

Intervention-enabled reconciliation of livelihood sustainability and forest conservation in biosphere landscapes

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Abstract

Livelihood diversification is increasingly promoted as a pathway to reconcile biodiversity conservation with poverty reduction, yet empirical evidence of its welfare effects in forest-dependent contexts remains limited. This study examines how participation in alternative livelihood initiatives influences household income in the Omo Biosphere Reserve, Nigeria, where conservation efforts interact with intense livelihood pressures and accelerating forest loss. Using cross-sectional data from 426 households, the research applies propensity score matching (PSM) to address selection bias and generate credible causal estimates of the economic impacts of interventions such as fish farming, grasscutter rearing, mushroom cultivation, and snail farming. The results show that engagement in these initiatives significantly enhances household income while reducing dependence on forest extraction, thereby contributing to improved economic resilience amid environmental and livelihood shocks. Participation is shaped by household size, educational attainment, and frequency of contact with extension services, underscoring the importance of human capital and institutional support in driving livelihood transitions. However, persistent structural barriers, including limited access to credit and entrenched socio-cultural norms, continue to constrain broader uptake, particularly among the most vulnerable households. These findings underscore the need to reconfigure current support mechanisms by expanding access to inclusive financial services and tailoring extension delivery systems to local socio-cultural contexts. The study concludes by advocating for a strategic recalibration of livelihood diversification policies within conservation landscapes. Such recalibration is vital not only to safeguard threatened forest ecosystems but also to promote equitable, long-term livelihood opportunities for communities whose well-being remains intricately linked to forest resources.

1. Introduction

Forests and biodiversity-rich landscapes play an indispensable role in maintaining ecological stability, supporting livelihoods, and fostering sustainable development (Ullah et al., 2023). In this context, UNESCO-designated biosphere reserves serve as model regions for reconciling biodiversity conservation with the sustainable use of natural resources (UNESCO, 2021). These areas provide multiple ecological and socioeconomic functions, including carbon sequestration, soil and water conservation, and climate regulation (Van Cuong et al., 2017; Yang, 2024). At the same time, they sustain local populations through subsistence agriculture, extraction of non-timber forest products, and small-scale trade in forest resources (Duru et al., 2015; Roe, 2015; Sandifer et al., 2015). However, the balance between conservation and livelihood needs remains fragile. Across Sub-Saharan Africa, many rural communities continue to rely heavily on unsustainable forest extraction for survival, creating a feedback loop between poverty, environmental degradation, and declining resource availability (Banerjee, 2013; Polesny et al., 2014; Nguyen, 2015; Wassie, 2020; Kumar, 2022). This dependency, driven by limited access to alternative income sources and persistent socioeconomic marginalisation, exacerbates biodiversity loss and undermines forest resilience (Fonta and Ayuk, 2013; Loiseau et al., 2016; Eswaran et al., 2019; Chomini et al., 2022). The growing population in biodiversity hotspots further intensifies these pressures, leading to increased exploitation of forest resources (Fisher et al., 2007; Mittermeier et al., 2011; Aukema, 2017).

To address this challenge, alternative livelihood interventions have emerged as a key component of sustainable forest management and poverty alleviation strategies. These interventions aim to realign income

generation with conservation outcomes by promoting biodiversity-based enterprises such as fish farming, beekeeping, mushroom cultivation, ecotourism, and carbon trading (Bishop, 2013; van den Boog et al., 2018; Panwar, 2023; Delgado et al., 2023). The logic underpinning these initiatives is that income diversification can reduce forest dependency, enhance resilience to shocks, and support the sustainable use of natural resources (Kassegn, 2021; Yussuf et al., 2022; Habib, 2023).

In Nigeria, such interventions have been implemented in the Omo Biosphere Reserve, a critical conservation landscape characterised by high biodiversity and significant human pressure. The Omo project adopted a collaborative, community-based approach to develop and manage biodiversity enterprises that could simultaneously reduce pressure on forest resources and promote economic empowerment. While conceptual frameworks for alternative livelihoods are well established, empirical evidence on their effectiveness within biosphere reserves remains limited, particularly regarding their income effects and participation dynamics. Existing research often examines community forestry or ecotourism initiatives (Ali et al., 2015; Kebebe et al., 2017; Abdeta et al., 2025; Betseha, 2025), but few studies systematically evaluate how participation in biodiversity-based livelihood projects affects household income in West African conservation settings. Against this backdrop, this study pursues two interrelated objectives: (1) to identify the socioeconomic and institutional determinants influencing household participation in alternative livelihood interventions; and (2) to evaluate the causal impact of participation on household income within the Omo Biosphere Reserve. By applying propensity score matching to cross-sectional data from 426 households, this research contributes to the empirical literature on conservation–livelihood trade-offs by offering robust evidence on how intervention participation shapes income dynamics and forest dependence. The findings are expected to provide policymakers and conservation planners with valuable insights for designing integrated strategies that foster livelihood sustainability and biodiversity conservation in biosphere landscapes.

