Archives of Agriculture and Environmental Science 8(4): 603-610 (2023)
https://doi.org/10.26832/24566632.2023.0804022

e-ISSN: 2456-6632

This content is available online at AESA

Archives of Agriculture and Environmental Science

Journal homepage: journals.aesacademy.org/index.php/aaes

ORIGINAL RESEARCH ARTICLE

Impact assessment of farm mechanization on potato production in Dadeldhura district, Nepal

Kapil Khadka[1*], Anupam Tiwari[2], Manju Yogi[3], Shiba Hari Dhakal[1], Ashok Rijal[1] and Kedar Devkota[4]

[1]Faculty of Agriculture, College of Natural Resource Management, Agriculture and Forestry University, Tikapur, Kailali, NEPAL
[2]Faculty of Agriculture, College of Natural Resource Management, Agriculture and Forestry University, Kaski, NEPAL
[3]Faculty of Agriculture, Agriculture and Forestry University, Chitwan, NEPAL
[4]Department of Agricultural Economics and Agribusiness Management, Agriculture and Forestry University, Chitwan, NEPAL
[*]Corresponding author's E-mail: khadkakapil942@mail.com

ARTICLE HISTORY

Received: 02 October 2023
Revised received: 10 December 2023
Accepted: 19 December 2023

Keywords

Cost minimization
Mechanization
Mini-tiller
Potato cultivation
Resource efficiency

ABSTRACT

Potato is one of the major cash crops in Nepal but farmers can't maximize profits due to the low adoption of farm machinery and technology. There is insufficient research on agricultural mechanization and its effectiveness in the study area. Therefore, the goal of this study, which was carried out in the Dadeldhura district in 2022, was to assess the problem of farmers' potato cultivation yielding less profit than they might have due to a lack of agriculture equipment and technology adoption. Purposive and simple random sampling were used to select 90 respondents from four local bodies of the Dadeldhura district. Primary data were collected from a household survey with a pre-tested semi-structured questionnaire and Key Informant Interview (KII). Secondary data were collected from annual PMAMP, MoALD, FAO reports, etc. MS Excel and SPSS (26.0) were used to analyze and interpret the collected data. The study divided farmers into groups based on whether they used bullocks or mini-tillers, and it found that mechanical power was mostly used during land preparation and irrigation phases. Fragmented land and lack of capital were major constraints to promoting mechanization. The study showed that mini-tiller users had a greater B: C ratio than bullock users. Similarly, the average variable cost of production per hectare was substantially lower in mini-tiller users than in bullock users. The results underlined the financial viability of mechanized potato farming and stressed the necessity of removing barriers to automation and developing regulations to support small-scale mechanization. The study concluded that mechanization might be extended beyond the stages of irrigation and field preparation to further improve cost-effectiveness and increase the profitability of potato cultivation for farmers in the Dadeldhura district. Overall, the study emphasized the necessity of strategic interventions to encourage automation and enhance the profitability of potato farming in the area.

Citation of this article: Khadka, K., Devkota, K. P., Tiwari, A., Yogi, M., Dhakal, S. H., & Rijal, A. (2023). Impact assessment of farm mechanization on potato production in Dadeldhura district, Nepal. *Archives of Agriculture and Environmental Science*, 8(4), 603-610, https://dx.doi.org/10.26832/24566632.2023.0804022

INTRODUCTION

Potato is one of the potential crops to meet global food demand and maintain food security (Devaux André *et al.*, 2019). Currently, it is harvested on an estimated 16.49 million ha of farmland globally, with a total production worldwide stands at 359 million tons. Asia Concentrates 50% of the world's potato production (FAOSTAT, 2020). Agriculture is Nepal's major economic activity; which employs 65 percent of the population and accounts for 27 percent of its GDP (MOALD, 2022). In Nepal, Potato ranks seventh in terms of cultivation area, third in terms of production, and second in terms of productivity (AITC, 2078), contributing around 6.35 percent of the Agriculture GDP. Although potato yields are in increasing order in Nepal, the production still falls short of meeting national consumption. Data from the fiscal year 2021/22 revealed that Nepal imported around 327,672 tons of potatoes worth NRs 8.20 billion (MoALD, 2023), showing the urgent need to increase both the area and production of potatoes. Dadeldhura district, with its conducive climate and market access, holds great potential for commercial potato production (Super Zone profile, 2021). However, despite having better market access and suitable climate, various factors such as traditional cultivation practices, low technology adaptation, less machinery use, lack of awareness of machinery use, high cost of the machine, land fragmentation, and workload to women contribute to suboptimal potato production in the Dadeldhura district. Low adoption of proper and affordable mechanization technology may act as a barrier to reaching optimum production. The 15th Five-Year Plan (2019) has set a strategy to boost the current productivity of potatoes from 16.65 MT/ha to 22 MT/ha by 2080/81 B.S (NPC, 2019), emphasizing the use of modern technologies by farmers. Potato productivity could be increased significantly by incorporating mechanization into different stages of the growth cycles and harvesting. Although previous studies indicate that potato yields in Nepal have significantly increased, in-depth examination of the obstacles to the best production in particular areas, such as Dadeldhura, are not available. This research is crucial in addressing gaps related to farm mechanization in the Dadeldhura district. The primary objective of this study is to assess the current status of farm mechanization in Dadeldhura district, specially focusing on its adoption by potato producers. In the end, it aims to support equitable access to technology and the expansion of potato growing in the Dadeldhura area in sustainable manner.

