AGROFORESTRY BENEFITS AND PREFERENCES IN UGANDA: SOIL AND WATER FOREST PROTECTION SERVICES IN LANDSCAPE PROTECTION

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Abstract

While Uganda is suggested to have made positive progress in achieving Sustainable Development Goals (SDGs), the country is still susceptible to climate change impacts. Moreover, gender disparities still exist due to fundamental aspects in society that hinder, for example, women's contribution to food and nutrition sovereignty. The study aimed to explore the preferences for agroforestry benefits from ecological and socioeconomic aspects, including soil protection and regulation services, and water protection services in Uganda.

The study used an online questionnaire, and a total of a number (n=1138) of responses was collected, coded, and subjected to descriptive analysis and multinomial logit model regression. Preferences for soil protection and water protection services together ranked 78%, demonstrating strong ecological influence. The preference for food and fruit was found to have a positive significant connection with preferences for saving nature and water protection. Gender positively and strongly impacted various agroforestry benefits and services. Food and fruit production illustrated positive, strong, and significant influence and connection with ecological factors (water, soil, and nature). The consequences in one area either directly or indirectly affected the others, which highlighted the need for integrated approaches in agroforestry systems in Uganda.

Key words: agroforestry preferences, climate change, food security, gender disparities, soil protection, water protection services, sustainable development

Introduction

Agroforestry systems present a complex mechanism in Uganda that integrates agricultural, forestry, and ecological practices and approaches. Environmental, socio-economic, and cultural factors can explain the preferences and determinants of the benefits derived from agroforestry systems in Uganda (Bamwesigye et al., 2020a, Bamwesigye et al., 2020b, Bamwesigye et al., 2022, Awazi et al., 2022). The Agroforestry paradox directly contributes to achieving Sustainable Development Goals (SDGs) due to the enormous benefits to the environment and society resilience and sustainability (Bamwesigye et al., 2019, Awazi et al., 2022).

While Uganda is suggested to have made positive progress in achieving SDGs, the nation is still vulnerable to climate change impacts. Gender inequality still exists due to structural aspects in society, especially in resources management such as land, and yet they are the prime contributors to food and nutrition activities. Besides, the women being the primary household cooks in Uganda, experience wood fuel/firewood hardship (Tumwebaze et al., 2011, Bamwesigye et al., 2019, Bamwesigye et al., 2020b, Bamwesigye et al., 2022, Bamwesigye et al., 2024).

Not many studies have explored the elucidation of agroforestry practices and operations in Uganda's particular situation, emphasizing the benefits of nature preservation, soil protection, biodiversity, and socioeconomic health (Tumwebaze et al., 2011, Bamwesigye et al., 2024).

The integration of trees within agricultural landscapes significantly contributes to soil health and quality (Moore et al., 2014) and water-soil provision and protective services (Moore et al., 2014, Ureta et al., 2022). Some studies indicated that agroforestry schemes are connected with improved soil organic carbon, which are vital for maintaining and sustaining soil fertility and soil protection by reducing erosion (Tumwebaze et al., 2011). Tree litter and root systems enhance nutrient cycling and organic matter incorporation into the soil, leading to long-term improvements in soil structure and moisture retention, both of which are essential for sustainable farming (Ureta et al., 2022).

A crucial factor influencing agroforestry practices is the need for environmental conservation. Combining agricultural activities with tree planting is pivotal in preserving local ecosystems and biodiversity in areas. Soil and water protection services provided by agroforestry systems demand attention. It urgued that tree root architecture improves and facilitates water infiltration and retention in soils (Quinion et al., 2010).
The aim of the current is to study the preferences agroforestry benefits of ecological of water and soil protection services
The study hypothesized that the preference for ecological benefits (soil conservation, and water protection services) is significant in determinants of agroforestry benefits' preferences.