2. Theoretical framework

The Sustainable Livelihoods Framework (SLF) developed by the UK Department for International Development (DFID, 1999) and further expanded by Scoones (1998) provides the conceptual foundation for this study. The SLF emphasises how individuals and households combine different assets, human, social, natural, physical, and financial capital, within a given institutional and vulnerability context to pursue livelihood strategies that lead to desirable outcomes such as income improvement, reduced vulnerability, and environmental sustainability. The framework is particularly useful in understanding how rural households living in resource-dependent communities balance livelihood needs with ecosystem conservation goals (Ullah and Bavorova, 2024). Within the SLF, livelihood strategies are influenced by the extent of access to assets, which in turn is shaped by institutions, policies, and processes. In the context of the Omo Biosphere Reserve, rural households are heavily dependent on forest resources for their survival, exposing them to trade-offs between sustaining their livelihoods and conserving forest ecosystems (Adams and Hutton, 2007). The introduction of alternative income-generating programmes, such as beekeeping, snail farming, and mushroom production, aims to increase financial capital while reducing pressure on natural capital. However, the extent to which these interventions succeed depends on the interaction between household assets and institutional support mechanisms such as extension services, training, and community participation (Ullah et. al., 2024).

In this sense, the SLF offers a lens through which to analyse the determinants of participation in alternative livelihood interventions and their subsequent impact on household income and forest dependency. Furthermore, the SLF recognises that livelihood outcomes are not only a product of asset endowments but also of the enabling environment, the policies, institutions, and processes that govern access, rights, and incentives. In Nigeria's Omo Biosphere Reserve, the structure of community-based management institutions and the role of extension agents serve as mediating mechanisms influencing how interventions are adopted and sustained. Understanding these linkages helps explain why some households successfully transition to sustainable livelihoods while others remain dependent on the forest.

Accordingly, this study employs the Sustainable Livelihoods Framework as its guiding theoretical lens to examine how livelihood capitals and institutional processes interact to shape household participation in alternative income interventions and their implications for income sustainability and forest conservation. The framework provides an analytical pathway to assess how improving access to assets and strengthening institutional support can reconcile the persistent trade-off between economic survival and ecological preservation.

3. Methodology

3.1. Study area

This study was conducted in the Omo Biosphere Reserve (OBR), located in Ijebu-East Local Government Area of Ogun State, southwestern Nigeria (see Fig. 1). The OBR derives its name from the River Omo, which flows through the reserve and contributes to its ecological significance. Established in 1977 under UNESCO's Man and the Biosphere (MAB) Programme, it remains Nigeria's first designated biosphere reserve and one of the earliest in Africa (UNESCO, 2001; Isichei, 1995). Geographically, the reserve lies between latitudes 6°35' and 7°05' N and longitudes 4°05' and 4°40' E, covering an estimated 130,600 hectares (Akinyemi et al., 2019; Adeyemi, 2017). The Omo Reserve forms part of a contiguous forest complex that includes Oluwa and Shasha Forest Reserves, together representing a significant portion of Nigeria's remaining tropical rainforest cover (Fasona et al., 2022). The reserve is ecologically characterised by humid tropical rainforest vegetation, with dry evergreen mixed deciduous forest dominating the northern sector and wet evergreen forest in the southern portion. Average annual temperatures range between 25°C in October and 31°C in January, while rainfall patterns are typically bimodal, supporting both natural vegetation and agricultural production (Adeyemi et al., 2022; Akinyemi et al., 2019). The Omo landscape harbours a rich diversity of flora and fauna, including economically and ecologically valuable tree species such as *Khaya ivorensis*, *Cordia millenii*, and *Triplochiton scleroxylon*, as well as wildlife such as the African elephant, pangolin, and grasscutter (Ayodele et al., 2020). Despite its ecological importance, the reserve faces severe pressures from deforestation, agricultural encroachment, hunting, and fuelwood collection, all of which threaten its biodiversity and ecological balance (Anwadike et al., 2020).

Approximately 5,000 households reside within the boundaries of the biosphere reserve and heavily depend on natural resources for their livelihoods (UNESCO Man and the Biosphere Programme, 2025). Dominant activities include small-scale farming, timber and non-timber forest product (NTFP) harvesting, hunting, and fishing, reflecting a pattern of resource dependency common to forest-based communities in West Africa.

This dependence has contributed to deforestation, habitat fragmentation, and soil erosion, creating tension between the need for livelihood sustenance and biodiversity conservation. To address these challenges, Omo Biosphere Reserve was selected as one of the pilot sites for the Green Economy in Biosphere Reserves (GEBR) Project, jointly supported by the Korea International Cooperation Agency (KOICA) and UNESCO, in collaboration with the Forestry Research Institute of Nigeria (FRIN) and the National Committee on Man and the Biosphere (MAB) (UNESCO, 2019; Falemara et al., 2019). The project aimed to integrate livelihood diversification with environmental conservation, reduce poverty, and promote sustainable use of forest resources. Within the reserve, the initiative introduced several eco-friendly enterprises, including snail rearing, mushroom cultivation, grasscutter farming, and fish farming, designed as alternative income-generating activities to reduce pressure on the forest ecosystem. Implementation activities under the project were spatially distributed across selected local communities. For example, grasscutter production units were established in four villages to minimise wildlife hunting, snail boxes were distributed to trained farmers, while mushroom cultivation was facilitated through the renovation of classrooms at Plantation High School, enabling both students and teachers to participate in production and income generation. Additionally, fishponds and water reservoirs were rehabilitated to facilitate year-round aquaculture production. These community-based interventions aimed to enhance economic resilience, reduce forest dependency, and strengthen local stewardship of the biosphere reserve. Unlike previous studies (Mshelia et. Al., 2022; Chenge & Osho, 2018) that focused primarily on the ecological or biophysical aspects of forest degradation, this research situates the Omo Biosphere Reserve within a broader socioeconomic and policy framework, emphasising the role of alternative livelihood interventions in achieving a balance between sustainable income generation and forest conservation. This makes the reserve a suitable site for assessing the trade-offs and synergies inherent in livelihood diversification efforts under Nigeria's evolving biosphere reserve management paradigm.