Farm mechanization is an application of engineering technology in the production process to boost worker productivity and efficiency. Increasing land productivity, increasing the level of cultivated land, moving toward commercialization, and achieving food security are the goals of mechanization (Emami *et al.*, 2018). Mechanization helps to reduce labor requirements, workload, and cost of cultivation (Shrestha, 2012). The main goal of mechanization is to better use resources (labor, energy). Mechanization in agricultural development helps scale up farming operations while increasing their timeliness, quality, and efficiency. To maximize the efficiency of inputs, numerous operations such as land preparation, planting, plant protection, harvesting, and threshing require a high degree of precision, which is made possible by the use of mechanization (Sarkar *et al.*, 2013).

The formal sector farm mechanization began in Nepal, after the foundation of the Agriculture Implement Research and Development unit at Birgunj in 2016 B.S. It is still in the infant stage and its promotion has received very little attention (AED, 2013). Small-scale mechanization has gained traction in Nepal since the 1970s when the 2WTs were introduced for transportation and agriculture in Kathmandu and the Pokhara Valley. After that, government programs continued to focus on large-scale machinery such as the 4WTS, its attachments, and combined harvesters (Justice and Biggs, 2020). To focus specifically on farm mechanization, the government of Nepal for the first time formulated the Agriculture Mechanization Promotion Policy (AMPP) on 13 August 2014 intending to promote agriculture mechanization and commercialization in agriculture. Facilitation of credit access, capital subsidies on agricultural machinery purchases, promotion of multipurpose machinery, separate number plates for subsidized vehicles used for agriculture, human resource development, and intellectual property rights for indigenous knowledge are the key provisions of the AMPP 2071 (GC *et al.*, 2019). Despite decades of investment and effort in mechanization in Nepal, the results are still inadequate. Without additional support mechanisms, the policy may not be sufficient to ensure increased and sustained use of appropriate farming machinery in Nepal (Brown *et al.*, 2021).

Mechanization activities are more concentrated in terai than in hills. Terrain roughness is inversely proportional to the degree of mechanization. Tractors are employed more often in flat areas than in rugged areas (Takeshima and Justice, 2020). Because of the plain landscape, easy access to roads, and proximity to the Indian border, the Terai region has a higher concentration of mechanization. Mechanization in the hilly region caught its momentum after 2010 with the introduction of the Chinese mini-tiller (Justice and Biggs, 2020). In recent years, with improved road connectivity in rural hills and mountains, the usage of tractors, power tillers, pump sets, and threshers has increased (Gauchan and Shrestha, 2017). However, Devkota *et al.* (2020) research suggests the dispersed character of households in hills makes it difficult to adopt mechanization effectively. The national average agricultural holding size is 0.96 ha, with 0.68 ha in the highlands and high hills, 0.77 ha in the mid-hills, and 1.26 ha in the Terai. Moreover, the out-migration trend in Nepal creates a farm labor shortage during peak hours, and increasing rural wages also discourage farmers from increasing production and utilizing resources efficiently (Paudel *et al.*, 2020). This justifies small-scale mechanization as a better option to deal with this issue in Nepal, especially Mid-hills (Ghimire and Timsina, 2014). Because of the geographical limits of hills and mountains, large machinery cannot be used; light and portable machines are suitable for hills. Mini-tillers are more likely to be used by households with a greater level of education, who live closer to input markets and have access to irrigation. There is a need to provide access to mechanization for households with lower social and economic capital in Nepal's mid-hills to promote inclusive access to technology (Paudel *et al.*, 2019).

MATERIALS AND METHODS

Study site

This study was carried out in four local bodies of the Dadeldhura district, namely Amargadhi, Ajaymeru, Navadurga, and Ganyapdhura. A preliminary study was conducted to gather information on the feasibility of the research. Direct observations and interactions with farmers and Agriculture extension staff were used to assess the study site's qualities. This data was utilized to prepare the interview schedule as well as rapport building with the farmers and related personnel.

