Detecting trade-offs, synergies and bundles among ecosystem services demand using sociodemographic data in Omo Biosphere Reserve, Nigeria

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Abstract

The complexity of the relationships among multiple ecosystem services (ES) is not fully understood. This could be because of the difficulty in assessing ES relationships, in general, and particularly, an uneven study of geographical distribution and the relationships among ES demand remains under-researched. Yet, understanding relationships among multiple ES can support policy and management decisions, from problem definition to interventions. This novel research focused on addressing some of the challenges, presenting relationships among ES demand undertaken in Omo Biosphere Reserve (OBR), Nigeria, to improve understanding and extend the geographical coverage of ES relationship studies. In this study, primary data were obtained using a questionnaire survey administered to 302 individuals in OBR. Multinomial regression, correlation and factor analysis were used to identify key ES, explain the influence of sociodemographic attributes on ES preferences and identify the trade-offs, synergies and bundles of ES demand, respectively. The results showed that there were 18 key ES demanded with more preference for provisioning ES such as crops than other ES. Few sociodemographic attributes were identified to influence people's preferences for ES. Furthermore, major trade-offs occurred between provisioning ES with synergies observed among provisioning, regulating and cultural ES. Of the six bundles identified, the first three bundles explained 53% of the total variance which involved environmental, health and basic needs. Our findings not only provide valuable information that could help achieve a well-managed landscape but also support decision-making process and management strategies that could potentially strengthen rural livelihoods.

Keywords: Trade-offs; Synergies; Bundles; Ecosystem services; Rural landscape; Biosphere Reserve

Introduction

The human population is projected to reach 8.6 billion in 2030 and 11.2 billion in 2100 (UN DESA 2017). This growth rate is expected to increase pressure on ecosystem services (ES) (Chawanji *et al.* 2018). ES such as food, fuel, freshwater, climate and flood regulation, aesthetics and tourism, not only contribute to meeting daily needs and livelihoods, but also to achieving sustainable development, especially for people in rural areas (Engelman 2010). However, humans have altered the ecosystems through over-exploitation, thus, compromising the ability of these ecosystems to sustain the supply of ES. This situation calls for more resilient, sustainable and well-managed ecosystems to meet both present and future demands for ES. According to the Millennium Ecosystem Assessment (MEA), one key effort towards achieving a well-managed ecosystem is to have an in-depth understanding of the complex relationships between ES (supply and demand) at varying scales (MA 2005). Such informed understanding could support the sustainable management of ES and anticipation of the impacts of environmental changes (Mouchet *et al.* 2014; Yang *et al.* 2015). While studies on relationship among ES focused more on the ES supply, the ES demand is still under-researched, which makes the complexity of the relationship among ES not to be fully understood. Relationships among ES can result in two situations: firstly, a state where a service increases at the cost of decreasing another service, which is termed trade-offs (Rodriguez *et al.* 2006); alternatively, where the use of one ES directly increases the benefits supplied by another service, which is referred to as synergies (Berry *et al.* 2016). Similarly, a set of ES often associate to form bundles (Saidi and Spray 2018). Identifying trade-offs, synergies and bundles will provide an improved understanding of ES relationships. Subsequently, such understanding will help to support ecosystem management and policy development (Spake *et al*. 2017).

Several studies have addressed relationships among ES. For example, Raudsepp-Hearne *et al.* (2010) analysed ES interactions using ES bundles in different landscapes in Quebec, Canada; and Haase *et al.* (2012) discussed an analytical framework in an urban area to determine relationships among ES using Leipzig-Halle, Germany as the case study. Briner *et al.* (2013) evaluated the trade-offs and synergies among food production, biodiversity conservation, carbon sequestration, and protection against natural hazards in central Valais, Switzerland. Also, Pena *et al.* (2018) analysed the relationship between ES (trade-offs and synergies) to reorient land use planning in Metropolitan Bilbao in Northern Spain. A more recent study by Schirpke *et al.* (2019) enhanced the understanding of interactions among multiple ES by integrating ES supply, flow and demand. Though the studies on ES trade-offs and synergies in the scientific community has gained increasing attention (Geijzendorffer *et al.* 2015; Cord *et al.* 2017), several regions remain unrepresented or under-represented (Howe *et al.* 2014). For instance, there is a paucity of information on ES relationships in Africa. This uneven geographical distribution of ES case studies could be a drawback in achieving sustained ecosystems globally because relationships among ES are context and site-specific (Gonzalez-Ollauri and Mickovski 2017).

Furthermore, there are limited practical applications of ES trade-offs and synergies studies in land management decision making (Daily *et al*. 2009). The reason for such neglect could be because studies focusing on multiple ES and their interdependence are still very few (Ring *et al.* 2010). Therefore, understanding trade-offs and synergies require broader studies that consider multiple ES in the same landscape (Tallis *et al.* 2008; Bennett *et al.* 2009). Recent studies have emphasised the need for integrating stakeholders in ES studies (Cord *et al.* 2017), stating that stakeholders' participation and engagement is one of the ways to improve methods of assessing ES (Gardner 2010). However, several ES studies depend largely on proxies obtained from secondary data such as land use data. Increasing dependence on secondary data could be the primary reason why no or little evidence is seen when integrating ES studies into policy and decision-making process.

