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## Forest Products Dependency and Protected Area Management: A Case of Yankari Game Reserve, Bauchi State, Nigeria

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### Abstract

Many local populations adjacent to protected areas, utilize natural forest resources as vital sources of goods, services, and income. Protected areas are becoming more widely acknowledged as essential parts of social-ecological systems where resources have historically been used by indigenous people. It is unclear what variables influence rural populations' dependence on natural forests and how important this dependence is for rural means of subsistence in the area of the study. The continued resource usage by local residents is a major challenge to the sustainability of many protected areas, which makes this especially important. This study investigates the socioeconomic factors influencing villagers' reliance on forests products. This work uses first-hand information randomly gathered among 255 households spread across 17 communities neighbouring Yankari Game Reserve in Bauchi State. A survey approach that integrated close-ended and open-ended questionnaires was used to gather data. Regression analysis revealed that the socioeconomic attributes of respondents, such as revenue sources, agricultural and livestock earnings, and land size, affect local communities' dependence on forest goods. Hence, effective conservation programs and strategies in addition to minimizing biodiversity loss, especially the loss of endangered species should take into account local livelihoods, such as the collection of forest products, as this practice can lead to habitat loss and biodiversity degradation.

Keywords: Forest, Fuelwood, Gum Arabic, Hunting, Protected Area, Rural Community.

### Introduction

A protected area (PA) is defined as a legally regulated space dedicated to the long-term preservation of biodiversity, cultural values, and environmental services (1). The global network of PAs has grown dramatically as an essential instrument for conservation; it currently covers approximately 21.24 million square kilometres (2). These places have historically been seen as static areas that are meant to last for a long period (3).

However, in favour of a "socially oriented paradigm," which balances conservation goals with the welfare of nearby communities, the conventional protectionist approach to managing PAs has come under growing scrutiny (4). According to critics, the protectionist framework overlooks the United Nation's Sustainable Development Goals, human rights, and community welfare (5). More people are beginning to see PAs as intricate parts of social-ecological systems (6), where native populations have long used resources (7, 8). The indigenous people in many tropical lowincome nations greatly relies on natural resources for their subsistence and the share of land designated as PAs has increased dramatically to address mounting conservation concerns (9). Globally, there are about 1.6 billion local residents who get their livelihoods entirely or in part from forest products (10).

Numerous research (11, 12) have emphasized the vital role forests play in maintaining and diversifying livelihoods and reducing poverty. Studies conducted in sub-Saharan Africa demonstrate that forest resources offer rural populations a consistent extra revenue stream (13, 14). Products from forests assist in providing basic necessities such as energy, housing, healthcare, monetary income, and jobs, particularly for the underprivileged (15). In poor nations, natural forests are crucial for rural livelihoods and biodiversity (16). In order to improve their standard of life, rural households must develop a portfolio of activities and social support networks

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(17). A livelihood comprises the skills, assets, and pursuits required for survival (17, 18). A livelihood is considered sustainable if it can bounce back from shocks and preserve resources for future generations without depleting natural resources, in accordance with the framework for sustainable rural livelihood (17, 18).

Firewood, grass fodder, thatching grass, edible plants, medicinal plants and gum Arabic are examples of common natural forest resources (19). Many studies have examined the financial advantages of natural forests, with a focus on poor countries (20, 21). Studies in North and South America, Asia, and sub-Saharan Africa have found that forests account for 14–20%, 10–20%, and 30-45% of family income, respectively. While some people only use trees to survive, others use them to augment other revenue streams, such as agriculture (12, 22-25).

According to studies on the subject, a household's reliance on forests is mostly determined by its socioeconomic situation (26). The degree of forest utilization, reliance, and importance as a subsistence resource vary by region, season, and social group (27). Household dependence on forests varies as well since communities are inherently heterogeneous (23). For instance, studies suggest that younger individual may have a greater dependence forest goods than the elderly, but that this association weakens when people achieve their maximum physical capacity (28, 29). Because larger families require additional resources to meet their subsistence needs, there is a positive correlation between the size of a household and its reliance on forest resources (28). Although, there is an association between more education and less dependence on forest resources because they offer chances for alternative livelihoods that may be more beneficial than those associated with forest extraction (30).

