

Ecosystem service preferences across multilevel stakeholders in co-managed forests: Case of Aberdare protected forest ecosystem in Kenya

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Abstract

A better understanding of Ecosystem Services (ES) contributes to sustainable use while conserving the ecosystems mainly in resource-rich developing regions. This paper explores multilevel stakeholder perceptions on the most important ES provided by Aberdare Forest Ecosystem (AFE). The importance rank matrix model was employed to establish the ES preferences of 15 selected key organisations involved in AFE co-management. A two-way ANOVA inferential analysis was used to compare the differences in ES type importance. The results revealed statistically significant differences between provisioning, regulating and cultural ES. Regulating ES were identified as the most important compared to provisioning and cultural ES; a gradual stakeholder preference shift from forest tangible goods. Water, wildlife habitat, flood regulation, carbon intake and climate regulation were identified as the most important ES by all the stakeholders. Therefore, it is important to understand the gradual changes in ES preferences by various stakeholders involved in the co-management of natural resources.

This knowledge could be important to the decision-makers in sustainable co-management planning for natural resources and to enhance sustainable utilization of ES.

Keywords

Ecosystem services, stakeholder perception, protected forests, Aberdare forest, Matrix model

Introduction

Forests have played an important role in supporting the livelihoods of many communities in both rural and urban areas (Djenontin et al. 2018). They cover about 22% of the earth's surface and are vital in regulating the hydrological cycle (Rieprich and Schnegg 2015, Tengö et al. 2017). In the tropical and subtropical regions, forests play a crucial role in both active and passive protection against natural hazards, such as soil erosion and floods during high levels of rainfall (Haurez et al. 2017). However, such roles of the forests are being threatened by anthropogenic impacts and complex environmental issues (Ehlers Smith et al. 2017, Tindall and Robinson 2017). Kenya's forests, just like in other parts of the world, are considered valuable assets because of their role in provisioning of various ecosystem services (ES). Aberdare Forest Ecosystem (AFE) is a compelling case for empirical ES analysis among forests in Kenya. It is a unique ecosystem with myriad benefits, the principal one being to protect and conserve water catchment for Kenya's major rivers. The AFE is one of Kenya's five main "water towers", which provides all the water for Nairobi county and adjacent counties of Murang'a, Kiambu, Nyeri and Nyandarua. However, continued demands for the forest resources have led to substantial changes such as; deforestation, conversion of previous forest areas to cultivated and grazing lands, illegal water abstraction points, introduction of exotic trees and grasses on the indigenous vegetation and sprawling of urban and peri-urban areas (Müller and Mburu 2009, Swallow et al. 2009 Wangai et al. 2019).

Assessing the interactions between people and the forest enhances understanding of the problems encountered for improved policy formulations (Grêt-Regamey et al. 2017). Studies have shown that incorporating ES information into decision-making contributes to environmental decisions that secure future outcomes of the ecosystems (Paavola and Hubacek 2013, Owuor et al. 2017, Ward et al. 2018). A recent approach, established by the Intergovernmental Panel for Biodiversity and Ecosystem Services (IPBES), embraces the role of indigenous local knowledge, human-nature relations, cultural and diverse values in ES also known as nature's contributions to people (NCP) in decision-making (IPBES 2016, Tengö et al. 2017). This approach recognises the role of various actors and institutions that support human-nature relations and the existence of different perceptions on NCP to people's good quality life (Pascual et al. 2017). IPBES aims to evaluate the state of knowledge on past, present and possible trends in multiscale interactions between people and nature considering different world views (IPBES 2014, Ward et al. 2018). The indigenous local knowledge can be assessed through analysis of stakeholders' social networks developed in different cultural contexts (Kilonzi and Ota 2019) as a result of continued interaction with the ecosystems. This explicit data generated by the key stakeholders integrates both local knowledge and international perspectives, important in development of conservation initiatives and management strategies (Brown and Sonwa 2015).

However, most ES assessment studies have focused on biophysical and economic mapping of ES, side-lining the social perspective (Chan et al. 2012, Fagerholm et al. 2016

). Additionally, most studies have emphasised more on global scales which makes their application on national and local scale challenging due to the unique nature of needs at different levels (Naidoo and Ricketts 2006, Palomo et al. 2013, Nedkov et al. 2018). Hence, the need to increase assessment at smaller scales, as well as ensure consistency in capturing all the relevant parameters necessary for decision-makers to address at the local level (Díaz et al. 2018, Owuor et al. 2017). Moreover, studies have shown reliance on participatory approaches that include local stakeholder viewpoints, since different stakeholders have different interests, perceptions and knowledge regarding the ecosystem and its services (Brescancin et al. 2018). In agreement with IPBES in capturing the current local knowledge on ES preferences, this paper explores the current ES (NCPs) preferences through the perception of selected key multilevel stakeholders involved in the co-management of AFE, using the importance rank matrix model, a local scale approach.

