Impact of Drudgery-Reducing Agricultural Tools on Women Farmers in Karnali Province, Nepal

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Abstract

This study examines the impact of the Drudgery Reduction Equipment and Tools Support (DRETS) initiative implemented under the Agricultural Sector Development Program (ASDP) on women farmers in Karnali Province, Nepal. Using a mixed-methods approach, the research draws on quantitative and qualitative data collected from 618 households across five districts to assess changes in labor use, productivity, income, and well-being following the adoption of drudgery-reducing agricultural tools. A production function framework was applied to analyze how capital inputs in the form of tools and equipment interacted with labor and material inputs to influence agricultural outcomes. The study finds that the introduction of appropriate, women-friendly tools significantly reduced the physical burden and time intensity of agricultural work without compromising productivity. Instead, farming efficiency improved, enabling women to maintain or increase agricultural output while relying on less manual labor. Reduced drudgery contributed to better health, lower fatigue, and improved time management among women farmers, allowing some to engage in additional productive or income-generating activities. The results indicate that gains in agricultural income were driven primarily by efficiency improvements associated with technology adoption rather than increased labor effort. Despite these positive outcomes, the study also identifies persistent constraints related to the affordability of equipment, limited access to repair and maintenance services, and prevailing gender norms that restrict women's full control over agricultural technologies. The study concludes that targeted mechanization is an effective strategy for reducing women's drudgery and enhancing economic empowerment in marginal regions, but its long-term impact depends on complementary measures addressing access, affordability, and gender-related barriers.

Keywords: Agriculture mechanization, drudgery reduction, labor efficiency, production function, women farmers

Introduction

Agriculture constitutes the fundamental backbone of Nepal's economy and societal structure, engaging approximately 60 percent of the population and contributing about 27 percent to the nation's gross domestic product (GDP) (World Bank, 2022). Despite its paramount importance, the agricultural sector in Nepal remains predominantly traditional and labor-intensive. The reliance on manual labor, rudimentary hand tools, and animal power persists, with limited penetration of modern technologies such as tractors, mechanical seeders, or harvesters, particularly in remote and topographically challenging regions like Karnali. This technological lag contributes to chronically low productivity, perpetuating cycles of poverty and food insecurity among rural households (Sharma et al., 2020).

Within this agrarian framework, women play an indispensable and disproportionately demanding role. They comprise over 70 percent of the agricultural labor force and are responsible for most subsistence farming activities (FAO, 2020). This disparity is exacerbated by significant male

out-migration for foreign and urban employment, a trend that leaves women as the *de facto* managers of both agricultural holdings and domestic spheres (Acharya & Koirala, 2020; Gartaula et al., 2020). Women are primarily responsible for the most labor-intensive tasks in the agricultural calendar, including sowing, transplanting, weeding, harvesting, threshing, and irrigation management. Concurrently, they bear the full burden of unpaid domestic chores and care work. Empirical studies estimate that women agriculturists in Nepal spend between 12 to 16 hours daily engaged in this dual burden of farm and household labor (Subedi et al., 2019).

This excessive and relentless workload culminates in a condition widely characterized as drudgery. Drudgery refers to arduous, repetitive, and physically exhausting tasks that consume immense time and energy while yielding disproportionately low economic returns (Bishop-Sambrook, 2005). For women farmers, the implications of drudgery are multifaceted and severe. Physiologically, it manifests in chronic health issues such as musculoskeletal disorders, back pain, joint complications, and general fatigue (Gartaula et al., 2012). Socially, it constricts the time available for rest, childcare, education, and participation in community governance or social networks, thereby reinforcing their social marginalization (Aryal et al., 2020). Economically, drudgery acts as a significant constraint on productivity and income generation, as women are deprived of the time and energy necessary to engage in more profitable, high-value agricultural activities or alternative income-generating enterprises (Theis et al., 2018).

Consequently, the reduction of drudgery has emerged as a critical objective for enhancing both agricultural productivity and gender equity in Nepal. A promising pathway toward this goal is the strategic mechanization of agriculture. Mechanization, in this context, entails the introduction and adoption of improved tools and equipment designed to replace or significantly reduce human physical labor (Pingali, 2007). This spectrum ranges from small-scale, affordable technologies like weeders, corn shellers, and chaff cutters to larger machinery such as power tillers and threshers. Evidence from various studies suggests that appropriate mechanization can reduce the physical labor burden on women by 30 to 40 percent, while simultaneously improving operational efficiency and crop yields (Pradhan et al., 2021). For instance, a mini-tiller can prepare land in a fraction of the time required for manual digging, conserving time and drastically reducing physical strain. Similarly, mechanical corn shellers enable women to process maize more rapidly and without the hand injuries associated with manual shelling (Paudel et al., 2020).