This study, therefore, identified trade-offs, synergies and bundles of key ES demand in Omo Biosphere Reserve (OBR), Nigeria to improve understanding and extend the geographical coverage of ES relationship studies. ES demand in this study was expressed as individual preferences as introduced by Wolff *et al.* (2015), though Cord *et al.* (2017) defined such preferences as "potential demand". The information presented in this study will help improve the understanding of how multiple ES interact and provide empirical evidence for ES management. Also, this study is intended to provide a valuable resource that could facilitate decision-making processes to achieve more productive and sustainably managed multifunctional ecosystems.

Methods

To achieve the aim of this research, firstly, we identified the ecosystem services that people prefer. This was followed by examining the influence of sociodemographic attributes on the preferred ES. Lastly, we identified the synergies, trade-offs and bundles among the prioritised ES demands.

Study area

Biosphere reserves are the "*principal internationally designated areas dedicated to sustainable development in the twenty-first century*" (UNESCO, 2017). The Man and the Biosphere Programme (MAB) strategy 2015-2025 proposes that biosphere reserves would achieve reconciling conservation with human needs. Hence, these sites have been a major scientific laboratory for environmental studies. Omo Biosphere Reserve (OBR) in Ogun State, Nigeria was designated as a biosphere reserve by the United Nations Educational, Scientific and Cultural Organization (UNESCO) MAB programme in 1977 (UNESCO, 2001). This reserve derived its name from river Omo that traverses it, located between Latitude 6^{o} 35' to 7 ^{o} 05' N and Longitude 4 ^{o} 19' to 4 ^{o} 40' E in the Ijebu area of Ogun State in southwestern Nigeria. OBR covers an area of 130,600 hectares and a Strict Nature Reserve of 460 hectares with more than 20,000 inhabitants living within its borders (Ola-Adams 2014). The reserve is characterized by a mixed moist semi-evergreen rainforest type of vegetation (White 1983). The forest estate has an estimated distance of about 20 kilometres from the Atlantic coast in its southern-most parts (Okali and Ola-Adams 1987). Majority of the inhabitants depend on farming, hunting, fishing, hired labour, timber contractors and on collection of non-timber forest products as their primary profession. For example, men's notable occupation is palm wine tapping while women collect and sell the leaves of *Thaumatococcus daniellii*, edible fruits and spices (Isichei 1995). Other profession includes mechanics, tailors, carpenters, blacksmiths and herbalists (UNESCO 2015). Most of the people living in and around the reserve are descendants of the Ijebu tribe, an extraction of the Yoruba ethnic group in Nigeria (UNESCO 2015).

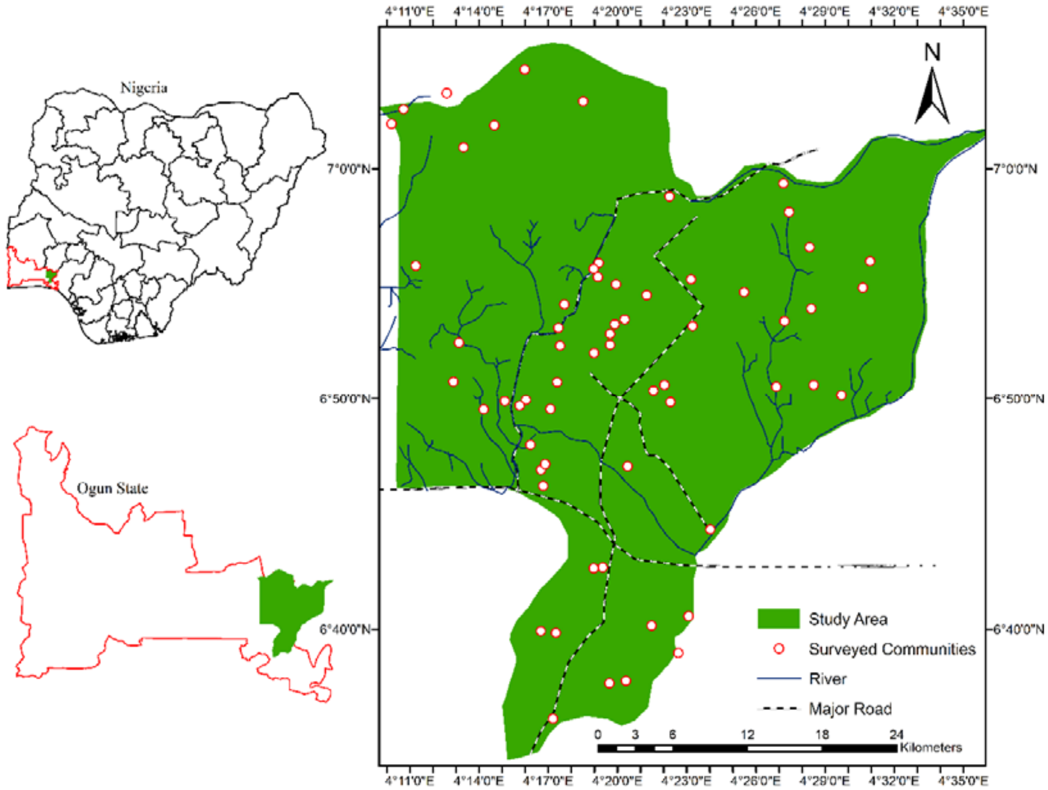


Figure 1. Map of Omo Biosphere Reserve showing the location of the surveyed communities.

