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Research Article

Environmental and Economic Role of Community Protected Area with Integration of Management Practices and Protein Bank in West Arsi Zone Oromia Region Ethiopia

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Abstract

This study explored how community-based protected areas in the West Arsi Zone of Oromia, specifically Negele Arsi sub-district, can be strengthened environmentally and economically through the integration of protein bank trees and improved management practices. The main purpose was to assess the ecological and economic advantages of incorporating protein-rich leguminous trees within community-managed conservation lands. The experiment was conducted using a randomized complete block design (RCBD) with four treatments, including a control, each replicated three times. Individual plots measured 5 m × 5 m, with spacing of 1.5 m between blocks and 1 m between plots. Seedlings of tree legumes were raised in nurseries at ATARC and transplanted for field establishment. Agronomic data were collected, integrated tree plantings were carried out, and fresh biomass was measured to evaluate dry matter yield, nutrient content, and the contribution of protein bank trees. Subsamples of fresh biomass were taken for laboratory analysis. Samples were oven-dried at 60 ℃ for 48 hours, ground, sieved (1 mm mesh), and analyzed for dry matter (DM), ash, and crude protein (CP) following standard procedures. Ash content was determined at 550 ℃ for 3 hours using a carbolite furnace, while CP was analyzed using the Kjeldahl method. Fiber fractions including NDF, ADF, and ADL were also determined. Data were organized in Microsoft Excel and statistically analyzed using SAS version 9.2, with mean separation carried out using the Fisher's LSD test at a 5% significance level. Results showed that integrating leguminous fodder trees into natural protected areas significantly affected ash content, organic matter, crude protein, neutral detergent fiber, and acid detergent fiber. These findings indicate that multipurpose tree legumes enhance both the quality and quantity of available forage resources in protected areas. Consequently, incorporating such trees can help address feed shortages by improving crude protein and organic matter levels. Further research is needed on optimal harvesting intervals and biomass yield of integrated tree legumes.

Keywords

Tree Legumes, Protected Area, Sesbania, Animal Feeds, West Arsi

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1. Introduction

Community-based protected areas (CBPAs) are recognized for their role in conserving biodiversity, restoring degraded ecosystems, and supporting rural livelihoods [7, 10]. In Ethiopia, they contribute significantly to the protection of soil, water, and vegetation resources, while enhancing community well-being, although their performance is often limited by weak management, low community participation, and insufficient livelihood-support interventions [11, 18].

In the West Arsi Zone of Oromia, CBPAs are especially important for addressing land degradation, increasing pasture availability, and sustaining ecosystem functions under pressures from population growth and climate variability [1]. However, these areas face challenges such as overgrazing, excessive fuelwood extraction, and competing land uses [8]. Integrating protein bank trees—fast-growing species with high protein content into CBPAs offers potential to improve livestock feed supply, enhance biodiversity, and generate economic benefits for local households [5, 15].

Improved management practices, including rotational grazing, enrichment planting, soil and water conservation measures, and participatory decision-making, can further strengthen ecological resilience and productivity [10, 11]. Combining protein banks with sustainable management approaches can transform CBPAs into multifunctional landscapes that support both environmental conservation and local livelihoods. In addition, it rehabilitates the degraded lands [2].

In West Arsi, where livestock rearing is a major livelihood, seasonal feed shortages remain a key constraint. Protein banks can help alleviate this by supplying high-quality fodder, reducing grazing pressure on natural pastures, and boosting livestock productivity [5, 15]. Strengthening CBPA management through community participation, capacity building, and improved conservation practices can also enhance biodiversity, restore soil fertility, and increase carbon sequestration, while creating opportunities for sustainable income generation through products such as fodder, fuelwood, and other non-timber forest products [7, 10].

Despite these potential benefits, there is limited scientific evidence on the combined ecological and economic impacts of integrating protein banks with improved management practices in Ethiopian CBPAs [1, 11]. This study seeks to fill that gap by generating evidence to guide policy, support extension services, and promote community-led conservation and development. The Objective of this research was to assess the environmental and economic benefits of integrating protein bank establishment and improved management practices into community-based protected areas in West Arsi Zone, Oromia, Ethiopia and to analyze the effects of integrated management practices on soil fertility, vegetation cover, and ecosystem services. It indeded to answer the following research questions: What is the current ecological condition and management status of CBPAs in the West Arsi Zone? And What are the environmental impacts of integrating improved management practices into CBPAs.

