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EXPLORING FARM HOUSEHOLDS ENGAGEMENT IN ECOSYSTEM BASED LIVELIHOOD DIVERSIFICATION STRATEGIES: A CASE STUDY OF BOMA-GAMBELLA TRANS-BOUNDARY LANDSCAPE, SOUTHWEST ETHIOPIA AND EAST SOUTH SUDAN

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ABSTRACT

This study investigates the engagement of farm households in ecosystem-based livelihood diversification strategies within the Boma-Gambella Trans-Boundary Landscape, located in Southwest Ethiopia and East South Sudan. The objective is to understand how various capital assets influence the choices of livelihood strategies among these households. Utilizing a Multinomial Logistic Regression model, the research addresses key diagnostics, including the Independence of Irrelevant Alternatives and multicollinearity, to ensure robust results. The econometric analysis reveals that various capital assets, such as social, physical, and natural capital significantly influence the livelihood strategy choices of farm households. The assessment of marginal odds ratio effects underscores the relationship between ecosystem-based capital assets and the selection of specific livelihood strategies, providing insights into the dynamics of rural livelihoods in the region. Furthermore, the findings contribute to the scientific understanding of rural livelihood strategies by highlighting the critical role of ecosystem services in enhancing income diversification. The implications of this research extend to policymakers and practitioners, emphasizing the necessity of strengthening social networks, improving infrastructure, and conserving natural resources to support sustainable livelihoods. This study underscores the importance of coordinated initiatives aimed at improving ecosystem-based income diversification strategies in the Boma-Gambella landscape and similar socio-ecological contexts across Africa. By fostering a holistic approach to rural development, the research advocates for integrated policies that align economic growth with environmental sustainability, ultimately contributing to the resilience and well-being of rural communities.

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Keywords: Ecosystem-based livelihoods, Livelihood diversification, Capital assets, Boma-Gambella Trans-boundary Landscape, Multinomial Logit Model. Southwest Ethiopia, East South Sudan

IINTRODUCTION

Across the globe and throughout history, farm households who depend on nature based systems have been responsible for maintaining landscapes to meet their food and livelihood requirements. Forest land, agricultural land, water bodies and wetlands are all essential components of these landscapes. Globally, local communities earn income from the use of wild natural resources. Marine, freshwater and forest resources are particularly important (FAO, IFAD, & WFP, 2015). Therefore, ecosystem services are major livelihood strategies for Global communities dependent primarily on nature (Sangha et al., 2018). However, human exploitation of biodiversity of the world is causing widespread biodiversity loss and decline in ecosystem conditions, leading to reduced benefits of ecosystem services (Diaz et al., 2015).

Ecosystems in the less-developed world are responsible for food sources for local communities (Agrawal et al., (2013), and thus, diverse landscapes play a crucial role in household economies (Godfray, Beddington & Crute, 2010). Most people in Sub-Saharan Africa rely on wild-harvested products and depend on landscape resources as major sources of livelihoods (Herndon & Butler, 2010), and landscape resources such as biodiversity and ecosystem services are, therefore, important in the context of Africa where the welfare of millions of rural people dependent on ecosystem services from landscapes.. The collection of wild resources provides considerable subsistence support to local livelihoods (Diamond, 2002). However, the world's ecosystems have been destroyed caused by human interaction and were responsible for a high degree of change in the delivery of ecosystem services. Vaezi, Ahmadi & Cerdà, (2017). emphasized that degraded ecosystems could create several environmental problems, such as ecosystem transformation, degradation; and change on ecosystem service delivery and therefore, result in environmental degradation and loss of ecosystem services.

Landscape changes from forest land, grassland, and wetland to agricultural land has a direct impact on ecological sustainability (Liu et al., 2019) and illogical land conversion leads to land fragmentation and negatively impacts ecosystem services and livelihood strategies (Brauman et al., 2007). Furthermore, as fragmentation has a significant impact on ecosystems (Peng, Zhou & Fan, 2016), changes to ecosystem services lead to positive or negative impact on livelihood strategies (Jones, Clark, & Panteli, 2013; Kindu et al., 2017).

As many local communities depend on the forest products such as wild meat, honey, medicinal plants and wood fuel to meet other important household expenses (Sunderland, 2011), ecosystem-based activities such as forestry and fisheries are critically important sources livelihoods for local communities, especially in rural areas. Threats to these livelihood sources due ecosystem degradation have severe knock-on effects on food security. Although, biodiversity provides an important ecosystem services at times of food insecurity and seasonal food gaps (Sunderland, 2011), human exploitation of biodiversity of the natural world is causing widespread ecosystem service loss and declines in ecosystem conditions, leading to reduced benefits of ecosystem services (Butchart, Walpole & Collen., 2010; Halpern et al., 2008). Moreover, the world's ecosystems have been destroyed caused by human interaction and were responsible for a high degree of change in the delivery and significance of ecosystem based livelihoods. These conditions result in ecosystem transformation, degradation, and change on ecosystem based

livelihoods (Tolessa, Senbeta & Kidane, 2017), and therefore, result in functional impairment (Fu et al., 2017). Therefore, the world faces a daunting set of intersecting challenges to meet the dietary needs while eliminating extreme poverty and food insecurity (Godfray et al., 2010).

According to Foley, Ramankutty, & Brauman, (2011), maintaining biodiversity and ecosystem services in landscapes and ensuring food security are the most important issues facing global sustainability goals. However, the growth and intensification of agriculture continue to be significant contributors to the degradation of biodiversity and loss of ecosystem services (Tilman et al., 2011). The degradation of biodiversity and loss of ecosystems are likely to aggravate poverty, and would have an adverse impact on food security, livelihood options and quality of life of local communities.

In the context of ecosystem conservation, important issues considered in a socio-ecological approach include food security, livelihood strategies, governance and capital endowments (Wittman, Abson, Kerr, & Blesh, 2017). However, the function, and services of ecosystems are not yet fully understood by ecologists, economists, and other scientists. Nevertheless, there are several studies and reviews that have documented the benefits of particular systems and their contributions to socioeconomic welfare and food security (de Groot et al., (2002), and indicates a growing source of ecosystems contribution to diversify ecosystem based income sources for households engaged in livelihood activities (Arnold, Köhlin & Persson, 2006).

The ecosystem-based approach emphasizes the integration of natural resource management with livelihood strategies. By engaging farm households in income diversification that aligns with the region's biodiversity, the study could promote sustainable land-use practices that enhance environmental resilience (Hobbs et al., 2014). This can reduce pressures on ecosystems and promote conservation efforts, especially in the trans-boundary landscape shared by Ethiopia and South Sudan (IUCN, 2021). Therefore, biodiversity conservation and the preservation of ecosystem services is vital for the sustainability of ecosystem service values and functions, enhancing income diversification livelihoods in the Boma-Gambella landscape. By aligning household livelihood strategies with sustainability of ecosystem, the approach supports the regeneration of natural systems, ensuring the availability of these services for future generations (MEA, 2005).

In the Boma-Gambella Trans-boundary landscape, ecosystem sustainability faces mounting challenges that significantly impact local livelihoods and community resilience. The region's ecosystems, which support unique biodiversity, including vital flora and fauna, are under threat from deforestation, land degradation, and the overexploitation of natural resources (Gebremedhin & Hailu, 2019; Tadesse et al., 2021). These pressures are compounded by climate change, which brings increasingly unpredictable weather patterns, resulting in more frequent droughts and floods that disrupt traditional agricultural and pastoral practices (UNEP, 2020).