Material and methods
The study was conducted in Uganda, East Africa. Uganda borders South Sudan in the North, Kenya in the East, Rwanda in the South West, Republic of Tanzania, and the Democratic Republic of the Congo (DRC) in the West.
The study collected data from the online questionnaire software Survio. The questionnaire was carefully constructed and approved as required. It was set according to quality requirements and restrictions, such as one person.
The questionnaire was then shared on numerous internet platforms. The questionnaire ran for three months and was then closed, and the data was downloaded for cleaning and analysis. The questionnaire was then subjected to pretesting. The pretesting results were controlled, and upon satisfaction, the results were deleted for better accuracy and consistency in data collection as well as quality of data.
A total of a number of one thousand, one hundred and thirty-eight responses (n=1138) were collected as fully and completed questionnaire responses between 18th January 2023 and 2nd April 2023. For quality purposes and integrity, the questionnaire had been set with protection from multiple responses.
Thereafter, the data was subject to cleaning and analysis.
Data analysis: Descriptive Statistics and Regression
The data was first coded and then subjected to analysis.
Descriptive statistical analysis was conducted to present the study findings more easy and comprehensive way. This is because descriptive statistics help readers understand and communicate the study's findings easily. Some of the advantages are;
They summarize the results/findings using measures such as mean, median, and standard deviation, hence understanding any amounts of data. Provide a clear overview of data, hence facilitating decision-making. They provide a basis for inferential statistics, hence the possibility for predictions or generalization. They help to understand the distribution and ranges of the data.
Make it easy for the study to compare different groups of data and understand various patterns and trends.

Regressions
The study conducted regression analysis to get to the bottom of the relationships and impact on various agroforestry benefits and socioeconomic variables.
The study used the general equation for a multinomial logit model (Equation 1) that gives the probability of an observation in category (j) out of J categories given a set of predictor variables (Ecological and socioeconomic variables). It is based on the idea of relative probabilities, using the function to make sure that the probabilities add up to 1.

$$P(Y = j / X) = \frac{exp(\beta_j \prime X)}{\Sigma_k \, exp(\beta_k \prime X)} \quad (1)$$

Where:
Y is the dependent variable (agroforestry benefit), a categorical variable with J categories (j = 1, 2, …, J). The equation can be further expanded to illustrate the various independent variables [$P(Y = j/X_1, X_2, ..., X_k) = \exp(\beta_{0j} + \beta_{1j}X_1 + \beta_{2j}X_2 + ... + \beta_{kj}X_k) / \Sigma_j \exp(\beta_{0j} + \beta_{1j}X_1 + \beta_{2j}X_2 + ... + \beta_{kj}X_k)$].
Where X is a vector of predictor variables (X_1, X_2, …, X_k) such as gender, age, employment, income among other variables as used in the models herein.

β_j is a vector of coefficients for category j. Each category has its own vector of coefficients (β_1, β_2, …, β_j). These coefficients are the coefficients of the predictor variables on the log-odds of being in category j compared to a reference category.
$\beta_j'X$ is the inner product of the coefficient vector β_j and the predictor variable vector X. This is the linear predictor for category j.
$\Sigma_k \exp(\beta_k'X)$ is the sum of the exponentiated linear predictors across all J categories. This is a normalization term, the probabilities for all categories add up to.

Results

The data collected gave insights into the nature and characteristics of the studied population. The gender distribution indicates a significant majority of males, accounted for 64% of the respondents, while females represented 36%. This disparity suggests a potential area for further investigation regarding the factors influencing gender representation in the sample.
The employment status data showed that a half of the respondents (52%) were students. Unemployment accounted for 17% of the population, and 31% of the respondents were employed. The studied age data showed that the youth were majority, with 60% of respondents aged 18-30. The age group between 31 and 45 years old comprised 32%, while 46 and plus years of age consisted 8% of the sample. The survey results revealed significant demographic trends among the respondents studied. The findings indicated a youthful population.

Regression Results

Preference for Water Protection services

Preference for water protection services as a proxy of agroforestry benefits (Model 1) showed that saving nature ("Save Nature") has a negative but significant relationship with water protection (0.028). Forest soil conservation services (0.000) and forest food and fruit products (0.000) disclosed positive and significant connections and influence on water protection services provided by agroforestry (Model 10, Tab. 1). On the other hand, preference for Firewood and wood fuel/energy had a negative and not statistically significant impact on water protection services (0.090).
The preferences for saving nature (0.001) and Firewood and Energy needs (0.001) had negative but very significant associations with water protection services preference. In contrast, Soil Conservation and protection preference (0.000) and forest food and fruits (0.001) had strong positive and very significant connections with water protection services (Tab. 1).
Model 3 used socioeconomic factors, i.e., *Gender, Age, Employment, and Income in Ugandan Shillings (Income UGX)*. Gender had a positive and very strong significant impact on water protection services preference [(0.000) (Tab. 1)].