2. Material and Method

2.1. Description of the Study Area

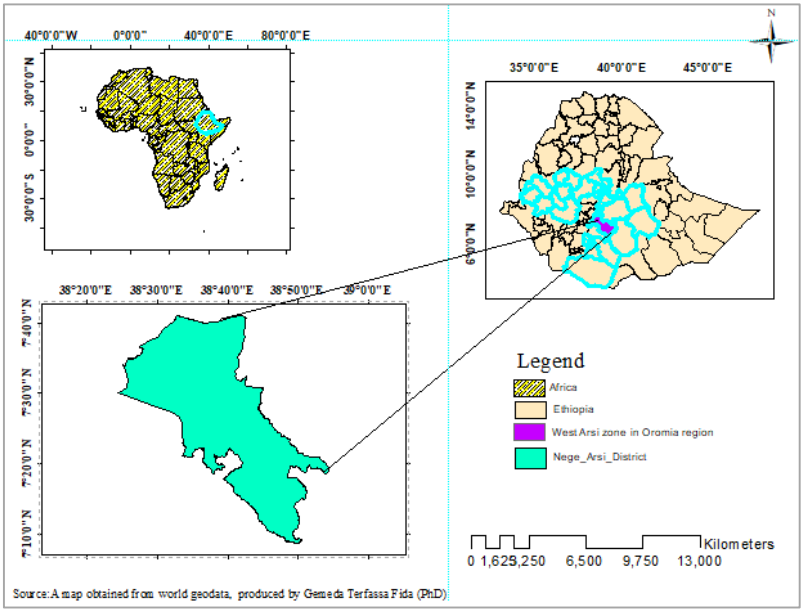

Figure 1. *Map of study area.*

The research was carried out in Negelle Arsi district, west arsi zone oromia regional state Ethiopia. The site is situated approximately 237.9 km southeast of Addis Ababa. Geographically, it extends between 7.15 °–7.75 ° N latitude and 38.35 °–38.95 ° E longitude, with elevations around 1,500 m above sea level (Figure 1). The district forms part of the Great Rift Valley and is bordered by Shashamane and Kofale districts to the south, the Southern Nations, Nationalities and Peoples' Region (SNNPR) to the west, Adami Tulu Jido Kombolcha district and Lakes Abijatta and Langano to the north, and Heban Arsi zone to the east.

2.2. Procedure and Implementation of the Experiments

The experimental site within the district was chosen based on road accessibility, security, and economic conditions. At Adami Tulu Agricultural Research Center (ATARC), different mixed vegetable crops were first established and later transplanted to Negelle Arsi. The experiment followed a Randomized Complete Block Design (RCBD) with four treatments, including a randomized control, replicated across three timelines. Treatments consisted of three leguminous species: Cajanus cajan, Sesbania sesban, and Leucaena leucocephala.

Multifunctional trees (MFTs) are species cultivated to serve multiple purposes, such as soil conservation, shade provision, fuelwood, timber, fodder, and medicinal uses [13]. For instance, Cajanus cajan is widely valued in livestock production since its leaves and pods are highly palatable and rich in protein [9]. Similarly, Leucaena leucocephala generates substantial biomass, ensuring a reliable source of fodder during dry periods, thereby enhancing livestock productivity and offering additional income opportunities for farmers [6]. Sesbania sesban also plays a critical role in ruminant nutrition; its foliage contains high levels of nitrogen and phosphorus, making it a valuable supplement to protein-deficient diets and improving digestibility for cattle and goats [14].

Each treatment plot measured 5 m × 5 m with a thickness of 1.5 m.

Figure 2. *The procedure of nursery establishments to transplanting.*

All agronomical managements were undertaken for the experimental site.

2.3.1. Sampling and Method of Data Collection

All agronomic and physical attributes of the multipurpose trees including survival rate, plant height, branch number, and canopy cover were recorded. Plant height and canopy length were measured in meters, while diameter at breast height (DBH) was assessed at 60 cm above ground level using a caliper. Fresh biomass samples were collected to evaluate the fodder production potential of integrated multipurpose trees within the protected area. Biomass yield was determined by harvesting three representative plants per plot, after which fresh weights were recorded to estimate protein bank contributions, dry matter availability, and overall nutritive value. Subsamples were taken, processed, and prepared for dry matter determination and laboratory analysis. Sample preparation, drying, and proximate analysis were conducted by the Animal Feed and Rangeland Management Research Unit at ATARC.