3.2 Sampling procedure and data collection

The study population consisted of households from forest-dependent communities, where agriculture, hunting, and forest product collection were the primary sources of livelihood. A multi-stage sampling technique was used to ensure a representative sample. Firstly, convenience sampling was used to select seven of the ten communities that benefited from the project. This selection was based on the accessibility of the communities, as the remaining three benefiting communities were ravaged by insecurity. Secondly, stratified sampling was employed to categorise households into beneficiaries and non-beneficiaries, ensuring adequate representation of both groups. Finally, simple random sampling was employed to select sample households from the list of beneficiaries who participated in the initiative. The snowball sampling procedure was employed to select non-participant households from the vicinity of the randomly sampled project households. Snowball sampling was applied to identify non-participant households due to the absence of a complete list of non-beneficiaries. In total, 426 households were selected, comprising 211 programme beneficiaries and 215 non-beneficiaries.

The data collection instrument was a structured questionnaire that included sections on household demographics, income sources, participation in alternative livelihood interventions, challenges faced during project participation, and livelihood variables. Data collection was conducted in February 2024 with the assistance of trained enumerators, all of whom were fluent in the local language and familiar with the study

area. Before the main data collection, a pre-test was conducted to refine the questionnaire. The pre-test was conducted with 20 respondents from non-sampled communities to ensure that the questions were clear and effectively captured the required information. Data from the pre-test were not included in the main analysis but were used to improve the final survey instrument.

3.3 Data analysis

Multinomial logistic regression (MLR) was used to analyse factors influencing household participation in different livelihood intervention options. The multinomial logistic regression model is given as:

$$P(Y = j|X) = \frac{e^{X\beta_j}}{\sum_{k=1}^j e^{X\beta_k}}$$

1

Where $P(Y = j|X)$ is the probability of household i choosing intervention j , where the dependent variable has multiple outcomes, i.e., 1 if the household participates in a selected enterprise of the project and 0 otherwise. X represents the explanatory variables (Table 1), and β_j is the coefficient for each intervention category. Model fitness and robustness were checked using Likelihood Ratio Tests, Wald Tests, and Pseudo R-squared values for the multinomial model. The overall model (χ^2) is highly significant (at less than 1% level).

Propensity score matching (PSM) was used to analyse the impact of participation on household income. The PSM was applied to assess the impact of the alternative livelihood interventions on the income of the participant. The model is as follows:

$$ATT = E(Y_1 - Y_0|P(X))$$

2

Where ATT represents the Average Treatment Effect on the Treated, and Y_1 are Y_0 outcomes for treated and control groups, respectively, and $P(X)$ is the estimated propensity score. The Balancing Property Test and Rosenbaum Bounds Sensitivity Analysis were employed to ensure proper matching in the PSM analysis (Rosenbaum et al., 1983; Peel et al., 2012).

Table 1
Overview of variables used for inferential analytical methods

Variable	Specification	Mean	S.D.	Min	Max
Treatment variable					
Livelihood programme participation	yes = 1, no = 0	0.25	0.43	0	1
Outcome variable					
Household income	thousands NGN	1,307.82	1,250.43	9.34	12,303.40
Independent variables					
Household head characteristics					
Age	Years	49.42	4.46	36	64
Gender	1 = male, 0 = female	0.18	0.39	0	1
Ethnicity	Yoruba = 1, others = 0	0.91	0.29	0	1
Religion	Christianity = 1, others = 0	0.57	0.50	0	1
Marital status	married = 1, otherwise = 0	0.93	0.26	0.00	1.00
Education	years of schooling	10.37	4.09	0.00	16.00
Farm experience	Years	20.92	8.96	2.00	42.00
NTFPs collection experience	Years	23.12	9.61	3.00	45.00
Farm-household and biophysical characteristics					
Distance to core of the reserve	Minutes	60.42	23.55	15.00	125.00
Farm terrain	flat = 1, steep = 0	0.78	0.41	0.00	1.00
Institutional characteristics					
Participation in community meetings	Number of community meetings attended monthly	3.37	1.50	2.00	5.00
Access to credit	yes = 1, no = 0	0.25	0.44	0.00	1.00
Extension services interaction	Visits per year	0.57	0.80	0.00	4.00
Note: S.D. stands for standard deviation, NGN for Nigerian Naira.					

