structured questionnaire. The interview schedule was prepared based on the literature review of past similar studies and finalized after pretesting among 10 farmers. Both qualitative and quantitative questions were included in the interview. Likert scale was used to quantify the perception-based question. The reliability and validity of the interview schedule were tested by calculating Cronbach's alpha. Data were collected using enumerators. Focus Group Discussion (FGD) was conducted in each surveyed district with stakeholders comprising farmers, extension workers, and local leaders. Perception-based questions and pertinent issues were discussed in FGD, which helped validate the data collected from the household survey and provided insights into relevant issues. Secondary data was collected through a desk review. Published articles and journals, statistical information, and past studies on similar topics were used as references for the study.

Data analysis

Primary data collected from the field survey 2023 were used for descriptive and inferential analysis. The collected data were entered into a Microsoft Excel sheet and processed to fulfill the specific objectives. Descriptive statistical tools such as frequency, mean, ratio, standard deviation, percentage, minimum, maximum, etc. were applied to summarize the socioeconomic characteristics of mechanization adopter farmers. Most of the other inferential analyses were done with the help of STATA software.

Scaling technique

The indexing method was used to rank reasons for the adoption of farm machinery and factors hindering the adoption of farm machinery based on the response frequencies. The scaling technique provides the direction and extremity attitude of the respondents toward any proposition. Past studies have used a similar ranking method (Ghimire et al., 2018; Panta et al., 2020). Reasons for adoption and hindering factors for adoption were ranked using a five-point Likert scale as strongly agree, agree, neutral, disagree, and strongly disagree. The weighted average mean was used to calculate the index value for each statement variable to rank by using the following formula;

$$I_i = \sum \frac{s_i f_i}{N}$$

Where S_i represents scale value, f_i is the frequency of responses by farmers, and N is the total number of respondents under study.

Econometric model: Multiple OLS regression model

Multiple OLS regression model was used to analyze the factors affecting the overall adoption of farm mechanization. The selection of independent variables was made based on similar past studies.

The multiple linear regression model (OLS) was appropriate for analyzing determinants of farm mechanization among the sampled farmers as the dependent variable is continuous. However, when some of the Classical Linear Regression (CLR) model assumptions are violated, The parameter estimates of

the above model may not be the Best Linear Unbiased Estimator (BLUE). Thus, the presence of heteroscedasticity, multicollinearity, and endogeneity problems should be checked before fitting important variables into the regression models for analysis (Emmanuel and Maureen, 2021).

$$Y_i = b_0 + b_i X_i + \mu_i$$

Where Y = Average farm machinery per household, X_i = explanatory variables included in the model, and μ_i =Error term. The dependent and independent variables, types, descriptions, and expected signs are presented in Table 2.

Table 2. Description and expected sign of the determinant variables used in OLS regression.

Variables	Variables type	Description	Expected sign
Average farm machinery per HH	Dependent	The average number of farm machinery in an HH	
Subsidy	Dummy	1 if the household received a subsidy for machinery and 0 otherwise.	+
Ecological zone	Dummy	1 if the sampled household is in terai geography and 0 otherwise.	+
Age	Continuous	The age of the farming household (HH) head is measured in years.	-
Gender	Dummy	1 if the household head is male and 0 otherwise.	+
Occupation	Dummy	1 if the respondent's main occupation is agriculture and 0 otherwise.	+
Education	Continuous	Years of schooling of household head in number.	+
Land	Continuous	Total land owned by farmers in hectares.	+
Family size	Continuous	Total number of members in a family.	-
Economically active members of the family	Continuous	Number of members in the family between the ages of 15 to 59.	+
Educated members of the family	Continuous	Number of educated (literate) members in a family.	+
Family members abroad	Continuous	Number of family members out of country.	+
Membership	Dummy	1 if the respondent is involved in groups/cooperatives and 0, otherwise.	+
Membership duration	Continuous	Number of years since involvement in groups/cooperatives.	+
Distance	Continuous	Distance from extension office measured in Km.	-

Diagnostic tests

The OLS regression model was tested for normality, multicollinearity, and heteroscedasticity specification tests. Multicollinearity was detected using the variance inflation factor (VIF) test. As a general principle, the value of VIF greater than ten (10) exhibits a problem in data due to multicollinearity (Ghimire et al., 2023). Secondly, the heteroscedasticity test in the data was assessed using the Breusch-Pagan/Cook Weisberg test. A histogram and scatter plot matrix were performed for the normality test.