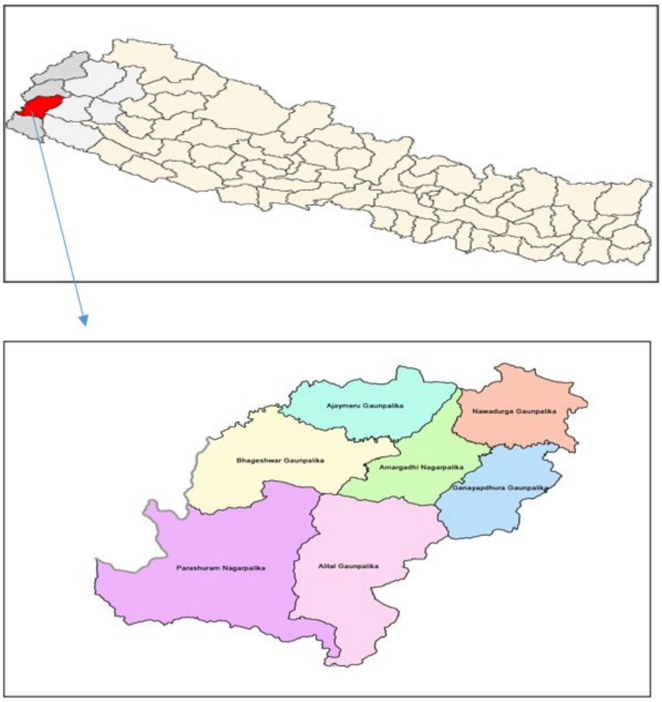

Figure 1. *Map of the study site.*

Sampling procedure

The sampling frame of farmer-producing potatoes was prepared with the help of the zone office. A total of 90 households were selected based on purposive and simple random sampling. The semi-structured interview schedule was pretested on 10% of the respondents before being administered to actual respondents. The household survey was conducted with the help of a pre-tested semi-structured questionnaire to collect first-hand information during May and June 2022. Key informant interview (KII) was conducted with progressive farmers, extension workers, farm managers, and other stakeholders related to potato production and mechanization to obtain the key information. Moreover, the secondary data were obtained through reviewing different publications including annual reports of PMAMP, MoALD, FAO, and different journals.

Data analysis

General Descriptive method

The information collected from the site was first coded and entered into the computer. Data were entered in MS Excel and the Statistical Package for Social Science (SPSS) program (Version 26.0) for analysis. Descriptive statistical tools like mean, standard deviation, frequency, and percentage were used to analyze and describe data.

Chi-Square test

Chi-square was used to study whether two variables were associated or independent of each other.

$$\chi 2 = \sum \frac{(O_{ij} - E_{ij})^2}{E_{ij}}$$

Where, χ^2=Chi-square

O_{ij} = observed frequency of each ijth term

E_{ij} = indicates the expected frequency of ijth term

i= 1, 2, 3……….r

j= 1, 2, 3………..k

Independent T-test

The independent t-test was applied for the difference between the two means keeping other variables constant. The formula for the independent t-test is as follows:

Suppose U and V represent the two groups to compare. Similarly, mU and mV represent the means of groups U and V, respectively. In the same way, let nU and nV represent the sizes of groups U and V, respectively. The t-test statistic value can be calculated as follows:

$$t = \frac{mU - mV}{\sqrt{\left(\frac{s^2}{nU} - \frac{s^2}{nV}\right)}}$$

s^2 is an estimator of the common variance of the two samples; which is calculated as follows:

$$s^2 = \frac{\sum(x - mU)^2 + \sum(x - mV)^2}{nU + nV - 2}$$

Indexing

The problems faced by respondents on mechanization and during the cultivation of the potato were ranked with the help of the forced ranking technique. The problems were ranked into 1st important problem, 2nd important problem, 3rd important problem as low and very low, and least important. The formula given below was used to find the index for the intensity of problems faced by producers (Miah, 1993).

$$I\ imp = \sum = \frac{Sifi}{N}$$

Where,

I imp = index of importance

∑ = summation

Si = ith scale value

Fi = frequency of i th importance given by the respondents

N = total number of respondents

Benefit cost ratio

Cost-benefit analysis was calculated by the total cost and gross return from the potato cultivation. The cost of production was calculated by summing the variable cost items in the production process (Rymbai *et al.*, 2012). Gross return, income was calculated from product sales. Thus, the benefit-cost analysis was calculated by using the formula below:

B/C ratio= Gross return / Total cost

RESULTS AND DISCUSSION

Socio-economic and demographic characteristics of categorical variables

It was found that the majority of the household heads 73.3% of the overall study, 75.6% of the mini-tiller user, and 71.1% of bullock user potato farmers were males. Gender has no association with the adoption of mini-tillers (Table 1). However, Aryal *et al.* (2019) suggest that Male-headed households were more likely to adopt power tiller and thresher. The majority (81.1%) of farmers' major occupation was agriculture, and the remaining 18.9% had a major occupation in the non-agriculture sector. Farmers whose major occupation was not agriculture were more inclined to use the mini-tiller than bullock, due to lack of time for bullock caring. Occupation of mini-tiller users and bullock users was found to be statistically significant at a 10% level of significance. The study showed that on average 84.4% of household heads were literate at different levels and 15.6% were illiterate. A higher secondary level of education was pursued by 53.4% of household heads of mini-tiller users compared to only 26.6% of household heads of bullock users. The education of the household head was statistically significant at a 10% level of significance. Brahmin is the dominant ethnicity with 44.4 % in the study area. Most of the mini-tiller users were Brahmin (60%) followed by Chhetri (28.9%) and Dalit (11.1%), respectively. The ethnicity of mini-tiller users and bullock users was found to be statistically significant at a 5% level of significance. Paudel *et al.* (2019) also reported that the educated household and upper caste (Brahmin and Chhetri) household were more likely to adopt mini-tillers compared to uneducated and lower caste. In both the mini-tiller user and bullock user farmer categories, the nuclear family was found to dominate at 75.6% and 77.8%, respectively.

