

Assessing factors influencing household dependency on forest resources in Nyaruguru District, Rwanda

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Abstract

In Rwanda, particularly in Nyaruguru District, many rural households continue to rely heavily on forest resources due to poverty, limited livelihood opportunities, and inadequate access to alternative energy sources. This increasing dependence contributes to pressure on forest ecosystems and challenges sustainable forest management efforts. The study aimed to assess the level of household dependence on forest resources and identify the socio-economic, environmental, and institutional factors influencing this dependence in Nyaruguru District. A cross-sectional study design was employed, and primary data were collected from 398 households and key informants using structured questionnaires and interviews. The findings showed that forest resources were widely used for household energy, construction materials, food, medicinal purposes, and income generation. About 35.7% of households used forest products daily, while 24.1% used them two to three times per week. Energy needs were the main reason for dependence, reported by 91% of households. Forest resources also contributed significantly to household livelihoods, with 33.7% of households obtaining between 10% and 25% of their income from forest products, and 16.1% earning more than half of their household income from forest-related activities. The study further revealed that larger household size, lower education levels, low household income, proximity to forests, and limited access to alternative energy sources increased dependence on forest resources. Institutional factors such as limited awareness of forest conservation policies and low participation in community forest management systems also influenced household reliance on forests. The study concluded that household dependence on forest resources in Nyaruguru District is driven by interconnected socio-economic, environmental, and institutional factors. The findings emphasize the need to promote affordable alternative energy sources, strengthen community-based forest management, improve environmental awareness, and support income-generating activities that reduce pressure on forest resources while enhancing sustainable livelihoods.

Keywords: Environmental factors; Forest dependence; Household livelihoods; Socio-economic factors

1. Introduction

According to the Food and Agriculture Organization (FAO, 2022), forests play a critical role in sustaining rural livelihoods worldwide, with an estimated 1.6 billion people depending directly or indirectly on forest resources for income, energy, food, and shelter. Beyond subsistence use, contemporary empirical literature increasingly emphasizes that household dependence on forest resources is shaped by an interaction between socioeconomic characteristics and environmental access factors. In a multi-country analysis conducted across 24 tropical nations, Angelsen, *et al.*, (2018) demonstrated that forest-based income contributes between 20% and 35% of total household income in forest-adjacent communities, particularly among poorer and land-constrained households. At the same time, Masera, *et al.*, (2020) observed that fuelwood remains the dominant forest product for household energy, with approximately 2.3 billion people globally relying on biomass as their primary cooking fuel, a situation that disproportionately affects rural

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households in developing regions. These findings highlight that household dependence on forest resources is not only an ecological phenomenon but also a socioeconomic survival strategy shaped by poverty, energy access, and land ownership structures.

Across the African continent, household dependence on forest resources is particularly pronounced due to persistent rural poverty, limited access to modern energy services, and heavy reliance on rain-fed agriculture. Ndegwa, *et al.*, (2020) noted that over 60% of rural households in Sub-Saharan Africa rely on forest products as their primary source of cooking energy. In addition, Fisher, *et al.*, (2021) found that between 25% and 45% of household income in forest-adjacent communities is derived from forest-based activities such as fuelwood collection, charcoal production, wild food harvesting, and small-scale timber extraction. Environmental proximity to forests has been shown to significantly increase household dependence levels, particularly among land-poor and less-educated households in Southern Africa (Tesfaye, *et al.*, 2022). However, Curtis, *et al.*, (2018) cautioned that such high dependence is often associated with localized deforestation, forest degradation, and biodiversity loss where population growth and agricultural expansion intensify pressure on forest landscapes.

Regionally, within East Africa, forest ecosystems remain central to rural livelihoods, particularly in forest-adjacent communities where dependence levels are significantly high. In Kenya, a study by Mutune, *et al.*, (2020) in Kakamega and surrounding forest zones found that approximately 48% of rural households derived between 20% and 40% of their annual income from forest-related activities, including fuelwood collection, charcoal production, and sale of non-timber forest products (NTFPs). The study further revealed that over 70% of sampled households relied on fuelwood as their primary source of cooking energy, with dependence highest among land-poor households located within 3 kilometres of forest boundaries. Similarly, in Uganda, Banana, *et al.*, (2019) reported that in communities adjacent to Budongo and Mabira forest reserves, forest products contributed about 32% of total household income, while nearly 65% of households depended primarily on biomass energy for domestic use. The Ugandan study also demonstrated that households residing closer to forest reserves were twice as likely to engage in commercial charcoal burning and firewood sales compared to those living farther away.

At the national level, Rwanda presents a compelling context for assessing the interaction between socioeconomic and environmental factors and household dependence on forest resources. Nsabimana, *et al.*, (2021) reported that Rwanda's forest cover stands at approximately 30% of the national land area, reflecting sustained national investments in reforestation and landscape restoration. Despite these gains, Maniriho and Bikorimana (2020) emphasized that biomass energy still accounts for over 80% of household energy consumption, with rural households relying predominantly on fuelwood and charcoal sourced from natural forests and woodlots. Empirical studies in rural Rwanda further indicate that forest products contribute between 15% and 35% of total household income, particularly among smallholder farmers with limited landholdings and minimal off-farm employment opportunities (Nsabimana, *et al.*, 2021). These findings demonstrate that household dependence on forest resources in Rwanda is shaped by both socioeconomic conditions and environmental accessibility.