RESULTS AND DISCUSSIONS

Socioeconomic characteristics of respondents

Among 125 households participating in the study, 47% of the respondents were from the hill region, and 53% were from the terai region. The average age of the respondents who participated in the study was 48 years old, whereas 26 years old was the youngest and 75 years old was the eldest respondent. Among participant households, 108 were male-headed, and 17 were female-headed. Since the target group of the study is farmers, most participants, i.e. 119 respondents, had agriculture as their main occupation. In contrast, only six people had a main occupation other than agriculture. The average family size of participating households was 7.88, more than the national average of 4.37. The average number of years in school (education) was 7.2. 67.34 % of studied household members were educated, less than the national literacy percentage of 76%. The average annual income of the households participating in the study was Rs. 3,94,240, and the average annual income from agriculture was 2,09,120. About 53% of the total income

of the households studied was found to be from agriculture. Among the households studied, the economically active population was 65%, while according to the 2078 census, the national economically active population is 61.96%. No family members from 86% of the surveyed households had migrated abroad for employment, while family members from 14% of studied households had migrated abroad for employment. Out of the studied households, 96 were found to be members of the cooperative, while 29 households were not. The average period of membership in the cooperative was found to be five years and six months, while the minimum period of membership was one year and the maximum was twenty-eight years.

Table 3. Socioeconomic characteristics of sampled households in the study area.

Socioeconomic characters	Hill	Terai	Total
No. of respondents	59 (47%)	66 (53%)	125
Average age of respondent (years)	47.97	48.94	48.48
Female household head (%)	11 (18.6%)	6 (9.09%)	17
Average family size	5.92	9.65	7.88
Average education of respondent in years	7.31	7.14	7.2
Main occupation as agriculture (%)	91.5	98.48	95.2
Educated family member percentage	71.06	65.3	67.34
Average annual Income (NRs)	387457.6	400303.03	394240
Contribution of Agriculture in total income (%)	59.55	46.83	52.73
Economically active family member %age	67.62	63.1	64.7
Members of Family Abroad (%)	6 (10.16%)	12 (18.18%)	18 (14.4%)
Cooperatives/Group membership (%)	52 (88.13%)	44 (66.66%)	96 (76.8%)
Years of Membership	6.36	4.83	5.6
Average distance from extension office (km)	7.33	7.67	7.5

Land ownership

Most of the respondents were farmers with their land. The average land of farmers participating in the study was 1.32 hectares, more than the national average. This is due to the participation of respondents' dependence on agriculture. About 88% of the total cultivable land was reported cultivated, and 61% of the land was irrigated less than the province's average irrigated area.

Table 4. Land characteristics of the studied households.

Land parameters	Hill	Terai	Total
Average Land holding (ha)	0.86	1.74	1.32
Cropped land percentage of total holding	69.67%	96.60%	88.35%
Irrigated land percentage of total holding	48.65%	66.37%	60.94%

Mechanization in the study area

Machinery in study area

The nature of the machinery used in the Terai and hills differs. The plot size in the hilly region is small and the terrain is slope, but in terai, the plot size is large, and flat. Small and medium-sized tools are used more in the hills, while large-sized tools are mostly preferred in the Terai. In hilly districts, machinery like mini-tillers, Corn-shellers were abundant, while tools like threshers, pump-sets, and 4-wheeled tractors were used more in Terai. General tools like spades, hand hoes, etc used in agriculture are excluded from this study.

Subsidy scheme in farm machinery

The study examined how much of the agricultural machinery in every household was purchased by the farmers at full price and how much was purchased through the subsidy program provided by the

government. Among the machinery possessed by surveyed households, 100% was purchased through grant support, while some essential tools and equipment were purchased without grant support. All the power tillers found in the study were purchased through grant assistance, and 20% of the 4-wheel tractors were purchased through grant support. 58% of the total machinery in the survey was purchased through grant support. This shows that the subsidy program has promoted agricultural mechanization.