Tab. 1: Water protection

Variables	**Model 1**		**Model 2**		**Model 3**	
	Coefficient	*p-value*	*Coefficient*	*p-value*	*Coefficient*	*p-value*
Age	−0.163	0.139			−0.076	0.463
Income (UGX)	5.479	0.546			2.376	0.638
Gender	−0.191	0.147			0.359	0.000
Employment	−0.068	0.477			0.113	0.189
Save Nature	−0.346	0.028	−0.475	0.001		
Firewood/Energy	−0.265	0.090	−0.485	0.001		
Forest Incomes	0.152	0.250	0.082	0.542		
Soil Conservation	0.807	0.000	0.746	0.000		
Food & Fruits	0.599	0.000	0.521	0.001		
GoU Effort	−0.150	0.113				

Preference Soil Protection Services

Tab. 2: Soil Conservation services

Variables	**Model 4**		**Model 5**		**Model 6**	
	Coefficient	*p-value*	*Coefficient*	*p-value*	*Coefficient*	*p-value*
Gender	0.0118	0.923			0.216	0.009
Age	−0.240	0.022	−0.226	0.013	−0.194	0.050
Employment	0.039	0.663			0.082	0.315
Income (UGX)	4.209	0.485			3.521	0.490
Save Nature	−0.191	0.202				
Firewood/Energy	−0.335	0.022	−0.319	0.016		
Forest Incomes	−0.389	0.002	−0.380	0.003		
Water Protection	0.759	0.000	0.750	0.000		
Food & Fruits	0.349	0.016	0.306	0.026		
GoU Effort	0.062	0.487				

Models 4, 5, and 6 examined the factors influencing the preference for soil conservation services in Uganda as a forest benefit. Preference for forest water protection services was consistently very significant and had a positive impact throughout, representing a strong positive connection with forest soil conservation function (Tab. 2).

Preference for forest income as a proxy of agroforestry showed a consistently negative and statistically significant relationship with preference for forest soil conservation services (Models 4 and 5: 0.002 and 0.003), respectively (Tab. 2).

The study also found a strong and positive connection between preference for forest food and fruit preference and soil conservation services (Model 4 and 5: 0.016 and 0.026, respectively).

Preference for firewood and wood fuel energy was found to have a strong but negative influence on preference for forest soil conservation services (Model 4 and 5: 0.022 and 0.016), respectively (Tab. 2).

Model 6 displayed a strong and significant positive influence of Gender on preference for forest soil conservation services (0.009). This means socioeconomic factors such as Gender and age influence preference for soil conservation in Uganda in one way or another (Tab. 2).

Discussion of Results

Water protection and regulation services

The results suggested that observed preferences for agroforestry benefits negatively impact nature and are related with decreased water protection services potential.

If the measure/approach captures deforestation or unsustainable harvesting, the results highlight the crucial role of maintaining forest cover for effective water resource management. This underscores a key benefit of agroforestry incorporating trees into agricultural landscapes that can moderate the negative impact of deforestation on water protection services (Pantera et al., 2021).

The negative but continuously statistically significant connection between firewood & energy and water protection services needs some context. It may be the result of the wood fuel use dependency and the other effects on forest and water management. The negative effect of this could be lessened by implementing sustainable agroforestry practices that promote various sustainable fuel sources and the efficient use of wood. The consistently positive and statistically significant relationships between the preference for soil conservation and the preference for forest food and fruits and the preference for water protection services of the forest showed that the mechanisms of human soil health protection and the integration of trees into crop production are protective (Agúndez et al., 2022). Through agroforestry, soil health is improved, and diversified plant communities are encouraged, enhancing water infiltration, reducing runoff and maintaining water availability for water protection (Pantera et al., 2021).