International experiences from neighboring South Asian countries like India and Bangladesh further corroborate the benefits of gender-responsive agricultural tools. The introduction of lighter, ergonomically designed equipment tailored for women has been shown to reduce time spent on specific tasks by up to 35 percent and markedly decrease the prevalence of occupational health problems (Aryal et al., 2020; Singh et al., 2020). By liberating time and conserving energy, mechanization creates opportunities for women farmers to engage in other productive, educational, or leisure activities, thereby enhancing overall household welfare and personal well-being (Doss, 2018).

Notwithstanding these demonstrated benefits, women farmers in Nepal confront a multitude of barriers that impede the widespread adoption of mechanized tools. The primary obstacle is

financial; the majority of women farmers are from smallholder households with highly constrained cash incomes, rendering the initial purchase cost of machinery prohibitively expensive (Sharma et al., 2020). A second barrier is accessibility; in remote, hilly regions like Karnali, poor road infrastructure and underdeveloped markets severely limit the availability of tools and spare parts (Paudel et al., 2020). A third significant challenge is the knowledge and training gap; even when equipment is provided through development projects, women often lack the technical skills and confidence to operate and maintain them effectively (Pradhan et al., 2021). Finally, deep-seated cultural and gender norms frequently inhibit women's access to and control over technology, as intra-household decision-making power regarding significant purchases typically resides with male members (Acharya et al., 2020).

In response to these multifaceted challenges, initiatives like the Agriculture Sector Development Programme (ASDP), supported by the Government of Nepal and international development partners, have been launched. A key component of ASDP is the Drudgery Reduction Equipment and Tools Support (DRETS) sub-program, which specifically focuses on providing women farmers with access to agricultural equipment coupled with essential training for its operation and maintenance (Agriculture Sector Development Programme [ASDP], n.d.-a). Preliminary reports from the program indicate positive outcomes, including self-reported reductions in labor hours and increases in income among beneficiaries who received tools such as mini-tillers, threshers, and chaff cutters (ASDP, n.d.-b).

Despite these encouraging initial signs, a robust empirical understanding of the impact of such mechanization interventions on women farmers in Nepal remains underdeveloped. Existing studies have predominantly captured short-term, perceptual outcomes, such as immediate labor savings or seasonal income variations (Pradhan et al., 2021). There is a conspicuous scarcity of research investigating longer-term socio-economic impacts, including sustained income growth, shifts in household decision-making dynamics, or tangible advancements in women's empowerment metrics (Doss & Quisumbing, 2020). Furthermore, while international literature extols the potential of gender-friendly mechanization, its efficacy and adoption patterns within Nepal's unique socio-cultural and geographical context particularly in its most disadvantaged regions like Karnali Province are not sufficiently documented (Gartaula et al., 2020).

This study seeks to address these critical research gaps by conducting a rigorous examination of the impacts of the DRETS initiative on women farmers in Karnali Province. Utilizing a convergent mixed-methods design incorporating household surveys, in-depth interviews, and focus group discussions the research investigates the effects of mechanization on women's workload, health, agricultural income, and overall socio-economic well-being. Furthermore, it employs a production function economic model to quantitatively dissect the contributions of capital (tools), labor, and material inputs to agricultural output. In doing so, this study aims to provide a holistic evidence base that informs policy and programming for gender-responsive agricultural mechanization in Nepal and similar contexts.

Objectives

This research was focused on evaluating the work conducted under the Drudgery Reduction Equipment and Tools Support (DRETS) program implemented by ASDP in Karnali Province, Nepal. The specific objectives of the study were:

- To evaluate the extent to which the provided agricultural tools and equipment reduce the physical workload and drudgery experienced by women farmers.
- To assess the economic impact of these tools by analyzing changes in production costs, agricultural output, and household income.
- To identify the persistent barriers and challenges that hinder the optimal adoption and utilization of the tools.

Literature Review

Studies consistently show that women form the backbone of Nepal's agricultural labor force primary responsibility for subsistence farming, livestock care, and post-harvest processing (FAO, 2020). Time-use studies report workdays exceeding 14 hours, with high physical strain and limited rest or skill-building opportunities (Acharya & Koirala, 2020). Male out-migration has been empirically linked to increased workloads for women, who must simultaneously manage productive and reproductive roles, heightening health risks and economic vulnerability (Gartaula et al., 2020; Subedi et al., 2019).