Identifying preferred ecosystem services

Previous studies (Raudsepp-Hearne *et al.* 2010; Turner *et al.* 2014; Pena *et al.* 2018; Chawanji *et al.* 2018; Schirpke *et al.* 2019) adopted the use of proxies such as land use map to identify ES for ES interaction analysis. However, several researchers (Bennett *et al.* 2009; Burkhard *et al.* 2009; Seppelt *et al.* 2011) have questioned the accuracy of using land use/land cover data for assessing ES and the associated proxies (quality land use/land cover) are not always available for most local ES studies. Hence, this study used local knowledge to obtain data on the ES demanded as well as identification of their importance to livelihoods. We identified 65 communities within the boundaries of the OBRA, where the one-on-one questionnaire survey was conducted to identify the most relevant ES to the local communities within the OBR. Three hundred and two adult (above 18 years) respondents were sampled using purposive and snowball sampling to retrieve information including the sociodemographic, important and prioritised ES.

Examining factors influencing the preferences for ES

Multinomial logistic regression was used to predict more than two categories of dependent variables based on an independent variable. In this study, we modelled the probability of preferred ES as a function of sociodemographic factors using univariate multinomial logistic regression with a generalized logistic link. The dependent variable had four possible discrete outcomes: no preference, low preference, medium preference and high preference. In a multinomial logistic regression model, the estimates for the parameters identified were compared to a reference category. Here, the probability of no preference for ES demand was used as the reference category. The multinomial logistic regression model can be expressed as follows:

$$log\left(\frac{\pi_i}{\pi_r}\right) = \beta_{1i} + \beta_{2i}\mathcal{X}$$

Where π_i is the probability of the categories of preferred of ES (low preference, medium preference and high preference), π_r is the probability of the reference categories (no preference); $\mathcal{X}$ is the independent or predictor variable (gender, age, education level, income level, household size, occupation) and β_{1i} and β_{2i} are the regression coefficients that were estimated using maximum likelihood. Model goodness-of-fit was evaluated using the chi-squared statistic.

Analysing ecosystem services demands' trade-offs, synergies and bundles

The preferred ES were analysed to understand the linkages between them. The primary data collected from the questionnaire survey were subjected to square-root transformation to give a more uniform distribution for Pearson's correlation analysis. The analysis was conducted to calculate the pairwise relationships between the preferred ES using R statistical software (R version 3.5.3) (see Cord *et al.* 2017; Schirpke *et al.* 2019). The correlation coefficients indicated the strength and direction of each ES pair. Based on the classification by Cohen (1992), the correlation coefficients were classified into; high correlation ($r \geq 0.5$), moderate correlation ($0.3 \leq r < 0.5$) and weak correlation ($0.1 \leq r < 0.3$).

Pearson correlation coefficient can be expressed as.

$$r_{xy} = \frac{n\sum x_i y_i - \sum x_i \sum y_i}{\sqrt{n\sum x_i^2 - \left(\sum x_i\right)^2}\ \sqrt{n\sum y_i^2 - \left(\sum y_i\right)^2}}$$

Where r_{xy} is Pearson r correlation coefficient between x and y, n is the number of observations while x_i and y_i are values of x and y for ith observation respectively. Following previous studies (e.g. Turner *et al.* 2014; Williams *et al.* 2017), principal component analysis (PCA) was used to determine preferred ES bundles. The PCA analysis helped to understand the multivariate interrelationships between the ES and to uncover the underlying structure in the ES demand by identifying sets of associated ES preferred in OBR. The Kaiser-Guttman criterion, eigenvalue>1 was used to determine the PCA axes adequate to characterise the non-random structure in the data (Plieninger *et al*. 2013). Varimax rotation was used and items with factor loadings of greater than 0.49 were included.

Results

Demographics and frequencies

As presented in Figure1, the majority (66%) of the respondents were male, while about half of the sampled population were between 36 and 55 years. Over 40% of the respondents earned between ₦10,000 and ₦30,000 per month with the highest household population being between 3 and 4 persons. The sample included a higher share of farmers (73%), possibly because the landscape supports farming activities and most of the respondents only had primary and secondary education, limiting their chances to get white-collar jobs in the city.

