INTEGRATED ECOSYSTEM ASSESSMENT TO DEVELOP A SUSTAINABLE MANAGEMENT PLAN FOR OWABI WILDLIFE SANCTUARY IN GHANA

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Integrated ecosystem assessment to develop a sustainable management plan for Owabi Wildlife Sanctuary, Ghana

by

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Table of Contents

Acknowledgements ii

Table of Contents iii

List of Tables v

List of Figures v

List of Acronyms vi

Summary vii

1 Introduction 1

1.1 Background 1

1.2 Problem Statement 2

1.3 Purpose of Study and Research Questions 3

2 Methodology 5

2.1 Methodological framework 5

2.2 Research Methods 5

2.3 Data Collection methods 10

2.4 Statistical analysis 12

3 Previous Management Plan and Activities of Local Communities 14

3.1 Main management measures 14

3.2 Activities of the local communities in the previous management plan 16

3.3 Community characteristics derived from the interviews. 17

3.4 Current activities of local people based on the community interviews 18

4 Ecosystem Services of Owabi Wildlife Sanctuary 19

4.1 Provisioning Services, Current Use and Frequency of Use, Use level and Quantities 19

4.2 Regulating Services and Current use 21

4.3 Cultural Services and Current Use 22

4.4 Habitat Services 23

5 Carrying capacity and Sustainable use level of Ecosystem services of Owabi 24

5.1 Drinking water 24

5.2 Sand 25

5.3 Biological resources 25

6 Stakeholders associated with ecosystem services of Owabi 27

6.1 Interest and influence matrix of stakeholders of Owabi 27

6.2 Power and influence level of stakeholders by communities 29
6.3 Potential conflicts and synergies to communities use of services 29
7 Management and Sustainability of Owabi 31
7.1 Communities support of measure to ensure Owabi sustainability 31
7.2 Implications for the sustainability of ecosystem services of Owabi 32
7.3 Recommendations for management by the Government 33
8 Discussion 35
1 Ecosystem services assessment: comparison with literature 35
2 Involvement of stakeholders in ecosystem assessment 35
3 Lack of data for carrying capacity and sustainable use of ecosystem services: 36
4 Influence of Stakeholder selection and analysis 36
5 Questionnaire approach to ecosystem assessment 37
8.6 Limitations and uncertainties related to data collection and interpretation 37
9 Conclusions 39
9.1 Previous Management measures and activities of the local people (RQ1) 39
9.2 ecosystem services and the amount being harvested by communities (RQ2) 39
9.3 Carrying capacity of ecosystem services and sustainability of the use level (RQ 3) 39
9.4 Main users of Owabi ecosystem services and the potential synergies and conflict among communities and other users (RQ 4) 40
9.5 Management and sustainability of Owabi (RQ5) 40
References 42
Appendices 47
Appendix 1. Community characteristics (demographic and socio-economic) of respondents 47
Appendix 2. Provisioning Services, Current and Frequent Use, Use level and Quantities 49
Appendix 3. Unit value for estimating the quantities of ecosystem services used by communities from Owabi. 53
Appendix 4: Maximum productivity or NPP of the eight provisioning ecosystem services from Owabi 54
Appendix 5. Measures supporting sustainability of Owabi by fringe communities 55
Appendix 6. Questionnaires used for expert and community interviews 56
Appendix 7: Recorded expert interviews 60

List of Tables

Table 1: Types of ecosystem services, indicators and unit of measurement that would be derived from Owabi. Adapted from (De Groot et al., 2010a, b and UNEP-WCMC, 2011, Roy Haines-Young et al., 2006) 8
Table 2: Showing the population status of chosen fringe communities for the year 2010 12
Table 3: Specific provisioning services provided by Owabi 19
Table 4 : Quantity of provisioning services used with (mean interval) by all the total household of fringe community of Owabi (kg/ha/yr) 21
Table 5: Performance/Sustainable use of the eight provisioning services from Owabi by total households of fringing communities 24
Table 6: Stakeholders involvement in Owabi ecosystem services 27
Table 7: Sustainability dimension for Owabi ecosystem service (for the year 2025)... **Error! Bookmark not defined.**

List of Figures

Figure 1: Location of Owabi Wildlife Sanctuary 2
Figure 2: Conceptual Framework for Owabi Wildlife Sanctuary (adapted from De Groot, 2006 and Ansah, 2014) 5
Figure 3: Benefits obtained by communities from Owabi 18
Figure 4: Current use of provisioning services by respondents 20
Figure 5: Average per year frequency use of provisioning services of respondents 20
Figure 6: Current use regulating services of Owabi by respondents 22
Figure 7: Current use cultural services of Owabi by respondents 22
Figure 8: Interest and influence grid for the stakeholders of Owabi 28
Figure 9: Potential conflicts and synergies to communities in relation of using services from Owabi 29
Figure 10:Measures supporting sustainability of Owabi by fringe communities 31

List of Acronyms

CITES	Convention of International Trade in Endangered Species of Wild Fauna and Flora
ES	Ecosystem Services
EPA	Environmental Protection Agency.
FC	Forestry Commission
GWSC	Ghana Water and Sewerage Corporation
GSS	Ghana Statistical Service
KNUST	Kwame Nkrumah University of Science and Technology
NGO	Non-Government Organization
NPP	Net Primary Productivity
NTFPs	Non-Timber Forest Products
PURC	Public Utility Regulation Commission
RMSC	Resource Management Support Center
RQ	Research Question
TEEB	The Economics of Ecosystems and Biodiversity
WD	Wildlife Division
WRC	Water Resource Commission

Summary

Decision makers recognize that sustainability of natural or semi-natural landscapes, improves human well-being, conserves biodiversity and forest productivity. However, decision making and management planning should integrate the landscapes' ecosystem services, but this is not sufficiently considered and is challenging especially when landscapes are susceptible to different land uses. This result in over-exploitation and degradation of their ecosystems such as forest.

The Owabi Wildlife Sanctuary is a semi-deciduous moist forest in the north-west of Kumasi. The sanctuary provides different ecosystem services. However, the sanctuary's ecosystem services are in high demand by different users and land use encroaches in its area. Owabi's 2014-management plan ignored the recent increases in demand of different ecosystem services and how this demand improves human well-being without exceeding Owabi's carrying capacity. The management plan should therefore be reviewed to ensure the sustainability of Owabi.

The thesis aims to contribute to develop a sustainable management plan by integratively assessing Owabi's ecosystems and their services. This will identify the ecosystem services provided by the sanctuary, their carrying capacity to provide services in the future and the conflicts and synergies among its users. Five fringing Owabi communities and fifty households were interviewed using structured household questionnaires. Also, two experts from the Wildlife Division and the Ghana Water Company Limited were interviewed. Finally, the previous management plan was reviewed. The data were quantitatively and qualitatively analyzed.