Household income was estimated by summing income from different sources, including agriculture, livestock, forest products (both timber and non-timber), wage income, income from alternative livelihood projects, and other sources (Mulenga et al. 2011; Suleiman et al. 2017).

4. Results and discussion

4.1 Household characteristics

Table 1 presents the description of the variables used for inferential analyses, covering household, farm, and institutional characteristics that shape participation in alternative livelihood programmes. The average household head was 49 years old, with roughly 20 years of farm experience and 23 years of experience in non-timber forest product (NTFP) collection, indicating a strong dependence on forest-based income before intervention. About 25% of households participated in livelihood programmes, while the mean household income was approximately ₦1.3 million, with high variability reflecting the wide range of economic conditions among rural households in the Omo Biosphere Reserve.

Households were small on average (3.5 members) and cultivated modest land areas (3.1 ha). Most heads were married (93%), Yoruba (91%), and Christian (57%), with an average of 10 years of schooling. Institutional exposure appeared limited: only a quarter of respondents had access to credit, and the average number of extension visits per month was below one. The average distance to the core of the biosphere reserve was 60 minutes, suggesting that physical proximity to conservation zones could be an important determinant of both resource use and participation decisions.

The low rate of participation in community meetings (3 per month) and limited interaction with extension services reveal weak institutional embeddedness among rural households, which could constrain the uptake of conservation-compatible livelihood options. This finding aligns with Wordofa et al. (2021) and Kebebe et al. (2017), who reported that institutional proximity and information networks play pivotal roles in shaping households' livelihood strategies.

4.2 Socioeconomic differentiation between beneficiaries and non-beneficiaries

Table 2 compares the demographic, economic, and spatial attributes of programme beneficiaries and non-beneficiaries. The contrast between the two groups reveals a clear pattern of livelihood segmentation and adaptive responses within the Omo Biosphere Reserve. Beneficiaries were notably younger (mean = 42 years) than non-beneficiaries (49 years), indicating that youth and middle-aged individuals are more inclined toward participation in livelihood diversification initiatives. This pattern is consistent with evidence from Babulo et al. (2008), Bhandari et al. (2013), and Habib et al. (2023), suggesting that younger farmers are more open to adopting new income strategies and conservation-linked innovations.

Household size also differed markedly: beneficiary households averaged 5.5 members compared with 3.5 for non-beneficiaries. Larger families may face higher consumption demands, prompting diversification into programme-supported activities, a dynamic echoed by Ellis (2000) and Barrett et al. (2001). Beneficiaries also reported a greater number of income sources (5.35 versus 3.80), highlighting the programme's role in promoting multi-sectoral income generation and reducing vulnerability to environmental and market shocks (Musyoka et al. 2023; Nguyen et al. 2023).

Conversely, non-beneficiaries controlled larger farm areas (3.06 ha versus 2.07 ha), implying that households with limited land endowments are more motivated to seek off-farm or alternative livelihood opportunities. Distance to the reserve also emerged as a spatial differentiator: non-beneficiaries resided further away (66 minutes) than beneficiaries (54 minutes), suggesting that proximity to conservation projects increases exposure to programme interventions (Utama et al. 2024; Latip et al., 2018).

In terms of human capital, beneficiaries had slightly lower levels of education (8.6 years) than non-beneficiaries (10.2 years), suggesting that less-educated households may be more dependent on natural resources and thus more receptive to livelihood interventions targeting forest users. This observation supports the argument of de Sherbinin et al. (2018) that education expands livelihood choices beyond those based on natural resources.

Furthermore, differences in livelihood experience reveal a structural transition. Beneficiaries had longer histories of NTFP collection (25.6 years versus 18.7 years) but less off-farm experience (17.7 years versus 20.7 years), suggesting that participants were initially more forest-reliant before shifting toward non-extractive, alternative livelihoods. This pattern reflects the gradual movement away from direct forest dependency toward more sustainable income.

Table 2
Comparison between beneficiary and non-beneficiary households

Variables	Beneficiaries		Non-beneficiaries		t-test
	(n = x)		(n = x)		
	Mean	S.D.	Mean	S.D.	
Age (in years)	42.41	9.38	49.43	4.55	-3.02*
Household size (in persons)	5.54	1.02	3.48	1.08	0.59
Income sources (in units)	5.35	1.11	3.80	1.16	5.01***
Land area (in hectares)	2.07	1.18	3.06	1.08	-4.03***
Distance from SNR (in minutes)	54.25	25.17	65.97	21.36	-2.77**
Farm experience (in years)	21.61	8.70	20.20	9.17	1.64
NTFPs collection experience (in years)	25.57	9.44	18.65	9.76	0.99
Off-farm experience (in years)	17.68	9.24	20.71	9.76	1.07
Education level	8.58	3.82	10.15	4.33	-2.10**

4.3 Household income sources

Beneficiaries reported more income sources, averaging 5 distinct streams (Fig. 2). Their total household income (10.5 million Naira) remained lower than that of non-beneficiaries (12.7 million Naira). This outcome reflects the programme’s targeting strategy, which prioritises poorer, forest-dependent households characterised by limited capital, low asset endowments, and high vulnerability. Among non-beneficiaries, off-

farm income accounts for the largest share of household income at approximately 36%, followed by timber products at 46% and farm income at 14%. Income from non-timber forest products contributes only about 3%, while project-related income is virtually absent at around 1%. This income structure suggests a strong reliance on a few relatively high-return activities, particularly off-farm employment and timber extraction.