At the local level, Nyaruguru District exemplifies the complex interaction between socioeconomic and environmental factors and household dependence on forest resources. The district is predominantly rural, characterized by hilly terrain, high population pressure, and limited access to modern energy infrastructure. Forest ecosystems within and around Nyaruguru provide critical resources, including fuelwood, timber, construction materials, medicinal plants, and wild foods. Drawing from evidence in comparable highland districts of Southern Rwanda, Habiyaemye, *et al.*, (2022) indicated that over 70% of households rely on forest-derived biomass as their primary cooking fuel, while forest-related activities contribute substantially to household income, particularly among low-income and land-poor households. Increasing population growth, agricultural expansion, and limited livelihood diversification have further intensified pressure on forest resources, raising concerns about environmental degradation and long-term sustainability.

Consequently, while forest resources in Nyaruguru District deliver significant socioeconomic benefits to rural households, rising dependence driven by poverty, limited alternative energy access, and close environmental proximity presents serious sustainability challenges. A systematic assessment of how socioeconomic factors (income, education, household size, occupation) interact with environmental factors (distance to forests, land ownership, and availability of alternative energy sources) is therefore essential. This study addresses this critical gap by assessing socioeconomic and environmental factors and household dependence on forest resources in Nyaruguru District, Rwanda, with the aim of generating evidence to inform policies and interventions that balance livelihood improvement with forest conservation.

2. Research Methodology

2.1. Description of the Study Area

The proposed study was conducted in Nyaruguru District, located in the Southern Province of Rwanda. The district is characterized by extensive forest cover, including parts of the Nyungwe forest ecosystem, making it a suitable area for examining household dependence on forest resources. Nyaruguru District is bordered by Burundi to the south, Gisagara District to the east, Huye and Nyamagabe Districts to the north, and Rusizi District and Burundi to the west. It lies between 2°20' and 2°45' South latitude and 29°10' and 29°35' East longitude, and is administratively divided into 14 sectors, 97 cells, and 332 villages, with an estimated population of approximately 318,126 people (NISR, 2022).

The district is predominantly rural, with agriculture constituting the main livelihood activity, complemented by livestock keeping, small-scale trade, and forest-based activities. Households depend on forest resources for fuelwood, construction materials, medicinal plants, and non-timber forest products (NTFPs). The population structure is characterized by a young age distribution, with a high proportion of individuals under 35 years, which influences labor availability but also contributes to pressure on natural resources due to limited formal employment opportunities (Nyaruguru District, 2025).

Nyaruguru experiences a tropical highland climate with annual rainfall ranging between 1,200 and 1,800 mm and average temperatures of 16–22°C, supporting dense and diverse forest ecosystems. However, increasing human activities such as smallholder farming, fuelwood collection, and timber harvesting continue to exert pressure on forest resources (Nyaruguru District, 2025).

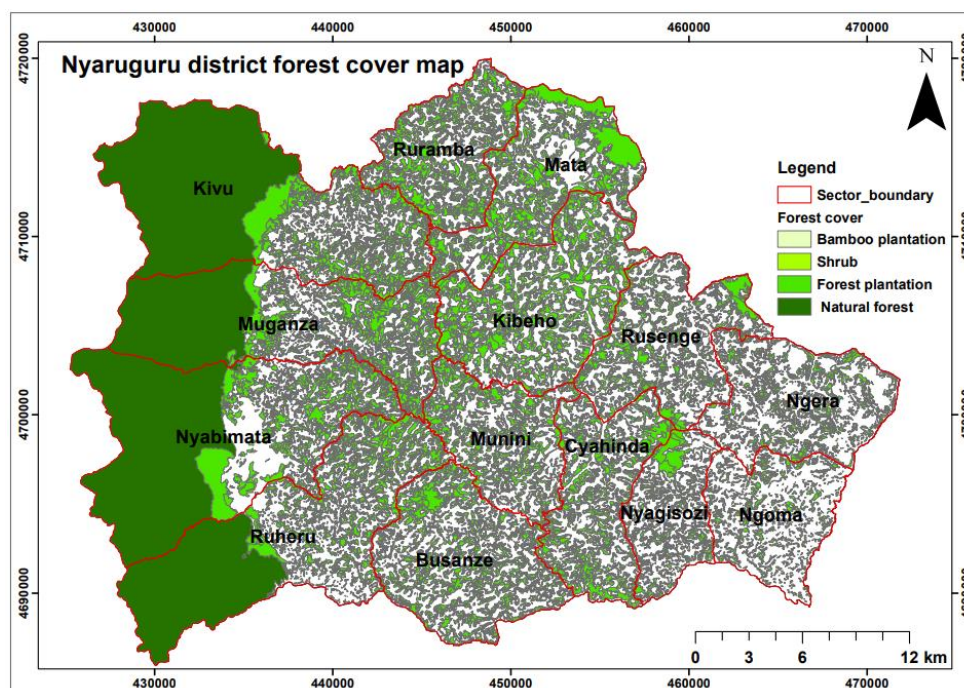


Figure 1 Administrative map of Nyaruguru District

2.2. Research Design

The study adopted a cross-sectional descriptive research design to assess household dependence on forest resources and the socio-economic and environmental factors influencing it in Nyaruguru District, Rwanda. This design was appropriate because it enabled the collection of quantitative data at a single point in time to provide a snapshot of forest dependence patterns and associated household characteristics. The descriptive component allowed measurement of the extent and frequency of forest resource use, while the analytical component used correlation and regression analysis to examine relationships between socio-economic and environmental factors and forest dependence. Overall, the design provided both descriptive insights and statistical evidence on determinants of household reliance on forest resources.