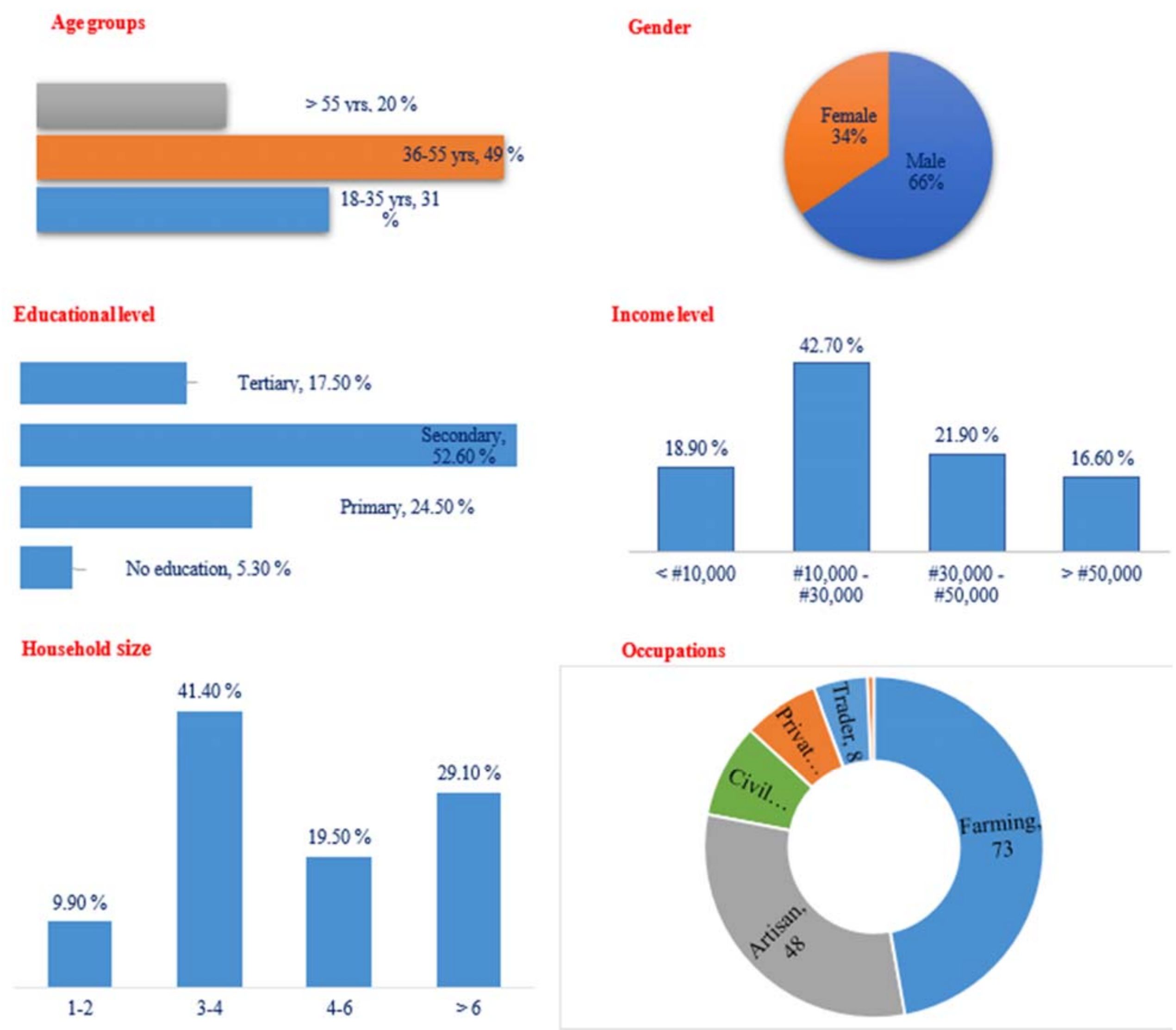
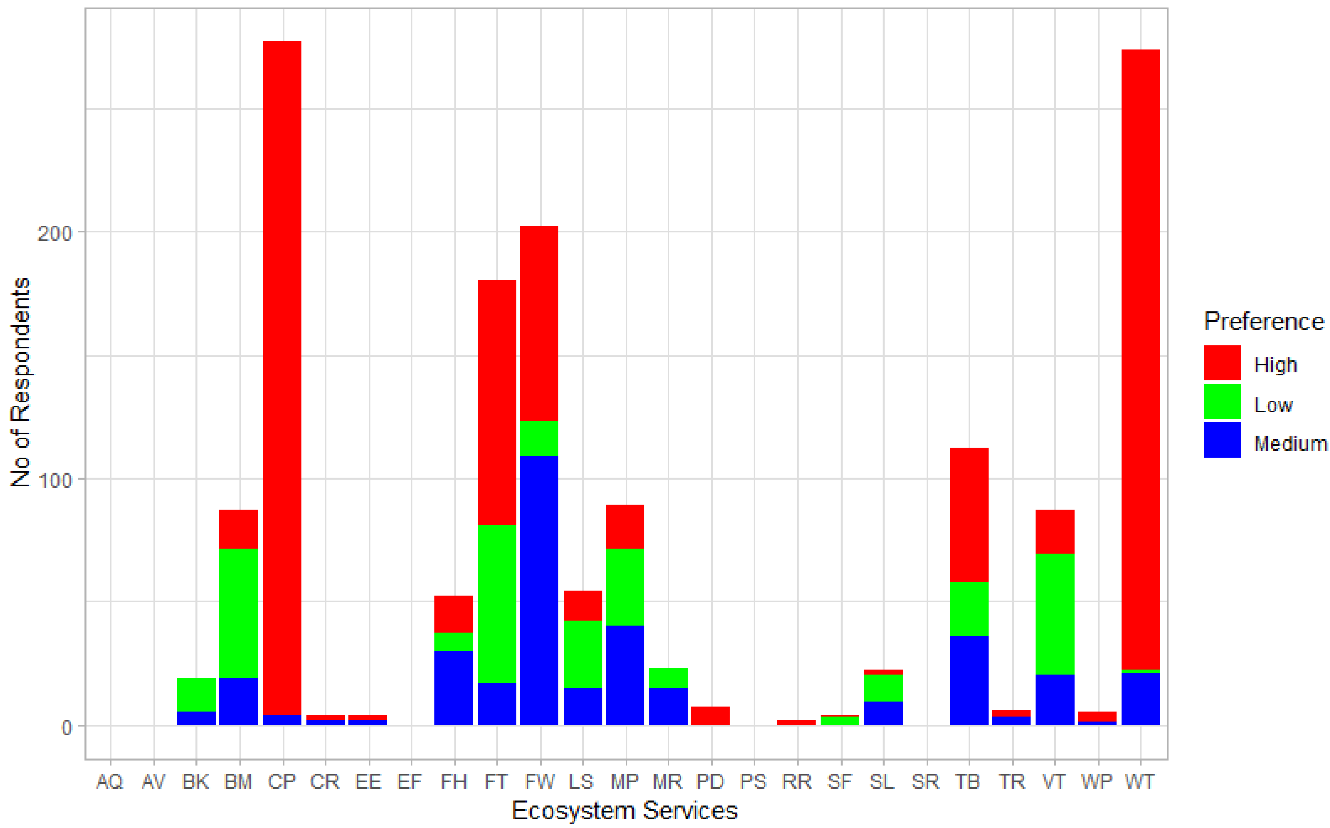