The importance matrix rank model is among the most popular participatory approaches (Burkhard et al. 2009) that allows involvement of relevant stakeholders and provides comprehensive measurable data which is understandable and easy to map (Burkhard et al. 2014, Jacobs et al. 2015). This method has been used in various case studies to solve challenging socio-ecological complexity and has resulted in quality decisions that cater for the high policy demands in natural resource management (Jacobs et al. 2015). Various ES components such as management capacity, ES use and importance, demand, among others can be assessed using the matrix rank model (Burkhard et al. 2014). Some of the case studies done using the model include:

1. the installation of offshore wind parks in the North Sea in Germany that established new forms of human effects on environment, using new technology in the marine and coastal environments (Burkhard et al. 2011),
2. the method was also applied in the boreal areas in northern Finland in the forestry ecosystem and in the German island of Sylt to examine the impact of tourism on the ecosystems (Gee 2010) and
3. in the Kenyan coast to assess the flow of ES from mangrove forests (Owuor et al. 2017).

Credibly, matrix rank model has been used to identify ES, establish stakeholder opinions on the ES, as well as establish scientifically sound and politically legitimate results that have been proved efficient, fast, accessible and easily adaptable (Jacobs et al. 2015).

The paper organisation is as follows; the materials and methods section describe the study area, the stakeholder selection criteria and justification for their selection to participate in the survey. It also describes in detail, the matrix rank method used in data collection and analysis. The results and discussion section provide the findings of the study on the various ES types, the rank scores by each organisation and the ES estimate of locations within the AFE. The last section provides the conclusions and recommendations of the study.

Materials and Methods

Study area

AFE is within four administrative counties of Kiambu, Nyeri, Nyandarua and Murang'a, located in the central region of Kenya. AFE is approximately 226,522 ha, whereby the Forest Reserve covers an area of 149,822 ha and the National Park covers 76,700 ha (Fig. 1) (KFS 2010). The forest ecosystem is on a series of mountainous ranges that vary in altitude ranging from 2,000 m on the eastern forest boundary to 4,000 m at the peak towards the northern edge of the range. The rainfall distribution is greatly influenced by the altitude (Massey et al. 2014). The eastern region experiences an equatorial type of climate, which is wet and humid with reliable rainfall of 1,400-2,200 mm and extended wet seasons. On the western side, rainfall reduces sharply from about 1,400 mm at the forest border to less than 700 mm (Langat et al. 2017Wambugu. et al. 2018). The forest ecosystem has myriad benefits, the principal one being to protect and conserve water catchment for Kenya's major rivers (KFS 2010, Massey et al. 2014). AFE provides 80% of the water to Nairobi county and the adjacent counties of Kiambu, Muran'ga, Nyandarua and Nyeri through Ndakaini and Sasumua dam reserves. Over four million farmers depend on its rich soils for tea and coffee farming (KFS 2010).

Background on AFE management

Two approaches characterise the management of AFE. The first approach is through construction of an electric fence around the forest reserve as a strategy to stabilise the human-wildlife conflict that affected the area. Over the years, the need for more agricultural land intensified because of increased population growth, resulting in encroachment on the forest boundary. This led to human-wildlife conflict as a result of crop damage by the wildlife and, in turn, killing of the endangered species. To solve these issues, under the management of the Rhino Ark charitable trust, the AFE was entirely fenced with hot-wired upright electric posts to deter wildlife from escaping (Massey et al. 2014). The electric fence protecting over 2000 km² took over 21 years to construct and was completed in 2009.

The second approach is through co-management which follows the direction of the Kenya Forest Act in 2016. Co-management, also referred to as collaborative or participatory forest management, incorporates various stakeholders in a variety of roles (Berkes 2009). The Forest Act provides a framework and incentives for stakeholders' involvement in forest co-management to enhance the contribution of the forest sector in the provision of economic, social and environmental goods and services (Kenya Forests Act 2016). It also aims at improvement of livelihoods through promotion of participation by the community forest associations (CFAs) in sustainable land use and biodiversity conservation activities. It has also been widely perceived that the co-management represents progressive thinking on efforts to reduce the extent of illegal activities and to enhance sustainable resource use (Movuh 2012). For instance, the CFAs are granted user rights to the forest resources on

condition that the rights promote the conservation efforts of the forest (Matiku et al. 2013, Wambugu. et al. 2018). Therefore, this study focused on understanding the ES preferences of the various stakeholders involved in the co-management of AFE.