I followed TEEB's classification of ecosystem services and assessed sixteen service categories and twenty specific services. The services were grouped under provision, regulating, cultural and habitat. I only quantified provisioning services because data on other services were lacking. Provisioning services mostly used by the fringing communities include fishes, bushmeat, fruits, snails, drinking water, firewood, herbs and construction sand. The result shows that the fringing communities annually extract about 2000 tons of seven provision services (fishes, bushmeat, fruits, snails, firewood, herbs and construction sand) and also extract 32,000 m^3 of drinking water annually. This represent an annual average of 2.4 tons of the seven provision services and 8.5 m^3 drinking water per number of households. Drinking water had the highest contribution (3,000-32,000 m^3 per year) while snails contributed least (0-10 ton per year).

To determine the sustainable use level of these provisioning services harvested by the total number of household in Owabi, I computed the ratio between the maximum harvest and the net primary productivity (maximum productivity) of these services. Harvest greater than 10% of the net primary productivity was considered unsustainable (based on expert advice and literature). The fringe communities used drinking water, fishes, sand and bushmeat unsustainably. This indicates over-exploitation and degradation of the Owabi sanctuary. To improve the future sustainability of these services only 10% of their productivity can be used.

All other services were analyzed qualitatively. Considerable percentage of the respondents acknowledge regulating service (climate regulation 36%, clean air 30%, windbreak 24%, watershed/wetland protection 22%, flood protection 12%, erosion prevention 4% and water purification 2%), cultural services (recreation 16%, aesthetic beauty 12% and ecotourism 6%). The interviewed experts also valued the regulating services (wetland/watershed protection and CO_2 regulation) and cultural services (ecotourism and research). All the communities and experts recognize habitat services (maintenance of migratory birds an genetic diversity).

The use of Owabi's ecosystem services is user specific as different users place importance to different services. Ten user groups were identified and can be differentiated by institution and scale. These users includes fringe communities, District Assembly, Chiefs, Wildlife Division, Ghana Water Company Limited, Water Resource Commission, Kwame Nkrumah University of Science and Technology, Global community and Wildlife Society. Potential conflicts in managing the different ecosystem services merge between the fringe communities and the Wildlife Division. These communities view the Wildlife Division as a government body that hinders their extraction activities. However, synergies among neighboring communities and traditional authorities exits. Fringe communities do not perceive their extraction activities to be harmful.

The three main management measures that should ensure Owabi's sustainability is also supported by the communities and include, the annual communities allocation of non-timber forest products (NTFPs), full conservation protection (i.e. no entry) and zoning areas for conservation and harvesting. Allocating NTFPs to communities stabilizes the future provisioning services. It also increases the value of other services. The full conservation measure stops entry for communities but protects wildlife and provides drinking water. This measure stops all degradation and in the future ecosystem services will improve and increase slowly. This measure is likely most preferred by decision makers. However communities should be compensated with alternative livelihood programs. Zoning areas for conservation and harvesting will have positive future effects since some areas are protected, while extraction can still continue in designated harvest areas.

I recommended that the Wildlife Division together with Ghana Water Company Limited should integrate these measures to create a more robust management plan for sustainably using Owabi's ecosystem services. When full protection is required, alternative livelihood programmes can be developed and implemented to compensate fringe communities using information gathered in this thesis. Also, local communities should be involved during planning stages to include their needs and predict possible synergies and conflicts. Finally, planting of trees can be established in affected areas to reduce degradation and support community extraction.

Providing a sustainable management plan ensures the sustainability of Owabi's landscape by conserving biodiversity, enhancing forest productivity and stimulating the prosperity of the fringe communities who depend on these landscape.

1 Introduction

1.1 Background

The concept of ecosystem services has become a central point of discussion in policy agenda, conservation planning as well as environmental impact assessment (Burkhard et al., 2010). This attention has yielded the integration of global and European current policies together with the concept of ecosystem services (European Commission, 2009 and Perrings et al., 2011). This can be exemplified by the global strategic plan for biodiversity on the Convention of Biological Diversity for the period of 2011-2020 and the founding of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) in Busan June 2010 (Editorial, 2010). Policy actions, environmental planning decisions and management scenarios have relevant effect on the ecosystem services (Chatzinikolaou et al, 2018) and largely influence land management (Fisher et al., 2008; Carpenter et al., 2009 and Von Haaren & Albert, 2011).

This thesis relies mostly on the framework of The Economics of Ecosystem and Biodiversity (TEEB) which provides indicators necessary to identify the effect of landscape management on ecosystem services (Carpenter et al., 2009; De Groot et al, 2010b and Strien et al., 2009) which is relevant for Owabi Wildlife Sanctuary. This will provide relevant information for policy makers from Owabi to identify and prioritize intervention (Layke, 2009; OCDE, 2001) and ensure sustainability of its ecosystem services and landscape.

Landscape sustainability can be defined as the capacity of a landscape to provide a landscape-specific ecosystem in a long-term for improving human well-being (Wu, 2013). This implies to any landscape type being natural or semi-natural ecosystem that can continuously provide services for human well being. The concept has been recognised by many policymakers in various countries in a long term to conserve biodiversity, forest productivity and prosperity of communities depending on them (McDonald & Lane, 2004). Ensuring the sustainability of biodiversity, forest productivity or a landscape function requires at least two things. (1) the use of the resources by depending communities and (2) the ability of the resources to sustain the harvest needed for the people depending on them, i.e. a sufficient carrying capcity (Robinson & Bennett, 2000). For the purpose of this thesis, both things are important for the sustainability of Owabi Wildlife Sanctuary's ecosystem services. Extraction of Owaabi resources must meet the socio-economic needs of the people harvesting them but at the same time should also limit the loss in biological diversity and environmental degradation.

The Owabi Wildlife Sanctuary (hereafter as Owabi) covers an area of about 13km^2 and is classified as 'moist semi-deciduous north-west subtype' (Hall & Swaine, 1976). It is located 23km north-west of Kumasi, Ghana's second largest city (Ashanti region see Figure 1). It is characterized by the northern part (inner site) and southern part (catchment area) of the Sanctuary. Owabi is one of the only two protected wildlife Sanctuaries and the only inland Ramsar site in Ghana being managed by the Wildlife Division (WD). It was designated as a wetland of international importance under the Ramsar Convention by the Government in 1988 (FC, 2014). The forest cover of the area consists largely of secondary vegetation and small

portions of riverine forest, aquatic vegetation and exotic plantation each providing different ecosystem services. The forest of Owabi houses different mammals and bird species which are listed under the Convention of International Trade in Endangered Species of Wild Fauna and Flora (CITES) (Badu-Boateng & Poku, 2009). The area has the opportunity for ecotourism development because of its aesthetic beauty, its composition of endangered flora and fauna species as well as the ability to use the place for hiking and camping which can leave excitement and possibilities to learn about nature (Amuquandoh, 2011). Owabi houses an artificial lake which was dammed to provide supplementary water supply to the people of Kumasi and its environs. The dam and its associated waterworks are the responsibility of the Ghana Water and Sewerage Corporation (GWSC).