Figure 2. Socio-demographic information of the sampled population in OBR (n = 302; ₦ = USD$30

Identification of preferred ecosystem services



(AQ = air quality, AV=aesthetic values, BK=beekeeping, BM=bush meat, CP=crop, CR=climate regulation, EE=environmental education, EF=erosion and flood control, FH=fish, FT=fruit, FW=firewood, LS=livestock, MP=medicinal plant, MR=mushroom, PD=pest and diseases, PS=pollination and seed dispersal, RR=recreation and recreation, SF=maintenance of soil fertility, SL=snail, SR=spiritual and religious, TB=timber, TR=tourism, VT=vegetable, , WP=water purification WT=water)

Figure 3. Respondents' preference for ecosystem services in Omo Biosphere Reserve

In total, 25 ES were identified from the questionnaire survey (Figure 2). Each identified ES was ranked based on perception and use. The provisioning ES such as crop, fruit, firewood, timber and water were of high priority (91.72%, 59.60%, 66.89%, 37.09% and 90.73% respectively) to the people while many of the cultural and regulating ES, for example, aesthetic values, spiritual and religious, erosion and flooding control, pollination and seed dispersal, water purification do not have any response and were of no preference. Specifically, the result showed that crop. fruit, water, firewood and timber were the five most highly preferred ES in Omo Biosphere Reserve.

Table 1. Multinomial logistic regression analysis to predict preference for ES using sociodemographic factors

Dependent variables		**Independent variables (Coefficients)**							
		Crops[c]	**Fruits[c]**	**Livestock[b]**	**Mushroom[b]**	**Pest & Dis Ctl[c]**	**Timber[b]**	**Vegetable[b]**	**Water[c]**
Gender	Intercept	1.543	-1.101	-18.804	-32.872	-26.381	-2.455	-19.116	1.833
	Male	**-1.556***	0.181	0.583	0.380	-12.659	-0.206	-0.492	-0.212
Age	18 - 35yrs	-.353	-0.226	-0.846	0.239	25.927	0.457	**5.365***	1.047
	36 -55yrs	-.286	-0.683	-0.109	-1.633	13.577	1.549	-0.438	0.94
Education level	No education	.234	0.251	-17.768	-0.798	9.546	1.019	**6.164***	-0.241
	Primary education	-1.250	0.596	-1.791	-1.093	-37.356	0.625	-14.405	0.595
	Secondary education	.846	-0.537	**-2.179***	-1.510	-0.287	1.154	3.038	0.801
Income level	₦10,000	**-2.042***	-0.148	1.287	17.071	-24.85	-1.349	-2.391	-4.357
	₦10,000 - ₦30,000	-.129	-0.432	0.315	0.844	-38.288	-0.256	-2.726	-1.864
	₦30,000 - ₦50,000	-.955	0.157	0.101	17.519	-26.505	**-1.836***	-1.454	**-2.789***
Household size	1 - 2	1.358	-0.102	1.094	1.544	20.809	0.185	-19.461	1.378
	3 - 4	**1.091***	-0.3	1.200	-0.989	24.576	0.203	**-3.656***	**1.311***
	5 - 6	1.261	-0.601	-1.298	1.022	48.249	0.289	-3.145	0.428
Occupation	Farming	**2.365***	1.865	16.598	13.942	-23.387	-1.053	13.703	0.987
	Hunting	-12.631	18.471	0.750	15.086	82.526	17.907	19.03	14.54
	Artisan	1.080	0.719	17.085	14.449	-37.805	0.269	14.016	3.18
	Private company	2.493	0.912	0.572	-0.662	-11.722	0.612	2.153	13.643
	Trader	1.281	-13.987	-1.168	-2.609	-12.779	-12.255	21.406	14.58
Model fitting information	R^2	0.423	0.273	0.316	0.518	0.816	0.250	0.500	0.375
	χ^2	85.904	86.520	78.822	64.507	34.246	74.762	48.924	90.571
	P	< 0.01	< 0.01	< 0.05	< 0.01	< 0.01	<0.05	<0.05	<0.001