Socio-demographic characters of continuous variables

The average age of the household head of mini-tiller users was 44.47 years and of the bullock user was 45.07 years with not any statistically significant difference between the means (Table 2). The overall mean of family size in the study area was 6.14. The annual income of mini-tiller users and bullock user farmers

Table 1. Association of socio-demographic characteristics of respondents (Categorical variable) with the adoption of farm machinery in Dadeldhura district, 2022.

Socio-Demographic Variable	Overall (N=90)	Mini-tiller User (n=45)	Bullock User (n=45)	Chi-square value	p-value
Gender of HH					
Male	66 (73.3)	34 (75.6)	32 (71.1)	0.227	0.634
Female	24 (26.7)	11 (24.4)	13 (28.9)		
Occupation of HH					
Agriculture	73 (81.1)	33 (73.3)	40 (88.9)	3.554*	0.059
Non-agriculture	17 (18.9)	12 (26.7)	5 (11.1)		
Education Level					
Illiterate	14 (15.6)	5 (11.1)	9 (20.0)		
Literate	19 (21.1)	9 (20.0)	10 (22.2)		
Primary	21 (23.3)	7 (15.6)	14 (31.1)	8.121*	0.087
Secondary	27 (30.0)	17 (37.8)	10 (22.2)		
Intermediate & above	9 (10.0)	7 (15.6)	2 (4.4)		
Ethnicity					
Brahmin	40 (44.4)	27 (60.0)	13 (28.9)		
Chhetri / Thakuri	36 (40.0)	13 (28.9)	23 (51.1)	8.821**	0.012
Dalit	14 (15.6)	5 (11.1)	9 (20.0)		
Family Type					
Nuclear	69 (76.7)	34 (75.6)	35 (77.8)	0.062	0.803
Joint	21 (23.3)	11 (24.4)	10 (22.2)		
Member in abroad					
Yes	17 (18.9)	9 (20.0)	8 (17.8)	0.073	0.788
No	73 (81.1)	36 (80.0)	37 (36.5)		

Figures in parentheses represent the percentage; **, and * indicates significance at 5% and 10% level respectively (Source, field survey 2022).

Table 2. Association between socio-demographic characteristics of respondents (Continuous variable) and adoption of farm machinery in Dadeldhura, 2022.

Variable	Overall (n=90)	Mini-tiller User (n=45)	Bullock User (n=45)	Mean difference	t-value	p-value
Age of HH	44.77	44.47	45.07	-0.6	-251	0.802
Family Size	6.14	6.24	6.04	0.2	0.451	0.653
Total Male	3.27	3.20	3.33	-0.13	-492	0.624
Total Female	2.88	3.04	2.71	0.33	1.305	0.195
Economic active members	3.61	3.67	3.56	0.11	0.356	0.723
Total Annual Income (NRs.)	256366.67	312244.44	200488.89	111755.55	2.8920***	0.005
Total Land Holding (ha)	0.53	0.64	0.42	0.21	3.199***	0.002
Potato Cultivated Area (ha)	0.25	0.29	0.20	0.084	2.951***	0.004
Distance from the near market (Km)	13.33	12.09	14.56	-2.46	-988	0.326

*** indicates significance at 1% level; (Source, field survey 2022).

was found to be statistically significant at a 1% level of significance. GC *et al*. (2019) and (Moniruzzaman *et al*., 2021) also revealed that income is the major determinant for investment in mechanization. Similarly, the average land holding was found to be 0.64 ha and 0.42 ha by the mini-tiller user and bullock users respectively.

The size of the land holding of the mini-tiller user household was found to be significantly higher than the bullock user at a 1% level of significance. The average potato cultivated area was found to be 0.29 ha in mini-tiller users and 0.20 ha in bullock user households which was statistically significant at a 1% level of significance. This aligns with the finding of Aryal *et al*. (2019) in Bangladesh; which reflects that larger farms get an advantage to reduce labor prices.