Attempting to solve forest water protection services in Uganda is not an isolated factor; the present investigation showed that agroforestry benefits have a considerable character/role in enhancing water protection services. The study findings highlight basics for sustainable agroforestry methods that promote and support forest conservation, effective and optimal resource utilization, and enhanced soil health to guarantee lasting water security.

Therefore, promoting and supporting the adoption of agroforestry systems that integrate trees into agricultural landscapes, emphasizing soil conservation, efficient and sustainable fuelwood production and use, and responsible forest food harvesting and consumption to enhance water protection services.

Soil Protection services

All the variables related to agroforestry benefits and preferences for soil conservation were consistently significant, which showed how important agroforestry and forests are in maintaining soil health and quality (Table 2). The benefits of water protection services associated with forests were statistically significantly related to better soil conservation (Table 2). The positive coefficient indicates that increases in soil conservation accompany increases in water protection services (Franco et al., 2001, Pantera et al., 2021).

Forest incomes from agroforestry were negatively associated with soil conservation practices directly derived from it. This could be interpreted in several ways. It could also be that the relationship specifies that regions with higher potential forest incomes have greater forest use pressure, which in turn results in worse soil conservation (Franco et al., 2001, Pantera et al., 2021).

Agroforestry systems incorporating fruit trees and other food-producing plants within the forests are positively affiliated with an enhanced desire for soil conservation services (Schuler et al., 2022).

This positive relationship might be explained by the protective role of tree canopies on the soil, better soil structure due to organic matter addition through leaf litter and root systems, and reduced soil erosion due to shade. Wood fuel and firewood's negative and highly significant effect on soil conservation services suggests that an increase in agroforestry for firewood and wood fuel production will likely adversely affect soil health and quality.

Gender roles or approaches and practices, especially in agroforestry systems, may lead to better soil conservation results. Women's participation in agroforestry, particularly in management and maintenance, is likely to benefit soil conservation efforts (Bamwesigye et al., 2019, Bamwesigye et al., 2024).

Conclusion

At the height of forest and land degradation in Uganda, climate change-related impacts and vulnerabilities are felt in numerous communities across the country and region. This research study examined the perceptions of agroforestry and preferences for its benefits, soil conservation and water protection services in Uganda.

Survey results (n=1138) highlighted a high preference for the ecological benefits of agroforestry, i.e., saving nature, soil and water protection services. The socioeconomic preferences for forest incomes and forest foods and fruit production had considerable and uniform preferences.

The preference for saving nature together with soil protection and water regulation and protection services showed the prospective for successful projections incorporating ecological and environmental resilience goals.

Firewood dependency not only threatens forest conservation but also results in the degradation of biodiversity. Gender, employment, and age of the respondents were found to impact choices towards various agroforestry benefits and services. The significant impact of gender suggested that women's participation has the potential for better conservation outcomes in agroforestry practices in Uganda.

The findings showed that outcomes in one area of agroforestry benefits either directly or indirectly affected the others, which highlighted the need for integrated approaches in agroforestry systems in Uganda.

It is crucial to develop integrated agroforestry systems that promote the sustainable management of forest resources. These systems should aim to improve water and soil protection and management, enhance fruit and food production, and increase overall ecosystem productivity.