In contrast, for beneficiaries, timber products account for approximately 62% of household income, while off-farm income accounts for 23% and farm income for 11%. Income from non-timber forest products and the GEBR project each contribute about 2%. Although these latter shares are relatively small, their presence reflects the integration of project-supported activities into household livelihood strategies, which is absent among non-beneficiaries.

The similarity in certain income sources, particularly farm and off-farm income, indicates that participation in the alternative livelihood programme does not fully replace existing livelihood strategies but instead complements them. However, the relative contributions differ substantially. For example, off-farm income constitutes over one-third of total household income among non-beneficiaries, compared to less than one-quarter among beneficiaries. This supports livelihood diversification theory, which posits that rural households often combine multiple income-generating activities as a risk management strategy rather than substituting one activity for another (Ayana et al., 2022; Ellis, 2004; Barrett et al., 2001).

Despite having more income sources, beneficiaries derive relatively modest income from each activity. The combined contribution of non-timber forest products and project income among beneficiaries remains below 5% of total household income, reinforcing the idea that diversification among poorer households is primarily aimed at income stabilisation rather than rapid income growth. Previous studies similarly observe that households with limited assets tend to diversify into low-return but accessible activities due to barriers to more lucrative livelihood options (Reardon et al., 2009; Ellis & Freeman, 2004). This finding is consistent with the broader conservation–livelihood literature, which emphasises that livelihood interventions in protected areas often deliver gradual welfare improvements while prioritising livelihood stability and ecological sustainability over immediate income gains (Brockington et al., 2021; Roe et al., 2020).

In contrast, the dominance of off-farm income among non-beneficiaries, accounting for 36% of total income, suggests stronger integration into higher-paying labour markets or non-agricultural employment opportunities. Such engagement is often associated with higher levels of education, broader social networks, and greater mobility. Comparable patterns have been reported in rural livelihood studies, where households with stronger asset bases concentrate on fewer but more profitable income sources (Torres et al., 2018; Barrett et al., 2005).

The presence of project-derived income among beneficiaries, although modest at approximately 2% of total household income, is nonetheless significant for welfare and conservation. Project income represents a deliberate shift away from exclusive reliance on extractive forest-based activities and contributes to reducing pressure on protected forest resources. Even small income shares from alternative livelihoods can play an important role in smoothing consumption, meeting basic needs, and lowering dependence on unsustainable resource use, particularly during periods of economic or environmental stress (Wunder et al., 2018; Angelsen et al., 2014; Paul et al., 2025).

4.4 Determinants of household participation in the alternative livelihood project

The multinomial logit model is employed to identify the determinants of participation in various alternative livelihood options, and the results are presented in Table 3 below.

Ethnicity was negatively associated with participation in snail farming among non-Yoruba groups ($p < 0.1$), whereas Christian affiliation was positively associated with participation ($p < 0.1$). This may reflect social or cultural preferences influencing enterprise choice (Rivera-Santos 2015). Among the Yoruba, the culturally dominant ethnic group in the study area, snail consumption and farming are traditionally accepted and even regarded as a delicacy. This acceptance is often embedded in cultural practices and dietary norms passed down through generations. Conversely, many non-Yoruba ethnic groups, such as the Hausa or Fulani, may hold cultural or religious reservations about snail consumption, viewing it as taboo, unclean, or non-preferred. These beliefs likely discourage their participation in snail-related enterprises.

The positive and significant effect of education on participation in snail farming and mushroom cultivation suggests that individuals with higher levels of education may have better access to information and greater awareness of the economic and nutritional value of these enterprises. Educated individuals are also more likely to engage with extension services, training programmes, and entrepreneurial opportunities, thereby increasing their likelihood of participating in specialized or emerging agribusinesses such as snail and mushroom farming. These results align with existing literature, which emphasises the role of education in enhancing agricultural productivity and entrepreneurial engagement (Kebebe & Shibru, 2017).

Similarly, larger household sizes are more involved in the fishery ($p < 0.05$). The observed association between household size and participation in fishery-based enterprises reflects the labour-intensive nature of these activities, in which larger households can provide additional labour (Mitu et al. 2021; Tikadar et al. 2022). Additionally, access to assets, such as family labour, can help rural households cope with income uncertainty and improve their socioeconomic status. It is widely believed that access to productive assets, including land and human capital, can significantly enhance the welfare of rural households (Ellis and Freeman 2004; Kristjanson et al. 2004; Bezu et al. 2012).

The frequency of contact with extension agents was consistently significant across all enterprises ($p < 0.01$), with higher contact frequencies substantially increasing the likelihood of participation in all livelihood strategies. The positive association between extension service contacts and enterprise participation across all livelihood choices indicates that continuous advisory support can play a crucial role in encouraging diversification. This supports the notion that targeted extension services can enhance rural households' resilience and economic outcomes by promoting participation in a broader range of income-generating activities (Cattaneo 2010; Neglo et al. 2021; Mhlongo et al. 2023).