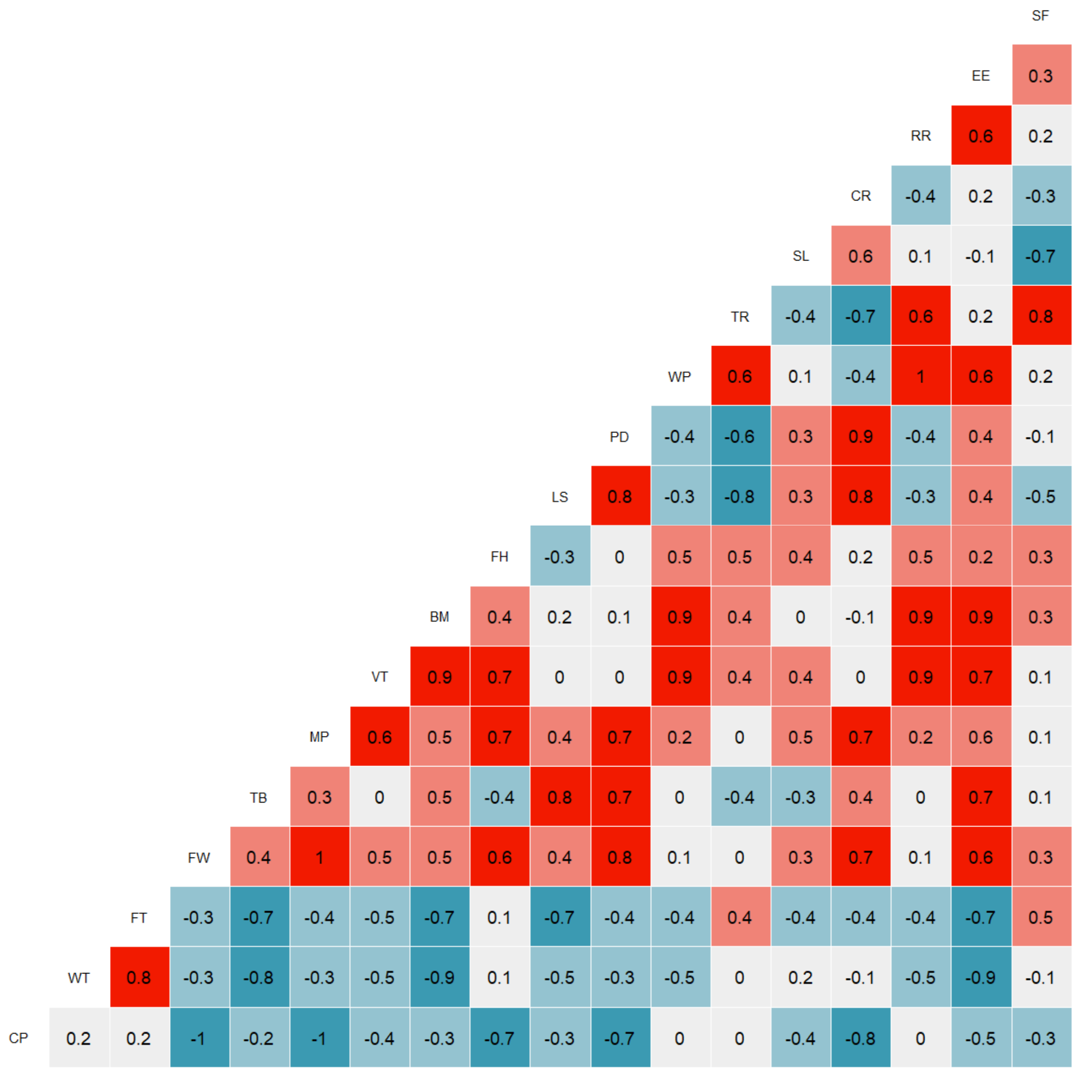
a is low preference (which does not have significant value, therefore, not presented)
b is "middle preference" & c is "high preference"
The reference category is "no preference"

Factors influencing ecosystem services preferences

In Table 1, multinomial logistic regression (MLR) models were fitted to predict the probability of the ES preferences using the sociodemographic factors as the predictor variable. Regression models with a statistically significant value of $p < 0.05$ were retained, representing 8 ES out of the 18 key ES. Furthermore, according to the result of the MLR model, the sociodemographic factors that explained which respondent would more likely prefer the key ES (such as crops) were household size of 3-4 people, when the respondents were farmer, age group of 18-35 years, and no education. While the results indicated that respondents would less likely prefer certain ES, for example, crops when they are male, have an income level of ₦10,000, it also showed less preference for timber when their income level is between ₦30,000 and ₦50,000.