However, because of the management strategies of PAs, the local population is forced to depend more and more on surrounding areas for access to forest resources (31), leading to intense exploitation which can lead to forest fragmentation and degradation. To design targeted interventions, plans, policies, and sustainable management practices, it is essential to comprehend the variables that lead to forest reliance (32). To preserve a balance between reliance on forests and the conservation of biodiversity, scholars,

decision-makers, and professionals can create data-driven strategies that promote household diversification and sustainable resource management by understanding the depth of forest use and identifying patterns of reliance among communities (33). This is particularly crucial because the ongoing resource utilization by local people poses a significant challenge to the survivability of many PAs (8). Rural populations dwelling in or close to these places often rely on natural resources over time, which exacerbates pressures on biodiversity and conservation efforts (34).

Rural communities around Yankari Game Reserve typically engage in a variety of livelihood activities, including subsistence farming, livestock rearing, gathering forest products, fishing, and hunting (35). Diversification is a widely used approach to managing vulnerability and mitigating risk (36). Nonetheless, the degree to which households depend on forest resources differs, influenced by factors such as the individual's age, household size, and level of education (27, 28).

Understanding the factors that influence livelihoods options is vital for the effective management of Yankari Game Reserve, as activities like small-scale farming, livestock rearing, and forest product collection contribute to deforestation and environmental degradation within and around the country's protected areas (35). Collection of forest products is especially concerning because, while it serves as a key livelihood for many rural communities adjacent to the protected area, it adversely affects biodiversity (37). This activity presents a major challenge for protected areas, which are often located in regions where local populations rely heavily on natural resources (38).

Finding ways to balance conservation efforts with the livelihood needs of local communities will be crucial for enhancing the effectiveness of protected areas. Ideally, this involves a thorough understanding of local social-ecological systems and patterns of resource use (39). To safeguard and conserve plant and animal life in line with the Bauchi State Wild Animal Protection Law (40) and to promote biodiversity conservation and sustainable utilization as outlined in Nigeria's National Environmental Policy (41), it is crucial to evaluate local communities' dependence on forest products and the variables that affect this reliance (42).

This research aims to examine the variables that influence rural households' dependence on forests resources around the PA because it more correctly captures the forest's contribution to rural lives, the proportion of income from forest products to overall earning is used to quantify household reliance on natural forest resources (37). This study evaluates the livelihoods of indigenous people using the sustainable rural livelihood framework (18). The framework is a useful tool for incorporating indigenous livelihoods into conservation planning and action since it emphasizes the impact of economic, ecological, and social factors variables on local subsistence strategies (18).

## Methodology

### **Study Area**

This research was conducted in the surrounding of Yankari Game Reserve, located in the Duguri, Pali, and Gwana districts of the Alkaleri Local Government Area in Bauchi State. Yankari Game Reserve (09°45'N 10°30'E), covering a space of 2,244 km<sup>2</sup>, is situated in north eastern Nigeria (Figure 1). Figure 1 is a map displaying the sampling villages in the study area. Established as a Game Reserve in 1956, it was the first of its kind in Nigeria and was designated a National Park in 1991, administered by the National Parks Service

(35). Although, in 2006, Yankari National Park returned to a game reserve, with the Bauchi State government taking over its administration (43). The PA is located in the Sudan Savannah plant habitat and is divided by the Gaji River. It features two primary habitat types: dry savanna wooded areas and riverine vegetation, which comprises flood-prone places. Typical tree species in the woodlands include African mahogany (Afzelia Africana), Wild syringa (Burkea Africana), African kino tree (Pterocarpus erinaceus), Sau (Isoberlinia doka), and Rura (Monotes kerstingii), while the riverine vegetation is characterized by khaya wood (Khaya senegalensis), Black plum (Vitex doniana), Paperbark acacia (Acacia sieberiana), Tamarind tree (Tamarindus indica), and West African copal tree (Daniella oliveri) (35).