Table 5. Machinery in the study area.

Ecological zone	Mini-tiller	4-wheel tractor	Thresher	Corn-sheller	Pumpset	Chaff cutter	Motor	Sprayer	Total	Average Machinery per HH
Hill	50	5	5	12	0	3	2	17	94	1.59
Terai	15	23	6	1	27	3	16	25	116	1.76
Total	65	28	11	13	27	6	18	42	210	1.68

Table 6. Subsidized Machineries distribution in the study area.

S. No.	Machinery	Total	Subsidized no.	Subsidized percentage
1	Mini tiller	53	44	83
2	Power tiller	12	12	100
3	Thresher	11	6	55
4	Corn sheller	8	7	88
5	Pump set	27	6	22
6	Chaff cutter	6	3	50
7	Motor	18	14	78
8	Sprayer	42	21	50
9	Tractor	25	5	20
	Total	202	118	58

Machinery considered essential and already established technology, such as pump sets and four-wheel tractors, were acquired without or with minimal subsidy. Conversely, innovative and recently introduced technologies, like power tillers, were exclusively purchased with subsidies. In the past, machinery such as mini tillers and corn-shellers were acquired solely with grant support in hilly districts. Over time, as the financial benefits of using these tools became apparent, the same equipment was procured without subsidies. This demonstrates that the subsidy program has played a role in disseminating new technologies and machinery among farmers.

Source of Information

Among the farmers who participated in the study, 56% received information about mechanization from agricultural extension offices. This included the agriculture division of the local government, agricultural knowledge centers under provincial governments, the Prime Minister's Agriculture Modernization Project under the federal government, the Agricultural Research Council, and other governmental and non-governmental organizations. 10% of the respondents received information from the internet (smartphone), 12% from groups/cooperatives, while 22% received information from other sources like friends, neighbor. This implies that the agriculture extension office under the 3-tier government plays an important role in promoting mechanization in agriculture.

Reasons for Adopting Farm Machinery

In the study, farmers were asked to rank the reasons for using machinery in agriculture through close-ended questions. Respondents were given five possible answer options: lack of human resources, cost reduction, time-saving, source of income, and grant support. The five-point Likert scale was used to prioritize the response. According to the results of the indexing method, cost reduction has been ranked as the primary reason for

adopting farm machinery, while alternative sources of income have been ranked the lowest. This study indicates that the major reason for using agricultural machinery is to minimize production costs.