Stakeholder selection and justification

The initial list was developed after a literature search on stakeholders involved in the co-management of AFE (Kenya Forests Act 2016) that comprised of 50 organisations grouped into the following categories: public institutions, NGOs, community-based organisations, development partners, business groups, faith-based organisations and educational institutions. The second step involved a pre-survey to 10 randomly selected stakeholders representing organisations in each category. During the survey, the stakeholders were required to nominate other organisations whom they considered important and influential in the forest management, including their own institutions. The final list was developed following the nominations in the pre-survey that comprised of 15 multilevel stakeholders/ organisations classified into three groups; community-based organisations (CBOs), government organisations (GOs) and Non-governmental organisations (NGOs).

They include;

- Community-based organisations (n = 4): Community Forest Associations (CFAs) whose role is to co-manage the forest together with other stakeholders. Water Resource Users Association (WRUA), mandated to end water use conflicts and sensitise farmers on water catchment management. Ndakaini Dam Environmental Conservation Association (NDEKA) which coordinates conservation projects in Ndakaini dam catchment and lastly, Kijabe Environmental Volunteers (KENVO) whose focus is on AFE conservation through income-generating projects and protection of endangered bird species.
- Public/government organisations (N=8): Kenya Forest Service (KFS), mandated to ensure forest protection and conservation. Kenya Wildlife Service (KWS), obligated to conserve and manage wildlife and enforce related laws. Kenya Forest Research Institute (KEFRI), focuses on forest science and research. Kenya Tea Development Authority (KTDA), provides effective management to the tea growing sector, including the tea farmers. Kenya Water Tower Agency (KTWA), established to coordinate and oversee the protection, rehabilitation and management of all water towers and the riparian zones. Kenya Water Resource Users Association (WRMA), a state cooperation in charge of all water resources and working closely with WRUA. Nairobi City Water and Sewerage Company (NCWSC), supply water to Nairobi county from AFE and manage Ndakaini and Sasumua dams and, lastly, the Nyayo Tea Zone (NTZ) whose mandate is to promote forest conservation by providing tea buffer zones and assorted tree species to check against human encroachment into the forestland.
- NGOs: (n = 3): World Wide Fund (WWF), focuses on forests and water catchment management through downstream water users. The Nature Conservancy (TNC), whose aim is to conserve forest resources and the Rhino Ark, mandated to manage

the electric fence around the national park in collaboration with KWS and support community-based conservation initiatives.

Fig. 2 shows the detailed number of stakeholders involved in the co-management of the AFE.

Data collection and analysis

This work is based on data collected between September 2017 and August 2018 using a questionnaire method, with qualitative and quantitative interviews to the selected key organisations involved in the co-management of AFE. Before the interviews, the participants were taken through an introductory session in which they refreshed their familiarity with the ecosystem types in Aberdare forest, defined what ES is and discussed the ES classification using the Millennium Ecosystem Assessment (M.E.A) framework. Second, the ES matrix approach was then explained to them. Participants were encouraged to make their scores individually, particularly in cases where representatives in an organisation were more than one, such as in the case of CFAs, KWS and KFS. Verbal consent was also obtained prior to the interviews.

The questionnaire was structured under three main questions, whereby in the first question, the stakeholders were asked to list all the ES they obtained from the AFE. "*What kind of ES did you obtain from AFE?*" ES were also explained as benefits, revenues or returns obtained from the AFE or are of importance to the organisation or community at large. The respondents were allowed to list the ES without necessarily categorising them according to Millennium Ecosystem Assessment framework. Upon exhaustive listing, the stakeholders were presented with the list of possible ES to identify any other obtained ES. The second question required the stakeholders to rank the identified/listed ES using the Likert scale: 0 = not important, 1 = very least important 2 = least important, 3 = medium in importance, 4 = important; 5 = very important, in their perspective to denote the level of ES importance (Burkhard et al. 2009). Follow-up questions to clarify the reasons for the importance rank scores assigned to the various ES were asked where necessary. The last section required the stakeholders to estimate the locations of the identified ES (for the provisioning and cultural ES) on an AFE map provided by use of a marker. Maps can be used as a communication tool to visualise the locations where ES are produced or used (Burkhard et al. 2009).