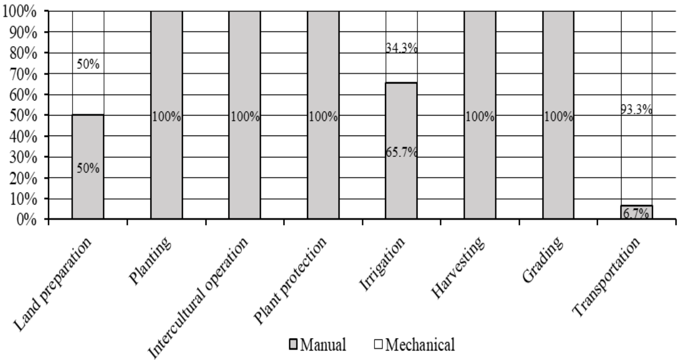

Figure 2. *Mechanization at different stages of potato cultivation in Dadeldhura District, 2022.*

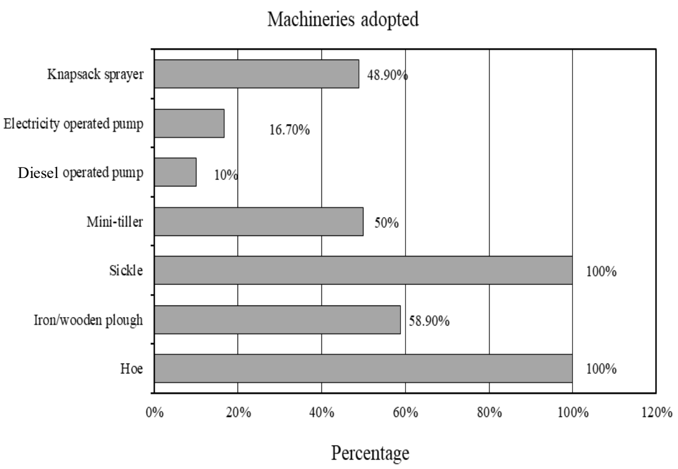

Figure 3. *Machineries tools and equipment adopted by potato growers in Dadeldhura district, 2022.*

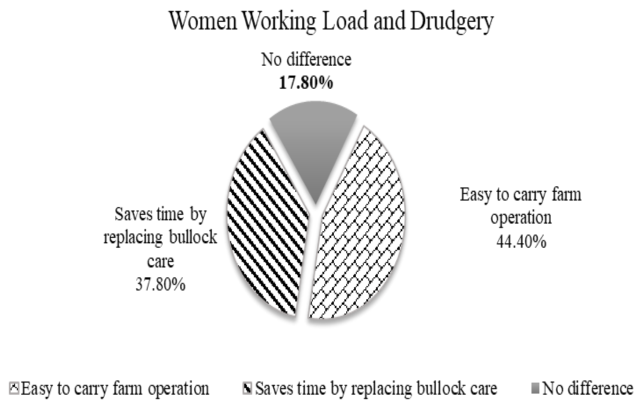

Figure 4. *Women's working load and Drudgery, 2022.*

Machinery used during different stages of potato production

The figure below shows that during land preparation 50% of farmers use machines (mini-tiller) (Figure 2). During irrigation, 34.3% used electric and diesel-operated motors and 93.3% of farmers used machines for transportation. Similarly, during planting, earthing up, Plant protection, harvesting, and grading no mechanical power machines were used which shows most of the stages of potato cultivation were completely based on manual labor. In Nepal, Mechanization in potato production is in the primary stage as compared to that of other countries (Basnyat and KC, 2016).

Machinery and tools adopted during potato cultivation

From the study, it was found that 50% of household heads used a mini-tiller, 58.9% used a traditional plow, and 100% used a hoe for the tillage and land preparation (Figure 3). During potato plantation, 100% of sampled farmers used hoe. 48.9% of sampled farmers used a sprayer for plant protection measures. 10% used diesel-operated pumps and 16.7% used electrically-operated pumps for irrigation. No any farmer used potato harvester and potato planter machines for harvesting and planting respectively. All the farmers (100%) in the study area used sickles and hoes for harvesting. Shrestha (2012) revealed that only 23 % of total farm power was from mechanical power; most of the farm operations in Nepal are still carried out by human and animal power.

Women's working load and drudgery

The table below shows that out of 45 mini-tiller adopter respondents, 44.4% of respondents' household female members found it easy to carry out farm operations for potato cultivation (Figure 4). After using a mini-tiller, women need not break clods manually which were formed by the traditional plough. Similarly, 37.8% of respondents' household female members found that after using a mini-tiller rather than a bullock the time for bullock care was saved. In the study area, mostly the women went out into the jungle or community forest to fetch the fodders for bullocks and other livestock. It shows that the adoption of mini-tillers helps to reduce the drudgery among women in the study area. Aryal and Kattel (2019) suggest that gender-friendly mechanization technology helps to reduce the women's working workload (time and energy).