Although it is small, Owabi is a significant area for WD and can be used to showcase the fundamental linkages between conserving and preserving of relevant ecological processes. It serves as an opportunity for researchers, environmentalist, students etc. to explore the area for scientific and socio-ecological studies.

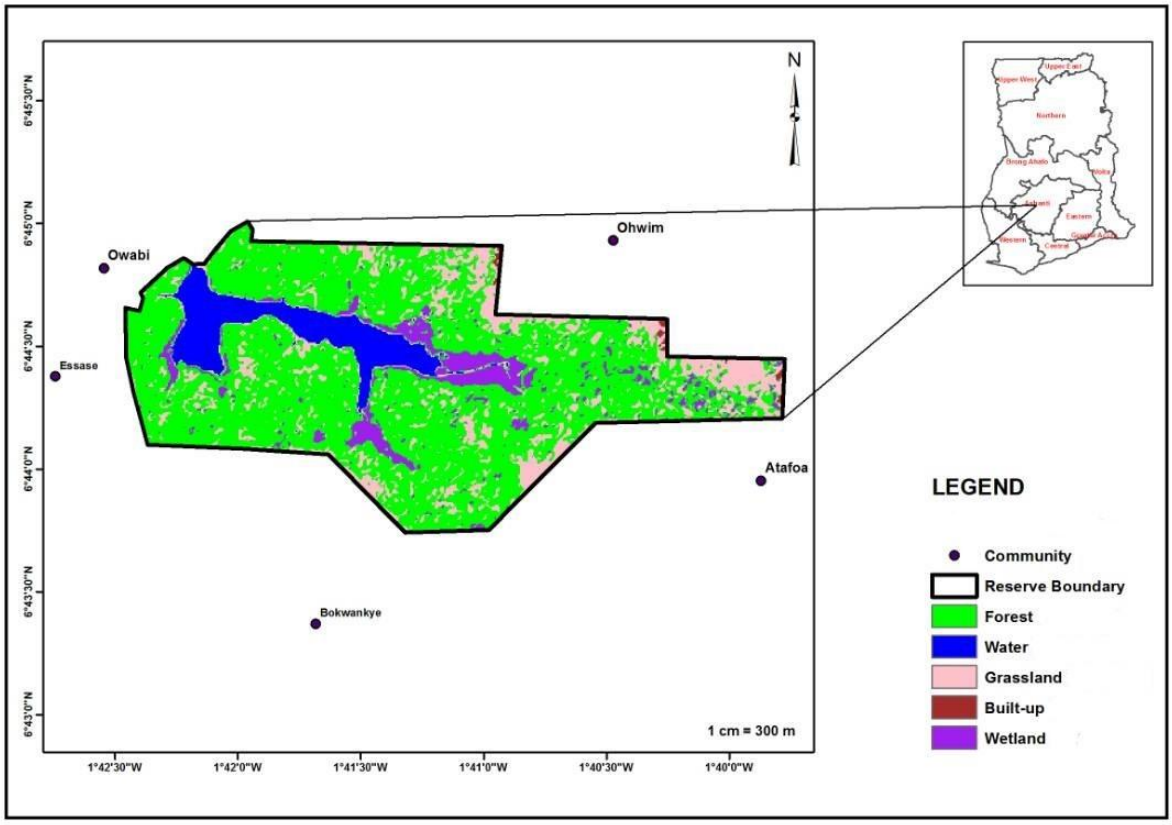

Figure 1: Location of Owabi Wildlife Sanctuary

1.2 Problem Statement

Owabi is under serious threat. Even though some part of the area is protected (inner site), it faces severe interrelated issues from population pressure, poaching, illegal logging, land tenure, land-use practices like local developments which inevitably have direct bearing with its management plan (Forestry, 2014). The area is being encroached by farming activities, sand winning and locating of land for local development (e.g. building of houses) which threatens the flora and fauna species as well as having a great impact on the quality of water supplied by

the dam (Ameyaw & Dapaah, 2017). This is being worsened by the land tenure between landowners and GWCL especially on the catchment area. This aggravating situation is a result of the misunderstanding of management responsibility for the outer Sanctuary. This shows lack of management in the whole Owabi area. The staff of the WD do not consider the outer Sanctuary as part of the Sanctuary Site and therefore do not patrol the area. This makes the area prone to activities impacting on the ecosystem services of the area. This can result in the disappearance of sensitive species with large territories requirement (Dowsett, 2009). Moreover, GWCL does not pay anymore compensations to landowners for the earlier land acquisition for Owabi establishment. This encourages illegal allocation of lands for sand winning, construction of houses and illegal exploitation of resources. This may cause flooding in the dam and wetlands area as well as impact the water quality through erosion and sand transport during rainfall.

In reference of this, the Forestry Commission developed an important management plan for the Owabi Wildlife Sanctuary Site in 2014 (although very broad). However, encroachment from farming activities, continued sand winning and allocation of plots for developers still persist (Ameyaw & Dapaah, 2017). The management plan mentioned some of the ecosystem services provided by Owabi but did not include the quantities that can be used without trespassing limits. Examples of this can be seen in objectives of the plan which includes "reducing pressure on the biological resources of the Sanctuary/Ramsar Site'' and "protecting the immediate catchment area of the dam and guarantee the sustained water supply for the area" (Forestry, 2014). A recent study shows encroachment in the area especially at the catchment area which indicate a high demand of Owabi ecosystem services. This demand has resulted in the potential reduction of some of Owabi's ecosystem services (Ameyaw & Dapaah, 2017). Therefore, a review and development of a new management plan for the whole area (both inner and catchment) is urgently needed. Policymakers can use them to ensure sustainability in deciding on land-use options.

Often, insufficient information on ecosystem functions and benefits is lacking, especially when land-use options are subjected to trade-offs and such information is limited (De Groot, 2006). This raises questions, such as, what was considered in the development of Owabi's management plan in 2014? Specifically, were demand for ecosystem service considered? And how many of these demands can be met for community wellbeing? How many benefits can be obtained without destroying the area? Therefore, this knowledge gap needs to be recognized and reduced. Defining the carrying capacity or use limits of these ecosystem services is very critical for policymakers in making decisions. Hence the relevance of this thesis.