In response, ecosystem-based livelihood diversification strategies have become essential. Such approaches, including agroforestry, integrated crop-livestock systems, and sustainable hunting and fishing practices, offer pathways for households to adapt sustainably while maintaining economic stability (Wondimu, 2018; Tesfaye et al., 2022). These strategies allow communities to reduce reliance on fragile ecosystems, thus helping to mitigate environmental degradation.

The study based on exploring how ecosystem based natural systems are interdependent and support human wellbeing, taking ecological opportunities and limits into account (Smith et al., 2020). The study in addressing the sustainability of income diversification options among farm households is, therefore, innovative (Jones & Williams, 2018). Moreover, the study

considers a variety of ecosystem based livelihood strategies (Maestre, Salguero-Gómez & Quero, (2012), examines how livelihood strategies are used by farm households to diversify their sources of income, and provide a thorough understanding of the ways in which ecosystem based livelihoods sustain a variety of economic endeavors (Garcia-Llorente, Martin-Lopez, & Nunes, 2016). This adds novel perspectives of the study to the most ecological issues related on how farm households interact with and benefits from ecosystem-based income diversification livelihood strategies (Díaz et al., 2015; Quintas-Soriano, Castro, & Castro, 2019).

This study investigates the engagement of farm households in sustainable practices by examining the interplay between ecosystem stewardship and livelihood resilience in the Boma-Gambella landscape (Gebremedhin & Hailu, 2019). Findings from this research aim to inform policy development that promotes sustainable ecosystem management and livelihood resilience, ultimately supporting adaptive capacity across this sensitive Trans-boundary region (Tadesse et al., 2021; UNEP, 2020).

The outcomes of the research could therefore, inform international, national and regional policy frameworks, encouraging governments and institutions to integrate ecosystem-based livelihood strategies into their rural development agendas. This would promote harmonized policies that support both human well-being and ecological balance, ensuring that development initiatives do not compromise the environmental integrity of the trans-boundary landscape (World Bank, 2017).

RESEARCH METHODOLOGY

Description of the study area

The Boma-Gambella Landscape is a trans-boundary landscape between Ethiopia and the Republic of South Sudan, which stretches from Gambella region in South-western Ethiopia to the Boma landscape of the Jonglei States in the Republic of South Sudan (Emerson et al., 2017). The area lies between $33^0$0'0" E – $36^0$0' 0" E Longitude and $5^0$0’ 0" N– $8^0$0' 0" N Latitude with total area of 2,789,540.76 Hectares. It encompasses the Boma National Park of South Sudan and the Gambella National Park of Ethiopia.

An important feature of the landscape is its hydrology, manifested by the expansive networks of both seasonal and permanent wetlands. There are various permanent and non-permanent wetlands such as the Sudd, Duma, Lower Abobo, and Lower Gilo wetlands that play significant role in regulating the micro-climate and harboring endangered species. Even though Boma-Gambella landscape falls within two sovereign countries, Ethiopia and the republic of South Sudan; it is bonded with shared cultural values, ecosystem functions, prospect and challenges. It has similar geological settings. It is drained by five rivers, the Baro, Gilo, Akobo, Pibor and the Baher-el Jebel Rivers. Pibor, Akobo, Gilo, Alwero, and Baro rivers form Sobat river system, contribute up to 40% of the water of the White Nile at Malakal and 15% at Lake Nasir (Jonker et al., 2015). For this study, the geographic scope is restricted to the Boma-Gambella Trans-boundary landscapes

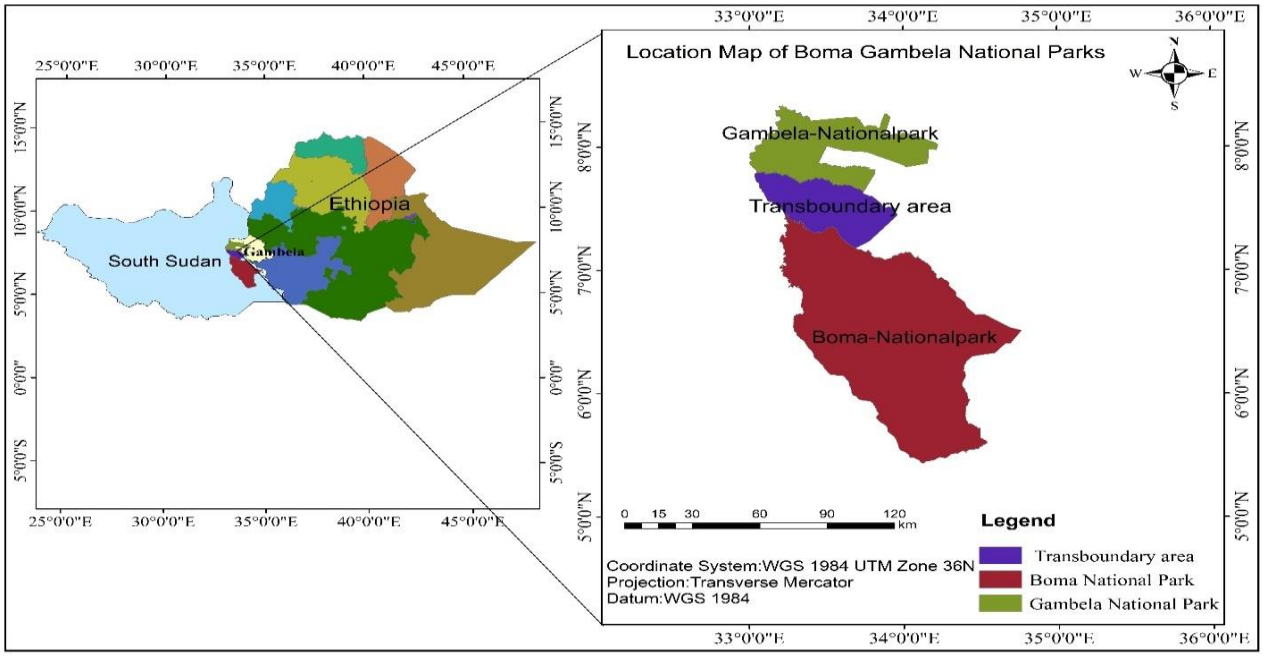

Figure 1. Boma-Gambella trans-boundary landscape

The dominant ethnic groups' inhabited in the area are Anywaa, Nuer and Murule. Agro-pastoral, agricultural and Pastoral activities are major On-farm livelihood strategies in Boma-Gambella Trans- Boundary Landscape (Andretta, 1989). The major livelihoods of farm households are livestock, hunting, fishing and crop production. Important livestock products are milk, meat, butter and blood (Brahimi, 2007). Besides cattle other small livestock such as goats, sheep and chicken are kept (USAID, 2001). Despite the strong emphasis on pastoralism and the societal and cultural significance of cattle, farm households in the landscape cultivate on a limited scale (Brahimi, 2007). Farm households living in the areas of high soil fertility and consistent rainfall are more focused on agriculture (USAID, 2001).

Important crops grown in landscape are sorghum, maize and pumpkin (Brahimi, 2007). Hunting is also an important source of food (Laudati, 2011), though have been restricted by the government (Andretta, 1989). Fish are caught at water pools, swamps and rivers (Mayai & Jok, 2013). Fish, and wild fruits as well as wild meat are important foods during the hunger gap and during periods of food insecurity and crisis (Brahimi, 2007). However, farm households in the landscape have limited opportunities for alternative livelihoods activities such as wage labor for the government, international agencies or other employers, trade, sale of livestock and agricultural products, and other casual labors.