Proximity to residence was significantly associated with fish farming and mushroom cultivation ($p < 0.05$), suggesting that accessibility and reduced travel time influence participation decisions. This may be particularly relevant for fish farming, as the fishpond is centrally located in the study area and closer to residential areas than other enterprises, making it easier to monitor and manage on a daily basis. Studies

have shown that proximity to livelihood activities significantly influences participation, as reduced travel time lowers opportunity costs and enhances engagement (Aung et al. 2023; Haque et al. 2025).

Table 3
Multinomial logit estimation of household involvement in the alternative livelihood project

Variables	Snail farming		Grasscutter farming		Mushroom production		Fish farming	
	Coefficient	S.E.	Coefficient	S.E.	Coefficient	S.E.	Coefficient	S.E.
Age	-0.002	0.037	-0.003	0.035	-0.038	0.049	-0.009	0.044
Gender	-0.142	0.439	0.119	0.382	-0.389	0.566	-0.605	0.572
Ethnicity	-1.235	0.704 *	-0.038	0.35	-0.031	0.486	0.185	0.418
Religion	0.529	0.287 *	-0.139	0.292	0.155	0.394	-0.479	0.397
Marital status	0.396	0.391	0.050	0.396	-0.398	0.679	-0.45	0.576
Education	0.074	0.044 **	0.030	0.040	0.115	0.064 *	-0.005	0.048
Farm experience	0.018	0.018	0.026	0.017	0.036	0.024	-0.005	0.023
Involvement in forest resources	-0.243	0.204	-0.223	0.199	-0.261	0.273	0.166	0.259
Household size	0.115	0.159	0.117	0.150	-0.034	0.207	0.358	0.207 *
Distance from your house (minutes)	0.002	0.007	0.012	0.007 *	0.016	0.009 *	0.016	0.009 *
Terrain	-0.134	0.392	-0.178	0.381	-0.472	0.558	-0.034	0.480
Participation in meetings	0.263	0.331	-0.190	0.316	-0.165	0.438	-0.849	0.430 **
Farmers organisation member	-0.286	0.757	-0.109	0.708	-0.095	0.96	0.493	0.799
Access to credit	0.276	0.798	0.031	0.749	0.176	1.014	-0.025	0.833
Extension visits	2.367	0.273 ***	2.109	0.268 ***	2.757	0.313 ***	2.324	0.307 ***
Constant	-4.278	2.09 **	-3.456	1.982 *	-3.558	2.77	-3.724	2.537
Number of observations	426							
Note: ***, **, *, indicate significance at $p < 0.01$, $p < 0.05$, and $p < 0.1$ level respectively.								

Variables	Snail farming		Grasscutter farming		Mushroom production		Fish farming	
	Coefficient	S.E.	Coefficient	S.E.	Coefficient	S.E.	Coefficient	S.E.
Dependent variable mean (SD)	1.087 (1.330)							
Pseudo R2	0.190							
Chi-square	219.223							
Prob > chi2	0.000							
Bayesian crit. (BIC)	1322.858							
Akaike crit. (AIC)	1063.374							
Note: ***, **, *, indicate significance at $p < 0.01$, $p < 0.05$, and $p < 0.1$ level respectively.								

4.5 Impact of the alternative livelihood project on household income

The average treatment effect for the treated (ATT) results, presented in Table 4, measures the difference in outcomes between participants and non-participants with similar propensity scores.

The results show that before matching (the unmatched sample), programme participants had an average total income of NGN 176,733.02, while non-participants had an average income of NGN 142,199.05. The estimated difference in total income was NGN 34,533.97, with a standard error of 1,651.21 and a t-statistic of 20.92, indicating a significant difference between the two groups even before controlling for selection bias.

After matching (ATT estimation), programme participants had an average total income of NGN 179,078.67, while non-participants had an average income of NGN 79,668.25. The estimated difference due to programme participation was NGN 99,410.43, with a standard error of NGN 3,516.42 and a t-statistic of 28.26. The high t-value suggests a strong and statistically significant impact of programme participation on total income.

A balance check using the pstest command shows that the mean total income for participants was NGN 180,000, compared to NGN 79,668 for non-participants. The standardised bias was 25.6%, and the t-test yielded a statistically significant difference ($p = 0.003$). The percentage bias t-test yielded a t-value of 28.62, confirming that the matched sample effectively reduces bias and improves the reliability of the estimated impact. The variance ratio (1.92) suggests a moderate level of variability between the groups.

These results depict that household participation in the alternative livelihood project significantly increases total income, hence contributing to household welfare. This finding aligns with the study by Kanel and Niraula (2004), who observed that participation in community alternative livelihood projects enhances household

livelihoods by meeting basic needs, supporting income-generating activities, and improving access to forest resources.

Table 4
Effect of household participation in the alternative livelihood programme on household income
(Propensity Score Matching)

Variable	Sample	Treated	Controls	Difference	S.E.	T-stat
Household income	Unmatched	176,733.02	142,199.05	34,533.97	37,584.60	20.92***
	ATT	179,078.67	79,668.25	99,410.43	78,713.32	28.26***
Note: S.E. stands for Standard Error.						