Ecosystem services demands' trade-offs, synergies and bundles

There were only 9 (6 positive, 3 negative) significant pair-wise correlations between ES, which were all highly correlated ($r \geq 0.5$) (Figure 3). The negative correlation primarily occurred between the provisioning ES. Also, water and environmental education were negative while the medicinal plant and firewood were positive. The positive correlation predominantly appeared between the regulating, provisioning and cultural services. Positively correlated ES are assumed to be synergistic, while negative correlations implied trade-offs (Tomscha and Gergel 2016).



(CP=crop, WT=water, FT=fruit, FW=firewood, TB=timber, MP=medicinal plant, VT=vegetable, BM=bush meat, FH=fish, LS=livestock, PD=pest and diseases, WP=water purification, TR=tourism, SL=snail, CR=climate regulation, RR=recreation and recreation, EE=environmental education, SF=maintenance of soil fertility)

Figure 4. Pearson's correlation matrix between the ES attributes. Colour toward blue represents negative correlations while those toward red explain positive correlations. Number in each cell identifies correlation value

Table 2. Factor loadings derived from the PCA of ES, the eigenvalues and the total variance explained of the six bundles.

Items	Bundles[a]					
	Environmental	Health	Basic need	Utilities	Forest product	Seafood
Relaxation and Regulation	.942					
Water Purification	.926					
Tourism	.786					
Environmental and Education	.764					
Climate Regulation		.936				
Snail		.936				
Medicinal Plant		.807				
Crop			.909			
Water			.823			
Fruit			.751			
Bush Meat				.970		
Vegetables				.775		
Livestock				.586		
Timber					.825	
Pest and Disease Control					.729	
Firewood					.712	
Soil Fertility Maintenance*						
Fish						.615
Eigenvalue	3.714	3.323	2.5	2.188	1.832	1.331
Percent of total variance explained [b]	20.635	18.461	13.889	12.156	10.176	7.395

[a]Factor loadings from PCA with varimax rotation; [b]Total cumulative percent of variance explained = 82.711%; *The item did not significantly load onto any factor.

Table 2 presented the principal component analysis using varimax rotation. Eigenvalues greater than 1 were retained. Also, factor loadings below 0.5 were suppressed to identify the preferred ES bundles. The total cumulative percentage variance explained from the six bundles was 82.711%. Of all the 18 key ES analysed, only soil fertility maintenance did not significantly load onto any factor. The environmental bundle accounted for the highest percentage of total variance at 20.635%. The seafood bundle explained just 7.398% of the total variance and only fish was loading strongly onto this bundle.

Discussion

This study presented methods for identifying trade-offs and synergies among ES demands using sociodemographic data. It empirically identified ES demand bundles in a rural landscape, providing information for landscape management and policy development. First, we identified the key ES demand using people's preferences. Then, we assessed the sociodemographic factors influencing choices for ES. Further, the study showed trade-offs and synergies formed among the ES demands, while presenting the possible sets of ES demands that could be grouped.

Identification of preferred ecosystem services

We described the potential ES demand for people living in OBR by identifying their preferences. The people identified and appreciated a wide range of ES provided by the ecosystems. Notably, provisioning ES were easily identified and ranked as the highest priority, while regulating and cultural ES were less identified and preferred, corroborating findings in previous studies (Fisher *et al.* 2011; Orenstein and Groner 2014; Ouko *et al.* 2018). A possible reason why provisioning ES was more appreciated could be linked to direct dependence on these ES for daily livelihoods. Iniguez-Gallardo *et al.* (2018) explained that management strategies and the activities of different stakeholders were the two major factors influencing how people prioritise ES, especially in protected areas. While this statement might be true, it is not the case for Biosphere Reserves, including OBR because only a fraction of the area, that is the core area, is protected while the transition and buffer zones are accessible. Furthermore, Casalegno *et al.* (2014) suggested that people's preferences could generally depend on their interest, ecosystem features and management system. From our study, we argue that people's perception of ES was probably due to the dependence on ES for daily needs and their sociodemographic characteristics. This finding not only provides a better understanding of people's demand on the ecosystem to improve decision making but also serves as an input for further analysis geared towards ecosystem management.