Field-based studies document that women are disproportionately engaged in labor-intensive activities such as paddy transplanting, weeding, and manual harvesting. These tasks are strongly associated with chronic musculoskeletal disorders, declining labor productivity, and long-term health deterioration (Gartaula et al., 2012; Bishop-Sambrook, 2005). Evidence from Nepal and comparable South Asian contexts confirms that such drudgery perpetuates poverty and constrains women's economic mobility (Doss, 2018).

Impact evaluations of small-scale mechanization initiatives in Nepal indicate measurable reductions in labor time and perceived workload following the adoption of mini-tillers, pedal threshers, and reapers (Pradhan et al., 2021; Paudel et al., 2020). Similar empirical findings from India and Bangladesh show that lightweight, ergonomically designed tools reduce work-related injuries, improve task efficiency, and free time for education, income generation, and community participation (Aryal et al., 2020; Singh et al., 2020). These studies also report secondary effects on women's decision-making power and intra-household bargaining dynamics (Doss & Quisumbing, 2020).

Empirical research further identifies significant adoption constraints. Quantitative and qualitative studies highlight high upfront costs, limited access to credit, inadequate rural infrastructure, and weak supply chains for spare parts as major barriers for women farmers (Sharma et al., 2020; World Bank, 2022; Paudel et al., 2020). Program evaluations reveal that gender-targeted subsidies and financing mechanisms remain insufficient or poorly implemented (ASDP, n.d.-a). Gender-focused empirical studies show that sociocultural norms systematically exclude women from machinery-related decision-making. Evidence demonstrates that tools provided to women's groups are often appropriated by male household members, undermining intended empowerment outcomes

(Subedi et al., 2019). Lack of women-focused training and technical support further reduces effective and sustained use of mechanization (Pradhan et al., 2021).

Thematically, the literature frames women's agricultural labor as fundamental yet undervalued, embedded within structurally gendered production systems. Nepal's continued reliance on manual agriculture, contrasted with mechanization trajectories in other developing economies, is widely interpreted as a core driver of low productivity and persistent gender inequality (Pingali, 2007). Drudgery is conceptualized not only as physical burden but as a structural constraint that locks women into cycles of poor health, time poverty, and limited empowerment (Doss, 2018). Recent scholarship advances the concept of gender-responsive mechanization, emphasizing tools adapted to women's physical capacities, sociocultural contexts, and control over resources (Theis et al., 2018; Aryal et al., 2020). The literature argues that mechanization can be transformative when embedded within supportive institutional arrangements, training systems, and gender-sensitive policies.

Karnali Province is thematically portrayed as an extreme case of agrarian hardship, where remoteness, fragile ecology, poverty, and food insecurity intensify women's drudgery due to near-total dependence on manual labor (CBS, 2021; Gartaula et al., 2012). Policy documents position ASDP interventions as strategic responses to these structural constraints, with explicit emphasis on women's workload reduction and gender equity (ASDP, n.d.-a). The DRETS initiative under ASDP represents a direct response to this need. Its strategy involves the direct distribution of appropriate agricultural equipment to individual women and women's groups, complemented by training on use and maintenance. Preliminary internal reports suggest that these interventions have yielded positive results, including increased agricultural income, reduced time spent on the most laborious tasks, and improved health outcomes among beneficiary women (ASDP, n.d.-b). However, these findings often rely on anecdotal or short-term data, underscoring the need for rigorous, independent research to assess the sustained impact, economic viability, and broader empowerment outcomes of such programs in this challenging context.

Research Gaps

A review of existing studies indicates clear gaps in the evidence on drudgery-reducing agricultural tools for women farmers in Nepal. First, there is limited longitudinal and empirical research that quantifies long-term socio-economic outcomes, such as sustained income growth and shifts in labor allocation, particularly in structurally disadvantaged regions like Karnali. Second, although prior research documents the technical advantages of gender-responsive tools, it pays insufficient attention to the socio-cultural norms and institutional constraints that continue to shape women's access to mechanization, their control over tools, and their ability to translate adoption into tangible benefits. Third, the use of economic modeling approaches, especially production function analysis, to disentangle the relative contributions of capital inputs, labor, and material use to productivity gains in women-centered agriculture remains weakly developed in the Nepalese context. This study addresses these gaps by integrating empirical evidence with economic modeling to generate a more rigorous understanding of how mechanization influences not only agricultural productivity, but also women's health, time use, and empowerment outcomes.

