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ORIGINAL RESEARCH ARTICLE

Gender division of labour in traditional biomass energy systems in rural Nepal

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ABSTRACT

Traditional biomass remains a dominant household energy source in many low- and middle-income countries, yet its gendered labour implications remain insufficiently examined at local scales. This study investigates the gendered division of labour and associated health burdens in firewood-dependent households in Krishnapur Municipality, Kanchanpur district, Nepal. A mixed-methods cross-sectional design was applied combining household surveys (n = 70), focus group discussions, and key informant interviews with forest user groups and ward officials. Quantitative data were analyzed using descriptive statistics, correlation tests and cross-tabulations, while qualitative data provided contextual explanations of labour norms and decision-making. Results revealed a persistent gender asymmetry in firewood-related tasks: women accounted for 65.7% of collection, 70% of arranging, and 58.6% of cooking activities, whereas men predominated in wood slicing (65.7%) and mechanized transportation. Overall, women contributed 43.1% to total workload compared to 21.7% for men and 35.1% jointly. More than half (54.3%) reported health problems linked to carrying and burning firewood, and distance to collection sites was strongly correlated with health complaints ($r = 0.693$, $p < 0.01$). Despite high reliance on firewood, 83% of households expressed willingness to shift to cleaner fuels, constrained primarily by economic limitations and forest access. The study contributes empirical evidence to gender-energy scholarship by quantifying task-specific labour burdens and linking them to health risks and time poverty. Findings highlight the need for gender-responsive clean cooking policies, improved financing mechanisms, and targeted community forestry interventions to reduce women's workload and accelerate equitable energy transitions.

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INTRODUCTION

Access to affordable and clean household energy remains a persistent development challenge in many low- and middle-income countries (LMICs), where traditional biomass fuels such as firewood continue to dominate cooking and heating systems. Despite rapid progress in electrification and renewable energy deployment, an estimated 2.3 billion people globally relied on solid biomass for cooking in 2022, exposing households particularly women and children to labour-intensive fuel collection and household air pollution (IEA, 2022). The literature consistently demonstrates that biomass-dependent energy systems contribute to gendered time poverty, musculoskeletal strain, and high exposure to household air pollution, with adverse implications for health and productivity (Rodgers, 2024; Kadota *et al*., 2020). In Nepal, biomass fuels remain central to household energy, especially in rural settlements where economic constraints, sociocultural norms and limited infrastructure restrict transitions to cleaner fuels such as liquefied petroleum gas (LPG), biogas and electricity (Acharya & Marhold, 2019; Sharma &

Baral, 2025). Although national policies have promoted clean cooking technologies and biogas subsidies, uptake has been uneven, and fuel stacking remains common (Pokharel & Rijal, 2021). Within these systems, gender is a critical axis of inequality: women and girls disproportionately engage in fuel collection, transportation, preparation and cooking, often walking long distances and carrying heavy loads under difficult terrain (Agarwal, 2009). This uneven labour distribution contributes to health risks, reinforces time poverty, and limits opportunities for education, social participation and market engagement. Despite growing recognition of the gender–energy nexus, several knowledge gaps persist. First, empirical studies in South Asia rarely quantify task-specific workload distributions along the firewood supply and use chain, relying instead on broad qualitative claims about women's labour burdens. Second, existing Nepalese studies have emphasized indoor air pollution or fuel-choice determinants but have seldom integrated gender-disaggregated time-use data. Third, limited research links gendered workloads to health outcomes, forestry governance, and household willingness to transition to cleaner fuels (Ang'u *et al.*, 2023; Tornel-Vázquez *et al.*, 2024). Finally, micro-level evidence from peri-rural municipalities in the Terai region of Nepal remains scarce, despite high forest dependence and evolving community forestry practices. This study addresses these gaps by providing a mixed-methods gender-disaggregated analysis of firewood-related labour in Krishnapur Municipality, Nepal. Specifically, it quantifies gender differences in five core tasks collection, transportation, slicing, arranging and cooking and examines associated health burdens, institutional constraints and willingness to adopt cleaner energy alternatives. By linking gendered labour inequalities to environmental scarcity and energy transition dynamics, the study advances understanding of gendered energy poverty and offers evidence to support gender-responsive clean cooking interventions in rural South Asia.