2.3. Source of data

This study relied exclusively on primary data collected from households in Nyaruguru District using structured questionnaires and key informant interviews. The questionnaires gathered quantitative data on socio-demographic characteristics, environmental and access factors, institutional and policy factors, market and infrastructure conditions, household dependence on forest resources, and conservation practices. Key informant interviews were conducted with local leaders, environmental officers, forest management officials, and community representatives to obtain qualitative insights on forest dependence trends, gender roles, livelihood constraints, access to alternative energy, environmental impacts, and conservation practices. The use of primary data enabled the collection of current, context-specific information and allowed for triangulation of quantitative and qualitative findings, improving the reliability and depth of analysis.

2.4. Population of the study

This study was conducted among households located in Nyaruguru District, in the Southern Province of Rwanda. According to the Fifth Rwanda Population and Housing Census (PHC5) 2022 published by the National Institute of Statistics of Rwanda (NISR, 2023), Nyaruguru District has a total of 73,805 households, which constitute the target population of this study. Households are the unit of analysis for assessing the extent of dependence on forest resources and the associated socio-economic and environmental factors.

2.5. Sample Size Determination

The sample size for the study was determined using Yamane's (1967) formula, which provides a simplified method for calculating a statistically valid sample size with a specified level of precision. This approach ensures that the selected sample is representative of the target population while maintaining feasibility for data collection.

The formula is expressed as:

$$n = \frac{N}{1 + N(e)^2}$$

Where:

n = required sample size

N = total population (households of Nyaruguru District)

e = level of precision (margin of error), typically 5% (0.05)

Therefore, the final sample size for this study was 398 households.

$$n = \frac{73,805}{1 + 73,805(0.05)^2} = 398$$

Table 1 Distribution of Households by Sectors in Nyaruguru District

No.	Sector	Total Households	Proportion (%)	Sample Allocation
1	Busanze	5,602	7.6%	30
2	Cyahinda	5,748	7.8%	31
3	Kibeho	5,311	7.2%	29
4	Mata	5,089	6.9%	28
5	Munini	5,904	8.0%	32
6	Muganza	5,246	7.1%	28
7	Ngera	5,401	7.3%	29
8	Ngoma	5,649	7.7%	30
9	Nyabimata	5,150	7.0%	28

10	Nyagisozi	5,357	7.2%	29
11	Ruheru	5,443	7.4%	29
12	Ruramba	4,912	6.6%	26
13	Rusenge	4,938	6.7%	27
14	Kivu	4,050	5.5%	22
	Total	73,805	100%	398

Source: NISR, 2023

This proportional allocation ensures that each sector is fairly represented in the study according to its population size. By applying multistage sampling, purposive selection of forest-adjacent sectors followed by proportionate stratified and simple random sampling of households, the study maintains scientific rigor and enhances representativeness. The final sample size of 398 households is statistically sufficient to generalize findings to the entire district at a 95% confidence level with a 5% margin of error.

2.6. Data Analysis Methods

The data collected through structured questionnaires was coded, entered, and analyzed using the IBM SPSS Statistics. Descriptive statistics were used to summarize the characteristics of the respondents and key study variables. Frequencies and percentages described categorical variables such as gender, marital status, occupation, access to alternative energy, and types of forest products used. Tables and charts were used to present patterns of forest use, frequency of dependence, and the proportion of household income derived from forest resources.

Inferential statistics were employed to test relationships between variables. Chi-square tests examined associations between categorical independent variables (e.g., education level, access to energy, proximity to forest) and the level of household forest dependence. Multiple regression analysis was used to assess the combined effect of socio-economic and environmental/access factors on the dependent variable while controlling for other variables. This helped determine the strength, direction, and statistical significance of predictors influencing forest dependence. Multiple regression analysis determined which socio-economic and environmental factors significantly predict household forest dependence and quantify their relative contribution. Statistical significance was tested at a 95% confidence level ($p < 0.05$). Qualitative data obtained from interviews were analyzed using thematic analysis.

2.7. Ethical Considerations

All participants were informed about the purpose of the study, its objectives, and the procedures involved in data collection. Information provided by participants was treated as strictly confidential. Prior to data collection, authorization was sought from relevant local authorities in Nyaruguru District. The study also complied with institutional ethical guidelines for research involving human subjects.