2.3.2. Data Analysis

(i). Chemical Analysis

Subsamples were oven-dried at 65 ℃ for 72 hours, ground, and sieved through a 1 mm mesh before chemical evaluation. Ash content was determined by incinerating the material at 550 ℃ for three hours. Crude protein (CP) was analyzed using the Kjeldahl method following standard procedures, while fiber fractions including neutral detergent fiber (NDF), acid detergent fiber (ADF), and acid detergent lignin (ADL) were determined according to the protocol of [17].

(ii). Statistical Analysis

Agronomic and chemical composition data were first organized in Microsoft Excel and subsequently analyzed using SAS software (version 9.9.2). One-way ANOVA was applied to test treatment effects, and mean comparisons were performed using the Least Significant Difference (LSD) test at a significance threshold of $p < 0.05$.

3. Result and Discussion

3.1. Agronomic and Physical Parameters

Table 1. *Agronomic and physical characteristics of integrated multipurpose tree legumes in protected areas.*

No	Treatments	Physical parameter of integrated multipurpose tree legumes					
		Survival rate	Plant height	DBH	Branch No	Canopy	
						L1	L2
1	*Cajunus cajun*	12.67 ±0.33^{b}	1.85 ±0.31^{b}	0.89 ±0.15^{ab}	11.33 ±5.93^{b}	98.89 ±16.02^{b}	65.56 ±22.31^{b}
2	*Lucinia leucocephala*	17.00 ±3.22^{b}	1.69 ±0.48^{b}	0.98 ±0.26^{ab}	12.44 ±5.61^{b}	72.78 ±15.88^{b}	45.56 ±10.94^{b}
3	*Control*	0.00 ±0.00^{c}	0.00 ±0.00^{c}	0.00 ±0.00^{b}	0.00 ±0.00^{b}	0.00 ±0.00^{c}	0.00 ±0.00^{c}
4	*Sesbania sesban*	23.33 ±0.88^{a}	3.64 ±0.37^{a}	2.11 ±0.80^{a}	38.56 ±3.58^{a}	142.22 ±9.69^{a}	108.89 ±6.94^{a}
Overall mean		13.25 ±2.67	1.79 ±0.42	1.00 ±0.29	15.58 ±4.67	78.47 ±16.43	55.00 ±12.97
CV		21.90	13.07	14.18	19.52	17.09	19.63
P<0.05		<0.0001	0.0005	0.0486	0.0017	0.0003	0.0020

*Mean with the same letter is not significantly different. CV=Coeffients of variation, DBH=Diameter at breast height, L_1=larger canopy, L_2=smaller canopy

Survival rate, plant height, DBH, branch number, and canopy coverage differed significantly ($p < 0.05$) among treatments. As presented in Table 1, Sesbania sesban recorded the highest survival percentage, followed by Cajanus cajan and Leucaena leucocephala. In terms of growth, Sesbania sesban also attained superior mean height compared to the other two species. Similarly, DBH and branch number varied significantly, with Sesbania sesban outperforming both Cajanus cajan and Leucaena leucocephala. Overall, integrating leguminous tree species demonstrated clear differences in growth performance indicators under protected conditions.

3.2. Chemical Composition of Integrated Multipurpose Forage Legumes

Table 2. *Chemical composition of integrated multipurpose tree legumes (Mean ±SE) in Negelle Arsi district.*

No	Treatments	Chemical compositions parameters						
		DM%	Ash%	OM%	CP	NDF	ADL	ADF
1	*Cajunus cajun*	92.30 ±0.15^{ab}	4.99 ±0.46^{c}	92.80 ±0.70^{a}	18.90 ±0.33^{a}	16.87 ±2.49^{b}	3.06 ±0.95	9.38 ±0.99^{b}
2	*Lucinia leucocephala*	92.93 ±0.18^{ab}	4.38 ±0.41^{c}	95.62 ±0.41^{a}	18.46 ±0.26^{a}	25.60 ±3.00^{b}	5.91 ±0.91	16.58 ±3.09^{ab}
3	*Control*	91.83 ±0.59^{b}	10.36 ±0.42^{a}	87.97 ±2.00^{b}	5.71 ±0.42^{b}	38.64 ±2.00^{a}	6.02 ±2.04	23.87 ±0.35^{a}
4	*Sesbania sesban*	93.00 ±0.12^{a}	7.20 ±0.70^{b}	93.68 ±1.58^{a}	20.40 ±2.27^{a}	18.82 ±4.46^{b}	4.44 ±1.44	12.21 ±3.61^{b}
Overall mean		92.27 ±0.20	6.73 ±0.74	92.52 ±1.02	15.87 ±1.85	24.98 ±2.90	4.86 ±0.70	15.51 ±1.94