Methodology

Research Design

The study was conducted in Karnali Province, one of Nepal's most remote and socio-economically disadvantaged regions (CBS, 2021). It employed a convergent parallel mixed-methods research design, enabling the simultaneous collection and integration of quantitative and qualitative data for triangulation and comprehensive interpretation (Creswell & Plano Clark, 2017). The study population comprised 618 beneficiary households affiliated with 29 pre-existing agricultural groups and cooperatives that had received drudgery-reducing agricultural equipment under the Agriculture Sector Development Program (ASDP) three years prior to the study. These households were distributed across five districts: Surkhet, Dailekh, Jajarkot, Rukum West, and Jumla, ensuring representation of Karnali's diverse agro-ecological and topographical contexts. A stratified random sampling technique was applied to ensure representativeness and minimize selection bias. Stratification was based on district and caste/ethnicity, capturing both geographical variation and socio-cultural diversity within the beneficiary population.

Data Collection Tools and Methods

Quantitative Data Collection

A structured household survey was administered to all 618 sampled households using a pre-tested questionnaire. The survey captured information on Demographic and socio-economic characteristics, Agricultural production (crop types, cultivated area, yields), Production costs (inputs, labor, machinery use), Agricultural income across three reference periods and Base Year (prior to equipment support): Year 1 (first year after support) and Year 2 (second year after support)

Qualitative Data Collection

To generate in-depth contextual insights, 82 households were purposively selected for qualitative inquiry. Data collection methods included:

- In-Depth Interviews (IDIs): Conducted primarily with women farmers to explore experiences of tool use, changes in drudgery, time allocation, health outcomes, and persistent constraints to the 82 households.
- Focus Group Discussions (FGDs): Facilitated with members of 29 agricultural groups of study districts to capture collective experiences, community-level effects, and shared challenges.
- Key Informant Interviews (KIIs): Conducted with ASDP personnel, local government officials, and cooperative managers to understand institutional perspectives, implementation processes, and programmatic challenges.

Data Analysis, Validity, and Credibility

Quantitative Analysis

Quantitative data were cleaned, coded, and analyzed using SPSS. Descriptive statistics, including frequencies, means, and medians, were used to summarize household characteristics and production trends.

Economic analysis was conducted using a production function framework, expressed as:

$$Y = A \cdot f(K, L, M)$$

Where:

- Y = Agricultural output, measured as agricultural income (NPR)
- A = Total Factor Productivity (efficiency parameter)
- K = Capital input (cost of machinery and tools)
- L = Labor input (cost of women's labor hours)
- M = Material inputs (cost of seeds, fertilizers, pesticides)

Given data limitations, the production function was operationalized as a linear input aggregation:

$$A = \frac{Y}{(K+L+M)}$$

Growth accounting analysis was applied to decompose changes in agricultural output into contributions from capital, labor, material inputs, and efficiency gains attributable to technology adoption.

Qualitative Analysis and Credibility

Qualitative data from IDIs, FGDs, and KIIs were transcribed, translated, and analyzed using thematic content analysis following Braun and Clarke (2006). Codes and themes were developed iteratively and cross-validated across data sources.

Credibility and validity were strengthened through:

- Methodological triangulation (quantitative and qualitative integration)
- Source triangulation (households, groups, and institutions)
- Consistency checks between narrative accounts and quantitative trends

Ethical Considerations

Ethical principles were strictly adhered to throughout the study. Informed consent was obtained from all participants prior to data collection. Participants were informed of the study's purpose, voluntary participation, and their right to withdraw at any time. Confidentiality and anonymity were ensured by removing personal identifiers from datasets. Interviews and discussions were conducted in private, culturally appropriate settings, respecting local norms and social sensitivities. The study posed no physical, psychological, or economic risk to participants.

Results

Adoption and Utilization of Tools

Under the ASDP-DRETS initiative, a total of 1140 pieces of agricultural tools and equipment were distributed to the beneficiary women of 66 groups for both collective and individual use. The equipment covered a wide range of agricultural operations: land preparation to post harvest activities.

Table 1: *List of Distributed Equipment.*

Name of Equipment and tools	No. of Equipment	Remarks
Mini tiller	57	Collective use
Combined Mill	56	Collective use
Corn Sheller	105	Individual use

Rice/Brush cutter	87	Collective use
Multi-crop Thresher	31	Collective use
Chaff cutter	57	Individual use
Winnower	82	Collective use
Refrigerator	2	Collective use
Jab Planter/ Seedling Transplanter	15	Collective use
Mini Weeder	12	Collective use
Secateur	75	Individual use
Ridge Maker	10	Collective use
Sprayer	26	Individual use
Wheelbarrow	42	Individual use
Fork	300	Individual use
Weighing Machine – Digital	31	Collective use
Ladder	29	Collective use
Gloves	93	Individual use
Folding Saw	30	Individual use
Total	**1140**	

Source: ASDP Management Information System (https://mis.asdp.gov.np)

The quantitative survey revealed a high rate of adoption among beneficiaries. As presented in Figure 1, the vast majority of women (68 percent) reported using the tools regularly in their farming operations. A further 15 percent used them as needed (e.g., for specific seasonal tasks), and 13 percent used them occasionally. Only a small minority (4 percent) reported not using the tools at all. This indicates a successful uptake and integration of the provided technology into the agricultural practices of the target group, with a total adoption rate (regular + as needed + occasional) of 96 percent. This high adoption rate is significant, as it surpasses many other technology adoption rates in similar rural contexts, often hampered by the barriers mentioned in the literature (Paudel et al., 2020).