The reserve experiences 900 to 1,000 millimetres of rainfall annually, with the wet season lasting from May to September. The temperatures vary between 18°C and 35°C. Wildlife comprises mammals like African elephant (*Loxodonta Africana*), African buffalo (*Syncerus caffer*), Roan antelope (*Hippotragus equinus*), Olive baboon (*Papio Anubis*), Patas monkey (*Erythrocebus patas*), Tantalus monkey (*Chlorocebus tantalus*), and Hippopotamus (*Hippoptamus amphibius*). Approximately 337 bird species are documented in the PA, highlighting its significance as an important bird area (IBA) (35, 43).



Figure 1: The Study Area Map Displaying the Sampling Villages

Bajari, Fulani, Baboli, Dugurawa, Guruntawa, Wukurnawa, Hausa, and Labur are some of the ethnic groups that border the protected area. Among their sources of livelihood are farming, hunting, gathering fuelwood, and raising animals (35).

### **Data Collection**

The research employed a survey approach that combined both structured and unstructured questionnaires for data collection to comprehensively evaluate household reliance on forest products in communities surrounding Yankari Game Reserve (44).

The data collection process commenced with community engagement sessions involving village leaders and elders. These sessions aimed to explain the study's objectives, procedures, and the expectations from participants. Verbal informed consent was obtained from community leaders, ensuring ethical compliance and fostering trust within the communities.

A multi-stage sampling method was used in this study. First, seventeen settlements located near the protected area were randomly selected to achieve geographic representation. Next, within each chosen community, fifteen households were randomly picked, resulting in a total sample of 255 households. Typically research, analysis can be effectively performed with sample sizes of 100 or more (45). The survey focused on household heads aged 18 and older, as they typically make decisions for their families related to resource use.

Data collection was carried out through in-person surveys conducted at the respondents' homes (46). The survey questionnaires were carefully designed information to gather on household characteristics, including demographics, primary income sources, and the extent of forest resource utilization. The villages chosen for the study were Gale, Dagudi, Mainamaji, Gaji, Gaji Gamu, Kafi, Bakin Dutse, Mai Ari, Jada, Kuka, Pali, Kwala, Kashera, Yalo, Garin Kweri, Walakerol, and Sarki Malla (Figure 1). The response form contained items designed to evaluate the response variable (forest income) along with the explanatory variables. The socioeconomic characteristics utilized as predictor variables included the number of revenue sources, age, education level, earning from farm output sales, earning from livestock sales, land size, earning from off-farm operations, and household size. In line with ethical

standards, participants consented to take part, were guaranteed confidentiality, and were assured that their information would only be used for the objectives of the study. Ethical clearance was secured from the management of Yankari Game Reserve in Bauchi State, Nigeria. The survey took place between January and July 2023.

To arrange and examine the data, the Sustainable Rural Livelihood (SRL) framework (Figure 2) was used. The Sustainable Livelihood Framework (SLF) is a comprehensive approach for analysing the various factors that affect people's livelihoods and the ways in which these factors interrelate. The main elements of the framework focus on livelihood assets, which include natural capitalsuch as land, water, and biodiversity; human capital—comprising skills, knowledge, health, and labour availability; social capital—encompassing social networks, relationships, and affiliations; physical capital-covering infrastructure, tools, and equipment; and financial capital—consisting of savings, credit, and income sources. The Sustainable Rural Livelihood (SRL) framework states that individuals require access to the stated five key types of assets to sustain their livelihoods. These assets are employed in different livelihood strategies, including agricultural activities, diversification of income sources, and migration (18). A livelihood is characterized as the set of abilities, assets, and pursuits required to maintain oneself. If a livelihood can withstand and recover from shocks and strains from the outside world while maintaining or expanding its resources and capabilities for both immediate and long-term needs without diminishing the base of natural resources, then it is said to be sustainable (18). People need to combine these assets in order to develop livelihoods. They need to manage and use the resources at their disposal while implementing various livelihood plans. The number of individual in a home, the number of years of the head of the home, the overall size of the farm, and institutional policies (rules and regulations, for example) all affect how assets are used and available (18). Using the asset categories and livelihood strategies described in the SRL framework (Figure 2), we arranged the data into themes for our study. The study focused on assets including farmland, household size, remittances, and gifts, as well as livelihood strategies like the number of livestock owned, collection of forest products, and

participation in off-farm activities among rural populations.