1.3 Purpose of Study and Research Questions

This research aims to contribute to the development of a sustainable management plan. Such management plan should include an integrated ecosystem assessment to sustainably manage Owabi wildlife Sanctuary (both inner and catchment). Assessing the consequences of this sustainable management plan for both ecosystem services and the local communities will help provide insightful information for policymakers on their management decisions. Most especially, it would help involved stakeholders like the landowners, the Atwima Nwabiagya District Assembly, Forestry Commission, Ghana Tourism Development Authority, Wildlife

Division and, fringe communities in the management and protection of the area, and also identifying the conflicts and synergies among them in terms of the land use and land tenure system. This assessment will spell out the ecosystem services being provided by the area and its carrying capacity (use limit) to continue providing these services sustainably without jeopardizing the integrity of the area. The ecosystem assessment that is performed by this thesis would provide the basis for further development of a sustainable management plan for Owabi.

The aim is elaborated in the following research questions (RQs):

RQ1. What are the main management measures and the activities of the local communities from the previous management plan?

RQ2. What are the main ecosystem services and the amount being harvested by communities?

RQ3. What is the carrying capacity of these ecosystem services and how do the current use levels affect their sustainability?

RQ4. Who are the main users of these services and what are the potential conflicts and synergies among users of Owabi's ecosystem services?

RQ5. What recommendations can be given to improve the management and the sustainability of Owabi?

The thesis has been structured into nine (9) chapters. The chapters has been done in a chronological manner to answer the research questions. The next chapters describe in detail the approaches and the results to answer all the research questions. This is followed by discussion in chapter 8. Finally, the major findings are presented in the conclusion part of chapter 9. This draw conclusions on the sustainability of Owabi's ecosystem services.

2 Methodology

2.1 Methodological framework

Ecosystem approach defined by Convention on Biological Diversity has been used strategically in sustaining land, water, and living resources use in a more integrated way that also promotes conservation (Shepherd, 2004). This approach has been used in many ways in linking the ecosystem to human wellbeing (Hails & Ormerod, 2013, De Groot, 2006; Millennium Ecosystem Assessment, 2005).

The methodological framework used in assessing the ecosystem services of Owabi was adapted from the conceptual framework of Millennium Ecosystem Assessment (2005), TEEB assessment (De Groot et al. 2010) and other approaches (Bastian et al., 2012; De Groot et al., 2017; Oudenhoven et al. 2012).

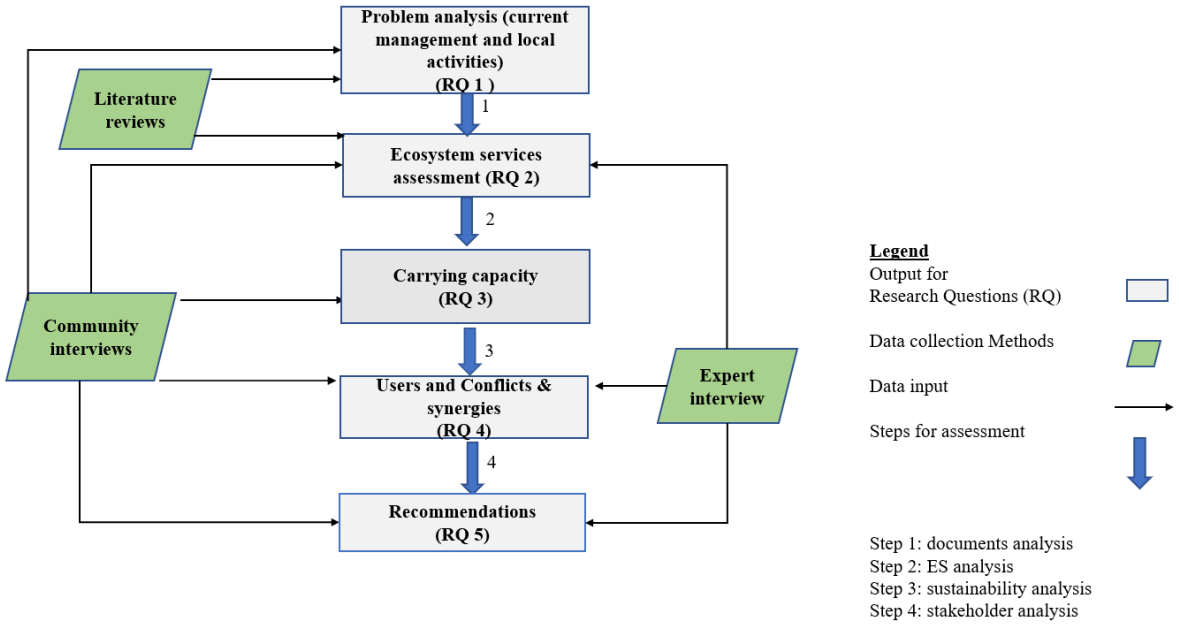

Figure 2: Methodological Framework for Owabi Wildlife Sanctuary (adapted from De Groot, 2006 and Ansah, 2014)

2.2 Research Methods

All the methods used in this thesis followed the methodological framework (Figure 2) that was developed and is being described below. This framework includes the methods for data collection and the tools for its analysis. The choice of these tools and methods were chosen solely to provide valuable answers to the research questions.

2.2.1 Policy Documents Analysis

Both content and thematic analysis were used in analyzing the policy document. This was done by skimming, reading and interpreting. This method of analyzing documents prove to be more efficient, exactness, cost-effective, stable and lack obtrusive (Bowen, 2009).

This Policy Document Analysis aimed at describing the current policies and management plan of Owabi. It clearly underlines the general overview of the ecosystem services provided by

Owabi, its current status, management targets, management constraints and the institutions involved in its management. Also, it identified the different users of these services as well as the activities of the communities which was further assessed through interviews interaction. Furthermore, this analysis provided the basis to assess the land tenure system of the area. Specifically, the current management plan developed by the Forestry Commission in 2014 was used. This method was used in answering RQ 1.

2.2.2 Ecosystem Service Analysis

Ecosystem goods and services from nature and landscapes are progressing in the light of scientist and policy makers. However, there is still a far fetch of satisfying a comprehensive scientific description of the interaction among different ecosystem services and the actual impact of its approach on decision making (Haines-Young, Roy; Potschin, 2010; Searle & Cox, 2009). There is often lack of information or verification challenges on these ecosystem services (Searle & Cox, 2009). This challenges includes (1) identifying a comprehensive indicator to measure capacity of ecosystem services, (2) complexity between land management and ecosystem service dynamics, (3) linking ecological processes and ecosystem services provision by quantifying services and (4) accounting for spatial and temporal scales of ecosystem services and its ecological process (Bastian, Haase, & Grunewald, 2012; Carpenter et al., 2009; De Groot et al., 2010b; Turner & Daily, 2008; van Strien et al., 2009; Villa et al., and Ceroni, & Bagstad, 2009). This makes it difficult and a challenge for scientists to provide input for ecosystem services and benefit to aid in decision making (De Groot, 2006). It is therefore important to have a robust and comprehensive framework to analyze ecosystem services (Ostrom, 2009; Posthumus et al., 2010).