**Figure 1***: Utilization Frequency of Provided Agricultural Equipment*
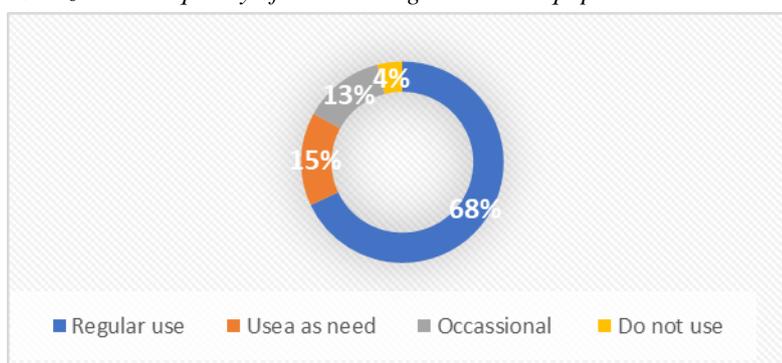
Source: Field Survey, 2025.

Perception of Drudgery Reduction

The subjective experience of drudgery reduction is a critical outcome measure. When asked about their perception of whether the equipment had reduced their physical workload, women respondents reported overwhelmingly positive feedback. As shown in Figure 2, nearly half (46.34 percent) strongly agreed that the tools had reduced their drudgery, while 29.27 percent agreed. Approximately 15.85 percent were neutral, potentially indicating tools that were less relevant to their primary tasks or usage difficulties. Only 8.54 percent disagreed, and no respondents strongly disagreed. This suggests that for over 75 percent of the beneficiaries, the intervention successfully achieved its primary objective of alleviating physical strain, aligning with findings from Pradhan et al. (2021) and Aryal et al. (2020).

**Figure 2:** *Women Farmers' Perception on Drudgery Reduction*
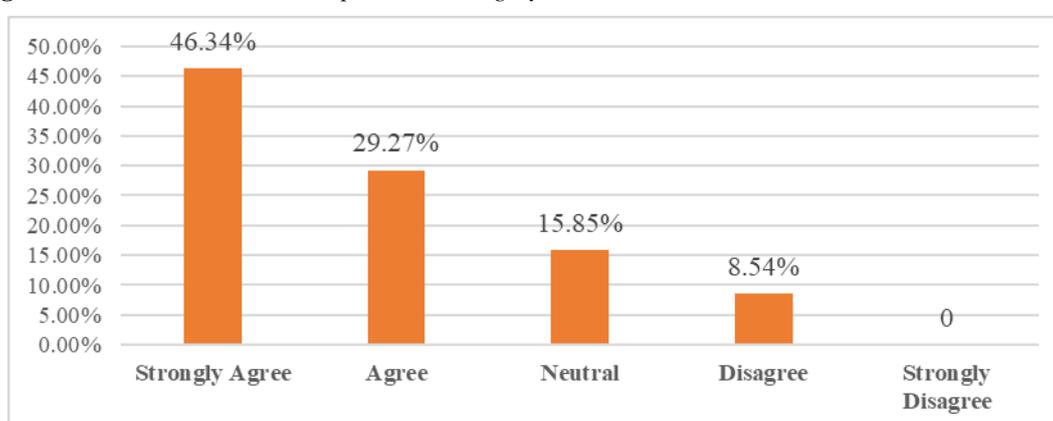
Source: Field Survey, 2025.

Quantified Drudgery Reduction and Time Re-allocation

The equipment provided to women farmers helped reduce their workload significantly across various agricultural activities throughout the year. The analysis revealed that the maximum reduction in working hours was 145 hours, while the minimum reduction was 20 hours. On average, each piece of equipment helped reduce women's drudgery by about 92.5 hours. This indicates that the introduction of such tools and technologies has effectively lessened the physical workload and time burden of women engaged in agricultural activities, contributing to greater efficiency and improved well-being.