Cost of production, revenue, net profit, and B: C ratio

The table below shows that the average variable cost of production by using a mini-tiller (NRs. 2,10,042.34/ha) was significantly lower as compared to using bullock (NRs. 2,26,433.5/ha) and the difference was statistically significant at a 5% level of significance. Kumari *et al*. (2020) revealed that Mini-tiller ploughing saved costs by 24% as compared to bullock pair in potato cultivation. Chemical fertilizer application by mini-tiller users (NRs. 5,231.27/ha) and bullock users (NRs. 3,207.32) was found to be statistically significant at a 10% level of significance. This finding aligns with Paudel *et al*. (2023); which reports that mini-tiller adopters invest more in fertilizer than non-adopters. The average land preparation cost was higher in bullock users (NRs. 31,562.26/ha) as compared to mini-tiller users (NRs. 14,661.08/ha) and the difference was statistically

Table 3. Cost of production of potato per hectare in Dadeldhura, 2022.

Particulars (NRs/ha)	Overall N=90	Mini-tiller user n=45	Bullock user n=45	Mean difference	t-value	p-value
Seed cost	84888.22	86253.02	83523.42	2729.6	0.630	0.530
FYM cost	34966.08	32793.67	37138.50	-4344.8	-1.247	0.216
Chemical fertilizer cost	4219.29	5231.27	3207.32	2023.9	1.90*	0.061
Micronutrients/Chemicals	1169.61	1339.26	999.97	339.29	1.085	0.281
Land Preparation cost (Human+oxen/Mini-tiller)	23111.68	14661.08	31562.26	-16901.1	-12.91***	0.00
Sowing cost (Human)	28034.00	28263.25	27804.75	458.5	0.330	0.742
Intercultural cost (Human)	14924.17	14958.01	14890.33	67.68	0.081	0.935
Harvesting and grading (Human)	23858.38	23121.50	24595.25	-1473.7	-1.365	0.176
Other costs (fuel, transportation,)	3066.49	3421.28	2711.70	709.5	3.845***	0.00
Total Variable cost	218237.92	210042.34	226433.50	-16391.1	-2.401**	0.018
Gross Revenue (NRs/ha)	390543.75	402235.50	378852.00	23383.50	1.702*	0.092
Net Profit (NRs/ha)	172305.82	192193.15	152418.50	39774.65	3.102***	0.003
B: C Ratio	1.816	1.947	1.686	0.26	3.871***	0.00

*,**, and*** indicate significance at 10%, 5%, and 1% respectively.

Table 4. Reasons behind not using mini-tiller in Dadeldhura district, 2022.

Reasons	Index	Rank
Small land holding	0.56	IV
Lack of capital	0.67	II
Difficulty in repair and maintenance	0.60	III
Lack of information about machinery	0.36	VI
Poor subsidy	0.54	V
Fragmented and scattered land	0.77	I

significant at a 1% level of significance. The cost of humans and bullocks for tillage was overused in potato production (Sapkota and Bajracharya, 2018). Paudel *et al.* (2023) reported that lower land preparation cost for mini-tiller adopters makes 15% lower on average variable cost than the non-adopter. Pingali (2007) also reported mechanization reduces labor use by more than 50%; the greatest reduction was found in land preparation.

From the study, we found the average gross revenue of the mini-tiller user (NRs. 4,02,235.50/ha) was significantly higher than the bullock user (NRs. 3,78,852.0/ha) at a 10% level of significance. The net profit was positive and the B: C ratio was greater than 1, which shows that potato cultivation is profitable in the study area. Net profit was significantly higher in mini-tiller users (NRs. 1,92,193.15/ha) as compared to bullock users (NRs. 1,52,418.50/ha). This finding supports Paudel *et al.* (2023), who report adoption of mini-tillers increases maize yield and profitability by 20-25%. The average B: C ratio of potato production in the study area was 1.816. The B: C ratio was significantly greater in mini-tiller users (1.947) than in bullock users (1.686). This is due to the reduction in the tillage cost by using a mini-tiller. Paudel *et al.* (2019) also found that the Cost of cultivation in mini-tiller adopter rice farmers was found lower, and gross revenue and profit was found higher than non-adopters. Moreover, the study of Verma (2006) finds average return from tractor-operated farms was 152 % for bullock farming; this is due to increased crop productivity due to better land preparation and timely planting.

Problem in mechanization adoption

Six problems were identified for mechanization adoption from field observation and KII. Responses are ranked by force scale ranking. Table 4 shows that the major problem behind adoption was fragmented land. Shrestha (2012) also suggests that small and scattered land acts as a barrier to promote mechanization in Nepal. Furthermore, fragmented land not only makes it difficult to adopt farm mechanization but also increases farm abandonment. Subedi *et al.* (2021) find that around 40 % of agricultural land in mid-hills has been abandoned. It implies that there is a need of the proper socio-physical feasible land policy to consolidate land and increase the scope of mechanization. Lack of capital is another important barrier to investing in mechanization. Alomia-Hinojosa *et al.* (2018) also find the lack of capital as the major constraint to adopting mini-tiller in Dadelhura. Besides these, difficulty in the repair maintenance, small land holding, poor subsidy, and lack of information about machinery respectively act as hindrances to promote mechanization in Dadeldhura. It is essential to create a noble intervention in existing policy and practice to promote mechanization in the country (Shrestha, 2012).