This thesis based its definition and assessment on TEEB (De Groot et al. 2010) in spite of the different definitions and classification (Díaz et al., 2015; R. Haines-Young & Potschin, 2018; Millennium Ecosystem Assessment, 2005) whiles accepting that such a complex system like an ecosystem has no complete unambiguous definitions. This classification and assessment was chosen basically to help differenciate between ecological phenomena, their contribution to human welfare, benefits generated as well as avoiding double counting as some services may provide input for others (Balmford et al., 2012; Fisher & Turner, 2008). Also, it clearly defines ecosystem services and the total bundles of these services, which is spatially and temporally explicit for policy intervention (De Groot et al. 2010) required for Owabi. There are four main categories of ecosystem services used to assess Owabi (see Table 1) based on literature reviews: provisioning, regulating, cultural and habitat services.

The first list of ecosystem services provided by Owabi was produced through its previous management plan. This first list was used to generate household questionannaires to validate these services. Moreover, some provisioning services were quantified to acknowledge the amount being used. No monetary valuations were made since most benefits obtained by households were mostly used by them and were not necessarily sold.

It is important to note that in developing ecosystem assessment, indicators are very necessary. Indicators are necessary to see the accurate change in measure of the service of interest for policy makers to priotise interventions (UNEP-WCMC, 2011; Oudenhoven et al., 2012). An

indicator for the ecosystem services provided by Owabi was added to Table 1 which was addapted on similar studies on ecosystem assessment (De Groot et al., 2010 a, b and R. Haines-Young & Potschin, 2018).

Defining the carrying capacity or the use limit is also very important for the sustainability of the ecosystem services being provided by Owabi. As explained by Haines-Young et al. (2006), **"Environmental limit",** where external pressure, such as over-exploitation or degradation, may diminish the quality of benefits that an ecosystem provides which will lead to critical point/level. This is an important basis for Owabi sustainability development and therefore a performance indicator depicting the carrying capacity or use limit for each service was added to Table 1. This was developed through expert advisory and literature search and shows the maximum quantity of services that could be used sustainably. This answers RQ 2 and 3.

2.2.3 Stakeholder Analysis

Grimble and Chan, (1995, p. 114), define stakeholder analysis as "an approach and procedure for gaining an understanding of a system by means of identifying the key actors or **stakeholders** in the system, and assessing their respective interests in the system". The question then is who is a stakeholder? A stakeholder becomes an individual or group that has the ability to significantly impact on (whether negative or positive) or is influenced by an area of interest (Glicken, 2000). In reference to these, stakeholders are then individuals that are being influenced by or that have an impact on Owabi negatively or positively. Stakeholder analysis is a very useful tool to assess who to consult. It is able to (1) predict possible conflict areas among stakeholders specially in the case of land tenure and land-use system of Owabi, (2) identify their relationships and most importantly (3) identify the approach required to consult each stakeholder (Kurtz, 2012). This analysis is relevant for the stakeholders of Owabi in order for them to adheres to policy intervention.

This thesis develop stakeholder analysis based on an adaptation from Kurtz, (2012). The steps involved:

1. Creating a list of stakeholders
2. Deciding on important and influential stakeholders
3. Creating influence/important matrix and
4. Deciding on method to consult stakeholders.

The stakeholder analysis was done through literature (Owabi management plan), community and expert interviews. Stakeholders were differentiated based on spatial level (local, national and international) and degree of relevance. They were further categorized by method of interest and the degree of influence in terms of "Key players, context setters, subjects and crowd" method (Ackermann & Eden, 2011, Reed et al., 2009 and De Lopez, 2001). This analysis was used in answering research question 4.

Table 1: Types of ecosystem services, indicators and unit of measurement that would be derived from Owabi. Adapted from (De Groot et al., 2010a, b and UNEP-WCMC, 2011, Roy Haines-Young et al., 2006)

	Type of Services	**Specific services from Owabi**	**Indicator for assessment (use indicator)**	**Unit of measurement**	**Performance indicator (sustainable use)**
Provisioning					
1	Food	Fishes, Bushmeat, Fruits, Snails	Amount extracted	Kg/ha	Net productivity (Kg/ha/yr)
2	Water	Drinking water	Amount extracted	Litres (L)	Max sustainable water extraction (L/yr)
3	Raw material	Firewood, sand for construction	Amount extracted	Kg	Net productivity (Kg/yr)
4	Genetic materials	Herbs	Amount extracted	Kg	Maximum sustainable harvest (Kg/yr)
5	Medicinal resources			Kg	Maximum sustainable harvest (Kg/yr)
6	Ornamental resources			Kg	Maximum sustainable harvest (Kgyr)
Regulating					
7	Air quality regulation	Good and clean air	Capacity to extract aerosols	Particles/m^3	Amount of earosols extracted (particles/m^3/yr)
8	Climate regulation	Micro-climate, Carbon sequestration	Greenhouse gas-balance	tonnes	Area of the forest (ha), C-sequestration by forest (kg/ha/yr)
9	Extreme event mitigation	Flood protection, Windbreaks	Role of forest in dampening extreme event	Number of incidence	Number of incidence/year
10	Regulation of water flows	Watershed/ wetland protection	Water-storage capacity	m^3	Area of forest to protect watershed/wetland (ha)
11	Waste treatment	Water purification	Water retention capcity in soil	Mm water/cm depth of soil	Maximum Nutrients (eg. S, N) removal and retention

Table 1: Types of ecosystem services, indicators and unit of measurement that would be derived from Owabi. Adapted from (De Groot et al., 2010a, b and UNEP-WCMC, 2011, Roy Haines-Young et al., 2006)

	Type of Services	**Specific services from Owabi**	**Indicator for assessment (use indicator)**	**Unit of measurement**	**Performance indicator (sustainable use)**
12	Erosion protection	Erosion prevention	Denitrification	Kg/ha	Maximum potential reduction in soil loss by area of forest [kg/ha/yr]
13	Maintenance of soil fertility	Improve soil fertility for farming	Vegetation cover root-matrix	Kg/ha	Amount of topsoil regenerated per ha/yr
14	Pollination				
15	Biological control				
Cultural					
16	Aesthetic information	Aesthetic beauty	Number of visitors with stated appreciation		Number of visitors
17	Recreation/tourism	Ecotourism	Number of visitors with stated appreciation		Maximm sustainable number of visitors
18	Inspiration for culture, art and design				
19	Spiritual/religious inspiration				
20	Information for cognitive development	Research, education and public awareness	Presence of features with education/research interest		Number of visitors/research/ articles
Habitat					
21	Nursery habitat	Maintenance of life cycles of migratory birds	Number of migratory birds		Bird species distribution
22	Genepool protection	Maintenance of genetic diversity	Areas for endemic species	ha	Area managed for gene conservation or conservation investments (ha)