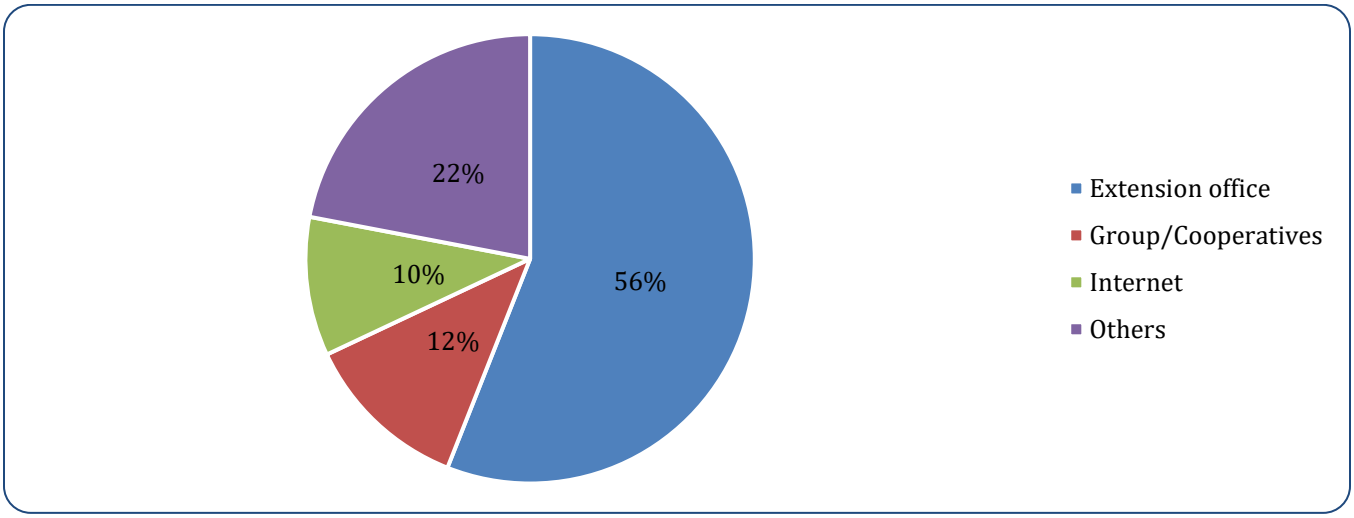

Figure 2. Sources of information for adoption of farm machinery.

Table 7. Reasons for adopting farm machinery.

Reason	Index value	Priority
Cost reduction	0.68	1
Lack of human resources	0.64	2
Grant Support	0.59	3
Time-saving	0.57	4
Source of Income	0.52	5

(Source: Household Survey 2023)

Factors hindering the adoption of farm machinery

During the study, respondents were asked to rank the reasons for the lack of complete mechanization in agriculture. Respondents were provided with five possible answer options in this closed-ended question format. The study revealed the absence of knowledge related to the operation and maintenance of farm machines as the primary reason for the lack of mechanization in agriculture. In contrast, lack of information was ranked the lowest.

Table 8. Factors hindering adoption of farm machinery.

Reason	Index value	Priority
Lack of operation and maintenance knowledge	0.70	1
Fragmented Land	0.60	2
High Operation cost	0.24	3
Economic deprivation	0.21	4
Lack of Information	0.20	5

(Source: Household Survey 2023)

Farmers' perception on the impact of mechanization on production cost and yield

Respondents were asked a close-ended question on impact of mechanization on cost of production and yield. About half (51%) of the surveyed households responded that production cost had decreased, while 42% felt production cost had increased with mechanization. 7% of respondents felt no significant difference in

production costs. Similarly, 76 % of the surveyed households responded that yield has increased with the use of machinery, and 17 % of the respondents felt no significant effect.

In comparison, 7% of the respondents felt a decrease in yield with mechanization. Out of the 24 studies reviewed, 22 indicated a decrease in total labour utilization per hectare in tractor-operated farms compared to those relying on animal draft power, twelve studies specifically noted labor reductions of 50% or more, and the most significant decrease in labor usage was observed in land preparation, with all studies reporting a reduction in labor input exceeding 75% (Pingali, 2007). Several studies have shown simple mechanization has also increased farmers return on investment (Acharya et al., 2020; Park et al., 2018).

Constraints in mechanization

Problems of mechanization

Although there are many benefits to mechanization in agriculture, there are also a few drawbacks. During the study, closed-ended questions were asked regarding mechanization problems, with answer options including pollution, repair and maintenance, fuel and power supply, accidents, and under-utilization. Respondents were asked to choose one problem they felt was major. Most respondents, i.e., 41% (51 respondents), cited repair and maintenance as the major problem of farm machinery. Likewise, 25% (31 respondents) identified pollution as a problem caused by mechanization, while 16%, 11%, and 7% felt that fuel and power supply, accidents, and under-utilization were problems associated with mechanization, respectively.