Conclusion

In a nutshell, farm mechanization in potato production is in the developing stage. Mechanical power was used only in the land preparation and irrigation stage of potato production. Mini-tiller was found to be an effective machinery for land preparation in Dadeldhura to reduce the land preparation cost and increase profit. Adoption of mini-tiller encourages the farmer to expand the area under cultivation as well as reduce the drudgery among women in the study area. Fragmented land and lack of capital act as an obstacle to promoting mechanization in mid-hills. Lack of repair and maintenance, small landholding, poor subsidy, and lack of information are other challenges in farm mechanization. So, plans and policies must be developed; that are geographically, ecologically, and socioeconomically feasible to promote small -scale mechanization in the mid-hills of Nepal. Mechanized potato cultivation (mini-tiller) was found to be more profitable than traditional (bullock) potato cultivation. However, most of the cultural operations: planting, earthing up, harvesting, and grading were completely based on manual power. Thus, focusing on the mechanization at other stages of potato cultivation besides land preparation and irrigation reduces the cultivation cost and ultimately makes potato farming more profitable.

Conflict of interest

The authors declare that there is no conflict of interest with the present manuscript.

ACKNOWLEDGMENT

We would like to acknowledge Agriculture and Forestry University for funding this study. We are thankful to site supervisor Mr. Khem Raj Joshi, Senior Agriculture Officer, Prime Minister Agriculture Modernization Project (PMAMP), and member supervisor Mr. Tilak Raj B.C, Senior Agriculture Economist, Ministry of Agriculture and Livestock Development, for their valuable suggestions and guidance.

REFERENCES

Agricultural Engineering Division (AED) (2013). Annual Report- 2072_73 , Nepal Agriculture Research Council, Khumaltar, Nepal.

AITC. (2078). Krishi Diary. In the Agriculture Information And Training Center , Government of Nepal. http://aitc.gov.np/downloadfile/agriculture diary 2078 for web_1619513804.pdf

Alomia-Hinojosa, V., Speelman, E. N., Thapa, A., Wei, H. E., McDonald, A. J., Tittonell, P., & Groot, J. C. J. (2018). Exploring farmer perceptions of agricultural innovations for maize-legume intensification in the mid-hills region of Nepal. *International Journal of Agricultural Sustainability*, *16*(1), 74–93, https://doi.org/10.1080/14735903.2018.1423723

Aryal, A., & Kattel, R. R. (2019). Drudgery reduction for women in the agriculture sector in Nepal: An analytical study. *Archives of Agriculture and Environmental Science*, *4*(4), 449–463, https://doi.org/10.26832/24566632.2019.0404012

Aryal, J. P., Rahut, D. B., Maharjan, S., & Erenstein, O. (2019). Understanding factors associated with agricultural mechanization: A Bangladesh case. *World Development Perspectives*, *13*(February), 1–9. https://doi.org/10.1016/j.wdp.2019.02.002

Basnyat Madhusudan, & Hari, K. C. (2016). Asian and Pacific Workshop on Potato Production. In Status of Potato Production and Whole-process Mechanization in Nepal (Issue June). https://un-csam.org/sites/default/files/2020-10/Proceedings_Potato Workshop_final_27 Dec 2019.pdf

Brown, B., Paudel, G. P., & Krupnik, T. J. (2021). Visualizing adoption processes through a stepwise framework: A case study of mechanization on the Nepal Terai. *Agricultural Systems*, *192*(June), 103200, https://doi.org/10.1016/j.agsy.2021.103200

Devaux André, Goffart Jean-Pierre, Petsakos Athanasios, Kromann Peter , Gatto Marcel , Okello Julius , & Suarez Victor, H. G. (2019). The potato crop: Its agricultural, nutritional and social contribution to humankind. In The Potato Crop: Its Agricultural, Nutritional and Social Contribution to Humankind. *Springer International Publishing*. https://doi.org/10.1007/978-3-030-28683-5

Devkota, R., Pant, L. P., Gartaula, H. N., Patel, K., Gauchan, D., Hambly-Odame, H., Thapa, B., & Raizada, M. N. (2020). Responsible agricultural mechanization innovation for the sustainable development of Nepal's hillside farming system. *Sustainability (Switzerland)*, *12*(1). https://doi.org/10.3390/SU12010374

Emami, M., Almassi, M., Bakhoda, H., & kalantari, I. (2018). Agricultural mechanization, a key to food security in developing countries: Strategy formulating for Iran. *Agriculture and Food Security*, *7*(1), 1–12, https://doi.org/10.1186/s40066-018-0176-2