Services in red coloured were not assessed in this thesis

2.2.4 Management and Recommendations for sustainability of Owabi

To contribute to the sustainable management plan for Owabi ecosystem services, a set of measures to support the performance indicators were developed. This was developed with the help of experts during interviews. They were asked to describe which measures according to them would be in favor of sustaining the management of Owabi as a stake and for the continued benefit to the communities. This approach has been proven more promising in similar studies (see for instance Haines-Young et al., 2006). The measures were based on the actual services being provided by Owabi. The communities were asked to rate among the measures they perceive to enrich and enhance the sustainability of Owabi for them to continue benefiting.

A summary scenario of the ecosystem services provided by Owabi in the future was qualitatively described. This was done by way of subjective classification i.e. increasing (↑), stabling (→) or decreasing (↓) value effect of all the ecosystem services provided by Owabi (provisioning, regulating, cultural and habitat). This was used to answer research question 5.

2.3 Data Collection methods

A combination of literature reviews and stakeholder's interviews (both community and expert) were used as a data collection input. Both tools were combined and integrated to reduce uncertainties in the services provided by Owabi as well as to gain information about the land use relationships among users. These tools are explained in detail in this section.

2.3.1 Literature review

Literature review was done to identify some of the ecosystem services provided by Owabi from which an indicator matrix (including performance indicator) was developed. Also, potential stakeholders involved in the usage of Owabi services were also identified. This was further used in developing the questionnaires for community interviews. This literature review moreover provided insightful information about the land tenure and objectivity of the current management of Owabi both in policy and institutional context.

2.3.2 Community interview

Community interview was done between the 2nd April 2018 to 21st May 2018 to assess the ecosystem services from the five fringe communities. This took about two months together with the data entries obtained from the interviews. It took approximately a week and a half for each fringe communities to be interviewed randomly and ended on 1st June, 2018 with the data entry. By developing a structured questionnaire the following topics were assessed; the ecosystem services, the users of these services, the relationship among communities and other users and the choice of measure for sustainable development for each fringe communities. The questionnaires were designed into four parts. The first part was in relation to the demographic, socio-economic characteristics, level of education and household composition. The second part was related to ecosystem assessment of Owabi. The third part was about the conflicts and synergies among users of the ecosystem services. And the final part of the questionnaire was on the support of measures for the sustainability of Owabi ecosystem services.

A total of 50 questionnaires were distributed. Ten questionnaires were distributed in each of the five fringe communities (Nwabi, Esaase, Bokwankye, Ohwim and Atafra). Per community

ten individual households answered the questionnaires and hundred percent response rate was achieved.

2.3.3 Expert Interview

A semi-structured questionnaire was developed to get access to information on the ecosystem services, its users, conflicts and synergies, sustainable indicators known by experts and measures for management. Experts were chosen with a pre-requisite knowledge to provide input necessary for thesis objectives and all have a direct connection to Owabi. With such relevant restrictions, only two experts were identified and interviewed, namely WD and GWCL. All the interviews were not allowed to be recorded but noted in the field book and summarized.

2.3.4 Fieldwork

A first meeting with the Assistant Manager of the Resource Management Support Center (RMSC), who is my local supervisor, was scheduled in 28th March 2018 to connect me with networks in Owabi. A second meeting was set on 29th March with the Wildlife Division (WD) who is in charge of managing the Owabi Wildlife Sanctuary, to get access to Owabi for site reconnaissance and to assess the status of the area. With a forest guard, we were able to get access to the forest area, riverain area as well as the dam site. This activity gave us a general idea of what ecosystem services being provided and the health status of the area.

A discussion with experts from the WD and Ghana Water Company Limited (GWCL) gave out possible fringe communities that benefited directly or indirectly from this ecosystem services. It was realized since the area is close to the big city Kumasi and more getting urbanized, not all fringe communities got direct benefits from the area. Some communities ignore the Sanctuary by trading in Kumasi whiles others still get benefit from the area. This was affirmed by testing of our questionnaire to assess the benefit obtained by fringe communities. Therefore, communities chosen were based on the following criteria:

1. Accessibility to the area.
2. Benefits derived from the area.
3. Distance to the Sanctuary i.e. communities less than or equal to 5km to or from the Sanctuary.
4. Time and fund availability

The possible fringe communities include Owabi, Esaase, Bokwankye, Ohwim and Atafra (see Figure 1)

The communities that were chosen fall under two districts called Nwabiagya District Assembly and Kumasi Metropolis and therefore a meeting was again scheduled to assess the population around the area. Together with the Ghana Statistical Service (GSS) and District Assembly, we were able to assess the population status of the possible fringe communities for the year 2010 (Table 2).

Table 2: The population status of chosen fringe communities for the year 2010

Community	Population	Source
Owabi	200	Atwima Nwabiagya District Assembly
Esaase	2,718	Atwima Nwabiagya District Assembly
Bokwankye	3,844	Atwima Nwabiagya District Assembly
Ohwim	15,743	GSS
Atafra	4,062	GSS
Total	**26,567**	

A total of fifty questionnaires were randomly administered to individuals from selected community households (ten each). This randomization was used in choosing households from the selected community to ensure population has known and a non-zero chance of being selected hence bias is avoided (Kumar, 2014).

2.4 Statistical analysis

IBM Statistical Package for Social Science (SPSS) version 25 was used to analyze the data from the community household questionnaires. The average, minimum and maximum values were calculated for the ecosystem services and their carrying capacity.

To calculate the use level and quantity of the provisioning services extracted from Owabi by the fringe communities, each respondents representing a household (n=50) from the community were asked to indicate the amount in kilograms of the services they used per month. Each of the services being used by respondents during the interview, were either in bundles (fuelwood), bucket or barrel (drinking water), paint rubber bowls (fishes) etc. of which pictures were taken. In the case where there were no measuring devices, respondents were asked to give a detailed description of the device that was used in bringing the items home. After collecting such information, the data was then compared with the checklist developed by experts from Resource Management Support Center-FC for estimating the quantity of services on the field. The ecosystem services being used by the total number of households of the fringing communities was estimated from Ghana population census (2010) and the average number of people computed.