**Figure 3***: Average Drudgery Reduced by Equipment*.
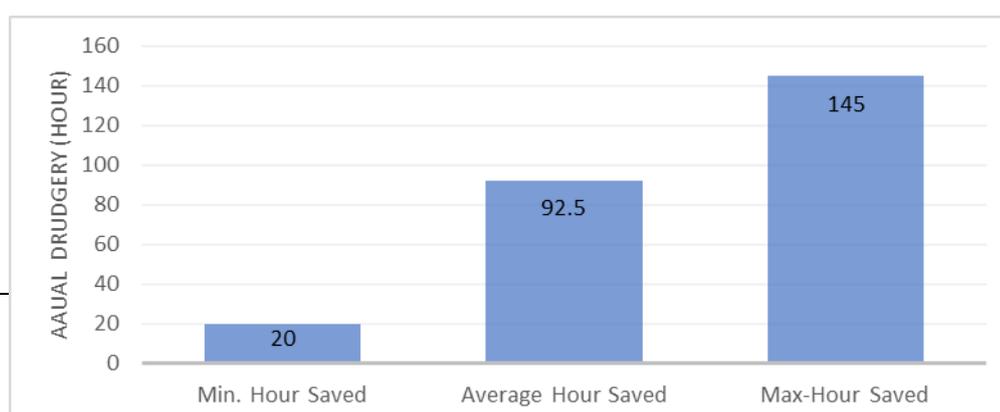
Source: Field Survey, 2025.

    Women farmers shared how they utilized the time saved from reduced drudgery through the use of agricultural equipment. Their responses were grouped into four main categories: household work, rest, additional income-generating activities, and social work.

    The majority of respondents (71 percent) reported using their saved time for household work, which continues to be a major part of their daily routine. Around 11 percent used the extra time for rest, while approximately 16 percent engaged in additional income-generating activities. A small portion, about 2 percent, spent their time on social work.

Figure 4: *Allocation of Saved Time by Women Farmers*
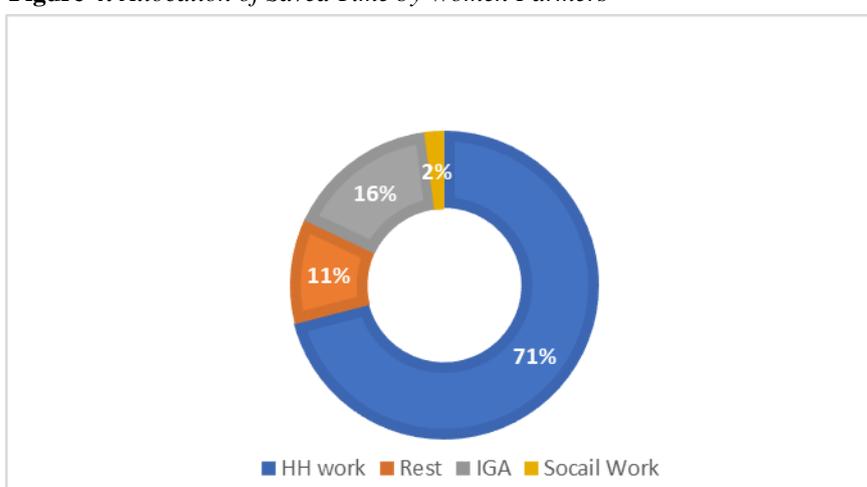
Source: Field Survey, 2025.

Impact on Agricultural Income and Costs

    The economic impact of the intervention was significant. The data on agricultural income for the median woman-headed household showed a remarkable upward trajectory (Table 2). Income from the sale of one major agricultural commodity increased from NPR 15,000 in the base year (before intervention) to NPR 50,400 in Year 1 post-intervention, and further to NPR 72,800 in Year 2. This represents a dramatic 44.4 percent increase in income from Year 1 to Year 2 alone, demonstrating a compounding positive effect rather than a one-time boost.

Table 2*: Median Agricultural Income and Input Costs (NPR)*

Year	Output (Y)	Capital (K)	Labor (L)	Materials (M)
Base	15,000	0	4,000	5,000
Year 1	50,400	15,000	4,800	10,000
Year 2	72,800	20,000	4,200	12,000

Source: ASDP Management Information System (https://mis.asdp.gov.np)

Production Function Model Analysis

The data from Table 2 was used to analyze the production function model

$Y = A \cdot f(K, L, M)$.

Efficiency Factor (A) Calculation

Assuming f (K, L, M) = K + L + M, the efficiency parameter A was calculated for each period.

Base Year: A (base) = 15,000 / (0 + 4,000 + 5,000) = 15,000 / 9,000 = 1.67

Year 1: A (year 1) = 50,400 / (15,000 + 4,800 + 10,000) = 50,400 / 29,800 = 1.69

Year 2: A (year 2) = 72,800 / (20,000 + 4,200 + 12,000) = 72,800 / 36,200 2.01

      The efficiency factor A increased by 19 percent from Year 1 to Year 2 (from 1.69 to 2.01), indicating a substantial improvement in the productivity of all combined inputs, driven by better technology (the tools) and improved resource management.