In the data analysis, the authors categorised all the identified ES as either provisioning (n = 10), regulating (n = 7) or cultural (n = 8) ES according to the Millennium Ecosystem Assessment (MEA) classification in 2005. Then, using the matrix method, the selected 15 organisations were placed in the y-axis of the matrix, while in the x-axis, the 25 ES identified and organised as per the MEA classification were placed. At their interception, the average rank scores by each stakeholder on each ES were provided. For the responses representing more than one interviewee, such as the case of KFS, KWS and CFAs, the rank-based non-parametric method was used to calculate the average rank scores (Shan 2014). The measures of mean for each of the identified/listed 25 ES were analysed by use of the SPSS version 21 software for descriptive statistics (Brown 2011).

Two-way analysis of variance (ANOVA) was used to find the difference amongst stakeholder groups about ES of importance. A post-hoc least significant difference (LSD) test was conducted to find out stakeholder groups multiple comparisons on ES importance/use.

Results and Discussion

Ecosystem Services from AFE

Stakeholders demonstrated wide knowledge on the various ES obtained, their spatial locations within the AFE, as well as the importance rank, based on their usage at the organisational and personal level. Each organisation ranked the identified ES according to importance, as shown in the matrix Suppl. material 1: 5 = very high importance, 4= high importance, 3= medium in importance, 2= little importance, 1= very little importance and 0= not important/not used.

For the provisioning ES, all the interviewed stakeholders identified the water and wildlife habitat as of very high importance (scores of 5) ES provided by AFE, followed by fertile soils which was interpreted as farming or food production by 93% of all the stakeholders. The least identified provisioning ES was medicine with only KENVO ranking it as of very high importance (score of 5). Interestingly, fish, a provisioning ES, was ranked as of high importance by the community-based organisations only, while the rest of the groups did not consider it (fish) as of importance (scores of 0) from AFE. Cumulatively, KENVO topped as the organisation that obtained most ES followed by WRUA and CFA, respectively. Statistical analysis was computed for each organisation group category to calculate the aggregate mean and significance values depicted by the P-value below 0.005 and F-value for each ES. In this category, results showed that micro hydropower and fish were statistically significant ($P = 0.002$) with community-based organisations ranking them as of most importance compared to governmental organisations and NGOs (means scores of 0). Community-based organisations recorded the highest mean scores for all the provisioning services while NGOs had the least mean score, apart from water and wildlife habitat that had an aggregate score of 5.00 as shown in Table 1.

In the regulating ES category, flood regulations, carbon intake and climate regulation were the most important regulating ES, identified by all stakeholders. Other regulating ES of importance included: genetic material, pollination, breeding grounds and seed bucking, respectively. KENVO identified the greatest number of regulating ES while KWS identified the least. The statistical test results showed similar scores (5.00) amongst the three organisation categories for flood regulation, carbon intake and climate regulation ES (Fig. 3). Their P-values could not be computed due to zero standard deviation. The rest of the regulating services did not have significant differences amongst the three groups as shown in Table 2.

In the last category of cultural ES, landscape beauty was ranked as of very high importance (score of 5) by all the interviewed stakeholders with the exception of CFA

(score of 4), followed by tourism/ecotourism, recreation, bird watching, cultural sacrifices, heritage practices and worship (score of 2) (Fig. 4). Some cultural ES were associated with Aberdare national park such as birdwatching, hiking and tourism, whereas others were associated with the general AFE, like landscape beauty. Community-based organisations reported the greatest number of cultural ES compared to the NGOs and government organisation. A two-way ANOVA analysis was also conducted for the cultural ES to understand the differences in importance amongst the three groups. Results showed that differences in importance ranks were statistically significant for all the cultural ES identified, apart from cultural sacrifices, worship and heritage practices which did not have any statistically significant outcomes as shown in Table 3.

Post hoc tests on ES importance rank

A post hoc test on the least significant difference (LSD) was computed to assess the differences amongst the three organisations on the various ES levels of importance. The results showed that, apart from water, the rest of the provisioning services had significant differences (Table 1). There was a difference in ES importance between:

1. community-based organisations and government organisations and
2. community-based organisations and NGOs, but there was no significant difference in importance rank between government organisations and NGOs (0.00).

For regulating services, the results showed that, apart from breeding grounds, the rest of the ES had no significant differences amongst the three groups (Table 2). In the category of cultural ES, apart from heritage practices and worship, the rest of the services had significant differences amongst the three groups (Table 3). Generally, there was a significant difference in ES rank importance between community-based organisations and the other two groups (GOs and NGOs).