Livelihoods in Boma-Gambella Trans-Boundary Landscape were under threat due to erratic climatic conditions, livestock diseases and the lack of infrastructure, which have been further challenged by recurrent cattle raids and armed inter-and intra-communal conflicts and coercive disarmament resulting in massive displacement, loss of assets and increasing food insecurity. Therefore, livelihoods of farm households have come under increasing stress in recent decades from intra- and inter-community violence and conflict, uneven development and poor infrastructure, and other challenging climatic conditions. Moreover, access to services is minimal, and essentially nonexistent, most of those facilities were operated by NGOs; however, presence of the government in terms of service delivery throughout the landscape is negligible.

The climate regularly affects agro-pastoralist and pastoralist activities with floods and droughts. The arid zones in the plains are particularly prone to droughts (Omondi, 2012). Much remains unknown about the situation of farm households in the landscape. This is due to the fact that farm household heads access to information, political participation and the involvement in community decision-making processes is limited (MSF, 2012; Omondi, 2012). Accesses to information and opportunities for participation seem to vary according to various factors such as gender, age, level of education and access to government institutions. In the study landscape, farm households, seem to hardly have access to information about governance and they can only marginally participate in community decision-making and political processes (Sommers & Schwartz, 2011). Furthermore, the decision makings are underrepresented and marginalized at the state and national levels and farm households' representation and participation were far more limited.

Instruments and Procedures of Data Acquisition

The study applied a combination of exploratory stakeholder consultation and engagement methods (Kvam, 2017) through intensive Focus Group Discussions (FGDs) and key informant interviews (KIIs); the use of qualitative content analysis (Ballou, Warriar & Deterding, 2021); and a questionnaire survey (Navarro-Rivera & Kosmin, 2013) to collect information on farm households' perception on determinants of livelihood strategies and food security.

Sampling Techniques and Sample Size Determination

In this study a multistage sampling procedure was used to select small sample units of survey respondents to ensure that all components have an equal probability of being chosen (Chauvet, 2015; Khan, 2020). Boma- Gambella Trans- Boundary Landscape was purposively selected at the principal stage as it is one of the most environmentally degraded landscapes due to anthropogenic and biophysical factors and facing landscape governance challenges as it is governed by two sovereign states, the republic of South Sudan (RSS) and Federal Democratic Republic of Ethiopia (FDRE) and the respective administrative states. Out of the 13 Woredas in Gambella National Regional State, Wanthwa, Abobo, and Jore Woredas were purposively selected because of their relative proximity to Gambella National Park and their vulnerability to the changing landscape; while from each Woredas, namely Mun, Pokedi and Ulaw Kebeles were selected randomly. Moreover, out of 11 counties in Jonglei state only Pibor County was purposively selected due to its relative location and proximity to Boma National Pak; and two Bomas, from Gumuruk and Verthait Payams were selected due to their relative accessibility and security. The overall sample size for the survey was determined by using Kothari (2004) sample size determination equation as recommended by Cohen et al., (2007) in educational research. The equation takes into account the desired confidence level (95 %), error margin (5%), in each kebeles and Bomas is known (i.e., 439 household heads). Accordingly, Kothari, (2004) sample size determination formula was applies to determine the required sample household heads used in this study.

$$n = \frac{z^2 * P * q * N}{(e^2(N-1)) + (z^2 * P * q)} \quad \ldots\ldots (1)$$

Where:

n = the required sample size

Z^2 = is the abscissa of the normal curve that cuts off an area α at the tails (1- α equals the desired confidence level. The value for Z is found in statistical tables which contain the area under the normal curve. e.g., Z=1.96 at 95%confidence level; and Z^2=3.841).

N= the population size (439)

P= the population proportion (assumed to be 0.5 since this would provide the maximum sample size)

q= 1-p

e = is the desired level of precision or margin of error (5% error or 0.05)

The sample size for the study was, therefore, 207 farm households determined by kothari (2004) sample size determination formula. It consists of 138 farm household heads from purposively selected kebeles in Gambella Landscape, of which 52 farm households were from Pokedi kebeles, Abobo Woreda and 46 were from Ulaw kebeles, Jore woreda, Anywaa zone, and 40 farm household heads from Mun kebele, Wanthwa Woreda, Nuer zone. Moreover, 69 farm household heads were selected from Boma Landscape, of which 42 farm household heads were from Gumuruk Boma and 27 were from Verthait Boma. The selection techniques of household heads for questionnaire survey from selected sites adjacent to Gambella national park was based on simple random sampling technique, whereas, data collection techniques from Gumuruk and Vertheit Payams of Jongelei state, South Sudan was based on snow ball sampling due to security reasons.

Research Design and Approach

This study adopted a mixed-methods sequential explanatory design that combines qualitative and quantitative approaches (Creswell & Creswell, 2017; Ivankova et al., 2006) to triangulate the data collected from farm household heads. In this design, the researchers collect and analyze quantitative data first, followed by qualitative data analysis. The study applied a combination of exploratory stakeholder consultation and engagement methods (Kvam, 2017), Focus Group Discussions (FGDs), qualitative content analysis to critically analyze the Focus Group Discussion (FGDs) and Key Informant Interviews (KIIs) (Ballou et al.,2021; UCLA, 2016); and questionnaire based survey (Navarro-Rivera & Kosmin, 2013) to collect information on factors influencing adoption of adaptation strategies in Boma-Gambella Trans-Boundary landscape. Eight focus group Discussions (FGDs), each with eight to ten participants, six from Gambella Regional State and two from Jongelei State were selected.

The study based on Ecosystem Based Approach which describes the links between the natural environment and human well-being (Henle et al., 2012; Smith et al., 2013). The Ecosystem Based Approach recognizes the critical role of ecosystems in supporting livelihood income diversification and seeks to ensure the sustainable use of natural resources while enhancing the resilience of livelihood systems and household food security (Mustafa et al., 2019; Bhattarai et al., 2021). Based on these premises, the study focused on livelihood income diversification strategies of farm households engagement in provisioning ecosystem services generated from on-farm, off- farm and non- farm activities. The study, therefore, tries to explore ecosystem based livelihood income diversification strategies of farm households for household food security in Boma-Gambella Trans-Boundary Landscape, Southwest Ethiopia and East South Sudan.

MODEL SPECIFICATION

Multinomial Logistic (MNL) Regression Model

The multinomial (MNL) logit model is a popular model in the strategy literature allowing researchers to examine multiple unordered strategic choices with multiple outcomes (Wulff, 2015). The model relies on the assumption of independence of irrelevant alternatives (IIA). That is the odds are not dependent on other available alternatives. Therefore, the odds of one choice versus an alternative choice are not dependent on the number of choice alternatives included. To test the IIA assumption, one may perform Hausman-Mcfadden test (1984) and Small-Hsiao test (1985).

Researchers in strategy formulation and implementation often wish to draw inferences about factors underlying the strategic choices. Because such choices are rarely binary, they regularly apply discrete choice models allowing for multiple outcomes such as multinomial logit/probit. However, when interpreting such models, scholars are faced with a set of different challenges than in the binary dependent variable case. One very critical difference is that in MNL logit analysis, the sign of the estimated model coefficients does not determine the direction of the relationship between an independent variable and the probability of choosing a specific alternative (Bowen & Wiersema, 2004), and thus unlike binary models a positive or negative signs on a coefficient in MNL logit model does not necessarily mean that an increase or decrease in the independent variable corresponds to an increase or decrease in the probability of choosing a particular mode of entry (Long & Freese, 2006). Instead, to be able to draw valid conclusions about relationships, scholars must rely on other interpretational devices such as the predicted probability of marginal effects (Wulff, 2015). The marginal effects are defined as the prediction function at a given value of the explanatory variable and thus inform about the change in predicted probabilities due to a change in a particular predictor. Therefore, to draw valid conclusion about the direction and magnitude of the relation between an independent and dependent variables in MNL model, one must depend on marginal effects (Bowen & Wiersema, 2004). A clear advantage of marginal effects is that they provide with rich and intuitively meaningful information not available through interpretation of coefficients (Wulff, 2015).