Subsistence income from forest products was valued using the local market price as well as



Figure 2: Conceptual Framework, Adapted From Past Studies (17, 18)

### **Data Analysis**

There were two phases to the data analysing process. First, the frequency of each variable was ascertained using descriptive statistics. Second, a linear regression model using Ordinary Least Squares (OLS) was then applied to assess how household socioeconomic attributes—such as land size, sources of revenue, and income from farming and livestock-affect the gathering of forest resources (48). The amount of income sources, revenue from animal sales, revenue from farm produce sales, land size, revenue from non-farm operations, and revenue from remittances and gifts are some of the important factors. The local commercial worth of all forest resources gathered during the preceding year was combined to assess forest income. The percentage of forest income to the entire household revenue demonstrated the reliance on natural forest resources (37). The proportional variables were explained by the OLS model (48). Compared forest revenue (CFR) showed the percentage of forest revenue within the entire household revenue (EHR), while total forest revenue (TFR), estimated in Nigerian Naira (N), represented the projected monetary worth of forest products. It is deduced as:

CFR=TFR/HER

Following that, a factor was made utilizing the logistic function as the OLS model's dependant variable. The following procedure was used to apply this change on the ratio of forest revenue to entire household revenue (EHR):

household pricing based on their own assessment

of the products (47).

Changed CFR = ln (CFR /1- CFR) [2] The natural log of the changed compared forest revenue (CFR) is the dependent variable after the transformation. Next, the common presentation of the Ordinary Least Squares (OLS) statistical equation is expressed like this:

Changed ln CFR (Y) = 
$$\beta 0 + \beta 1X1 + ... + \beta nXn + Ut$$
 [3]

In which:

Y = response variable (changed compared forest revenue, CFR)

X<sub>1</sub> to X<sub>n</sub> = explanatory variables (age, educational level, household income, household size, and forest income)

 $\beta 0$  = the value of the intercept of the dependent variable (Y)

 $\beta_1$  to  $\beta_n$ = coefficients of independent variables Ut= the error term

Statistical Package for the Social Sciences (SPSS) version 22 was used for all statistical analyses.

Summary statistics were initially used to determine the occurrences of the different variables. After that, the changed compared forest

[1]

revenue (CFR) = ln (CFR /1- CFR) was analysed in relation to household factors, including the number of revenue sources, revenue from livestock sales, and earnings from farm output.

### **Selecting Independent Factors**

This work utilized a number of factors, including age, education, household size, land size, farm revenue, non-farm revenue, remittances and gifts, number of revenue sources, livestock revenue, and livestock count, to identify relationships with forest reliance (Table 1). The justification for utilizing these variables in the analysis is given below.

**Age:** Previous studies indicate that different age groups have different degrees of reliance on forests. It has been observed that younger individuals may rely more on forest resources due to their physical ability to perform labour-intensive tasks such as harvesting (29, 30). However, it has been contended that because younger people are more likely to pursue employment possibilities in metropolitan regions than older people, they are typically less dependent on forest resources (49). It follows that in this study, age is anticipated to have an inverse connection with forest dependency.

Education level: Having more education is linked to using fewer forest resources. The cost of labour opportunity rises with education, which reduces the profitability of harvesting forest products (33, 50). Additionally, education opens doors to selfemployment, higher jobs, and jobs unrelated to the forest. Thus, it is anticipated that in this study, there will be an inverse relationship between forest dependency and greater levels of education. Remittances and gifts: In this study, gifts and remittances denote cash or items that households receive from friends, family, and other acquaintances. Studies show that remittances typically correlate negatively with reliance on forest products, which lessens the need for natural forest resources by households (51, 52). However, remittances and the use of forest resources seem to be favourably and greatly related, as indicated by certain research studies (53). The mixed results indicate that, depending on how the money is spent, remittances and gifts are expected to either increase or decrease reliance on forests in this study.

**Household size:** Larger households frequently rely more on forest resources. According to

studies, larger families typically possess greater needs on natural resources and more labour available to fulfil their demands and raises the amount of money derived from the forest (30, 50). Therefore, it is expected that household size and forest dependency will positively correlate.