Estimated Locations of ES in AFE

All the stakeholders were able to identify from the provided map the locations of the obtained provisioning and cultural ES, although regulating ES could not be spatially depicted due to their nature of occurrence. Most provisioning ES were associated with the Plantation Establishment and Livelihood Improvement Scheme (PELIS) that was introduced after enactment of the Kenya Forest Act in 2005 and 2016, to increase forest cover and restore degraded forests in the country. Various community-based organisations through the CFAs benefit from the PELIS by obtaining land allotments for crop cultivation, as well as tree planting through the agroforestry system (KFS 2010). The members are granted user rights to obtain various provisioning non-timber ES such as fish, honey, herbs/medicine, fuel wood, fodder for grazing their cattle and micro hydropower (KFS 2010). The participatory mapping was used to illustrate the spatial distribution of the ES by use of dots and colours (Fagerholm et al. 2012), as shown in Fig. 5. The areas designated for the PELIS programmes were labelled as PELIS with purple dots, indicating beehive keeping points. The blue dots represented legal water abstraction points within the AFE, as

well as Ndakaini and Sasumua main water catchments. Cultural ES were represented by red colour, indicating shrines in Kereita region in Kiambu county where most religious groups meet for worship, sacrifices and heritage practices, such as circumcision and initiation ceremonies. Regulating and some cultural ES, such as hiking, jogging, birdwatching, tourism and landscape beauty, were represented by the entire AFE, as reported by the stakeholders. The ES mapping was based on the stakeholders' perception and should be treated as estimates and not exact locations; however, this does not significantly influence the results on ES location.

Discussion

This study explored through stakeholder perception, the various ES obtained from AFE, the importance rank scores, as well as the estimated locations within the ecosystem. Additionally, the post hoc test was conducted to assess the differences in ES preferences amongst the three stakeholder groups. These results contribute to the discussion on the current preferences, on the ES knowledge and usage amongst the co-managers. It also helps to analyse the trends and to suggest suitable management plans, as well as conservation strategies for sustainable ES use. Different stakeholder groups have different perceptions and interests in the ecosystem in question, thus it is necessary to understand the motive behind certain actions or interests taken by specific stakeholders towards the ecosystem (Martín-López et al. 2012). Normally, observations of any changes in forest such as growth, productivity and damage influence the stakeholders' actions and decisions in relation to the current situations (Grêt-Regamey et al. 2017, Paavola and Hubacek 2013, Tengö et al. 2017). Besides, most community-based organisations have previously demonstrated high levels of compliance in the conservation projects if their interests are included in the decision-making process (Andrade and Rhodes 2012). For instance, the ultimate mandate of KWS is to ensure in-situ conservation of the forests which implies that a given population is maintained within the community in which it forms a part and in the environment in which it has developed (Braverman 2014). They emphasised the need to ensure minimal use of the forest's tangible goods, as depicted in the low scores in the importance matrix of the ES directly obtained from the forest, such as building materials. Similar sentiments were shared and promoted by Rhino Ark by sensitising the forest adjacent communities through CFAs on alternative livelihoods such as eco-agriculture innovations, ecotourism and beekeeping.

With regard to provisioning services, interesting findings indicate that all stakeholders identified water as the most important provisioning ES from AFE. These findings corroborate existing studies on AFE as an important water catchment providing water-related services to various regions in the country (Massey et al. 2014, Donde et al. 2015, Richard et al. 2016, Ojwang et al. 2017). All the stakeholder groups recognised the role of AFE as a water catchment, however, issues on water over abstraction and illegal abstraction points in the forest cropped up frequently amongst the stakeholders. During the data collection (period of April – August 2018), the AFE region experienced high rainfall, but the Ndakaini dam water levels remained below 30% of its full capacity, according to the NCWSC. As one of the emerging issues, the authors resolved the reasons for the low

water levels from the stakeholders' perspective. Most stakeholders reported insufficient rainfall in the higher altitudes of the forest moorland which feeds Ndakaini dam through underground seepage. The insufficient rainfall in the higher altitude was associated with degradation within the forest. Illegal water abstraction points were also cited as contributing factors to the low water levels in the dam. Despite the very high importance score on water ES, in-depth research is necessary to address such emerging issues to ensure the continued role of AFE as a water catchment area.