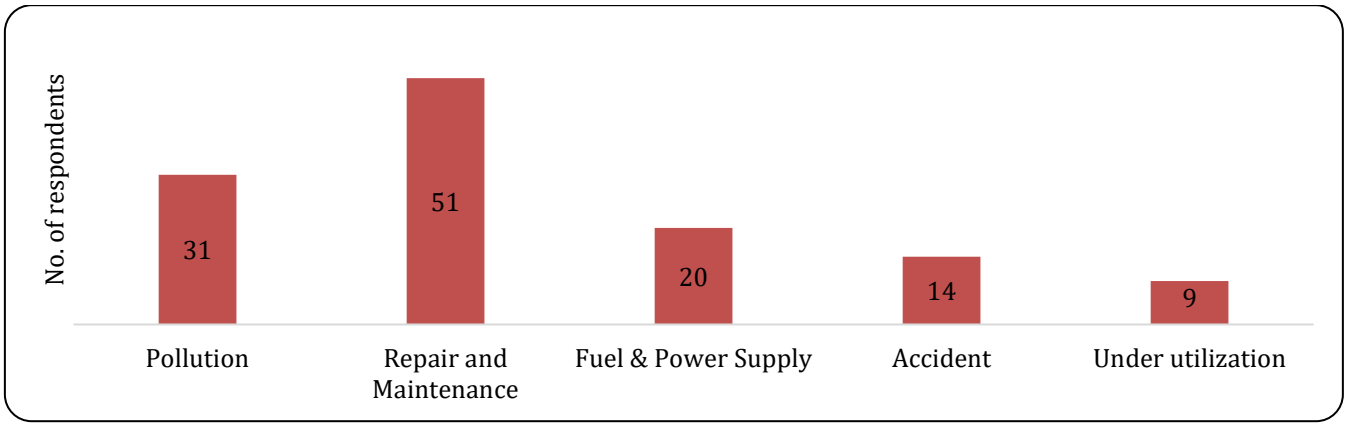

Figure 3. Major problems of farm mechanization perceived by farmers.

Repair and maintenance pose a major problem in rural areas. Pollution is a negative effect of mechanization in agriculture; air pollution and non-decomposable scraps are piling up. Another problem for mechanization is the lack of regular fuel and power supply. The lack of fuel availability wherever and whenever required and low voltage power supply has been problematic. Additionally, a lack of knowledge of operations has resulted in various accidents. In some cases, using machineries without feasibility studies and technical recommendations has been unproductive and economically unprofitable. Not all equipment available and distributed in the market is suitable for everyone.

Constraints in mechanization of women-led farming

During the study, a close-ended question was asked whether the farm machinery and equipment used in agriculture are women-friendly. Around 70% of the surveyed participants stated that the devices currently in use are not women-friendly, while only about 30 % reported that the devices are women-friendly. Some tools, such as Corn-shellers, rippers, and chaff-cutters, were women-friendly. However, heavy and labor-intensive machines are not suitable for women's usage.

Table 9. Number and percentage of participants responding women women-friendly mechanization.

Women Friendly	Frequency	Percentage
Yes	38	30
No	87	70
Total	125	100

Table 9 reflects the issue women face in mechanization extends beyond the lack of women-friendly tools and

involves limited financial access for women. Similarly, the low institutional development of women has been a barrier to their access to mechanization. Additionally, in some cases, social values and norms discourage women from engaging with agricultural machinery.

Constraints in repair of damaged machinery

During the study, a question was asked regarding whether or not the equipment was repaired. 68% (85) of the respondents did not repair the damaged machinery equipment, while 32% (40) repaired damaged machines. Although the problem of repair and maintenance is not severe in the Terai, in hilly zones, it is often cheaper to buy a new machine than to repair a damaged one. There are no garage facilities in the hills, and it is more expensive to transport equipment to a repair centre. Most suppliers do not provide repair services once the machines are sold.

Table 10. Percentage of respondents who repair and do not repair damaged machines.