Multinomial logistic regression (MNL) modeling was used to analyze how capital assets were associated with farm households' engagement in different livelihood strategies to diversify their livelihood incomes in Boma-Gambella Trans-Boundary Landscape. Multinomial regression logit model requires consideration of the presence of multicollinearity among the variables used in the model. Thus, variance inflation factor was used to test the multicollinearity problem among the variables and contingency coefficient was computed to see the degree of association among explanatory variables. The larger value of Variance Inflation Factor (VIF), usually values exceeds 10 indicates a serious multi-collinearity problem. The value of contingency coefficient ranges between 0 and 1. A value close to 0 indicates weak association and a value close to 1 indicates presence of strong association. Therefore, contingency coefficient value of 0.75 or above indicates a stronger relationship between explanatory variables and shows presence of multi-collinearity (Gujjirati, 2003). Multinomial logit regression model shows the determinant variables for each category versus the base/reference category. The SPSS version 20.2 was used to generate the parameter and marginal Odds Ratio (OR) estimate results. The parameter estimates of the multinomial logit model give only the direction of the effect of explanatory variables on the dependent variable, but the estimates neither stand for the actual size of change nor the probabilities (Chilot, 2007). However, the marginal Odds Ratio (OR) measures the expected change in the probability of a given choice that has been made in relation to the unit change in the explanatory variable, given

that all other variable being remain constant. Thus, the predicted probabilities are better interpreted using the marginal odds ratio effects of the multinomial model (Greene, 2003).

In this study, farm households' data for ecosystem based livelihood strategies were selected based on the activity choice approach which has been applied by Nielsen et al. (2013). According to Nielsen et al., (2013), ecosystem based livelihood strategies are a combination of the income generating activities, a household pursues to sustain or improve its livelihood. Accordingly, we defined main ecosystem based livelihood activities related to agro-pastoral /Food Crop-Livestock mixed/strategy, Agricultural /Food Crop/ livelihood strategy, Pastoral /livestock raising & fodder/ strategies as *On-farm livelihood strategies*, wild fruits & root collection, fishing, wildlife hunting & firewood collection as *Off-farm livelihood* strategies, handicrafts & charcoal trading as *Non-farm livelihood strategy* and mix *(on-farm, on-farm_off-farm and on-farm_non-farm)* livelihood strategies. For Multinomial Logistic regression analysis, four dependent variables such as *On-farm livelihood* strategies, *on-farm_off-farm livelihood strategies, on-farm-non-farm* livelihood strategies and mix (*on-farm_off-farm_non-farm)* of *livelihood* strategies were applied, where, *On-farm livelihood strategies* were used as base/reference category for estimating farm households' choice of engagement in various income generating livelihood strategies. To analyze the determinants of farm household heads decisions to engage in different livelihood strategies, the assumption is that in a given period, a rational household head is chosen to engage among different mutually exclusive livelihood strategies. For an outcome variable with *j* categories, let the j^{th} livelihood strategy that the i^{th} household chooses one or two livelihood strategy/ies or mix of strategies.

The dependent variable in this study can take the values 1 (on-farm), 2 (off-farm), 3 non-farm) and 4 (on-farm off-farm_non-farm) livelihood strategies and the independent/ explanatory variables are farm households capital assets (Table 4). In the MNL the predicted probabilities can be calculated as:

$$P_{ij=}\ \Pr\left(Yi = \frac{j}{x_i}\right) = \frac{\exp\left(X_i \beta_j\right.}{\sum_{j=1}^{4} \exp\left(X_i \beta_i\right)} \quad \text{(2)}$$

Where, βP_{ij} is the probability that the i^{th} farm households will choose alternative j (j = 1, 2, 3, 4), X_i are case-specific repressors thought to explain entry mode choice, β_j is the coefficient vector and contains the intercept $\beta 1_j$ and the slope coefficientsβk_j. Thus, there is one set of coefficients for each choice alternative. The model in Equation 1 has 4 (J) equations of which only 3(J–1) can be estimated. Therefore, to guarantee identification, β_j is set to zero for one of the categories. This category is the base category, and coefficients are interpreted with respect to that category. Setting $\beta_1 = 0$ and computing the predicted probabilities yields (Green, 2003):

$$P_{ij=}\ \Pr\left(Yi = \frac{j}{x_i}\right) = \frac{\exp\left(X_i \beta_j\right)}{\exp\left(X_i 0\right) \sum_{j=1}^{4} \exp\left(X_i \beta_i\right)} \quad \text{(3)}$$

$$= \frac{\exp\left(X_i \beta_j\right.}{1 + \sum_{j=1}^{4} \exp\left(X_i \beta_i\right)} \quad \text{(4)}$$

And for the baseline category, we have:

$$P_{ij=}\ \Pr\left(Yi = \frac{0}{x_i}\right) = \frac{\exp\left(X_i 0\right)}{\exp(X_i 0) + \sum_{j=1}^{4} \exp\left(X_i \beta_i\right)} \quad \text{(5)}$$

$$= \frac{1}{1 + \sum_{j=1}^{4} \exp\left(X_i \beta_i\right)} \quad \text{(6)}$$

With Equations 3 and 6, we can compute predicted probabilities in order to assess the relationship between a predictor and each outcome. Plotting the predicted probabilities provides a quick and informative way of presenting the relationship between a selected predictor and the predicted probabilities of the different alternatives.

The predicted probabilities in MNL logit model provide with very informative information about the direction and magnitude of the relationship, it may be difficult to precisely determine whether a relationship can really be established, especially at places where the curve is flat. To further make sense of our results, we may rely on another powerful interpretative device: marginal effects. The marginal effects are defined as the slope of the prediction function at a given value of the explanatory variable and thus inform about the change in predicted probabilities due to a change in a particular predictor. This has made authors argue that if one wishes to draw valid conclusions about the direction and magnitude of the relation between an independent and dependent variable in an MLM, one must calculate marginal effects (Bowen & Wiersema, 2004). Even though marginal effects for a multinomial model may be complicated to derive (Wooldridge, 2015), they have a quite distinctive and simple form (Greene, 2003) as:

$$ME_{ij} = \frac{\partial p_{ij}}{\partial x_{ik}} = \frac{\partial_{r\,(Y=j/x_i}}{\partial x_{ik}} = P_{ij}(\beta_{kj} - \beta_i \ldots\ldots\ldots\ldots\ldots\ldots \quad (7)$$

Where, $\beta_i = \sum_{m=1}^{4} \beta_{km}$ Pr $(Y = m/x_i)$ is a probability weighted average of the coefficients for different choice.

MODEL VARIABLES DESCRIPTION

Dependent Variables

The dependent variables have mutually exclusive outcomes of ecosystem based livelihood strategies: *On-farm livelihood strategies* comprised of three major activities such as Agro-pastoral livelihood strategies including staple & cash crop production, vegetable & root crops production, and livestock fodder & feed ingredients production; Agricultural: livelihood strategies including staple crop production and cash crop production; Pastoral: livelihood strategies including livestock raising and livestock fodder & feed ingredient production; *Off-farm:Livelihood strategies* including wild fruits & root collection, fishing, wildlife hunting, firewood collection & charcoaling, *Non-farm: livelihood strategies* including handicrafts, petty trade, preparation & trading of charcoal; and *Mix of livelihood strategies*.