Growth Accounting Analysis (Year 1 to Year 2)

To decompose the 44.4 percent output growth, growth accounting was performed.

- Growth Rates of Inputs:
  - $\Delta Y/Y$ = (72,800 - 50,400) / 50,400 = 22,400 / 50,400 = 44.4 percent
  - $\Delta K/K$ = (20,000 - 15,000) / 15,000 = 5,000 / 15,000 = 33.3 percent
  - $\Delta L/L$ = (4,200 - 4,800) / 4,800 = -600 / 4,800 = -12.5 percent
  - $\Delta M/M$ = (12,000 - 10,000) / 10,000 = 2,000 / 10,000 = 20.0 percent
- Average Cost Shares (Elasticities):

  The average share of each input's cost in the total input cost was calculated using a Tornqvist index (average of Year 1 and Year 2 shares).

Table 3: *Calculation of Input Cost Shares*

Input	Year 1 Share	Year 2 Share	Average Share
K	15,000/29,800 = 50.3 percent	20,000/36,200 = 55.2 percent	(50.3+55.2)/2 = 52.75 percent
L	4,800/29,800 =16.1 percent	4,200/36,200 = 11.6 percent	(16.1+11.6)/2 = 13.85 percent
M	10,000/29,800 = 33.6 percent	12,000/36,200 = 33.1 percent	(33.6+33.1)/2 = 33.35 percent

- Contribution of Inputs to Growth:
  - Contribution of K = Average Share of K * $\Delta K/K$ = 0.5275 * 33.3 percent = 17.58 percent
  - Contribution of L = Average Share of L * $\Delta L/L$ = 0.1385 * (-12.5 percent) = -1.73 percent
  - Contribution of M = Average Share of M * $\Delta M/M$ = 0.3335 * 20.0 percent = 6.67 percent
  - Total Input Contribution = 17.58 percent + (-1.73 percent) + 6.67 percent = 22.52 percent
- Residual (Efficiency Growth - $\Delta A/A$):
  - $\Delta A/A$ = $\Delta Y/Y$ - Total Input Contribution = 44.4 percent - 22.52 percent = 21.88 percent

Interpretation of Model Results:

      The growth accounting exercise reveals two powerful narratives:

- Input Contribution: Approximately 22.5 percent of the 44.4 percent income growth was explained by increases in capital (machinery use) and material inputs. The capital input (K) was the single largest driver, contributing 17.6 percent to growth. This underscores the critical importance of the tools themselves in boosting production, validating the capital investment made by the DRETS program.

- Efficiency Gains: The most significant finding is that 21.9 percent of the total growth is attributed to an increase in Total Factor Productivity (TFP). This is the "Solow residual" that represents doing more with the same (or even less) inputs (Pingali, 2007). It captures the efficiency gains from technological change—the superior productivity of using a mini-tiller over a hand hoe, or a thresher over manual beating. The fact that labor input (L) decreased by 12.5 percent yet output soared, and its contribution was negative (-1.73 percent), powerfully demonstrates the labor-saving and efficiency-enhancing nature of the technology. The tools did not just add power; they fundamentally improved the productivity process, a key goal of agricultural modernization.

Discussion

The findings of this study reinforce and extend the growing body of empirical evidence demonstrating that drudgery-reducing agricultural tools can play a transformative role in improving women's productivity, well-being, and economic outcomes in smallholder agriculture. The high adoption rate observed among women farmers in Karnali Province contrasts with the often-cited narrative of low technology uptake in remote regions, suggesting that when tools are appropriately designed, targeted, and supported through institutional programs such as DRETS, structural constraints can be partially overcome. This aligns with earlier studies in Nepal and South Asia that emphasize the importance of context-specific and gender-responsive mechanization in driving adoption (Pradhan et al., 2021; Aryal et al., 2020; Singh et al., 2020).

Consistent with prior research, the study confirms that women's agricultural labor in Nepal is characterized by extreme physical strain and time poverty, and that mechanization directly alleviates these burdens. The substantial reduction in labor hours and the strong perception of drudgery reduction corroborate findings by Gartaula et al. (2012) and Bishop-Sambrook (2005), who document the close association between manual agricultural tasks and chronic musculoskeletal problems among women. Qualitative narratives from this study further substantiate these outcomes, as women explicitly linked reduced bending, lifting, and repetitive motions to improved physical health and lower fatigue. Compared to earlier studies that primarily reported perceived workload reduction, this study strengthens the evidence base by quantifying time savings and linking them to productivity and efficiency gains.