First, the statistical analysis of the quantities of provisioning services used by the sampled households were calculated. The percentage of the sampled households that uses a specific provisioning services was also computed. The sample percentages gotten were then used in deriving the total number of households that uses a specific service annually. This was then multiplied by the quantities (average, minimum, maximum) used per year. In calculating the minimum and maximum quantity of services used by the total number of household, 10% of the average minimum and maximum quantities used by the sampled household was estimated. This was to show a realistic minimum and maximum quantities of services used by the communities.

The exact total number of households fringing Owabi was calculated from the population census, and the statistical mean of the average number of people in a household (appendix 1). With an average of 6 persons per household, a total population of 26567 people amounts to

4428 households in Owabi. Microsoft Excel was used to present the results graphically after the analysis.

3 Previous Management Plan and Activities of Local Communities

This section talks about the management measures of Owabi from the previous management plan with responsible institutions and organizations. It continues by explaining in detail the management of the ecosystem services (water and the biological resources) and its constraints. It further describes the socio-economic activities the local communities have in Owabi.

3.1 Main management measures

The government has the full control of Owabi Wildlife Sanctuary under the management authority of the Wildlife Division (WD). The WD under the Forestry Commission with set standards is responsible for the day to day management of the habitats for the variety of species including breeding sites for mammals, trees, birds, fish, amphibians, butterflies, reptiles and snails. They draw up plans and proposals from their normal routine of systematic biological monitoring on permanent transects in the area. They manage the area with infrastructures like equipment (e.g. flashlights, gun and binoculars), transport (e.g. three motorbikes and a vehicle), trails (two for visitors and patrols), visitor facilities, signs and administrative staffs (nine staffs present).

Management action taken by the WD includes patrolling the inner Sanctuary to capture poacher, remove snares and prevent illegal harvesting of fish resources. They also involve monthly cleaning of the inner boundary line as well.

The second government institution that is involved in the area is the GWCL. The area protects the Owabi catchment which was dammed by the GWCL to produce drinking water for the people that depend on it. The GWCL is responsible for the operationalization of the built dam and its associated works. They ensure that the dam is in good condition to provide its demanding services. Although the WD is responsible for the Sanctuary, the GWCL has the most mandate in the catchment area. They maintain the water treatment plant, a training school, staff housing and offices within the catchment area of the Sanctuary. They are also the responsible body to set quota for fishing.

There are also other institutions and organization involved, either formal or informal, involved in helping to manage the Sanctuary. This includes the Water Resource Commission (WRC), Land Commission, NGOs, chiefs and fringe communities. All these stakeholders make sure that the mandate of establishing the Sanctuary is maintained and the resources are kept in good conditions.

3.1.1 Water resources

The supply of water is inevitably linked with the creation of the Sanctuary. All the chosen fringe communities (Owabi, Esaase, Bokankye, Ohwim and Atafra) benefit from the water provisioning. GWCL provides drinking water to the communities through the establishment of pipe born water. It is said that the dam has out-live its expiring date (70years) and yet still produces this service as confirmed during the expert interview. Experts confirm that, presently the dam can potentially produce two million liters of drinking water per year i.e. approximately 30% of what it initially produced. This is a result of the dam not being renovated since 1920s

after human disturbances e.g. soil erosion into the dam after poachers have cut down trees. In spite of that, supplying of water to communities is very crucial to gain the support of local communities for effective management of the area.

3.1.2. Biological resources

The main biological resource from the area include NTFPs such as bushmeat, fuelwood and fishes.

Bushmeat is the most valued wildlife resource even though large games are rare. Although hunting of game is prohibited in the Sanctuary, hunting with snares and guns still occur. Hunting are largely limited to rodents which may occur in the inner area or the catchment area. Snares are mostly laid along the edges of the Sanctuary by hunters to protect their cultivated crops from wildlife predation. Although removing of snares are common measures undertaken by WD, bushmeat trade (e.g. duikers) still thrive in the area between chop-bar owners and hunters.

Fuelwood is a major source of energy for domestic purposes. In some communities the wood is used for bead making. Harvesting of fuelwood is restricted in the Sanctuary. However, there are evident of tree cutting and poaching of timber trees in the Sanctuary. Increasing pressure on fuelwood extraction in the Sanctuary still persist and as such cassia plantation was established by WD to supply fuelwood. Harvesting of the cassia plantations started in 1970 and still being utilized for the same purpose. Although the potential yield and the annual harvest of fuelwood have not been set for the whole area, a sustainable amount of fuelwood need to be supplied to take pressures off the forest area of the Sanctuary.

Fish harvesting is available for interested people in the communities. Presently Tilapia is the most common fish species being harvested from the dam. GWCL is said to provide quota for harvesting but the exact quota was not available in the management plan nor during the interview. The current management plan suggested a survey to be done by the Institute of Aquatic Biology in terms of the potential sustainable fishing yield. Furthermore the introduction of other fish species to improve the sustainability should be explored.

3.1.3. Management constraints

With all these management measures to take care of the Sanctuary, there are still hindering factors in achieving the full status of the area. Below are some of the constraints in the current management plan;

1. There is the absence of vivid policy guidelines and agreed management objectives for the whole area (both the inner and the catchment area).
2. There is no clear demarcation of the true boundary limits for the Sanctuary in terms of areas of protection and area for harvesting.
3. There is the absence of clear responsibilities between the WD and GWCL in relation to the reservoir and the catchment area. This was confirmed during the expert interview where WD patrols in the inner site but not the catchment area and GWCL takes care of the dam sites and not necessarily the catchment area.

3.2 Activities of the local communities in the previous management plan

There are various socio-economic activities that are on-going surrounding the establishment of the Sanctuary. There are land use conflicts especially in the catchment area between GWCL and landowning communities. As a result of that farmlands that were permitted in the catchment area are being given out for house development. This however, affects the security of the Sanctuary as a large area of the catchment has been encroached. Moreover, non-payment of compensation to landowners has also encouraged illegal allocation of land for house development. During expert interview with the GWCL, questions were raised about this situation. The GWCL seems to ignore payment because they claim to have paid any compensation long time ago and as such activities still persist.

Following the establishment of the dam and the surrounding lands, eleven settlements resettled in the year 1930s. Since then the population has been gradually increasing with an estimated population rate of 4.1% annually. The demand to meet the domestic need for the growing population has caused a considerable amount of pressure on the resources of the Sanctuary. The situation has again aggravated as a result of its closeness to Kumasi which exposes the area to further urban base pressure. Activities of the local communities that put pressure on the Sanctuary are explained below.

3.2.2 Agriculture

Most communities surrounding the Sanctuary practice subsistence crop farming and still the dominant sector in the area. Cocoa farming was the major land use in the communities but most of the farmlands were partly lost to the Sanctuary establishment. Common crops growing now are mainly maize, cassava, plantain and cocoyam. Most farm practices include slash and burn and bush fallow. Unsustainable farming practices like frequent bushfires and encroachment to the Sanctuary are still being practice.