MATERIALS AND METHODS

Study area and design

The study was conducted in Ward No. 2 and Ward No. 3 of Krishnapur Municipality in Sudurpashchim Province. The area is characterized by high reliance on community forests for biomass energy, limited access to cleaner fuels and heterogeneous ethnic composition. Janahit Community Forest constitutes the primary fuelwood source for surveyed households. A descriptive cross-sectional mixed-methods design was employed to examine gendered workload patterns in firewood-dependent households in Krishnapur Municipality, Kanchanpur District, Nepal. Mixed-methods approaches are widely used in time-use and gender-energy research as they allow quantitative measurements to be interpreted within sociocultural contexts (Stroud *et al.*, 2020).

Sampling procedures

Sampling frame and strategy: The sampling frame consisted of all households registered under the Community Forest User Groups (CFUGs) in the selected wards. A stratified random sampling strategy was used to ensure representation across major socio-economic and ethnic groups, consistent with best practices in household energy studies (Pachauri & Rao, 2013).

Sample size determination: The final sample included 70 households. Sample size was determined using Cochran's formula for finite populations assuming a 95% confidence level (Z = 1.96), maximum variability (p = 0.5) and ±10% precision due to logistical constraints. A finite population correction was applied for a total population of 310 CFUG-registered households. The resulting minimum required sample matched the achieved sample size (n = 70).

Data collection tools

Household survey: A semi-structured questionnaire captured socio-demographic characteristics, division of labour in firewood-related tasks, time spent in different activities, energy preferences and perceived health effects. The instrument was pre-tested on eight households, after which ambiguous items were rephrased. Pre-testing and refinement followed standard survey validation procedures (Lamm *et al.*, 2020).

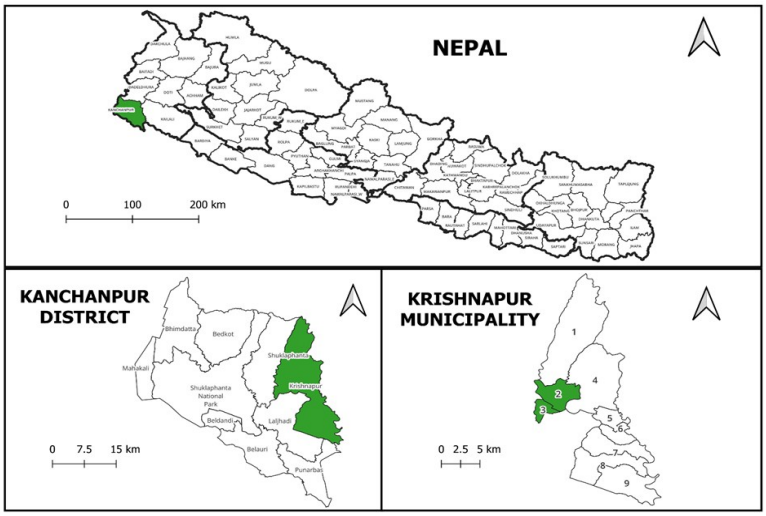

Figure 1. *Map showing the study area.*

Focus Group Discussions (FGDs): Two FGDs were conducted, one in each ward, including 4-5 women directly engaged in fuelwood collection and 3-4 men involved in household energy decisions. Discussions explored gender norms, intra-household negotiation, forest access and perceptions of energy transition.

Key Informant Interviews (KIIs): KIIs were conducted with CFUG representatives, ward officials, women's group members and agriculture/cooperative office staff to obtain institutional perspectives on forest governance and energy challenges.

Variables and measurements: Gendered labour was measured across five core tasks: (i) collection, (ii) transportation, (iii) slicing, (iv) arranging and (v) cooking. Workload was quantified by reporting which member(s) performed each task (men, women or both). Health burdens were self-reported and included musculoskeletal pain, respiratory issues, fatigue and related symptoms. Time spent collecting firewood was measured in hours per trip and linked to estimated distance from forests.

Ethical considerations

Participation was voluntary, verbal consent was obtained and confidentiality was ensured through anonymization. No personal identifiers are disclosed. Ethical approval was not applicable as the study did not involve medical interventions or minors.

Methodological limitations

Cross-sectional design limits causal inference; Self-reported time estimates may contain recall bias; Sample size limits advanced multivariate modelling; Seasonal variation in firewood demand was not captured; Forest accessibility can change over time, which the study could not track longitudinally.