Therefore, four dependent variables, such as On-Farm livelihood strategy, Off-farm livelihood strategies, Non-farm livelihood strategies and mix (On-farm_Off-farm_Non-farm) of livelihood strategies were applied, where the first category was used as a reference category.

Independent Variables: The independent variables are the various types of livelihood assets hypothesized to influence the choice of farm household heads to engage in ecosystem based livelihood strategies (Table 2)

Human Capital Assets: A dummy variable, gender of the head of the family, has a value of 1 if the head of the household is male or 0 otherwise. The gender of the household head represents the food security orientation between male-headed and female-headed households. Horrell & Krishnan (2007) argue that male-headed households are better positioned to source of income generating livelihood strategies than their female-headed counterparts.

Therefore, it is anticipated that, gender will be favorably correlated with households' levels of food security and negatively correlated with their selection of livelihood choices. The age of the household head is an indicator of the household head's

experience on diversification of income generating activities and it is assumed that, as the household head gets older and has more experience, the household's knowledge on livelihood diversification and food security issues increases. However, research on this variable yields contradictory results. Most studies confirm that as the household head gets older, households gain agricultural experience, become more risk-averse, and diversify their production (Bogale & Shimelis, 2009; Mitiku, Fufa, & Tadese, 2012). Households headed by older people are therefore more likely to be food secure than households headed by young households.

Table 1 Description of Dependent Variables

Dependent Variables	Abbreviations	Description of variable	Frequency	Percent
On-farm ecosystem based livelihood strategies	On-farm	Livelihood strategies including staple & cash crop production, vegetable & root crops production, and livestock fodder & feed ingredients production (Agro-pastoral); Livelihood strategies (staple crop production and cash crop production (Agricultural); livelihood strategies including livestock raising and livestock fodder & feed ingredient production (Pastoral:)	45	21.7
Off-farm ecosystem based livelihood strategies	Off-farm	Livelihood strategies (wild fruits & root collection, fishing, wildlife hunting, firewood collection & charcoaling)	109	52.7
Non-farm ecosystem based livelihood strategies	Non-farm	Livelihood strategies including handicrafts, petty trade, preparation & trading of charcoal	29	14
Mix of livelihood strategies	On-farm_Off-farm_Non-farm	Mix of all the above livelihood strategies	24	11.6

Source: Survey Data (2022)

In contrast, Gebre (2012) shows that as household heads get older, households become less productive and become more dependent on non-agricultural livelihoods, gifts, and remittances. Therefore, households with older heads are more food insecure than households with younger heads. Therefore, it is expected that there is either positive or negative association between household head age and food security. The level of education of the household head also influences the household's access to and use of information and builds its capacity to enhance food security. Makombe, Lewin & Fisher, (2010) and Idrisa, Gwary & Shehu, (2008) demonstrate that this variable has a positive effect on food security. That is, households with better-educated heads are more likely to receive information and use it in their decisions to engage in more diversified income generating livelihood strategies than those with less educated household heads.

Those farm household heads with higher level of education are assumed to have better management techniques, which can help them secure a year-round diversified income generating livelihood strategies and even preferred food. It is therefore; hypothesized that there is a positive relationship between food security and the level of education of the head of the households.

Social capital Assets: Access to social groups and connectedness has been defined as an individual's sense of belonging within individual relationships, a group, or a community (Plesko, Yu & Tobin, 2022). Access to social groups and connectedness play a significant role in determining food security, particularly in low-income communities (Clore, Agrawal & Kolm, 2024).

Research has shown that community connectedness, social networks, and social capital are crucial factors in maintaining food security (Gwenyth et al., 2018).

Table 2 Description of Independent variables used in binary and multinomial logistic regression models

Types of Livelihood Asset	Description	Independent Variables	Type	Expected signs
Human capital	The skills, knowledge, ability to labor and good health that together enable people to pursue different livelihood strategies and achieve their livelihood objectives.	Gender of household heads	Dummy,1 for male, otherwise "0"	+
		Age of household heads	Categorical	±
		Education Level of household heads	Categorical variable transformed in to Dummy	+
Social capital	Membership of more formalized groups which entails adherence to mutually-agreed or commonly accepted rules, norms and sanctions; relationships, networks and connectedness of trust amongst communities.	Access to social groups and connectedness	Dummy Dummy,1 if access, otherwise "0"	+
Physical capital	The basic infrastructure goods and services needed to support livelihoods.	Access to information communication networks	Dummy,1 if access, otherwise "0"	+
		Access to extension services	Dummy1 if access, otherwise "0"	+
Natural capital	Natural resource stocks from which resource flows and services useful to drive livelihoods (Forest land, water bodies & wetland resources)	Land holding size/ha/	Categorical	+
		Access to landscape-ecosystem resources	Dummy1 if access, otherwise "0"	+
Financial capital	The assets households require to deliver goods and services that provides resources to invest, grow and fuel economic activities	Access to credit services	Dummy,1 if access, otherwise "0"	±
		Annual income /ETBirr/*	/Continuous/Categorical	+

* Conversion of South Sudanese Pound (SDG) to Ethiopian Birr (ETB) based on 2021 national conversation rate of 1 SDG=0.0982 ETB.

Source: Survey Data (2022)

Farm household heads with low social connectedness may lack financial buffers through friends and family, leading to challenges in accessing food when resources are scarce (Plesko et al., 2022).The studies highlight the complex interplay of social connectedness with other social determinants of food security, emphasizing the importance of incorporating social connectedness to address food security and human well-being effectively. This suggests that social groups and organized communities can enhance food security by providing support, resources, and empowerment opportunities, particularly for marginalized communities.

Physical capital Assets: Access to desirable, sufficient, safe and nutritious food is a basic component of development and the health of a society. Amongst developing country goals and priorities, food security is of utmost importance. To achieve these goals, most observers of rural development believe that, the necessary condition for obtaining food security is access to information communication technologies networks. Information communication network consist of various collections of resources and technical tools that are used for connecting, spreading, storing and managing information (Pigato, 2004),

including an extensive scope of traditional & old technologies (Farhad et al., 2011; Sharma, Shahbaz, Kautish, & Vo, 2021) and modern media (Norad, 2002), such as radios, televisions, wireless phones (Lashgarara & Mohammad, 2011) and human interactions (Lashgarara et al., (2010). Moreover, access to extension services enhances households' access to diversify their livelihood strategies, and these help to improve the food security status and participate in different livelihood strategies. Thus, this study hypothesizes that the frequency of extension visits is expected to affect food security and the choice of livelihood strategies.

Access to landscape-ecosystem resources in this study refers to farm households' engagement or choice of land resources such as forest land, water bodies and wetland provisioning ecosystems to diversify livelihood income so as to maintain their household food security. In this regard there is considerable evidence that the ability to access landscape-ecosystem resources are positively correlated with income and/or welfare of rural households in regions that have remained primarily marginal (Jayne et al., 2003; Chamberlin & Ricker-Gilbert, 2016). The argument linking access to landscape-ecosystem resources to food security is related to the aspect of food availability. Burgess (2001) argues that under imperfect food markets, landscape-ecosystems can serve as a source of cheaper food relative to market-purchased food. Holden & Ghebru (2016) and Holden, Otsuka, Place, (2008) also provide comprehensive reviews of the literature examining the relationship between access to land resources and access to food. A growing body of evidence, from a variety of settings around the world, illustrates the positive correlation between access to landscape-ecosystems resources and livelihood diversification and further with household food security.