The reallocation of saved time offers critical insights into the gendered nature of labor and empowerment. While a majority of women continued to devote saved time to household responsibilities, reflecting deeply entrenched gender norms as noted by Doss (2018), a notable proportion used the additional time for rest and income-generating activities. This partial shift mirrors findings from India and Bangladesh, where mechanization reduced time poverty but did not automatically translate into leisure or empowerment without broader normative change (Theis et al.,

2018; Singh et al., 2020). Importantly, qualitative accounts from this study indicate emerging forms of economic agency, as women reported independent control over income generated through expanded or intensified agricultural activities. This suggests that drudgery reduction can act as an enabling condition for empowerment, even if it does not, by itself, dismantle existing gender divisions of labor.

The economic analysis provides one of the study's most significant contributions to the literature. Unlike many prior studies that focus on descriptive income changes, this research demonstrates that nearly half of the observed income growth was attributable to efficiency gains rather than increased input use alone. This finding resonates with Pingali's (2007) argument that mechanization is fundamentally a productivity-enhancing process, not merely a labor-substituting one. The observed decline in labor input alongside rising output underscores the labor-saving nature of the tools and directly challenges concerns that mechanization may marginalize women by displacing their labor. Instead, the results suggest that women's labor was reallocated more efficiently, supporting both higher output and reduced physical strain.

Despite these positive outcomes, the study also confirms the persistence of structural and socio-cultural barriers widely documented in the literature. High costs of fuel, maintenance, and spare parts remain critical constraints, particularly in remote areas with weak market infrastructure, echoing findings by Paudel et al. (2020). Gendered power relations within households also continue to shape technology use. Instances of initial resistance or male takeover of tool operation align with observations by Acharya et al. (2020) and Subedi et al. (2019). However, an important divergence from earlier studies is the reported decline in male appropriation over time, as women demonstrated competence and confidence in operating the equipment. This suggests that sustained exposure, training, and visible performance can gradually challenge gendered perceptions of technology as a "male domain."

Overall, the findings are consistent with, but also advance, existing scholarship by demonstrating that drudgery-reducing mechanization can simultaneously improve health, productivity, and economic outcomes for women in highly disadvantaged contexts such as Karnali. At the same time, the results caution against viewing mechanization as a standalone solution. Without complementary investments in training, repair services, financing, and gender-transformative approaches, the full empowerment potential of such interventions may remain unrealized. The study thus supports recent arguments in the literature that mechanization must be embedded within broader institutional and socio-cultural change processes to generate sustained and equitable outcomes for women farmers.

Conclusion

This study provides robust empirical evidence that the ASDP–DRETS intervention has substantially reduced agricultural drudgery among women farmers in Karnali Province while simultaneously improving productivity and income outcomes. The high adoption rate of tools (96 percent) indicates strong acceptance and integration of mechanized technologies into women's farming practices, despite operating in one of Nepal's most remote and resource-constrained regions. Moreover, the findings demonstrate that drudgery-reducing tools significantly lowered women's

physical workload, with an average reduction of approximately 92.5 labor hours per year per piece of equipment. This reduction translated into meaningful time savings, which women predominantly reallocated to household responsibilities, rest, and income-generating activities. While the continued dominance of household work reflects persistent gender norms, the allocation of saved time to income activities indicates emerging pathways toward economic empowerment.

Economically, the intervention generated pronounced gains. Median agricultural income increased sharply from the pre-intervention period to Year 2, reflecting not only higher output but also improved efficiency. Production function and growth accounting analyses reveal that while increased capital and material inputs contributed to output growth, nearly half of the observed income growth was driven by gains in total factor productivity. This confirms that mechanization under DRETS functioned primarily as a labor-saving and efficiency-enhancing innovation, allowing women to produce more with less labor input. Despite these positive outcomes, the study has limitations. The analysis relies on a limited post-intervention time horizon and focuses exclusively on beneficiary households, constraining causal attribution and generalizability. Income and labor data are partially self-reported, which may introduce recall bias. Moreover, the study does not fully capture intra-household power dynamics or long-term health outcomes, which are critical dimensions of women's empowerment.

The implications are clear. Gender-responsive mechanization, when combined with access, training, and institutional support, can simultaneously address productivity constraints and gendered labor burdens in marginal agrarian contexts like Karnali. However, sustained impacts will require complementary measures, including affordable financing mechanisms, continuous technical training for women, and deliberate strategies to prevent male appropriation of women-targeted technologies. Future research should adopt longitudinal and quasi-experimental designs to assess long-term empowerment, health, and structural transformation outcomes.

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