Ecological zone	Repair %	Don't repair %
Hill	22	78
Terai	41	59
Total	32	68

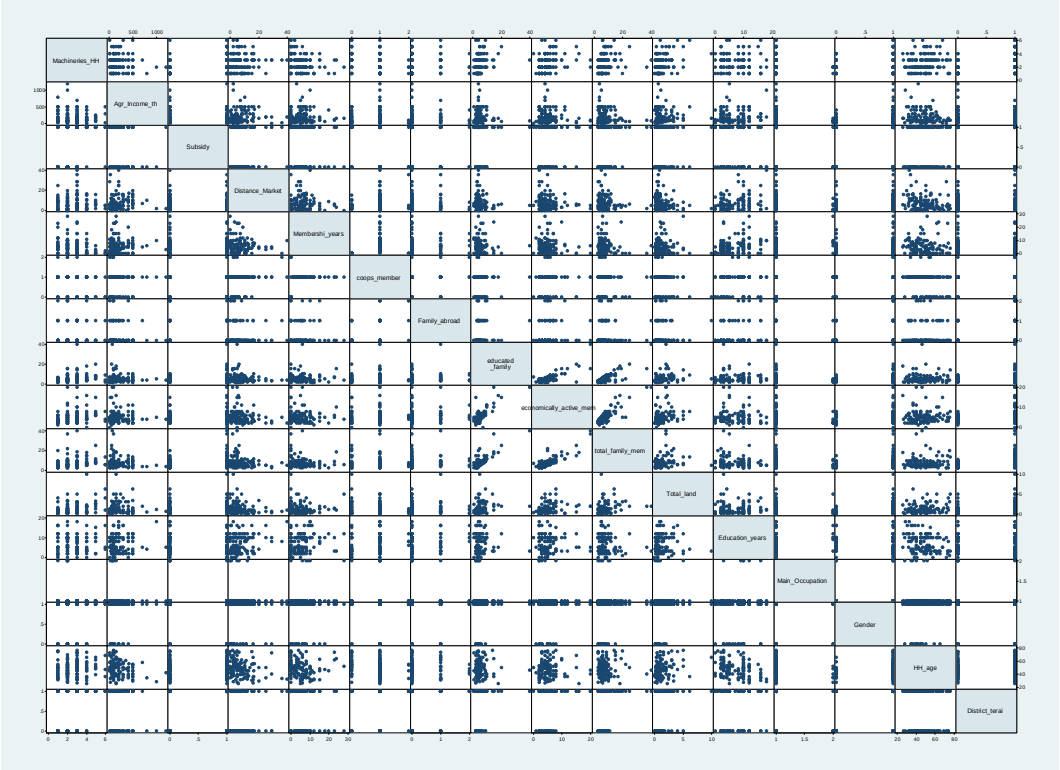

Figure 4. Scatter plot matrix of dependent and independent variables used in OLS.

Determinants of adopting farm machinery

Model specification tests

Few statistical tests were performed to assure the test of multicollinearity, heteroscedasticity, normality, and ovtest. Variance inflation factors (VIF) were calculated to test the potential multicollinearity necessary to ascertain regression variables' independence. With the regression model, the VIF was found to be low, with a mean of 1.93 and a maximum of 5.08, showing no multicollinearity problem in the dataset. Likewise, the Breusch-Pagan test resulted in a small chi^2 value of 1.04 and prob>chi^2=0.3214; ($p>0.05$), implying no heteroscedasticity problem in the dataset. Also, the normality test and Ramsey reset test were performed

and the result indicated good normality with a higher chi^2 value of 1.40.

The model has no omitted variables as the prob>F value exceeds 0.05. The histogram plot of the residuals (Figure 5) resembled a symmetric bell-shaped distribution with only one peak, explaining that the data is normally distributed with no presence of outlier. The reliability and validity of the Interview Schedule were tested by calculating Cronbach's alpha, which resulted in a value of 0.71. The Cronbach's alpha value greater than 0.7 implies that the scales used in the Interview Schedule are reliable and valid (Kennedy, 2022).

Determinants of adopting farm machinery

Table 11 shows that the model was statistically significant (P<0.001), indicating the model's goodness of fit to explain the hypothesized variables' relationships. The coefficient of multiple determinations (R^2) indicates that the variables included in the model explain 44 % of the variation in the number of farm machinery. The model showed that the provision of subsidies, ecological zones (Terai region), total land, economically active members in the household, and distance from extension services were positively significant determinants of adopting farm machinery in the study area. At the same time, total family members and membership in groups and cooperatives were negatively significant determinants of farm mechanization.

Table 11. Multiple OLS regression results for the determinants of adopting farm machinery by the sampled household.