**Farm income:** It is usually anticipated that households with greater access to agricultural resources will depend less on forest resources (54, 55). Research indicates that a decrease in forest dependency occurs with an increase in agricultural revenue (56). Consequently, it is expected that farm revenue and forest dependency will be inversely related.

**Land size:** The link between land size and forest reliance is debated. Bigger landholdings may need additional forest products to maintain soil fertility, according to certain research (50, 57). On the other hand, additional evidence suggests that reliance on forest products is decreased when crop yields improve (51, 58). In this study, it is expected that individuals with more landholdings should rely less on forest products because their income from agriculture will be higher (55).

**Non-farm income:** Since they are making more money from other sources, those who engage in profitable non-farm operations should be less reliant on forest products (59, 60). This perspective is supported by research studies which shows an inverse link between off-farm income and reliance on forests (61). It is expected that households would become less reliant on forest products as they possess greater availability of off-farm options.

**Number of revenue sources:** An increase in the number of revenue sources, such as improved off-farm jobs, easier access to financing, and higher agricultural output, may result in a decrease in reliance on forest resources (61). In contrast, it has been argued that more resources could make it possible for households to make more use of forest resources, which would raise the amount of money they make from forest products (60). As a result, it is predicted that the number of sources of income will have an inverse relationship with reliance on forests.

**Income from livestock:** Studies show a direct link between income from livestock and dependence on forest resources, i.e., more livestock is linked to a greater need on forests (49). Nonetheless, in a subsistence economy, livestock is frequently a major household asset, and a decrease in the need for forest products may be correlated with increased livestock sales revenue (62). This suggest that the effect that livestock have on a household's dependence on forests may differ depending on how important livestock are to the household's income and whether the money they provide is used to support or offset the need for forest goods.

### **Results**

### **Attributes of participants**

Respondents engaged in subsistence farming and livestock keeping. The main source of revenue for many of them is farming activities (86.3%) (Table 1).

### **Income sources of participants**

Respondents primarily earn income from farming, fuelwood, and non-farm activities (Table 3).

Table 1: Descriptive Attributes of P	articipants
--------------------------------------	-------------

Variable (N=255)	Participants (%)
Age (years)	
18-25	2.7
26-33	17.6
34-41	20.8
42-50	26.3
51-60	18.8
60	13.7
Education	
Informal	36.9
Primary	23.1
Secondary	32.2
Tertiary	7.8
Household size (number of individuals)	
1-5	8.2
6-10	55.7
11-15	36.1
Land area (acre)	
1-4	20.8
5-9	47.5
10-14	16.1
15+	15.7
Farm earning (Naira)	
<100,000	0.4
100-500000	13.3
501000>	86.3
Non-farm earnings (Naira)	
<20000	5.9
21-30000	2.4
31000>	8.3
Remittances and gifts (Naira)	
<50000	54.5
51-100000	9.0
10100>	6.4
Income source count	
2-4	8.6
5-7	59.2
8-10	15 3
Livestock earnings (Naira)	10.0
<100 000	52 5
100-300000	51
300000	5.1
300000~	5.4

Table 2: The Predictors Applied in the OLS Regression Analysis

11	5		
Predictors	Explanation Projected outcomes		outcomes
Response variable	The share of forest earnings in	Each	explanatory
Change_ CFR	relation to the entire household	variable's	predicted
	earning obtained from forest goods,	correlation	with the
	following the change (Naira)	dependent v	variable
explanatory variables			
Revenue sources	Count of household revenue sources	_	
Farm revenue	The revenue generated from	_	
	farming by the family head (in		
	Naira)		
Livestock revenue	The revenue generated from	_	
	livestock by the family head (in		
	Naira)		
Land area	The amount of land owned by the	_	
	head of the household (in acre)		
Non-farm revenue	The revenue generated from non-	±	
	farm operation by the head of the		
	household (in Naira)		
Remittances and gifts	The revenue a household head	±	
-	makes from remittances and gifts (in		
	Naira)		

### **Table 3:** Income Sources of Participants

Sources of earnings	Percentage (%)
Farming	100
Livestock keeping	64.7
Non-farm activities	16.5
Remittances and gifts	69.8
Edible plants	46.7
Medicinal plants	52.9
Gum Arabic	29
Wildlife collection	24.3
Fuelwood collection	81.6