No Treatments	Chemical compositions parameters						
	DM%	Ash%	OM%	CP	NDF	ADL	ADF
CV	0.61	13.20	2.51	12.81	21.67	6.07	27.16
P<0.05	0.0189	0.0001	0.0200	<0.0001	0.0045	0.4486	0.0140

*Mean with the same letters are not significantly different. CV=Coeffient of variation, DM=dry matter, OM=organic matter, CP=crude protein, NDF=Neutral detergent fiber, ADL=Acid detergent lignin, ADF=acid detergent fiber

The chemical composition results revealed significant differences ($p < 0.05$) among treatments (Table 2). Dry matter content (DM%) was notably higher in Sesbania sesban compared to the control. Ash percentage also showed significant variation, with Sesbania sesban and Cajanus cajan registering higher values than Leucaena leucocephala. Organic matter (OM%) and crude protein (CP) contents were greater in the integrated legumes than in the control, indicating their superior feed quality.

Fiber fractions (NDF, ADF, and ADL) also exhibited significant differences across treatments, except for ADL, which showed no statistical variation ($p > 0.05$). These findings suggest that incorporating leguminous tree fodders into protected areas enhances both the quantity and nutritive value of available feed resources. Similar observations were reported [18] who highlighted that multipurpose tree legumes improve livestock, feed quality.

In general, integrating forage tree legumes provides high-protein supplements that address feed shortages and improve livestock nutrition, consistent with the findings of [16].

3.3. Implications of Protein Bank Integration for Environmental and Socioeconomic Sustainability

Establishing protein banks in community-protected areas has multiple ecological and socioeconomic benefits. Ecologically, they improve the microclimate, enhance soil fertility, and strengthen ecosystem resilience. Socioeconomically, they increase fodder availability, diversify income sources, and support livestock productivity, thereby improving community livelihoods.

However, rapid land use changes in the Negelle Arsi area have led to forest degradation, loss of biodiversity, and increasing human pressure on natural resources. Declining forest cover directly threatens species richness, abundance, and distribution, especially of large mammals that are highly sensitive to habitat disturbance. This highlights the urgency of implementing sustainable conservation measures and integrating leguminous trees to mitigate biodiversity loss [8]. As [12] Sustainable conservation and utilization of the remaining dry land vegetation resources and rehabilitation of those that have already been degraded would provide economic, social and ecological benefits. Therefore, understanding people's beliefs and attitudes toward protected areas is a key factor in developing successful management plans to conserve those areas and having an effective protected area system is essential over the long-term [3, 4].

3.4. Conclusion and Recommendations

The study demonstrated that integrating multipurpose tree legumes into natural conservation areas significantly improves forage availability and quality. The higher crude protein and organic matter contents observed in tree-based legumes compared to the control confirm their potential as valuable feed resources. The marked differences across growth and chemical composition parameters further emphasize the contribution of these species to ecosystem services.

Therefore, the integration of protein bank tree legumes particularly Sesbania sesban should be promoted in community-protected areas. Scaling up such practices can enhance livestock feed resources, improve biodiversity conservation, and strengthen ecosystem resilience in the region.

Abbreviations

ADF	Acid Detergent Fiber
ADL	Acid Detergent Lignin
CBPAs	Community-Based Protected Areas
CP	Crude Protein
CV	Coeffient of Variation
℃	Degree Centigrade
DBH	Diameter at Breast Height
DM	Dry Matter
NDF	Neutral Detergent Fiber
OM	Organic Matter
SNNPR	Southern Nations, Nationalities and Peoples' Region

Author Contributions

Meseret Tilahun: Conceptualization, Data curation, Formal Analysis, Project administration, Software, Supervision, Validation, Visualization, Writing – original draft

Gemeda Terfassa: Conceptualization, Data curation, Methodology, Writing – review & editing

Conflicts of Interest

The authors declare no conflicts of interest.

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