5. Conclusions and policy implications

The findings of this study highlight the multidimensional nature of implementing the Alternative Livelihood Programme (ALP) in Nigeria’s Omo Biosphere Reserve, underscoring its implications for balancing household welfare with forest conservation. The results confirm that ALP participation significantly reduces forest dependence while enhancing income diversification, with participating households earning, on average, NGN 100,000 more than comparable non-participants. However, the scalability and sustained impact of such interventions are shaped by the interplay of demographic and institutional factors that influence livelihood decision-making around protected forest landscapes.

Socio-economic patterns reveal that beneficiaries were generally younger, had larger households, and lived closer to the reserve boundary, attributes that enhanced their responsiveness to externally supported livelihood innovations. Cultural and religious orientations emerged as decisive factors in enterprise selection: Yoruba households, where snail consumption is culturally accepted, showed higher participation in snail farming, while non-Yoruba groups demonstrated weaker engagement. This cultural embeddedness indicates that livelihood diversification strategies must align with local norms and values to ensure social acceptance and long-term adoption. Education also played a critical role in enabling participation in specialised enterprises such as snail and mushroom farming, emphasising the contribution of human capital to sustainable livelihood transitions. Similarly, household size positively influenced engagement in labour-intensive activities, such as fish farming, highlighting the advantage of family labour in sustaining these enterprises.

Institutional support mechanisms, particularly extension services, were instrumental across all livelihood options. Regular extension contacts facilitated knowledge transfer, confidence building, and enterprise management, thereby strengthening adaptive capacity and promoting a shift from extractive to sustainable practices. Spatial proximity also shaped participation: households located closer to project sites exhibited higher engagement, reaffirming the importance of physical accessibility and outreach effectiveness.

From a policy perspective, the results suggest that fostering sustainable livelihoods in forest-edge communities requires interventions that are contextually tailored and institutionally embedded. Strengthening extension networks and integrating education and capacity-building into programme design will be vital for maintaining participation and improving enterprise management. Furthermore, spatial targeting should be

incorporated into project planning to prioritise households within feasible access to conservation zones, ensuring both monitoring efficiency and equitable benefit distribution. Recognising that livelihood choices are socially and culturally embedded, programme design must go beyond economic incentives to include cultural sensitivity and participatory engagement.

Future pathways for scaling alternative livelihood interventions should integrate socio-cultural, institutional, and market-oriented strategies. Establishing long-term institutional support, strengthening local cooperatives, and enhancing market linkages will be essential to sustain income gains and reinforce conservation outcomes. Collaborative governance among forestry authorities, community-based organisations, and local institutions can create an enabling environment in which livelihood security and forest conservation objectives are mutually reinforcing rather than competing. Such integrative approaches will not only consolidate the welfare gains observed but also contribute to the broader goals of social resilience and ecological sustainability within Nigeria's biosphere reserves.

Declarations

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Consent to participate

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

Declaration of Competing Interest

The author declares that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Authorship contribution statement

Kazeem Jimoh: Investigation, Data collection, Formal analysis, Data curation, Visualisation, Writing – original draft. **Ayat Ullah:** Formal analysis, Data curation, Software, Writing – original draft review & editing. **Mustapha Yakubu Madaki:** Formal analysis, Data curation, Software. **Ibraheem Oduola Lawal:** Conceptualisation, Methodology, Investigation. **Kathrin Meinhold:** Conceptualisation, Methodology. **Bedru Balana:** Conceptualisation, Methodology. **Dietrich Darr:** Conceptualisation, Methodology. **Miroslava Bavorova:** Funding acquisition, Conceptualisation. **Patrick Van Damme:** Supervision, Validation. **Vladimir Verner:** Supervision, Funding acquisition, Conceptualisation, Visualisation, Writing – original draft review & editing.

Data Availability

The authors confirm that the data supporting the findings of this study will be available from the corresponding author upon reasonable request.