3. Results

Table 2 Socio-Demographic Characteristics of Respondents (n = 398)

Demographic Variable	Category	Frequency (n)	Percentage (%)	Cumulative %
Age of household head (years)	<30	102	25.6	25.6
	31–45	160	40.2	65.8
	46+	136	34.2	100.0
Gender of household head	Male	235	59.0	59.0
	Female	163	41.0	100.0
Marital Status	Single	60	15.1	15.1
	Married	282	70.9	86.0
	Divorced	26	6.5	92.5

	Widowed	20	5.0	97.5
	Separated	10	2.5	100.0
Education Level	None	48	12.1	12.1
	Primary	198	49.7	61.8
	Secondary	120	30.2	92.0
	Tertiary	32	8.0	100.0
	Vocational/Technical	0	0	100.0
Occupation	Farmer	310	77.9	77.9
	Trader	44	11.1	89.0
	Employee	28	7.0	96.0
	Casual Labor	10	2.5	98.5
	Other	6	1.5	100.0
Household Size	1–4 members	90	22.6	22.6
	5–7 members	216	54.3	76.9
	8+ members	92	23.1	100.0
Monthly Household Income (RWF)	<50,000	48	12.1	12.1
	50,001–100,000	124	31.2	43.3
	100,001–200,000	130	32.7	76.0
	200,001–500,000	78	19.6	95.6
	>500,000	18	4.5	100.1
Main Source of Income	Farming	312	78.4	78.4
	Livestock	38	9.6	88.0
	Business	32	8.0	96.0
	Salary	10	2.5	98.5
	Remittances	4	1.0	99.5
	Other	2	0.5	100.0
Land Ownership Status	Own land	290	72.9	72.9
	Rented land	108	27.1	100.0

Source: Primary data, 2026

This study found that household heads in Nyaruguru District were predominantly aged between 31 and 45 years (40.2%) and mostly male (59.0%), indicating that the farming population is largely composed of economically active adults. Most respondents had attained primary education (49.7%), showing generally low levels of formal education among household heads. Farming was the main occupation for the majority of respondents (77.9%), suggesting limited livelihood diversification. Household size was mainly medium (5–7 members) for 54.3% of respondents, while most households (63.9%) earned between 50,001 and 200,000 RWF monthly, indicating low income levels. In addition, 72.9% of households reported owning land, reflecting relatively high land tenure security among respondents. Overall, these socio-demographic characteristics indicate a population largely dependent on agriculture with limited economic alternatives.

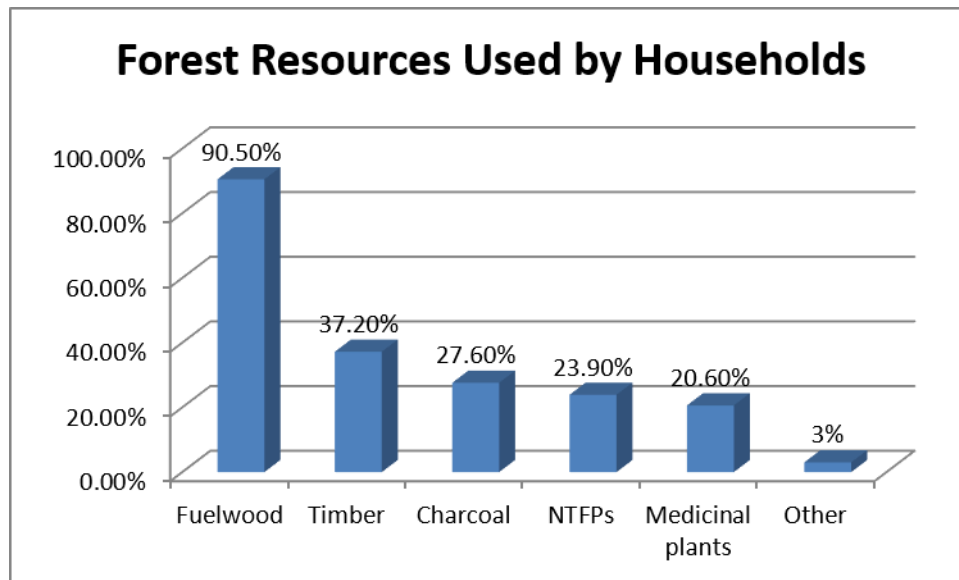


Figure 2 Forest Resources Used by Households

The findings indicate that fuelwood is the most commonly used forest resource, with 90.5% of households reporting its use. Timber is used by 37.2% of households, while charcoal is utilized by 27.6%. Non-timber forest products (NTFPs) such as fruits, herbs, honey, and mushrooms are used by 23.9% of households, and medicinal plants are collected by 20.6%. A small proportion (3.0%) of respondents reported using other forest products. Overall, the findings show that forest resources are widely used, with fuelwood being the dominant resource, followed by timber, charcoal, and NTFPs.