**Table 4:** Varieties of forest resources harvested by participants.

Forest resources	Percentage (%)
Consumable plants	46.7
Herbal plants	52.9
Gum Arabic	29
Wild animals	24.3
Firewood	81.6

# Dependence of Households on Forest Products

An OLS regression analysis was carried out using SPSS to examine the predictors of forest income, with the changed relative forest income as the dependent variable. Preliminary analysis revealed multicollinearity in the original dataset (Table 1), which outlines the descriptive attributes of the participants. To address this, a stepwise regression approach was applied, which selects variables based on their F-value probability. This method, which included standardizing variables to obtain zscores, corrected for multicollinearity. The final regression analysis, conducted with the refined set of variables (Table 2), which showed revenue sources, farm revenue, livestock revenue, land area, non-farm revenue, remittances and gifts as the explanatory variables. The average Variance Inflation Factor (VIF) was 1.31, indicating no significant variable interdependence (63). The autocorrelation test statistic of 1.79 fell within the acceptable range of 1.5-2.5, suggesting that residuals were not correlated. There was no evidence of non-constant variance as the scatter diagram displayed no systematic pattern. The regression model was significant, F (6, 248) = 64.805, p < .001, with an R<sup>2</sup> of .44, meaning it explained 44% of the variability in forest revenue based on the independent variables.

The OLS regression assessment highlighted several important factors influencing forest income. Key predictors include revenue sources

shown in Table 3 (t = 8.050, p < .001), farm revenue (t = -6.922, p < .001), livestock revenue (t = 3.972, p < .001), land size (t = -3.762, p < .001), non-farm revenue (t = -2.832, p < .005), and remittances and gifts (t = 2.679, p < .008). The results indicate an inverse relationship with forest income and both agricultural revenue (t = -6.922, p < .001) and area of the land (t = -3.762, p < .001). All predictors have a statistically significant impact on forest income dependency, demonstrating a strong association between the dependent factors and forest income (Table 4). It summarizes the results on factors influencing forest product dependency, identifying the key predictors that significantly affect reliance on forest resources (Table 5).

Explanatory variables	Coefficient	Std. Error	t-ratio	Prob.
Revenue sources	.417	.052	8.09	.000
Farm revenue	331	.058	-6.92	.000
Livestock revenue	.227	.057	3.97	.000
Land area	184	.049	-3.76	.000
Non-farm revenue	.130	.046	2.83	.005
Remittances and gifts	.139	.049	2.68	.008
Constant -3.500				
R <sup>2</sup> =.44				

**Table 5:** OLS Findings on the Factors Influencing Dependence on Forest Products

## Discussion

=64.805

=.700

= 255

p<0.001

F-ratio

SEE

Ν

Multiple income sources are a crucial component of rural means of subsistence in many developing nations (17). Households with greater assets tend to use more forest resources, which increases their revenue from forest goods (60). This is in agreement with the study's findings, which revealed that people dependence on natural forest products was favourably affected by the amount of revenue sources. The findings suggest that dependence on forest products is higher among households with several sources of income. In particular, earnings from forests rises by 417 percent for every single rise in the sources of household income. This matches the findings of certain studies were an increase in forest revenue alongside income from other sources has been identified (64). This finding suggests that an increasing number of households may depend on the forest's supplementary income sources, such as wood, fodder, wild edible plants, and medicinal plants. This is particularly relevant as the majority of respondents are subsistence farmers and livestock keepers, who might persist in utilizing the forest resources to sustain their means of living.

The results indicate an inverse correlation between respondent's reliance on natural forest products and farm earning, suggesting that households with higher farm earnings are less reliant on forest goods. Specifically, for every 1000 units increase in farm income, forest income decreases by 331 units. Similar observations have been made in Myanmar's Katha District and Quan'Pan, North Central Nigeria, where higher farm income corresponded to a reduced reliance on forest products (65, 66). These results suggest that lowering household reliance on forest resources may be facilitated by increasing farm revenue. Households may be able to depend less on forest goods as their farm income rises.