Other provisioning services, reported as of high importance, included wildlife habitat and fertile soils. The high wildlife habitat rank could be as a result of the electric fence around the forest that controls the outside movement of the wildlife, hence peaceful co-existence between people and wildlife (KFS 2010). The presence of the deep fertile soils around AFE for tea growing and food crop cultivation was attributed to the high scores for fertile soils in the importance rank matrix. Interestingly, community-based organisations reported only one food-related ES (fish) from the AFE with only one organisation (KENVO) ranking it as of very high importance (score of 5). This indicates a gradual shift from over-reliance on forest products for food or wild animals for protein, as has been documented in many developing countries (Egoh et al. 2012, Strauch et al. 2016) for agricultural crop production. The low scores on food/meat related provisioning ES (from the fish and wildlife) scores could also be associated with the current forest management policies, such as acquisition of forest access rights (Mwangi et al. 2012) or strict rules and penalties on wildlife hunting (Kenya Forests Act 2016).

On regulating services, flood regulation, carbon intake and climate regulation were reported to be of very high importance by all the stakeholders, with an equal rank importance to water, a provisioning service (scores of 5). The deep fertile soils, coupled with high vegetation cover, as well as conservation efforts by various stakeholders including NDEKA and NCWSC around the forest catchment, were attributed to flood reduction and climate regulation in AFE (Matiku et al. 2013). Moreover, stakeholders recognised the essential role of regulating services more than provisioning services with the exception of water and wildlife habitat. This is dissimilar to previous studies whereby people in resource-rich developing economies have reported their highest preference towards provisioning ES of direct benefits, followed by regulating ES and cultural ES (Hartter 2010, Martín-López et al. 2012).

In the cultural ES category, landscape beauty was ranked by all stakeholders as the most important cultural ES provided by AFE, followed by tourism and recreation, respectively. These findings match the case study done in the Ukrainian Carpathians mountain forests where all the stakeholders perceived tourism and aesthetic values (cultural ES) as of more importance to the forestry industry than provisioning ES (Zahvoyska and Bas 2013). Moreover, it could be as a result of economic advancement, whereby global studies have shown that, as countries progress economically, dependence on cultural and regulating ES increases while dependence on provisioning ES decreases (Hernández-Morcillo et al. 2013). However, the rest of the cultural ES were perceived as of little or no importance by most stakeholders which could be due to other factors, including lifestyle change, pre-existing norms and cultures, as well as financial and career status. For instance, medicine/

herbs from the forest and heritage practices (circumcision) were reported as of little or no importance (scores 0 - 2) by most stakeholders as a result of stakeholders' preferences to modern forms of treatment and the dwindling traditional medicine knowledge (Bussmann et al. 2006). The same could be applied to worship as a cultural ES, whereby most people no longer offer sacrifices in the forests and have adopted contemporary religions and worship in buildings rather than in the forests (Strauch et al. 2016).

Generally, the community-based organisations identified the greatest number of ES of importance compared to government organisations and NGOs, as normally, their own well-being is closely connected to ES since they live adjacent to the forests (Ramirez-Gomez et al. 2013). Moreover, government and NGOs group categories ranked most important ES in the regulating and cultural categories, compared to the provisioning services category, information useful in implementation of conservation policies, such as tree planting activities in the hotspot areas (Willemen et al. 2016).

This study matches a study conducted by Wambugu. et al. 2018 in Aberdare forest, whereby forest adjacent communities identified water as the most important provisioning ES from AFE, followed by firewood. With regard to provisioning services, 83% of the respondents valued the AFE predominantly for its regulating benefits, such as climate moderation, water catchment protection, flood and soil erosion control. This is similar to our findings whereby all stakeholder group categories ranked regulating ES as of very high importance (scores of 5) or of high importance (scores of 4). For cultural ES, government organisations (KWS and KFS) valued tourism as the most important due to the revenues accrued, while the adjacent communities cited disparities in benefits-sharing of the accrued revenues (Wambugu. et al. 2018). Similar views were reported by the CFA and WRUA in our study.

Another study on ES flow conducted by Owuor et al. 2017, in the Mida Creek marine reserve along the coastal region of Kenya, revealed that community practitioners generally showed higher and statistically significant differences from the researchers for provisioning services. Mangroves were identified as the most important ecosystems for the provisioning of most ES. Corresponding analysis where obtained in our study whereby the community-based organisations identified the greatest number of ES of importance compared to government organisations and NGOs.