3.1. Factors Influencing Household Dependence on Forest Resources

Table 3 Environmental / Access Factors (n = 398)

Indicator	Category	Frequency (n)	Percentage (%)
Distance to nearest forest	<1 km	140	35.2
	1–3 km	160	40.2
	4–6 km	78	19.6
	>6 km	20	5.0
Access to alternative energy	Electricity	68	17.1
	Gas	42	10.5
	Solar	52	13.1
	Biogas	20	5.0
	None	216	54.3
Reliability of alternative energy access	Very reliable	48	12.1
	Reliable	92	23.1
	Somehow reliable	134	33.7
	Not reliable	124	31.1
Size of land owned (ha)	<1 ha	112	28.1
	1–3 ha	198	49.7
	>3 ha	88	22.1
Type of land use	Crop farming	176	44.2

	Livestock	46	11.6
	Agroforestry	34	8.5
	Mixed	132	33.2
	Other	10	2.5
Availability of forest resources nearby	Very high	58	14.6
	High	122	30.7
	Medium	136	34.2
	Low	66	16.6
	Very low	16	4.0
Perceived distance as a barrier	Strongly agree	72	18.1
	Agree	124	31.2
	Neutral	98	24.6
	Disagree	76	19.1
	Strongly disagree	28	7.0

Source: Primary data, 2026

The findings indicate that 75.4% of households live within 3 km of a forest, suggesting high physical proximity to forest resources. More than half of households (54.3%) reported having no access to alternative energy sources such as electricity, gas, solar, or biogas. Only 35.2% reported having reliable or very reliable energy supply. In terms of land use, 49.7% of households own between 1 and 3 hectares of land, while 33.2% practice mixed land use. Regarding forest resource availability, about 44% of households reported high or very high availability of forest resources in their surroundings. However, 49.3% of respondents still perceived distance or accessibility as a barrier to forest resource use.

Table 4 Institutional / Policy Factors (n = 398)

Indicator	Category	Frequency (n)	Percentage (%)
Awareness of forest policies	Yes	182	45.7
	No	216	54.3
Enforcement of forest laws	Very strict	34	8.5
	Strict	72	18.1
	Moderate	136	34.2
	Weak	104	26.1
	Very weak	52	13.1
Legal access to collect forest resources	Very accessible	48	12.1
	Accessible	94	23.6
	Moderately accessible	148	37.2
	Not accessible	84	21.1
	Not available	24	6.0
Type of access	Legal (permitted)	86	21.6
	Informal	98	24.6

	Community-based	164	41.2
	No access	50	12.6
Influence of access rights on forest use	Very high	72	18.1
	High	108	27.1
	Moderate	124	31.2
	Low	78	19.6
	Very low	16	4.0
Received support/training on conservation	Yes	138	34.7
	No	260	65.3
Provider of support	Government	46	11.6
	NGO/Project	56	14.1
	Community organization	28	7.0
	Other	8	2.0
Type of support received	Training on conservation	74	18.6
	Alternative energy support	42	10.5
	Income-generating activities	28	7.0
	Tree planting programs	38	9.5
	Others	6	1.5
Perceived influence of institutional/policy factors	Very high	60	35.2
	High	102	25.6
	Moderate	140	15.1
	Low	76	19.1
	Very low	20	5.0

Source: Primary data, 2026

The findings reveal that 45.7% of respondents are aware of government rules governing forest use, indicating that more than half of households lack adequate awareness of formal forest regulations. Enforcement of forest regulations was perceived as moderate to weak by 60.3% of respondents, suggesting limited effectiveness of institutional control mechanisms. Regarding access rights, 62.9% of households reported having some form of legal or community-based access to forest resources, while 27.1% reported restricted or no access. In addition, only 34.7% of households reported receiving support or training related to forest conservation, mainly from NGOs and government programs. Overall, 35.2% of respondents rated institutional and policy influence on forest resource use as very high, while 25.6% rated it as high, indicating that governance factors are perceived as important in shaping forest use behavior.

Table 5 Market and Infrastructure Factors (n = 398)

Indicator	Category	Frequency (n)	Percentage (%)
Market accessibility for forest products	Very accessible	42	10.6
	Accessible	98	24.6
	Moderately accessible	164	41.2
	Not accessible	94	23.6

Perception of forest product prices	Very high	60	15.1
	High	122	30.7
	Moderate	142	35.7
	Low	54	13.6
	Very low	20	5.0
Accessibility of alternative energy sources	Very accessible	36	9.0
	Accessible	88	22.1
	Moderately accessible	164	41.2
	Not accessible	110	27.6
Condition of transport infrastructure	Very good	28	7.0
	Good	88	22.1
	Fair	158	39.7
	Poor	88	22.1
	Very poor	36	9.0

Source: Primary data, 2026

The findings indicate that market accessibility for forest products is generally limited, with 41.2% of respondents reporting moderate access and only 10.6% indicating very high accessibility. Regarding forest product prices, 45.8% of households rated them as high or very high, while 35.7% considered them moderate. Access to alternative energy sources remains low, with less than one-third of households reporting good or very good availability. Transport infrastructure is also constrained, with 39.7% of respondents rating it as fair and 31.1% as poor or very poor.