Financial capital Assets: Farm households who have access to finance would have a favorable impact on diversification of income generating livelihood strategies and are better food secure. This demonstrates the clear link between access to credit services and of household food security. Therefore, it is expected that having access to credit services will have a positive effect on farm household heads income diversification strategies and households' levels of food security through concerted decision-makings on diversifying livelihood strategies, while the more with annual income of the farm household heads will diversify various livelihoods and will have appositive effect on farm households' food security.

RESULTS

Demographic, Socio-economic and Livelihood Characteristics of Farm Households

The households' human capital, social capital, physical capital, natural capital and financial capital assets are important variables in relation livelihood strategies and food security. The study examines the respondents' capital assets; livelihood strategies and food security of farm the households in Boma-Gambella Trans-Boundary Landscape. Gender, age of the household heads and level of education were used to describe the respondents' human capital assets to relate with food security of farm households in the study area. Table 3 shows the descriptive statistics of the variables used in the model. The results show that out of the total of 207 sample farm household heads in the study area 97.1% were headed by a male with the remaining 2.9% households headed by female household heads. The results also reveal that the age of the respondents ranged from 22 to 68 years, with an average of 43.1 years with standard deviation of $\pm$12.5.

With respect to their educational status of the respondents 70% of the respondents were illiterate, while only 30% were literate with adult education, elementary education, certificate and diploma levels of education. Social groups and organized communities can enhance food security by providing support, resources, and empowerment opportunities, particularly for

marginalized communities. In this particular study, descriptive statistics show that only 24.2 % of the respondents have access to social groups and connectedness.

Physical capital Assets such as access to information communication networks and access to extension services account 23.2% and 17.9%, while, with regard to natural capital assets, farm household heads have mean land holding size of 1.86 with standard deviations of $\pm$ 0.59 and only 19.3% of household heads have access to landscape-ecosystem resources. The descriptive statistics for financial capital assets also indicate that 25.1% of farm household heads have access to credit services with annual average income of 4993.7 ETBirr with standard deviation of $\pm$2688.9.

Table 3 shows the main ecosystem based livelihood strategies of farm households in Boma-Gambella Trans- Boundary Landscape. The results reveal that farm household heads were engaged in on-farm off-farm ecosystem based livelihood strategies as reported by 52.7 % of the farm household heads followed by On-farm ecosystem based livelihood strategies (21.7%), On-farm_Non-farm ecosystem based livelihood strategies (14%) and Mix (on-farm_off-farm_non-farm) of livelihood strategies (11.6%).

Table 3 Descriptive statistics of the variables used in the model

Variables		Abbreviations	Description of variable	Frequency	Percent	Mean	St. Deviation
Dependent variables	Ecosystems based livelihoods strategies	On-farm	On-farm ecosystem based livelihood strategies	45	21.7		
		Off-farm	Off-farm ecosystem based livelihood strategies	109	52.7		
		Non-farm	Non-farm ecosystem based livelihood strategies	29	14		
		On-farm_Off-farm_Non-farm	Mix of livelihood strategies	24	11.6		
Independent variables	Gender of the Household Heads	G_HH	Male	201	97.1		
			Female	6	2.9		
	Age of Household Heads	AG_HH	18-34 Yrs.	54	26.1	43.05	12.513
			35-59Yrs	116	56		
			60-64Yrs	31	15		
			>=65Yrs	6	2.9		
	Access to information communication networks	ACC_INFO	Yes	48	23.2		
			No	159	76.8		
	Access to social networks & connectedness	ACC_SN	Yes	151	72.9		
			No	56	27.1		
	Access extension services	ACC_EXT	Yes	37	17.9		
			No	170	82.1		
	Access to credit resources	ACC_CR	Yes	52	25.1		
			No	155	74.9		
	Access to landscape-ecosystem resources	ACC_LSCP_ES	Yes	40	19.3		
			No	167	80.7		
	Education level of the Household Head	EDU_HH	Literate	62	30		
			Unable to read and write	145	70		
	Land holding size (ha)	LH_SIZ	0.5 - 1 ha	98	47.3	1.86	0.59
			1.1 - 2 ha	53	25.6		
			2.1 - 3 ha	43	20.8		
			> 3 ha	13	6.3		
	Annual income of household heads	ANN_INCM*	<5000	127	61.4	4993.7	2688.9
			5000-10000	68	32.9		
			>10000	12	5.8		

- Conversion of South Sudanese Pound(SDG) to Ethiopian Birr (ETB) based on 2021 national conversation rate of 1 SDG=0.0982 ETB

Source: Household Survey (2022)

ECONOMETRIC MODEL RESULTS

Model Fitting Information

Multinomial logistic regression also known as multinomial (MNL) logit is a classification method that generalizes logistic regression to multiclass problems, i.e. with more than two possible discrete outcomes (Malouf, 2002). It is a model that is used to predict the probabilities of the different possible outcomes of a categorically distributed dependent variable, given a set of independent variables. In the application of MNL In this study, the assumptions such as multi-collinearity between independent variables, and the outliers/highly influential variables were checked using variance inflation factor (VIF) and tolerance value (Green, 2003). VIF is the reciprocal of the tolerance value; small VIF values indicates low correlation among variables under ideal conditions VIF<3. A VIF $\geq$ 10 mean that variables are highly correlated. However it is acceptable if it is less than 10. Multi-collinearity exists when there is a correlation between multiple independent variables in a multiple regression model. The results indicate that, VIF for all variables lies between 1.075 and 9.058, and therefore, there is no problem of multi-collinearity in this particular study. Thus, it is acceptable since VIF is less than 10. The larger value of Variance Inflation Factor (VIF) values exceeds 10, indicates a serious multi-collinearity problem (Gujjirati, 2003). The multicollinearity test results have shown no serious problems among the continuous and categorical independent variables, since VIF < 10 for all variables in the mode (Table 4).

Table 4 Multi-collinearity Diagnosis among Model Variables

Variables	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B		Collinearity Statistics	
	B	Std. Error	Beta			Lower Bound	Upper Bound	Tolerance	VIF
(Constant)	-1.539	0.235		-6.547	0	-2.003	-1.076		
G_HH	-0.089	0.126	-0.017	-0.703	0.483	-0.337	0.16	0.931	1.075
AG_HH	0.028	0.048	0.023	0.59	0.556	-0.066	0.122	0.352	2.844
EDU_HH	-0.165	0.093	-0.085	-1.767	0.079	-0.349	0.019	0.227	4.406
ANN_INC	0.147	0.064	0.099	2.313	0.022	0.022	0.272	0.283	3.528
ACC_IFO	0.615	0.145	0.291	4.226	0	0.328	0.901	0.11	9.058
ACC_SNG	1.263	0.082	0.628	15.431	0	1.102	1.425	0.314	3.18
ACC_EXT	-0.247	0.191	-0.106	-1.292	0.198	-0.623	0.13	0.078	6.837
ACC_CR	-0.001	0.065	-0.001	-0.017	0.987	-0.129	0.127	0.525	1.905
LH_SIZ	0.098	0.038	0.105	2.554	0.011	0.022	0.174	0.3	3.336
ACC_LSCP_ESR	0.726	0.216	0.321	3.366	0.001	0.301	1.151	0.057	7.427

Source: Survey Data (2022)

The effect of explanatory variables on the influence of rural farm households' decision to diversify their livelihood sources is analyzed using a Multinomial Logistic (MNL) regression model. The 2 log likelihood ratio test (-9.972) shows that the estimated model fit for data analysis. The Likelihood Ratio Tests-Chi-square (469.490) suggested that the estimated model has an excellent explanatory power at p-value < 0.001 and

therefore, reject the hypothesis that adoption of livelihood strategies are independent of the explanatory variables and therefore, the hypothesis that explanatory variables are statistically significant and positively related to choosing livelihood strategies is accepted (Bowen & Wiersema, 2004). The Nagelkerke (Pseudo R-Square (R^2) value (0.987) result shows that 98.7% of the variance in explanatory variables was explained by the model.