Data analysis

Survey data were reviewed for completeness and coded in Microsoft Excel before export to SPSS (Version 16). Descriptive statistics (percentages, means and cross-tabulations) summarized workload and energy characteristics. Bivariate correlations assessed associations between distance to collection sites and health complaints. Qualitative data from FGDs and KIIs were analyzed thematically and used to contextualize quantitative findings.

RESULTS AND DISCUSSION

Sociodemographic characteristics

The sample included 70 households with near-equal gender representation among respondents (51% male, 49% female). The majority of households (56%) relied solely on agriculture, while 23% combined agriculture with employment, 13% with business, and 7% engaged in business alone. Ethnically, Chhetri households constituted 50%, followed by Janajatis (18%), Brahmin (13%), Dalit (9%) and others (10%). These patterns align with national rural trends in Nepal, where agricultural dependence and social hierarchies influence both energy use and intra-household labour allocation (Pokharel & Rijal, 2021; Ramirez *et al.*, 2024).

Energy use patterns

Firewood remains the primary household energy source. Survey data indicate 46% of households used both firewood and biogas, 37% relied solely on firewood, 14% used firewood and LPG, and 3% used all three sources. Fuel stacking, the simultaneous use of traditional and modern fuels, is consistent with recent South Asian studies (Ang'u *et al.*, 2023; Tornel-Vázquez *et al.*, 2024), suggesting that availability, cost, and task-specific preferences govern fuel choice. Most households obtained firewood from community forests (66%), with the remainder using both forest and flood residue (34%). High reliance on community forests reflects national patterns of rural biomass dependence and highlights the role of forest access in shaping workload (Laudari *et al.*, 2024). Willingness to shift to cleaner fuels was high (83%), yet persistent dependence on firewood indicates barriers such as affordability, limited access, and sociocultural norms, confirming prior evidence that stated preferences do not always translate into adoption (Ibe & Kollur, 2024; Ang'u *et al.*, 2023).

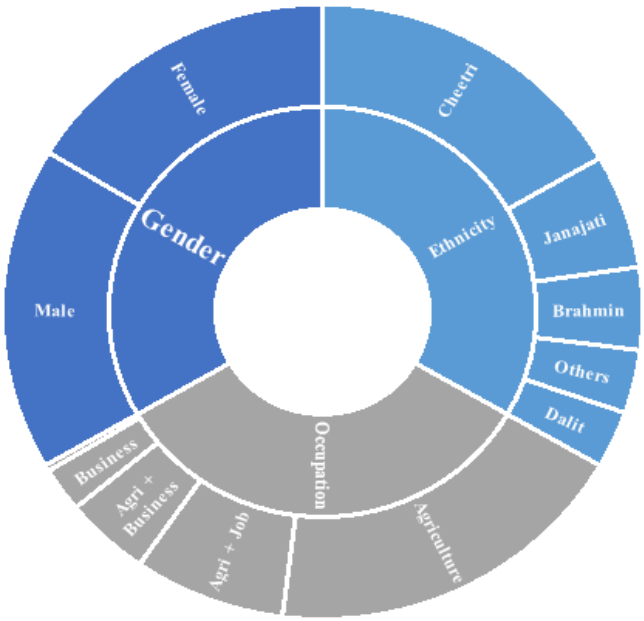

Figure 2. *Sociodemographic data (Source: Household Survey, 2022).*

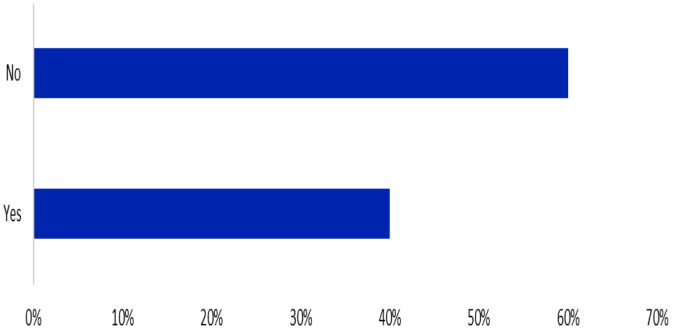

Figure 3. *Respondent supported by GoN/ NGO in Energy sector (Source: Household Survey, 2022).*