Variables	Coefficient	Std. error	t	Marginal effect (dy/dx)	Multicollinearity statistic	
					VIF	1/VIF
Subsidy	.88722	.18799	4.72	.88722***	1.19	0.83843
Ecological zone	.55509	.20887	2.66	.55509***	1.47	0.67920
Age	-.0003	.00842	-0.04	-.0003	1.32	0.75778
Gender	.04864	.26322	0.18	.04864	1.11	0.90166
Occupation	.16905	.43792	0.39	.16905	1.19	0.83696
Education	-.02631	.02279	-1.15	-.02631	1.34	0.74389
Land	.19646	.08606	2.28	.196468**	1.39	0.71924
Family size	-.11626	.03434	-3.39	-.11626***	5.08	0.19699
Economically active members of the family	.13180	.05371	2.45	.13180**	4.21	0.23741
Educated members of family	.05286	.03549	1.49	.05286	3.44	0.29101
Family members abroad	.03222	.19245	0.17	.03222	1.28	0.78107
Membership	-.51826	.23790	-2.18	-.51826**	1.49	0.67218
Membership duration	-.02143	.01795	-1.19	-.02143	1.31	0.76304
Distance	.02540	.01330	1.91	.02540*	1.24	0.80326
Constant	1.9078	.80443	2.37	-	-	-
Statistics						
Marginal effects after regress y = Fitted values (predict): 2.6048387						
F (14, 109)	6.21 (Prob > F= 0.0000)					
R-squared	0.4439					
Adj R-squared	0.3725					
Root MSE	0.95733					
Number of observations	125					
Diagnostic tests						
Variance Inflation Factor (VIF) 1.93 (mean VIF), maximum VIF=5.08						
Breusch-Pagan/Cook-Weisberg test)	Chi^2 (1) = 1.04, prob>chi^2= 0.3214 (constant variance)					
Ramsey RESET test	Model has no omitted variables (ovtest) F (3, 106) = 1.40, Prob > F = 0.2469					

***, **, and * are Significant at 1%, 5%, and 10% level of probability, respectively.

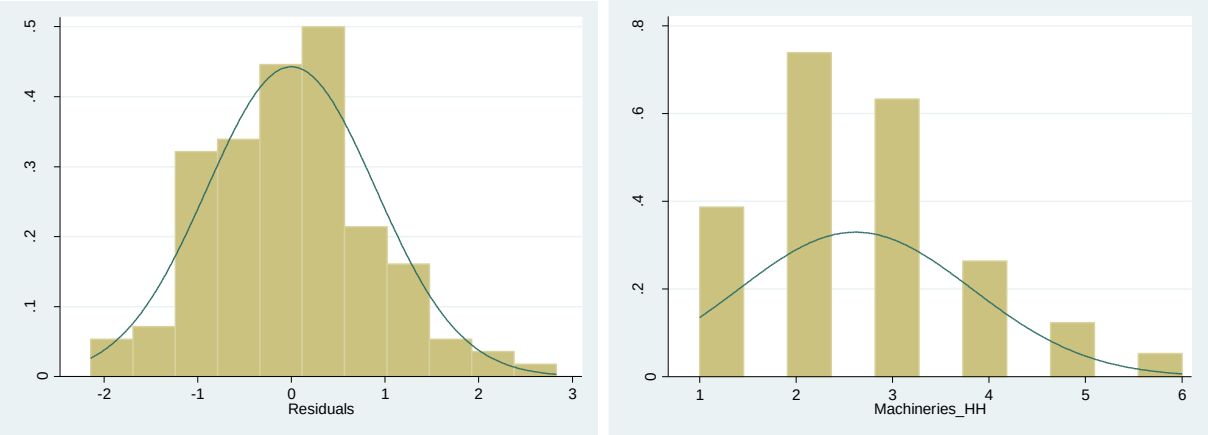

Figure 5. Histogram of the dependent variable and residuals for normality.

The result from the multiple OLS regression is in par with the result of studies conducted in adopting mechanization. In several studies (Arun et al., 2019; Ghosh, 2010, Akram et al., 2020; Mohammed et al., 2023, Gebiso et al., 2023), land holding was found positively significant with adoption of mechanization. With increasing land holdings, adoption of mechanization also increases. Mostly large land holding farmers prefer mechanization to reduce the cost of production and solve labor shortage problems which is not applicable in small land-holding farmers. Extension service also plays a vital role in the adoption of mechanization. The result showed distance from extension service is positively significant with adoption. Households farther away from extension services are less likely to adopt mechanization (Aryal et al., 2021; Sims & Kienzle, 2017). Farmers' visits will be more frequent if the service is available nearby. Extension service will increase awareness and sensitize the adoption of new technology. In a study by (Mohammed et al., 2023) access to extension service was highly significant with mechanization adoption. Owombo et al. (2012) also found that extension visits were positively significant when adopting mechanization.