References
Agúndez, D., Lawali, S., Mahamane, A., Alía, R., & Soliño, M. (2022). Development of agroforestry food resources in Niger: Are farmers' preferences context specific? World Development, 157, 105951.
Awazi, N. P., Tchamba, M. N., Temgoua, L. F., & Tientcheu-Avana, M. L. (2022). Agroforestry as an adaptation option to climate change in Cameroon: assessing farmers' preferences. Agricultural Research, 1-12.
Bamwesigye, D., Akwari, F. N., & Hlaváčková, P. (2019, January). Forest product export performance in tropical Africa: an empirical analysis. Forum Scientiae Oeconomia (Vol. 7, No. 1, pp. 73-83).
Bamwesigye, D., Hlavackova, P., Sujova, A., Fialova, J., & Kupec, P. (2020a). Willingness to pay for forest existence value and sustainability. Sustainability, 12(3), 891.
Bamwesigye, D., Doli, A., Adamu, K. J., & Mansaray, S. K. (2020b). A Review of the Political Economy of Agriculture in Uganda: Women, Property Rights, and Other Challenges. Universal Journal of Agricultural Research 8(1): 1-10, 2020
Bamwesigye, D., Chipfakacha, R., & Yeboah, E. (2022). Forest and Land Rights at a Time of Deforestation and Climate Change: Land and Resource Use Crisis in Uganda. Land, 11(11), 2092.
Bamwesigye, D., Yeboah, E., Ozbalci, S., Fialova, J., Kupec, P., Verter, N., & Asamoah, O. (2024). Climate Change and Potential of Agroforestry in Uganda: Youth Perceptions and Willingness to Participate in Adaptation and Transition Efforts. Forests, 15(12), https://doi.org/10.3390/f15122108
Franco, D., Franco, D., Mannino, I., & Zanetto, G. (2001). The role of agroforestry networks in landscape socioeconomic processes: the potential and limits of the contingent valuation method. Landscape and Urban Planning, 55(4), 239-256.
Moore, E. A., Munsell, J. F., Hammett, A. T., & Moore, K. M. (2014). Agroforestry preferences in refugee hosting communities in Cameroon. Agroforestry systems, 88(4), 735-752.
Pantera, A., Mosquera-Losada, M., Herzog, F., & Herder, M. (2021). Agroforestry and the Environment. Agroforestry Systems, 95(5), 767-774. https://doi.org/10.1007/s10457-021-00640-8
Quinion, A., Chirwa, P., Akinnifesi, F., & Ajayi, O. (2010). Do Agroforestry Technologies Improve the Livelihoods of the Resource Poor Farmers? Evidence from Kasungu and Machinga Districts of Malawi. Agroforestry Systems, 80(3), 457-465. https://doi.org/10.1007/s10457-010-9318-7
Schuler, H. R., Alarcon, G. G., Joner, F., dos Santos, K. L., Siminski, A., & Siddique, I. (2022). Ecosystem services from ecological agroforestry in Brazil: A systematic map of scientific evidence. Land, 11(01), 83.
Tumwebaze, S., Bevilacqua, E., Briggs, R., & Volk, T. (2011). Soil Organic Carbon under a Linear Simultaneous Agroforestry system in Uganda. Agroforestry Systems, 84(1), 11-23. https://doi.org/10.1007/s10457-011-9448-6
Ureta, J. C., Motallebi, M., Vassalos, M., Seagle, S., & Baldwin, R. (2022). Estimating residents' WTP for ecosystem services improvement in a payments for ecosystem services (PES) program: A choice experiment approach. Ecological Economics, 201, 107561.

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Souhrn
Ačkoli se naznačuje, že Uganda dosáhla pozitivního pokroku v plnění cílů udržitelného rozvoje, je země stále náchylná k dopadům změny klimatu. Kromě toho stále existují rozdíly mezi pohlavími, které jsou způsobeny základními aspekty ve společnosti, jež brání například tomu, aby ženy přispívaly k potravinové a výživové nezávislosti. Cílem studie bylo prozkoumat preference přínosů agrolesnictví z ekologických a socioekonomických hledisek, včetně služeb ochrany a regulace půdy a služeb ochrany vody v Ugandě.
Ve studii byl použit online dotazník a celkem byl shromážděn počet (n=1138) odpovědí, které byly kódovány a podrobeny deskriptivní analýze a regresi pomocí multinomického logitového modelu.

Preference služeb ochrany půdy a ochrany vody se společně umístily na 78 %, což ukazuje na silný ekologický vliv. Sociálně-ekonomické faktory palivové dřevo/dřevo, příjmy z lesa a potraviny a plody se umístily přibližně na 18 %, 30 % a 19 %. Bylo zjištěno, že preference potravin a plodů mají pozitivní významnou souvislost s preferencemi pro ochranu přírody a ochranu vody. Gender pozitivně a silně ovlivňoval různé agrolesnické přínosy a služby. Produkce potravin a ovoce ilustrovala pozitivní, silný a významný vliv a souvislost s ekologickými faktory (voda, půda a příroda). Důsledky v jedné oblasti buď přímo, nebo nepřímo ovlivňovaly ostatní, což zdůraznilo potřebu integrovaných přístupů v agrolesnických systémech v Ugandě.

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