In another study, Wangai et al. 2019 employed the ES matrix approach to spatially display potentials for regulating ES in the peri-urban areas of Nairobi and Kiambu counties. The findings indicated that destruction of vegetation cover has reduced the regulating ES potential while grasslands, wetlands and forests have comparatively high potentials for regulating ES. In our study, AFE was ranked as of very high importance in the provisioning of regulating ES, such as climate and flood regulation.

Conclusions and Recommendations

This study analysed stakeholders' preferences of ES obtained from the Aberdare forest ecosystem, using the matrix rank approach. The results revealed statistically significant differences amongst provisioning, regulating and cultural ES. In the provisioning ES category, all the stakeholders identified water and wildlife habitat as of very high importance (scores of 5) ES provided by AFE. In the regulating ES category, flood regulations, carbon intake and climate regulation were the most important regulating ES identified by all the stakeholders. While in the cultural ES category, landscape beauty was ranked as of very high importance (score of 5) by all the interviewed stakeholders with the exception of CFA (score of 4). Overall, water, wildlife habitat, flood regulation, carbon intake and climate regulation were perceived as the most important ES from AFE. Community-based organisations identified the greatest number of ES services compared to the government organisations and NGOs. However, all the stakeholders recognised the role of AFE in regulating ES provision. Therefore, it is important to understand the gradual changes in ES preferences by various stakeholders involved in the co-management of natural resources. This knowledge could be important to the decision-makers in co-management planning for natural resources and to enhance sustainable utilisation of ES.

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Author contributions

Kilonzi Francisca Mutwa - Conceptualisation, data collection, analysis, writing & reviewing of the final manuscript; Takahiro Ota - Conceptualisation, supervision, review & editing of the manuscript.

Conflicts of interest

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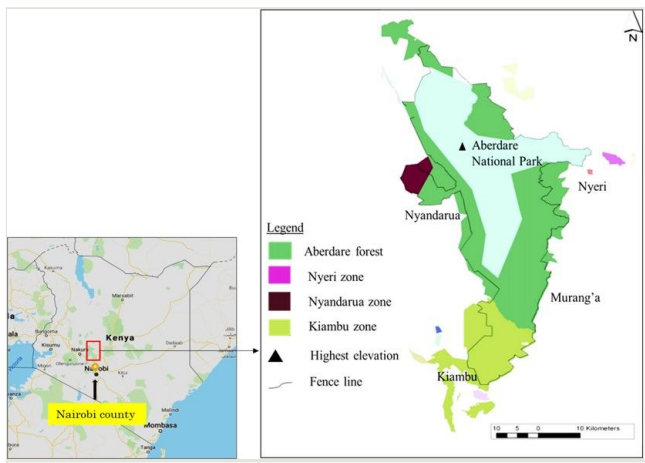


Figure 1. Aberdare Forest Ecosystem.

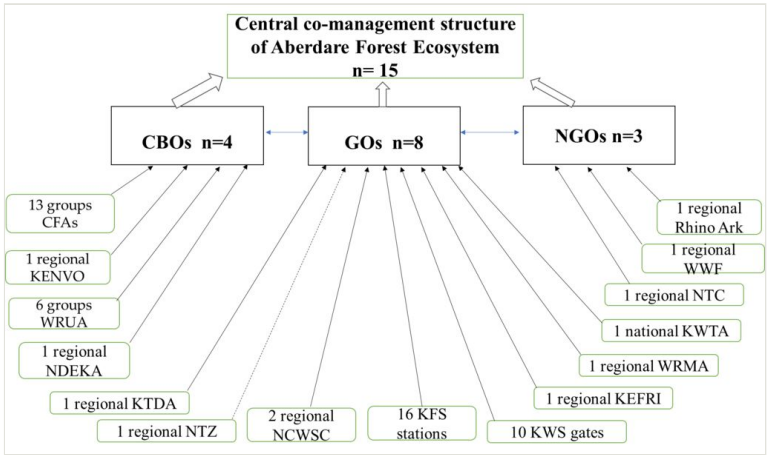


Figure 2.
Central co-management structure of Aberdare protected Forest Ecosystem.

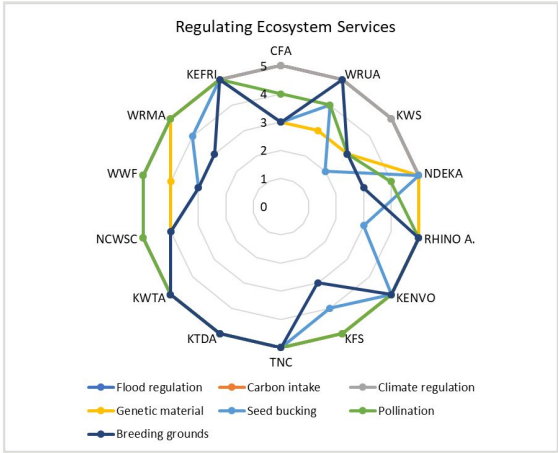


Figure 3. Regulating ecosystem services.