Multinomial Logistic Regression Model /MNL/ Results

Multinomial logit regression model shows the effects of variables for each category versus the reference category. Accordingly, the reference category is the household who choose On-farm alone as a livelihood strategy. The SPSS version 20.2 was used to generate the parameter and marginal estimate results. The parameter estimates of the multinomial logit model give only the direction of the effect of explanatory variables on the dependent variable, but the estimates neither stand for the actual size of change nor the probabilities (Wulff, 2015). However, the marginal odds ratio effect measures the expected change in the probability of a given choice that has been made in relation to the unit change in the explanatory variable. Thus, the predicted probabilities are better interpreted using the marginal odds ratio effects of the multinomial model (Greene, 2003). The multinomial logit model analysis shows that out of the total ten fourteen explanatory variables entered into the model three variables of human capital assets such as age (AG_ HH), Education level of household heads (EDU_HH), family size (FM_SIZ), and Two financial capital assets such as access to credit services (ACC_CR), annual income (ANN_INCM) were influencing rural household choice of livelihood strategies of On-farm-Non-farm livelihood strategies at different significant levels. Out of the total explanatory variables entered for determining On-farm_off-farm livelihood strategies seven three variables of human capital assets includes age of household heads (AG_HH), Gender of Household Heads (G_HH), Family Size (F_SIZ); two Variables of natural capital assets such as land holding size (LH_SIZ) and Access to Landscape Resources' (ACC_LSCPR); one variables from social capital assets such as Access to Social Network Groups (ACC_SNG) were influencing rural households choice of On-farm_Off-farm_Non-farm livelihood strategies at different significant levels. Furthermore, from ten explanatory variables entered to the model eight variables including age of household heads (AG_HH), Gender of household heads (G_HH), land holding size (LH_SIZ), annual income (ANN_INCM) were influencing rural household choice of On-farm, Off- farm, Non-farm and mix of livelihood strategies at different significant levels (Table 6). However, the magnitude effects of significant variables are not similar for the choice of livelihood strategies. Therefore, the following descriptions show the multinomial logit analysis results indicating the selection of each type of livelihood strategy affected by different factors and at different levels of probability.

Human capital Assets: The analysis of marginal odds ratio (β-Exp) effect shows that human capital was the most important determining force in livelihood diversification process, as all of the selected independent variables of human capital assets significantly affected farm households' engagement in ecosystem based livelihood strategies. The MNL logit model results of the marginal odds ratio effect results of age of household heads, show that the likelihood of farm household heads choice of off-farm livelihood strategies decreased by a factor of (OR < 1 = 0.439) relative to the choice of on-farm livelihood strategies alone as age of farm households

decreased by one year; and the likelihood of farm household heads choice of mix of livelihood strategies increased by a factor of (OR >1 = 6.401) relative to the choice of on-farm livelihood strategies alone as age of farm households increased by one year. The possible reason is that farm household heads, whose age is relatively older, leaving other factors constant, could be pushed to engage more in mix of livelihood activities. This is because, old farm households have more experience and sufficient knowledge on non-farm and mix of livelihood income sources from the environment and outside of on-farm activities to support their livelihoods compared to the younger farm households. Therefore, older farm household heads have to rely more on mix of livelihood strategies than the younger ones to support their livelihoods. This result is in contrary with studies by Bannett et al, (2015).

The marginal effect results of the Multinomial Logistic regression model also show that the odds-ratio (β-Exp) in favor of the probability of farm household heads to choose mixed income generating livelihood strategies increased by a factor of 6.401as the age of household heads increased by 1year relative to engaging only in on-farm livelihood strategies. This is mainly because old age groups are comparatively well aware of the environment, and therefore, can able to take risks in off-farm livelihood opportunities such as fishing in lakes & river banks, and wild meat collection in the forest areas. This is also probably because old age groups have a wide range experiences on diversifying income generating livelihoods from local resources.

Social capital Assets: The odds-ratio (β-Exp) results show that in favor of the probability of farm household heads to choose On-farm_Off-farm income generating livelihood strategies relative to engaging only in on-farm livelihood strategies decreased by a factor of (OR<1 = 0.187), as farm household heads do not have access to extension services and the probability of farm household heads to choose On-farm_Non-farm and mixed of livelihood strategies relative to choosing on-farm livelihood strategies increased by a factor of (OR $\geq$ 1 = 1.709 and 1.89) as access to extension services increased by one respectively.

Physical Capital Assets: The marginal effect of odds-ratio (β-Exp) results show that in favor of the probability of farm household heads to choose mix of ecosystem based livelihood strategies increased by a factor of 3.62 as access to information communication networks increased by one and influenced by a factor of 0.145 as access to communication networks decreased by one.

Natural Capital Assets: The majority of the farm households in the study area own an average of 0.59ha of land size which might have resulted in an inverse relationship between land ownership and On-farm livelihood diversification. Therefore, such small landholding size could not generate sufficient livelihood income to ensure household food security and thus, most farm households were pushed towards generating income through Off-farm and Non-farm livelihood strategies. The odds-ratio (β-Exp) of the MNL model results indicate that in favor of the probability of farm household heads to choose On-farm_Off--farm and mix of livelihood strategies relative to engaging only in on-farm livelihood strategies increased by a factor of 7.056 and 9.01 as land holding size (LH_SIZ) of farm household heads increased by 1ha respectively.

Table 5 Marginal effect results of Multinomial logistic regression model.

Capital Assets	Variables	Livelihood strategies								
		On-farm_Off-farm Strategies			On-farm_Non-farm Strategies			Mix of Strategies		
		β-Coefficients	Std. Error	OR/Exp(B)	β-Coefficients	Std. Error	OR/Exp(B)	β-Coefficients	Std. Error	OR/Exp(β)
	Intercept	0.648	7.756		11.502	3.643		25.244	6.387	
Human capital	G_HH	1.417	1.366	4.125	-19.968	1.404	0.869	6.342	1.819	5.678
	AG_HH	5.659***	1.847	0.439	0.834	1.282	2.302	9.521**	2.836	6.401
	EDU_HH	0.478	0.758	1.613	19.745**	2.157	0.681	16.345***	1.32	6.31
Social capital	ACC_IFO	10.081***	4.386	0.145	0.759	2.419	2.136	8.546*	3.62	3.722
Physical capital	ACC_SN	0.615	0.923	0.187	32.383***	1.2	1.709	26.992**	1.174	1.89
	ACC_EXT	-11.741*	2.217	7.96	-24.970***	1.587	6.99	-1.064**	4.499	0.345
Natural capital	LH_SIZ	-7.740**	3.583	7.056	0.452	1.283	1.571	-9.314***	2.514	9.01
	ACC_LSCP_ES_R	12.914***	2.262	2.46	-28.381***	3.637	0.72	36.002**	4.636	2.31
Financial capital	ACC_CR	0.344	0.831	1.41	-24.136*	1.054	3.29	-15.950***	1.535	4.84
	ANN_INC	11.188*	6.261	1.571	30.322***	0.923	1.47	5.629	4.787	2.784
Reference category:		On-farm Livelihood Strategies								
-2 Log Likelihood Model fitting		Intercept only 479.462 Final 9.972								
Likelihood Ratio Tests (Chi-square)		469.490								
Degrees of freedom		60								
Nagelkerke (Pseudo R-Square)		0.987								
Significance (P-value)		< 0.001								

***, **,* Significance level P-value < 0.01, 0.05 and 0.1 level of probability respectively

Source: Survey data (2022)