Table 6 Patterns of Household Dependence on Forest Resources (n = 398)

Indicator	Category	Frequency (n)	Percentage (%)
Frequency of forest resource use	Daily	142	35.7
	2–3 times/week	96	24.1
	Weekly	58	14.6
	Monthly	58	14.6
	Occasionally	44	11.0
Proportion of income from forest products	<10%	102	25.6
	10–25%	134	33.7
	26–50%	98	24.6
	51–75%	44	11.1
	>75%	20	5.0
Purpose of reliance	Food	104	26.1
	Energy	362	91.0
	Construction materials	148	37.2
	Cash income	82	20.6
	Cultural/traditional uses	54	13.6
	Medicinal use	74	18.6

Seasonal variations in forest use	High in rainy season	124	31.2
	High in dry season	78	19.6
	Constant throughout the year	196	49.2
Changes in forest product availability (5 years)	Increased	22	5.5
	Same	80	20.1
	Decreased a little	172	43.2
	Decreased a lot	100	25.1
	Don't know	24	6.0
Main barriers to accessing forest resources	Too far/difficult terrain	96	24.1
	Fear of fines	40	10.1
	Competition from others	88	22.1
	Lack of tools/time/labor	134	33.7
	Products scarce	74	18.6
	No barriers	32	8.0

The findings indicate that 35.7% of households use forest resources daily, while 24.1% use them 2–3 times per week, showing frequent dependence on forest resources. Energy needs are the main driver of use, with 91% of households relying on forests for cooking and heating, followed by construction, food, medicinal purposes, income generation, and cultural uses. In terms of income contribution, 33.7% of households obtain 10–25% of their income from forest resources, while 16.1% derive more than half of their income from them. Seasonal use patterns show that 31.2% of households increase reliance during the rainy season, 19.6% during the dry season, and 49.2% depend on forest resources throughout the year. Regarding trends, 68.3% of respondents reported a decline in forest resource availability over the past five years. Access barriers include lack of tools or labor (33.7%), distance or difficult terrain (24.1%), and competition from other users (22.1%). Overall, the findings show high dependence on forest resources with multiple livelihood functions, seasonal variation, declining availability, and several access constraints.

3.2. Relationship between Key Factors and Household Dependence on Forest Resources

Table 7 Chi-square Associations between Household Factors and Forest Dependence

Independent Variable	Category/Group	Forest Dependence (Low / Moderate / High)	Chi-square (χ^2)	p-value
Education level	None	8 / 25 / 15	28.7	0.001
	Primary	35 / 80 / 83		
	Secondary	25 / 55 / 36		
	Tertiary	4 / 12 / 10		
Age of household head	<30	10 / 40 / 52	16.2	0.023
	31–45	35 / 65 / 56		
	46+	27 / 67 / 36		
Household size	1–4	12 / 35 / 45	11.8	0.037
	5–7	40 / 90 / 84		
	8+	20 / 47 / 15		
Proximity to forest	<1 km	15 / 40 / 42	22.3	0.002
	1–3 km	35 / 70 / 69		

	4–6 km	20 / 30 / 30		
	>6 km	2 / 10 / 10		
Access to alternative energy	Electricity	10 / 25 / 6	34.1	0.001
	Gas	5 / 10 / 5		
	Solar	8 / 15 / 7		
	Biogas	4 / 6 / 3		
	None	45 / 91 / 96		
Membership in community forest management	Yes	30 / 60 / 60	7.5	0.023
	No	50 / 80 / 70		
	Not aware	12 / 13 / 13		
Awareness of forest policies	Yes	25 / 60 / 56	8.2	0.017
	No	67 / 93 / 87		
Market accessibility	Very accessible	5 / 20 / 17	12.6	0.013
	Accessible	18 / 50 / 49		
	Moderate	40 / 80 / 64		
	Not accessible	29 / 30 / 40		

Source: Primary data, 2026

The chi-square analysis shows significant associations between forest dependence and several household characteristics. Education level was significantly associated with forest dependence ($\chi^2 = 28.7$, $p = 0.001$), with lower education levels linked to higher dependence. Age of household head also showed a significant relationship ($\chi^2 = 16.2$, $p = 0.023$), with younger and middle-aged groups exhibiting higher dependence. Household size was significantly associated with forest dependence ($\chi^2 = 11.8$, $p = 0.037$), with medium-sized households showing the highest dependence.

Environmental and access factors were also significant. Proximity to forests was strongly associated with dependence ($\chi^2 = 22.3$, $p = 0.002$), with households closer to forests showing higher reliance. Access to alternative energy sources was highly significant ($\chi^2 = 34.1$, $p = 0.001$), with households lacking modern energy relying more on forest resources.

Institutional factors also showed significant relationships. Membership in community forest management systems was associated with forest dependence ($\chi^2 = 7.5$, $p = 0.023$), while awareness of forest policies was also significant ($\chi^2 = 8.2$, $p = 0.017$), with informed households showing slightly lower dependence. Market accessibility for forest products was significant as well ($\chi^2 = 12.6$, $p = 0.013$), with poorer market access linked to higher dependence.