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Figures

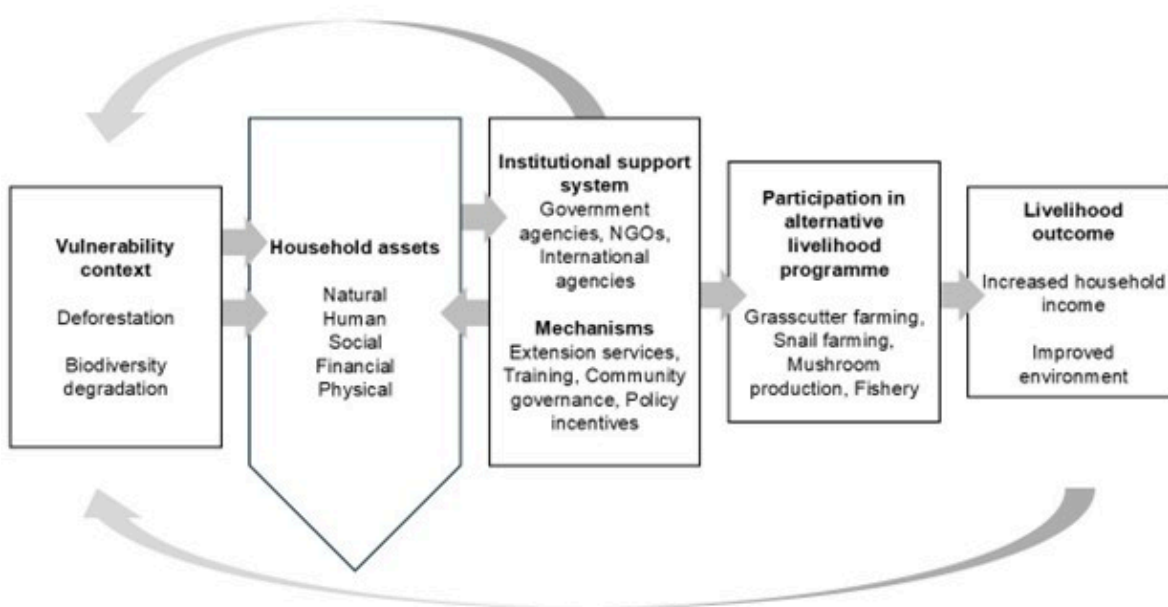


Figure 1

Conceptual framework linking livelihood capitals and institutional processes to household participation in alternative livelihood interventions and livelihood outcomes in the Omo Biosphere Reserve.

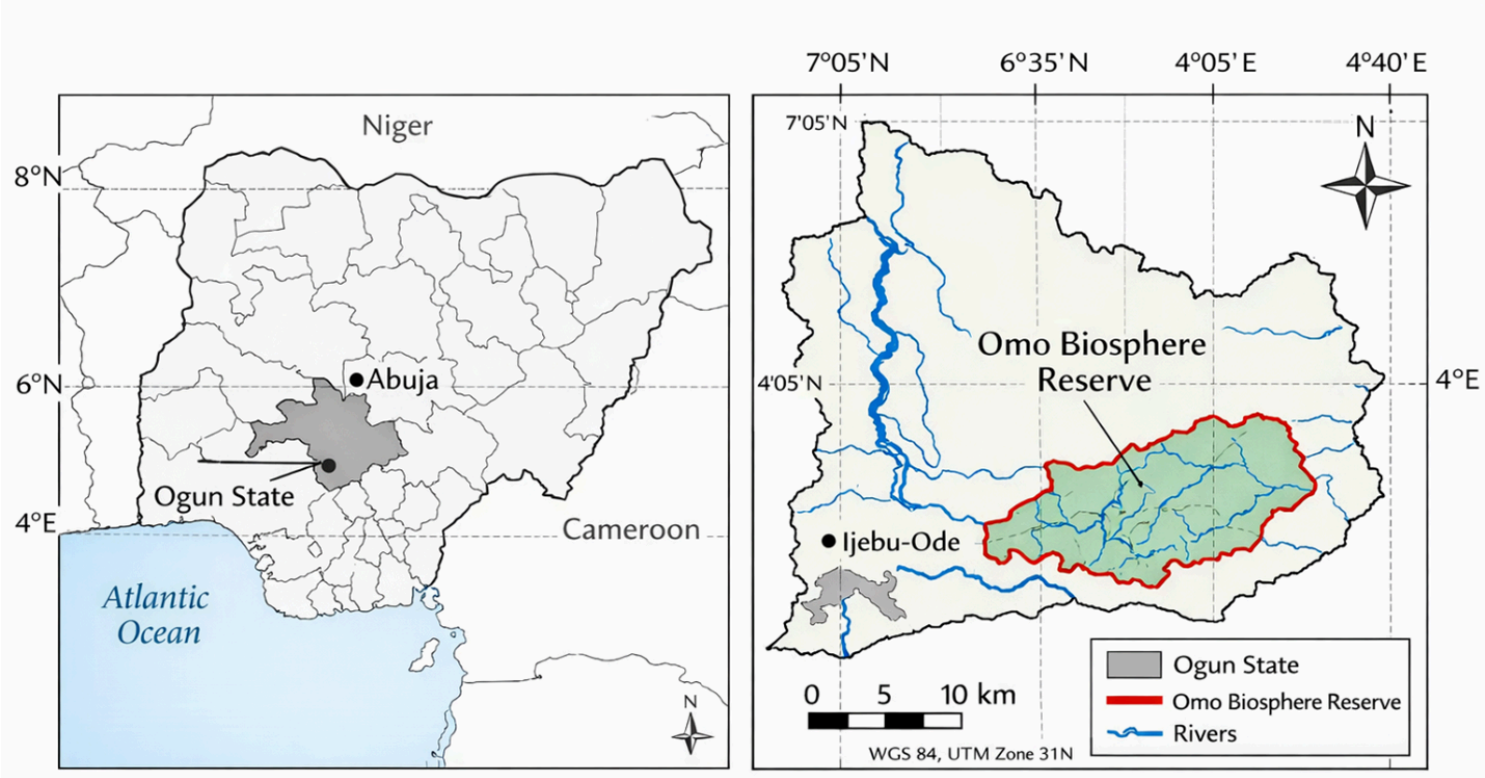


Figure 2

Map of the study area