Factors influencing ecosystem services preferences

Respondents prioritised ES differently, hence, the demand for each ES also differed. For example, while 98% of the respondents had preferences for crops, less than half of the respondents prioritised timber. We, therefore, sought to understand the sociodemographic attributes that could predict local people's preference for ES. While there may be several factors influencing local people's preference for ES, this study focused on sociodemographic factors. This study presented evidence that, in a rural landscape, young people with no formal education that practised farming had more desire for some key ES such as crops and vegetables. Though it is generally common for young people to migrate to the city to work, those without formal education may likely choose to settle in a landscape where they can access ES for daily livelihood. Notably, the result indicated that females would likely prefer crops than males. Majority of the female respondents (79%) were involved primarily in farming activities, a proportion higher than the male counterparts. In contrast, male respondents mostly engaged in other activities such as artisan and owning a private business. This result confirmed the previous report that women were the primary food producers in the world, producing between 60% and 80% of the world's food (Doss *et al.* 2018). Additionally, the results showed that the middle-income earners (₦30,000 to ₦50,000 per month) would less likely prefer timber, which could infer that it is the low- and high-income earners that preferred timber harvesting. The reason for this situation could be because most of the middle-income earners were either artisans or workers in a private company. Consequently, enhancing the technical skills of artisans and creating more jobs for people may reduce the attention and pressure forests from timber harvesting. This information would be valuable for ES conservation as well as livelihood intervention programmes.

Ecosystem services demands' trade-offs, synergies and bundles

Trade-offs and synergies are primarily the major forms of relationships among ES (Bennett *et al.* 2009). From our findings, the correlation among the ES was mostly weak and not significant,. A recent study by Schirpke *et al.* (2019) also reported similar results. Our results showed trade-offs among the provisioning ES (crops and firewood), between provisioning, cultural and regulating services (environmental education and water). This result is congruent to previous studies (Ricketts *et al.* 2004; Raudsepp-Hearne *et al.* 2010; Yang *et al.* 2015). Furthermore, trade-offs between provisioning ES could be driven by changes in land use. This change could affect the availability of ES, consequently, the demand as explained by Nelson *et al.* (2009). While such an explanation may hold, we also believe that the level of education could influence the trade-offs between provisioning and cultural ES as seen in the case of environmental education and water, fruit, and crop (see Figure 3). This implies that people seeking knowledge about the environment would likely appreciate and have more preference for cultural than provisioning ES. In contrast, the demand for regulating and cultural ES is majorly in synergistic relationships as reported by Lee and Lautenbach (2016). For example, people demanding climate regulation, pest and diseases control, water purification were also in need of recreation and relaxation (see Figure 3). It is important to note that ES demand trade-offs and synergies could be as a result of differences in individuals' demands. Furthermore, Schirpke et al. (2019) stated that the differences in ES demand could be linked to the changes in the beneficiary's landscape and land use. However, since our study was carried out in a single landscape with forest and agricultural land use, we believe such differences in ES demand could be related to people's occupation and activities within the landscape. For example, a farmer would demand more of a crop than tourism or environmental education, whereas a civil servant may likely appreciate water purification and climate regulation than firewood or fruits.

For a rural landscape, this research demonstrated that ES bundles could potentially provide landscape managers with a more nuanced perspective on how they might consider multiple demands across diverse stakeholders. This study analysed key ES in OBR to determine whether there was a common preference for groups of ES among the local people. In OBR, six types of ES bundles (environmental, health, basic food, utilities, forest products, seafood) were identified. There were close agreements with the bundles identified near Mount Baker Snoqualmie National

Forest in Washington (Williams *et al.* 2017). From the findings, three (basic food, utilities and forest products) of the six preferred ES bundles were provisioning ES, explaining people's dependence on provisioning ES. Assessing ES preferred bundles, on the one hand, could help to better understand the sets of ES people demand, and on the other hand, provide an understanding that could inform policies towards prioritising management strategies for ES to meet people's demands.

Conclusion

This study attempted to fill an important gap in ES assessments by analysing relationships among ES demands in a rural landscape within the context of a Biosphere Reserve. This study may be the first of its kind to assess trade-offs, synergies and bundles of ES demand as well as employing the use of primary data to analyse relationships among ES in sub-Saharan Africa. Key ES were identified and ranked based on people's preferences. In congruence with previous studies, provisioning ES remained the most prioritised ES types. This study demonstrated that sociodemographic factors could influence ES demand preferences, but further research is needed to examine other possible drivers. Besides, the assessment of trade-offs, synergies and bundles of ES preference provide a more nuanced perception of how landscape managers might consider multiple demands across diverse stakeholders.

A limitation of this study was that the data collected were not an actual ES demand, but a potential ES demand based on people's preferences and desires. However, this study could substantially improve the understanding of relationships among multiple ES in a rural landscape and provide valuable information for decision and policy-making. Future research should aim at including assessment of flow and supply of ES to better understand the relationships between the individual and multiple ES.

Acknowledgement

We appreciate the support of the Forestry Research Institute of Nigeria (FRIN). More importantly, we appreciate everyone that participated in the survey.

Compliance with ethical statement

- **Conflict of Interest**

  Opeyemi Adeyemi, Paxie Chirwa, Folaranmi Dapo Babalola, Pasicha Chaikaew, declare that they have no conflict of interest.

- **Funding**

  This research was supported by the South Africa's National Research Foundation (NRF)-African Renaissance Doctoral Scholarship with grant number; 11084.

- **Informed Consent**

  Informed consent was obtained from all individual participants involved in this research.

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