Table 8 Multiple Regression Analysis of Factors Influencing Household Forest Dependence (n = 398)

Predictor Variable	Unstandardized Coefficient (B)	Standard Error (SE)	Standardized Coefficient (Beta)	t-value	p-value
Age of household head (years)	0.152	0.058	0.123	2.62	0.009
Education level (categorical)	-0.318	0.072	-0.245	-4.42	0.001
Household size (members)	0.204	0.065	0.165	3.14	0.002
Monthly household income (RWF)	-0.176	0.054	-0.139	-3.26	0.001
Distance to forest (km)	-0.271	0.080	-0.201	-3.39	0.001

Access to alternative energy (Yes=1, No=0)	-0.342	0.089	-0.233	-3.84	0.001
Membership in community forest management	-0.198	0.072	-0.142	-2.75	0.006
Awareness of forest policies (Yes=1, No=0)	-0.129	0.061	-0.098	-2.11	0.036
Market accessibility (1=very accessible to 5=not accessible)	0.147	0.066	0.108	2.23	0.027

Model Summary: $R^2 = 0.432$, Adjusted $R^2 = 0.418$, $F(9, 388) = 32.6$, $p < 0.001$; Source: Primary data, 2026

The multiple regression analysis showed that the model was statistically significant ($F(9, 388) = 32.6$, $p < 0.001$) and explained 43.2% of the variation in household dependence on forest resources ($R^2 = 0.432$). Socio-economic factors were significant predictors of forest dependence. Household size had a positive effect ($B = 0.204$, $p = 0.002$), while education level ($B = -0.318$, $p = 0.001$) and monthly income ($B = -0.176$, $p = 0.001$) had significant negative effects. Age of household head also showed a positive effect ($B = 0.152$, $p = 0.009$).

Environmental and access factors were also significant. Distance to forests had a negative effect ($B = -0.271$, $p = 0.001$), and access to alternative energy sources also had a strong negative effect ($B = -0.342$, $p = 0.001$). Market accessibility showed a small but significant positive effect ($B = 0.147$, $p = 0.027$).

Institutional factors were significant as well. Membership in community forest management systems reduced forest dependence ($B = -0.198$, $p = 0.006$), and awareness of forest policies also had a negative effect ($B = -0.129$, $p = 0.036$).

4. Discussion of findings

The study examined the factors influencing household dependence on forest resources in Nyaruguru District and revealed that forest resources remain central to rural livelihoods, particularly for domestic energy, income generation, and subsistence needs. The findings demonstrated that fuelwood was the most utilized forest resource, with more than 90% of households relying on it for cooking and heating. This finding confirms the continued dominance of biomass energy in rural areas of Rwanda, where access to modern and affordable energy alternatives remains limited. The finding is consistent with Maniriho and Bikorimana (2020), who reported that more than 80% of rural households in Rwanda depend on fuelwood as their primary source of energy. Similarly, Masera et al. (2020) observed that biomass energy accounts for between 50% and 90% of household energy consumption in many developing countries.

The heavy reliance on fuelwood strongly supports the Theory of Environmental Dependence, which argues that poor rural households depend heavily on environmental resources because of limited livelihood opportunities and inadequate access to alternatives. In the context of Nyaruguru District, the findings suggest that forests are not merely supplementary resources but constitute a basic survival mechanism for many households. This indicates that efforts to reduce forest dependence cannot succeed without addressing broader issues of rural poverty and energy insecurity. In the researcher's view, continued dependence on fuelwood also reflects structural inequalities in access to clean energy technologies, especially in remote rural communities where electricity and gas remain inaccessible or unaffordable.

The study further revealed that household dependence on forest resources was strongly influenced by proximity to forests. Most households lived within three kilometers of forest areas, and chi-square as well as regression analyses confirmed that proximity significantly increased dependence on forest resources. This finding aligns with the Access Theory developed by Ribot and Peluso (2003), which emphasizes that access to resources is shaped not only by ownership but also by geographic location and physical accessibility. Households located near forests can collect fuelwood, timber, medicinal plants, and wild foods more easily and at lower cost than households located farther away. Similar findings were reported by Mendako, Tian, and Matata (2022) in the Democratic Republic of Congo, who found that households living close to forests exhibited higher forest dependence due to easier physical access and lower transportation barriers.

The findings additionally suggest that proximity creates both opportunity and vulnerability. While nearby forests provide an immediate livelihood safety net for rural households, excessive accessibility may accelerate overharvesting and environmental degradation. This interpretation is reinforced by the finding that more than two-thirds of households perceived a decline in forest product availability over the past five years. Such perceptions indicate increasing pressure on forest ecosystems resulting from unsustainable extraction, agricultural expansion, and climate-

related challenges. These findings resonate with the Sustainable Development Theory, which emphasizes the need to balance present livelihood needs with long-term environmental sustainability. The decreasing availability of forest products suggests that current patterns of forest use may not be ecologically sustainable if alternative livelihood and energy options are not strengthened.

The study also established that access to alternative energy sources significantly reduced household dependence on forest resources. More than half of households reported lacking access to electricity, gas, solar energy, or biogas, while only a minority described their energy supply as reliable. Regression analysis further showed that access to alternative energy had one of the strongest negative effects on forest dependence. This finding supports previous studies by Habiyaemye, Nsabimana, and Murenzi (2022), who found that low-income households in Rwanda were significantly more dependent on fuelwood due to limited access to cleaner energy technologies. The findings equally support the Sustainable Livelihoods Theory, which explains that households rely on available livelihood assets to survive under conditions of vulnerability. Where financial and physical capital are inadequate, households are forced to depend on natural capital such as forests.