Time and health burden of firewood collection

Collection times varied by distance to forest. Households within 1 km required 5–6 hours, 3 km households 6–12 hours, and >5 km households >12 hours per trip (Table 2). Distance to collection sites was strongly positively correlated with health problems ($r = 0.693$, $p < 0.01$), consistent with prior studies linking fuelwood transport to musculoskeletal injuries and cumulative fatigue (Kadota *et al.*, 2020; Schwinger *et al.*, 2022). These findings illustrate the compounded burden of energy poverty, where remote households face both time and health costs. Approximately 54.3% of respondents reported health issues due to carrying and burning firewood, primarily women, reflecting their disproportionate exposure to labour-intensive tasks and indoor air pollution. These results align with evidence from South Asia demonstrating that traditional biomass use is a significant gendered health hazard (Ranabhat *et al.*, 2015; WHO, 2021).

Gendered division of labour

Task-specific analysis highlights a stark gender asymmetry (Table 4). Women performed 65.7% of collection, 70% of arranging, and 58.6% of cooking, while men dominated wood slicing (65.7%) and mechanized transportation. Overall, women contributed 43.1% of total workload, men 21.7%, and 35.1% jointly. These findings are consistent with recent studies in Nepal and India demonstrating persistent gendered inequalities in biomass energy systems (Agarwal, 2009; Tornel-Vázquez *et al.*, 2024). The data reinforce the concept of "time poverty," where women's labour in energy procurement limits opportunities for education, economic engagement, and leisure (Blackden & Wodon, 2006; Rodgers, 2024).

Table 1. Energy related data (Source: Household Survey, 2022).

Energy related data		Percentage (%)
Household main source of energy	Firewood	37.0
	Firewood + LPG	14.0
	Firewood + Biogas	46.0
	All	14.0
Household source of firewood and amount collected	Community forest	66.0
	Both community forest and flood residue	34.0
Respondent willingness to shift energy source	Yes	83.0
	No	17.0
Frequency of firewood use by respondent	Regular	48.6
	Often	45.7
	Sometimes to supplement LPG	5.7

Table 2. Cross-tabulation between periphery of house and time taken (Source: Household Survey, 2022).

		Time			Total
		5-6 h	6-12 h	>12 h	
Periphery of house (%)	1 km	8.6	18.6	0.0	27.2
	3 km	11.4	27.2	0.0	38.6
	5 km	4.3	24.3	1.4	30.0
	>5 km	0.0	2.8	1.4	4.2
Total		23.3	72.9	2.8	100

Table 3. Correlations between distance of firewood collection site and health problem (Source: Household Survey, 2022).

		Distance of firewood collection	Health problems
Distance of firewood collection	Pearson Correlation	1	.693**
	Sig. (2 tailed)		0.00

**.Correlation is significant at the 0.01 level (2-tailed).

Table 4. Workload analysis for firewood (Source: Household Survey, 2022).

S. No.	Work	Men (%)	Women (%)	Both (%)
1.	Collecting firewood in forest	2.9	65.7	31.4
2.	Carrying wood from forest	27.1	10	62.9
3.	Firewood slicing	65.7	11.4	22.9
4.	Arranging firewood in home	2.9	70	27.1
5.	Using firewood at home	10	58.6	31.4
	Average workload among gender	21.72	43.14	35.14

Table 5. Ranking of causes for firewood collection and use as energy source (Source: Household Survey, 2022).

S. No.	Causes	Index value	Rank
1.	Limited awareness	2.54	IV
2.	Poor economic condition	3.70	I
3.	Unemployment	3.32	II
4.	Improper functioning of CFUG	2.37	V
5.	Traditional habits	3.05	III

Drivers of firewood dependence

Ranking analysis (Table 5) indicates that poor economic condition, unemployment, and traditional habits were the primary drivers of continued firewood use, followed by limited awareness and CFUG functioning. These findings confirm that both socio-economic and institutional factors jointly determine biomass reliance, echoing studies showing that financial constraints and governance gaps impede transitions to cleaner energy (Ibe & Kollur, 2024).