The results show that household reliance on livestock income and natural forest products are positively correlated, with higher livestock income being linked to increased reliance on forest resources. In particular, an increase in cattle revenue of 1000 units is correlated with a rise in forest income of 255 units. This aligns with certain research that found a direct correlation between the quantity of domesticated animals and reliance on forest resources in Katha District, Myanmar, and Southern Ghana (65, 67). This indicates that respondents with higher livestock incomes may rely more on forest resources, including animal feed and fuelwood, to assist their animals. This shows that raising more livestock may put more strain on forest resources.

The results demonstrate a positive correlation between household earning from non-farm operations and reliance on natural forest resources, with forest revenue increasing by 130 units for each 1000 units rise in non-farm earnings. This outcome challenges the prevailing view that non-farm revenue inversely impacts forest product reliance (20, 67, 68). Instead, it is consistent with findings that suggest reinvestment of off-farm income into agricultural production can enhance productivity (69, 70). Given that in this study, many respondents are subsistence farmers and animal breeders, the increased off-farm income may lead to a greater dependency on forest resources such as fuelwood and fodder, as nonfarm revenue mainly from the transportation of farm produce can support agricultural practices and potentially increases overall forest product usage.

### Conclusion

PAs are increasingly recognized as integral components of ecological and social systems (7, 71), with local populations relying on resources from both inside and outside these areas over time (9). This study investigates how households gather forest products and identifies the variables influencing this reliance. The findings reveal a significant correlation between rural populations' dependence on natural forests and socioeconomic factors, such as the number of income sources, agricultural income, land size, and animal income. Specifically, larger landholdings and higher farm incomes are associated with reduced reliance on forest products, highlighting an indirect association between land size, farm earning, and forest dependency. This implies that providing

alternative sources of income, could alleviate pressure on local forests and improve household incomes. Conversely, the study reveals that respondents with increased variety of revenue origins have a higher likelihood to depend on forest resources, highlighting a risk that limited and forest resources restricted income alternatives could exacerbate poverty. Additionally, households with more livestock earnings demonstrate a greater reliance on natural forest goods. Livestock keeping is a significant way of revenue generation for respondents at the research area, and as a result, they mostly rely on forest resources like fodder and forest wood to support their livestock operations. The study also reveals that households that receive more money from remittances and gifts and non-farm operations are more reliant on natural forest products. This greater dependency is explained by the possibility that remittances and off-farm income could be used to fund livestock and crop production, among other agricultural activities that could raise total productivity (70).

Therefore, successful conservation strategies and programs should not solely focus on minimizing biodiversity loss, particularly the loss of endangered species (72), but must also take into account rural means of subsistence and resource utilization (73), which are key drivers of ecosystem and environmental degradation (74). The sustainability of the Yankari Game Reserve necessitates a careful integration of conservation initiatives with the livelihoods of local communities. By implementing effective strategies and fostering collaboration among all stakeholders-including natural resource users, community members, and policymakers-it is feasible to create a future where biodiversity is safeguarded and local means of sustenance thrive. Further research could explore the dynamics of household reliance on forest products over time, especially in relation to interventions like alternative income programs or policy shifts, to assess their long-term sustainability. Additionally, studies could evaluate the effectiveness of different livelihood diversification strategies in decreasing dependence on forest resources, taking into account factors such as practicality, cultural acceptance, and economic sustainability.

### Abbreviations

CFR: Compared Forest Revenue, EHR: Entire Household Revenue, OLS: Ordinary Least Squares, PA: Protected Area, SPSS: Statistical Package for the Social Sciences, SRL: Sustainable Rural Livelihood, TFR: Total Forest Revenue.

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### **Author Contributions**

Audu Habu: conceptualization, funding acquisition, methodology, data collection, data analysis, data clarification, composition the initial draft, writing revisions, final approval. Nik Fadzly N Rosely: student supervision, conceptualization, methodology, data analysis, data interpretation, manuscript revision, final approval.

### **Conflict of Interest**

There were no reported conflicts of interest from the authors.

### **Ethics Approval**

This study was approved by the Management of Yankari Game Reserve (Approval Number: YETYCD/YGR/CON/10). All participants were verbally informed about the study and provided their consent before taking part.

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