The implication of this finding is that energy poverty remains one of the strongest drivers of forest dependence in rural Rwanda. In the researcher's assessment, the transition toward sustainable forest management cannot be separated from rural energy transformation. Policies promoting affordable solar systems, biogas, and rural electrification may therefore play a critical role in reducing pressure on forest ecosystems while simultaneously improving household welfare.

The study further found that education level and household income significantly influenced forest dependence. Households with lower education levels and lower monthly income were more likely to depend heavily on forest resources, while educated and economically stable households exhibited lower dependence. These findings are consistent with studies conducted by Mutsepe (2017) in Botswana and Habiyaemye et al. (2022) in Rwanda, which reported that poor households derive a larger share of their livelihoods from forest resources than wealthier households. The findings also support the Theory of Environmental Dependence, which argues that poverty intensifies reliance on natural resources due to limited access to alternative livelihood opportunities.

The inverse relationship between education and forest dependence further confirms the relevance of the Sustainable Livelihoods Theory. Education represents an important component of human capital that enables households to diversify income sources, adopt modern technologies, and access formal employment opportunities. The findings therefore suggest that improving rural education may indirectly contribute to environmental conservation by reducing excessive dependence on forests. In the researcher's perspective, this relationship demonstrates that forest conservation is not only an environmental issue but also a socio-economic development issue requiring investment in human capital development.

Household size was another important determinant of forest dependence. Medium and large households were more dependent on forest resources due to increased energy consumption and household subsistence demands. This finding corresponds with studies by Prakash (2018) and Mendako et al. (2022), which found that households with larger family sizes were significantly more dependent on forests for fuelwood, food, and income generation. Larger households naturally require more cooking energy, construction materials, and livelihood resources, thereby increasing extraction pressure on nearby forests.

Institutional and policy-related factors also shaped household dependence on forest resources. The study revealed low awareness of forest regulations, weak enforcement of forest policies, and limited access to conservation training programs. Although some households reported legal or community-based access to forests, support initiatives remained inadequate. These findings reinforce the Access Theory, which argues that institutional arrangements and governance systems significantly influence how people access and benefit from natural resources. Weak institutional support may reduce compliance with sustainable forest management practices and encourage informal or unsustainable extraction.

The findings further indicate that forest conservation efforts may not achieve long-term success if local communities are insufficiently involved in forest governance. In the researcher's view, strengthening community awareness, participation, and access to conservation incentives is essential for balancing livelihood needs with environmental sustainability. Community-based forest management programs should therefore focus not only on regulation enforcement but also on livelihood empowerment and equitable access to alternative resources.

Finally, market accessibility and infrastructure conditions significantly influenced household dependence on forest resources. Poor transport infrastructure and limited market accessibility increased household reliance on forests for subsistence and informal income generation. This finding supports previous African studies showing that weak market integration limits livelihood diversification opportunities and increases dependence on nearby natural resources. The findings imply that improving rural infrastructure and market access may reduce household vulnerability by expanding non-forest livelihood opportunities.

Overall, the findings demonstrate that household dependence on forest resources in Nyaruguru District is shaped by interconnected socio-economic, environmental, institutional, and infrastructural factors. The study confirms that forest dependence cannot be understood solely as an environmental issue, but rather as a multidimensional livelihood challenge rooted in poverty, limited energy access, weak institutional support, and constrained economic opportunities.

Despite some limitations explained previously, the findings have important practical and policy implications. The strong influence of socio-economic factors, including household size, income, and education, suggests that poverty alleviation programs, livelihood diversification initiatives, and education campaigns could reduce overreliance on forest resources. The significant role of environmental and access factors, particularly proximity to forests and availability of alternative energy, indicates that expanding access to clean energy sources and improving infrastructure could support sustainable forest use. Institutional factors, such as membership in community forest management systems and awareness of forest policies, were shown to decrease forest dependence, highlighting the potential of strengthening local governance, community participation, and policy enforcement to enhance conservation outcomes. Overall, these results underscore the need for integrated strategies that combine socio-economic development, energy provision, and institutional support to promote sustainable forest resource management in Nyaruguru District.

5. Conclusion

The study concluded that households in Nyaruguru District are highly dependent on forest resources for multiple purposes, including energy, construction, food, medicinal use, and income generation, with frequent and year-round utilization. Household socio-economic characteristics, such as larger household size, lower education, and limited income, significantly increase reliance on forest resources, while access to alternative energy, proximity to forests, and participation in community forest management reduce dependence. Environmental, market, and institutional factors also play important roles in shaping forest use patterns. Overall, the findings highlight the need for integrated interventions, including promotion of alternative energy sources, education, income-generating opportunities, and strengthened community forest management, to reduce unsustainable forest dependence while supporting livelihoods and sustainable forest use in the district.

Compliance with ethical standards

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Disclosure of conflict of interest

This study declared no competing interests

Statement of ethical approval

Ethical clearance was obtained from both UNILAK and Nyaruguru District: No: 1258.07.02.03/MD

Statement of informed consent

Informed consent was obtained from all individual participants included in the study.

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