Potential use of saved time

Respondents indicated that time saved from firewood collection would primarily be invested in agriculture (61.4%) and business activities (27.1%), with a smaller proportion (11.4%) allocating time to other pursuits (Figure 4). This underscores the potential economic gains of gender-sensitive energy interventions, suggesting that reducing women's workload through access to clean energy could enhance household productivity and livelihoods, consistent with evidence from Ethiopia and India (Ang'u *et al.*, 2023; Tornel-Vázquez *et al.*, 2024).

Policy and research implications

The findings highlight multiple leverage points for policy: i) promoting mechanized transport and task-sharing to reduce women's workload, ii) expanding clean cooking programs with targeted financing and gender-sensitive training, iii) strengthening community forest governance to ensure equitable access, and iv) integrating health and energy planning to mitigate musculoskeletal and respiratory risks. Future research should explore longitudinal effects of energy interventions on time-use redistribution, economic empowerment, and health outcomes in peri-rural South Asia.

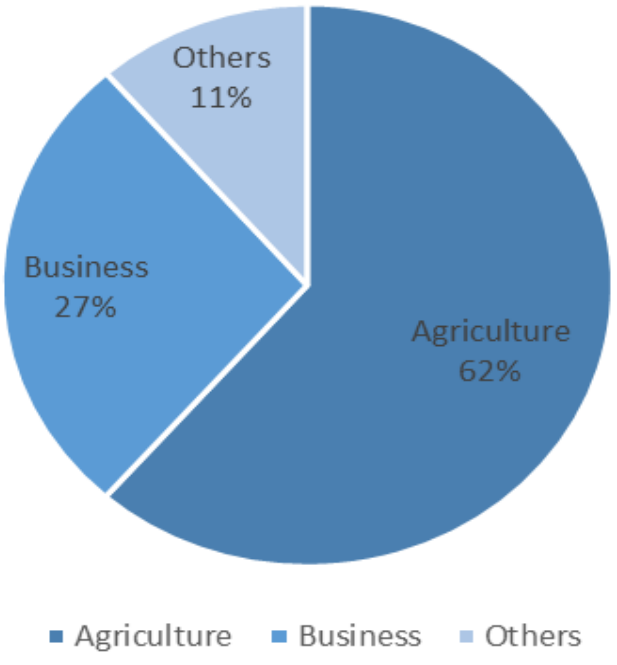

Figure 4. *Household willingness to use their time on if saved from firewood collection (Source: Household Survey, 2022).*

Conclusion

This study demonstrates that traditional biomass energy systems in Krishnapur Municipality, Nepal, perpetuate significant gendered labour inequalities. Women predominantly perform firewood collection, arranging and cooking, contributing 43.1% of total workload, whereas men are mostly engaged in slicing and mechanized transport (21.7%). Over half of respondents reported health problems related to firewood handling, with distance to collection sites positively correlated with health complaints ($r = 0.693$, $p < 0.01$). Despite widespread willingness (83%) to adopt cleaner fuels, economic constraints, limited institutional support, and persistent sociocultural norms inhibit full energy transitions. Time saved from reduced firewood collection would primarily be reallocated to agriculture and business, highlighting the potential for productivity gains if gendered workload burdens are alleviated. The findings emphasize the need for gender-responsive interventions, including improved access to clean cooking technologies, mechanized transport solutions, and equitable community forest governance. By quantifying task-specific labour, health risks, and energy transition barriers, this study provides actionable insights for policymakers, energy planners, and development practitioners seeking to promote equitable and sustainable energy systems in rural South Asia.

DECLARATIONS

Author contribution statement: Conceptualization: U.R. and L.K.; Methodology: P.B.; Software and validation: U.R., L.K. and P.B.; Formal analysis and investigation: PB and LK; Resources: PB; Data curation: P.B.; Writing—original draft preparation: U.R., L.K., P.B. and R.C.; Writing—review and editing: U.R., L.K., P.B. and R.C.; Visualization: L.K.; Supervision: U.R., L.K. and P.B.; Project administration: P.B. and R.C. All authors have read and agreed to the published version of the manuscript.

Conflicts of interest: The authors declare that there are no conflicts of interest regarding the publication of this manuscript.

Ethics approval: This study was conducted by following the ethical guidelines on survey studies of the institute.

Consent for publication: All co-authors gave their consent to publish this paper in AAES.

Data availability: The data that support the findings of this study are available on request from the corresponding author.

Supplementary data: No supplementary data is available for the paper.

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