FAOSTAT. (2020). https://www.fao.org/faostat/en/?#data/QCL/visualize

Gauchan, D., & Shrestha, S. (2017). Agricultural and rural mechanization in Nepal: Status, issues and options for future. *Institute for Inclusive Finance and Development (InM)*, *2*(July), 97–118. https://www.bioversityinternational.org/e-library/publications/detail/agricultural-and-rural-mechanisation-in-nepal-status-issues-and-options-for-future/

GC, A., Yeo, J. H., & Ghimire, K. (2019). Determinants of Farm Mechanization in Nepal. *Turkish Journal of Agriculture - Food Science and Technology*, *7*(1), 87–91, https://doi.org/10.24925/turjaf.v7i1.87-91.2131

Ghimire, S. R., & Timsina, J. (2014). Small Scale Mechanization Could Transform the Mid-Hill Economy of Nepal. *Researchgate*, *july*, 1–7. https://www.researchgate.net/publication/299949715%0ASmall

Justice, S., & Biggs, S. (2020). The spread of smaller engines and markets in machinery services in rural areas of South Asia. *Journal of Rural Studies*, *73*(October 2017), 10–20. https://doi.org/10.1016/j.jrurstud.2019.11.013

Kumari, N., Singh, P. K., & Singh, P. (2020). Promotion of mini power tillers among marginal and small farmers. *9*(3), 53–56.

Miah, A. Q. (1993). Applied Statistics: A Course Handbook for Human Settlements. Bangkok, Thailand: Asian Institute of Technology, Division of Human. Settlements Development.

MoALD. (2023). Statistical Information on Nepalese Agriculture. MoALD, 269. https://medium.com/@arifwicaksanaa/pengertian-use-case-a7e576e1b6bf

MOALD. (2014). Ministry of Agriculture and Livestock Development | Ministry of Agriculture and Livestock Development. https://moald.gov.np/

Moniruzzaman, -, Rahman, M. S., & Khan Sujan, M. H. (2021). Determinants of Small-Scale Mechanization for Potato Farming: A Case from Bangladesh. *Journal of Nepal Agricultural Research Council*, *7*(April), 75–82, https://doi.org/10.3126/jnarc.v7i1.36923

NPC. (2019). The Fifteenth Plan (2076/77-2080-81) National Planning Commission , Government of Nepal Kathmandu Nepal. https://npc.gov.np/images/category/15th_plan_English_Version.pdf

Paudel, G. P., Gartaula, H., Rahut, D. B., & Craufurd, P. (2020). Gender differentiated small-scale farm mechanization in Nepal hills: An application of exogenous switching treatment regression. *Technology in Society*, *61*(April), 101250, https://doi.org/10.1016/j.techsoc.2020.101250

Paudel, G. P., Gartaula, H., Rahut, D. B., Justice, S. E., Krupnik, T. J., & McDonald, A. J. (2023). The contributions of scale-appropriate farm mechanization to hunger and poverty reduction: evidence from smallholder systems in Nepal. *Journal of Economics and Development*, *25*(1), 37–61, https://doi.org/10.1108/jed-10-2022-0201

Paudel, G. P., KC, D. B., Rahut, D. B., Justice, S. E., & McDonald, A. J. (2019). Scale-appropriate mechanization impacts on productivity among smallholders: Evidence from rice systems in the mid-hills of Nepal. *Land Use Policy*, *85* (April), 104–113, https://doi.org/10.1016/j.landusepol.2019.03.030

Pingali, P. (2007). Chapter 54 Agricultural Mechanization: Adoption Patterns and Economic Impact. *Handbook of Agricultural Economics*, *3*(06), 2779–2805. https://doi.org/10.1016/S1574-0072(06)03054-4

Rymbai, D., Singh, R., Feroze, S. M., & Bardoloi, R. (2012). Benefit-Cost Ratio Analysis of Pineapple Orchard in Meghalaya. *Issue 1 Indian Journal of Hill Farming*, *25*(1), 9–12. www.kiran.nic.in

Sapkota, M., & Bajracharya, M. (2018). Resource Use Efficiency Analysis for Potato Production in Nepal. *Journal of Nepal Agricultural Research Council*, *4*(April), 54–59, https://doi.org/10.3126/jnarc.v4i1.19690

Sarkar, D., Roy, D., & Chattopadhyay, K. S. (2013). Effect of farm mechanization on agricultural growth and comparative economics of labour and machinery in west bengal.

Shrestha, S. (2012). Status of Agricultural Mechanization in Nepal. *4*(May), 1–4. https://www.researchgate.net/

Subedi, Y. R., Kristiansen, P., Cacho, O., & Ojha, R. B. (2021). Agricultural Land Abandonment in the Hill Agro-ecological Region of Nepal: Analysis of Extent, Drivers and Impact of Change. *Environmental Management*, *67*(6), 1100–1118, https://doi.org/10.1007/s00267-021-01461-2

Takeshima, H., & J., & E., S. (2020). Evolution of agricultural mechanization in Nepal. December.

Verma, S. (2006). Impact of Agricultural Mechanization on Production, Productivity and Employment of Labour. https://www.researchgate.net/