The results are in line with Ibekwe et al., (2010), who argue that small land holding size owned by farm households have negative and significant relationship with On-farm_Off-farm and On-farm-Non-farm income diversification strategies, while the findings are conquered with the Funmilola (2012), who reported a positive relationship between land holding size and Off-farm & Non-farm income diversification strategies. Moreover, adequate access to landscape-ecosystem resources for farm households is a crucial component with important implications for income diversification and food security. Accordingly, access to landscape-ecosystem resources increased the likelihood of Non-farm income diversification among farm households in the study area. Farm household heads with more access to landscape-ecosystem resources, such as forest land, water bodies and wetlands, derive greater proportion of ecosystem based livelihood income from Off-farm strategies and mix of strategies. The odds-ratio (β-Exp) results of the MNL model show that the probability of farm household heads to engage in off-farm and mix of livelihood strategies relative to engaging only in on-farm livelihood strategies increased by a factor of 2.46 and 2.31as access to landscape-ecosystem resources increased by one respectively and farm households choice of non-farm livelihood strategies decreased by factor of 0.72 for those farm households who do not have access to landscape-ecosystem resources. The results are supported by many findings as Devereux & Sussex (2000) and Christine et al., (2008).

Financial capital Assets: The marginal effect results of the MNL model confirm that in favor the probability of farm household heads to choose Non-farm and mix of income generating strategies relative to engaging only in on-farm livelihood strategies decreased by a factor of (OR >1 =3.29 and 4.84) respectively as access to credit services increased by one unit. The marginal effect results of the model show that households with large household income are more likely to diversify the livelihood strategies into off-farm, and mix of livelihood strategies. The possible reason could be that, farm households with large annual income can able engage in alternative livelihood strategies The result of the study is in line with study conducted by Wallole et al., (2021) who found that annual income has positive and significant effect on On-farm_Off-farm livelihood strategies and having adequate income sources can overcome financial constraints to engage in alternative livelihood strategies.

DISCUSSION

The study highlight the complexities of ecosystem-based livelihood diversification in the Boma-Gambella Trans-Boundary Landscape, a region shared between Southwest Ethiopia and East South Sudan. The study examines the interplay of various capital assets; human, financial, natural, and social, in shaping the livelihood strategies adopted by farm households.

The research reveals that farm households in this region rely heavily on the provisioning services of their surrounding ecosystems, with the most common livelihood strategies being a mix of on-farm and off-farm activities (52.7%) and on-farm activities alone (21.7%). This dependence on the natural environment underscores the importance of sustainable resource management to support the long-term well-being of these communities.

The study's quantitative analysis, using a Multinomial Logistic Regression model, provides nuanced insights into the factors influencing livelihood choices. Age emerged as a significant factor within the human capital assets,

with older household heads being more inclined to engage in a combination of on-farm, off-farm, and non-farm activities, leveraging their accumulated experience and knowledge.

Financial capital, measured by access to credit services and annual income, also played a crucial role. Households with greater financial resources exhibited a higher likelihood of diversifying their livelihood strategies, perhaps by investing in new ventures for mitigating risks associated with specific activities. This finding underscores the need to improve access to financial services for rural communities to enhance their capacity to adapt the changes in ecosystems services. The finding is concurrent with the studies of Davis et al. (2019) and Barrett et al. (2021).

The study emphasize the critical importance of natural capital, particularly land holding size and access to ecosystem resources, in shaping livelihood choices. Smaller landholdings often pushed households towards engaging in off-farm and non-farm activities to supplement their agricultural income, underlining the limitations of relying solely on on-farm activities in contexts where land is scarce. Conversely, access to diverse ecosystem resources, such as forests, water bodies, and wetlands, increased the likelihood of engaging in off-farm and mixed livelihood strategies, showcasing the potential of well-managed ecosystems to provide diverse income-generating opportunities. This result is in agreement with the findings of Ellis (2000) and Kassa et al. (2020).

Furthermore, the study demonstrates the significant role of social capital, specifically access to extension services and social network groups, in facilitating livelihood diversification. Households with better access to extension services and social networks were more likely to engage in a mix of livelihood activities, highlighting the benefits of information sharing, knowledge transfer, and community support in navigating the complexities of livelihood choices. The result is consistent with the findings of Asfaw et al. (2020).

The study's findings emphasize the need for a holistic approach to rural development that goes beyond merely focusing on increasing agricultural productivity. Policies should focus on strengthening all four types of capital assets such as human, financial, natural, and social, to empower farm households to make informed choices and adapt to changing circumstances.

CONCLUSION

This study examined the engagement of farm households in ecosystem-based livelihood diversification strategies within the Boma-Gambella Trans-Boundary Landscape, located in Southwest Ethiopia and East South Sudan. The main objective was to understand how various capital assets influence the choices of livelihood strategies among these households. The researchers utilized a Multinomial Logistic Regression model to analyze data collected through a mixed-methods sequential explanatory design that combined qualitative and quantitative approaches, including focus group discussions, key informant interviews, and a questionnaire survey.

The study found that farm households in the Boma-Gambella Trans-Boundary Landscape rely on diverse income-generating livelihood strategies derived from the provisioning services of the natural environment and ecosystems. The most common livelihood strategies are on-farm_off-farm (52.7%) and on-farm (21.7%), indicating the significant role of both agricultural and non-agricultural activities in the region.

The econometric analysis revealed that human capital assets, such as age, education level, and family size, were the most influential factors in determining livelihood strategy choices. Older household heads were more likely to choose a mix of on-farm, off-farm, and non-farm livelihood strategies compared to younger ones, who were more inclined towards off-farm activities alone. This highlights the importance of experience and knowledge in navigating diverse livelihood options. Financial capital assets, including access to credit services and annual income, also played a significant role, with households having better access to credit and higher annual incomes being more likely to pursue diverse livelihood strategies.

The study also emphasized the significance of natural capital assets, such as land holding size and access to ecosystem resources, which influence the choice of on-farm, off-farm, and mixed livelihood strategies. Households with smaller landholdings were more likely to engage in off-farm and non-farm activities to supplement their livelihoods, indicating the limitations of relying solely on agricultural activities when land resources are scarce. Access to ecosystem services, including, forest land, water bodies, and wetlands, increased the likelihood of pursuing off-farm and mixed livelihood strategies, demonstrating the importance of maintaining healthy ecosystems to support diverse livelihood options.

Furthermore, social capital, measured by access to extension services and social network groups, also impacted livelihood choices. Households with better access to extension services and social networks were more likely to engage in a mix of on-farm, off-farm, and non-farm activities, highlighting the role of information sharing and community support in facilitating livelihood diversification.

The study concludes by advocating for an integrated approach to rural development that focuses on strengthening human, financial, natural, and social capital assets. Policymakers are urged to prioritize the creation of ecosystem based livelihood strategies, improve access to information and social networking opportunities, enhance the productivity of on-farm activities, and promote opportunities in rural off-farm activities to support the diverse needs and constraints of farm households. By fostering a holistic approach that aligns economic growth with environmental sustainability, the study underscores the potential of ecosystem-based livelihood diversification strategies to enhance the resilience and well-being of rural communities in the Boma-Gambella landscape and similar socio-ecological contexts across Africa.

DECLARATIONS

CRediT Authorship Taxonomy: Azemir Berhanu Getahun: Writing-original draft preparation, formal analysis, methodology, visualization and software; Amare Bantider Dagnew: Conceptualization, data curation and writing-review and editing; Desalegn Yayeh Ayal: Investigation, supervision and writing-review & editing. Authors have read and agreed to the published version of the article.

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