The result showed subsidy is positively significant with adoption of mechanization. 58% of the machinery found in the study area were purchased with government grant support. In a study by (Khumbulani Sithembiso Nxumalo et al., 2020) financial assistance by the government had a positive relationship with usage of mechanization services. Smallholder farmers usually find investment in mechanization technology too expensive. The government must support them through subsidy and grant support programs (Sims and Kienzle, 2017). Subsidy will be useful when there is uncertainty about the effectiveness of new technology. It can allow farmers to experiment with the technology and learn from the experience before investing in it (Omotilewa et al., 2019). The adoption of machinery is also positively significant in ecological zones, i.e., the Terai region. Terai region has a higher rate of mechanization compared to the rest of the country and has the potential to expand and intensify (Karki et al., 2022). Large plot sizes, easy market access, open borders, and favorable geography are a few reasons for the expansion of mechanization in Terai. Wealth of the household is positively significant with the adoption of mechanization. Several studies have also found that a farmer's economic position is positively significant with adoption (Aryal et al., 2019; Mohammed et al., 2023). The higher the economically active population, the better the financial condition of the farming household, which will ultimately increase the adoption of mechanization.

As per the result of the study, family size and membership in groups or cooperatives are negatively significant with the adoption of mechanization. Results from various past studies have shown that membership in groups or cooperatives is positively significant with the adoption of mechanization, which contrasts with the result of this study. Most of the respondents from hilly region are members of groups and cooperatives but adoption of mechanization was low in the studied households. Similarly, in Terai, few cooperatives have operated custom hiring centers. Thus, members hire machines from a custom hiring center rather than purchase them. This has resulted in membership being

negatively significant in the possession of farm machines. Family size is negatively associated with the adoption of mechanization; with increasing family members, the adoption of mechanization decreases. A similar result was observed in the study by Akram et al., 2020. Large families supply labor required for agriculture operations, making households reluctant to adopt.

CONCLUSION AND RECOMMENDATIONS

The current global migration trend has caused labor shortages and high wages in the agriculture sector, increasing production costs. The application of farm machinery can be the means for cost reduction and promoting agricultural development. The result of the study has shown grant support and distance of extension service are positively significant with the adoption of mechanization. Penetration of new and advanced machinery has reached rural areas using matching grant programs. Due to a lack of information and low savings, farmer have not adopted machinery as expected. This implies that policymakers must invest more in effective extension services for quality and relevant information dissemination and grant support programs. Large land holding farmers have higher adoption than small holding farmers. For small-holding farmers, the government needs to establish a public custom hiring center so that adoption of machinery among marginal farmers will increase. Similarly, farmers with low purchasing capacity can be helped by government grant support. Nepalese agriculture is feminized, so machines manageable by woman is necessary to expand mechanization in agriculture. Studies have suggested repair and maintenance as major problems associated with mechanization. This government needs to establish service centers in remote areas and make it mandatory for suppliers to establish service centers. To solve the problem of haphazard distribution and under-utilization, purchase and distribution of machines approved by research institute must be mandatory.

Based on the result obtained from this study, data analysis, discussion, and published materials, the following suggestions are made for promoting mechanization in agriculture.

- Establish legal arrangements for purchasing and distributing machines and equipment that are technically feasible and economically profitable, following Agricultural Research Institute testing.
- Distribute machinery only upon the recommendation of relevant technicians.
- Make training in repair, maintenance, and operation mandatory alongside distribution.
- Replace the purchase of low-cost machines via price bidding with machines chosen by farmers in grant support programs.
- Provide insurance for agricultural machines.
- Ensure regular fuel and electricity supply for the operation of agricultural machinery.
- Establish government-run repair centers and custom hire centers.
- Fix maintenance rates to discourage variations in service charges.
- Increase access to finance to enhance women's access to equipment.

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