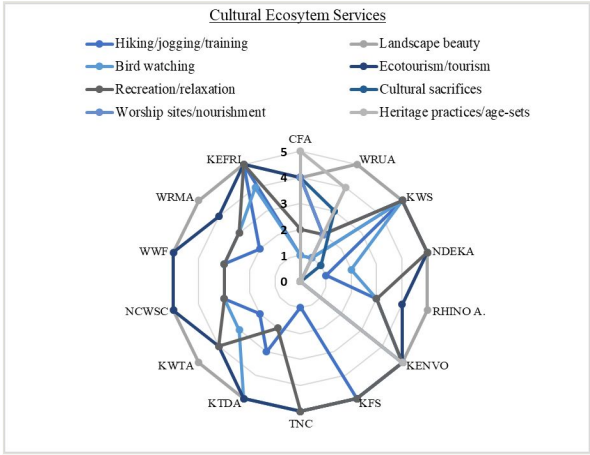


Figure 4.
Cultural ecosystem services.

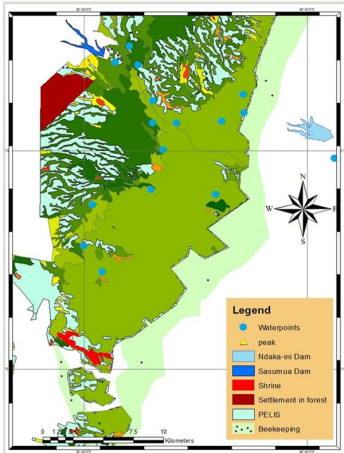


Figure 5.
Estimate location of selected provisioning and cultural ES in AFE.

Table 1.

Summary of ANOVA - test for the provisioning ES.

Provisioning Ecosystem Services	Community Organisations mean score	Government Organisations Mean score	NGO's Mean score	Aggregate mean	F-value	P-value
Water	5.00	5.00	5.00	5.00	-	-
Micro Hydropower	3.25	0.00	0.00	0.93	11.253	0.002
Fuelwood	3.75	1.29	0.00	1.71	3.652	0.061
Fish	3.25	0.00	0.00	0.93	11.253	0.002
Beekeeping	3.75	0.29	0.00	1.21	24.330	-
Wildlife	5.00	5.00	5.00	5.00	-	-
Fertile soil	5.00	4.86	5.00	4.93	0.458	0.644
Grazing	4.25	0.00	0.00	1.21	42.050	-
Medicine	2.50	0.57	0.00	1.00	4.966	0.029
Building materials	2.75	0.71	0.00	1.14	7.016	0.011

Table 2.

Summary of ANOVA-test for the Regulating ES.

Regulating ecosystem services	Community organisations mean score	Government organisations mean score	NGO's mean score	Aggregate mean	F-value	P-value
Flood regulation	5.00	5.00	5.00	5.00	-	-
Carbon intake	5.00	5.00	5.00	5.00	-	-
Climate regulation	5.00	5.00	5.00	5.00	-	-
Genetic material	4.00	4.57	4.67	4.43	0.687	0.523
Seed bucking	4.25	4.14	3.67	4.07	0.293	0.751
Pollination	4.25	4.71	5.00	4.64	1.363	0.296
Breeding grounds	4.00	4.00	4.33	4.07	0.114	0.894

Table 3.

Summary of ANOVA - test for the cultural ES.

Cultural Ecosystem Services	Community Organisations mean score	Government Organisations Mean score	NGO's Mean score	Aggrega mean
Hiking/ jogging/ Training	2.00	3.57	2.33	2.86
Landscape beauty	4.75	5.00	5.00	4.93
Birdwatching	2.25	4.00	3.67	3.43
Ecotourism	4.00	4.71	4.67	4.50
Recreation	3.50	3.86	3.67	3.71
Cultural sacrifices	3.00	0.14	0.00	0.93
Worship sites	2.75	0.00	0.00	0.79
Heritage practices	3.50	0.00	0.00	1.00

Supplementary material

Suppl. material 1: Matrix illustrating ecosystem services significance from AFE

Authors: Kilonzi & Ota

Data type: Matrix table

[Download file](#) (82.22 kb)