3.2.3 Bead making

Some communities (like Ohwim) are noted for ornamental bead making. In Ohwim alone, there are about 90 people engaged in bead making and the demand of wood for bead is high. Beads making requires a large amount of wood for kilns and the degradation of fallow lands by inappropriate practices has reduced tree cover areas and increased wood shortage. Most time is spent on collection of fuelwood by women and children which sometimes happen in the Sanctuary. About 144 tons of wood is estimated annually by bead makers in Ohwim.

3.2.4 Fish farming

The Owabi dam provides the only source of fishing in the area. Interested individuals from the community can access the lake for fishing. Usually, fishing is done by children with hook and line and men with boat and net.

3.2.5 Trade and market

Most of the working group in the communities engage in trading activities like foodstuffs, drinks, spare parts, wood products, plastic products etc. These trading activities are mostly

done by small-sized retailers usually located along the roads, waterways and residential neighborhoods.

3.3 Community characteristics derived from the interviews.

This section presents the demographical and socio-economic characteristics of communities that were interviewed. This was derived from the statistical analysis of the sample population from the chosen five fringing communities. It describes in details the gender and age distribution, education level, occupation and household composition of the respondents (see appendix 1).

3.3.1 Gender and Age of respondents

The results indicate a slightly different proportion of the respondents being male (58%) and female (42%). This can be attributed to fact that most households encountered requested males to respond in the case when both genders were available. This is due to the social structure of the communities where males are the heads of the family or the household. In other instances, where females responded, it was due to the fact that there was either a single mother parenting heading the family, or the males were not available at the moment.

With reference to the age distribution among respondents, this was somehow evenly distributed between age groups. This was represented as 32% corresponding to the age between 21-30years, 26% to 31-40year, 22% to 41-50years and 20% corresponding to the age above 50years (appendix 1b). This shows a majority of the respondents belonging to the active age group thus below 50years (80%).

3.3.2 Education levels of respondents

A greater proportion of the respondents (74%) have obtained the basic education while 22% and 2% have obtained secondary and tertiary education respectively. Also 2% of respondents out of the sample population had no formal education or are considered illiterate. The relatively high educational level confirms that the area is getting urbanized and shows the influence of the big city (Kumasi) in its vicinity. The result implies that majority of the population from the communities has attained at least basic or secondary education. This is relevant as it informs the understanding and acceptance of management interventions by these communities to decision makers.

3.3.3 Occupation and household composition

Occupation distribution among the fringe communities is very diverse. Although the majority of the respondent (30%) out of the total sample size engage in farming activities, there are several occupational activities that allow communities to obtain benefits in support of their work.

The household composition of the various respondents is very dependent. However, the average number of individuals within a household of the respondent is six (6). This informs the average number of people who depend on the benefit from the ecosystem services being provided by Owabi.

3.4 Current activities of local people based on the community interviews

Respondents from the community interviews benefited in several ways carrying out activities in Owabi (Figure 3). Even though Owabi is relatively small, respondents obtain benefit ranging from harvesting of good (36%) to hunting (2%). This shows that communities do not only acquire provisioning benefits but other services as well. Harvesting of goods include food, fuelwood, water, fruits etc.

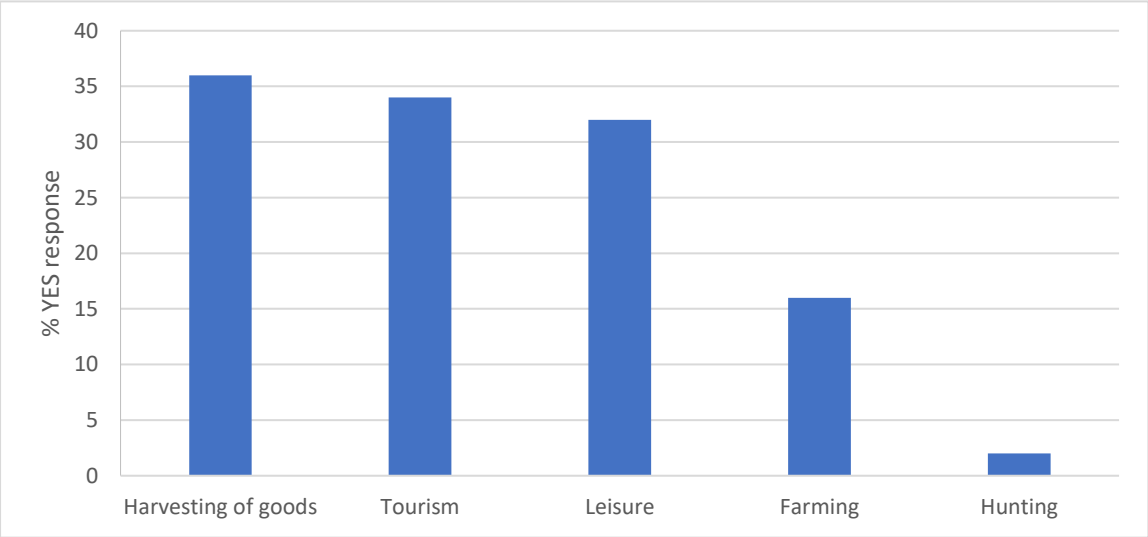

Figure 3: activities carried out by communities in Owabi

In chapter 4, a more detailed analysis is presented on the ecosystem services obtained from Owabi by the communities.

4 Ecosystem Services of Owabi Wildlife Sanctuary

This chapter presents the results of the analysis done on the ecosystem services used by the five fringing communities. It describes the benefits being derived in Owabi with a detailed description of services (provisioning, regulating, cultural and habitat), their current use and their quantities used. The performance and sustainable use of the provisioning services were further analyzed and presented (*see appendix 2*).

4.1 Provisioning Services, Current Use and Frequency of Use, Use level and Quantities

Respondents from the interviews benefited from provisioning services in diverse ways. This can be grouped under "Food, Water, Raw material, Genetic materials" of Table 1. A total of eight provisioning services was identified and added to the corresponding group in Table 1 which was based on the literature review and expert interviews. This was used to provide a wide range of specific provisioning services for respondents in the communities to choose.

The current use of the provisioning services from Owabi based on the expert interviews includes drinking water, fuelwood for home use, herbs, fishes, timber and bushmeat. However through the community interviews, some of this services were confirmed and a list of the provisioning services was provided in the Table 3.Table 3: Specific provisioning services provided by Owabi

Table 3: Specific provisioning services provided by Owabi

Eight (8) provisioning services provided by Owabi	
Fishes	Fuelwood
Fruits	Sand for construction
Snails	Bushmeat
Water for drinking	Herbs

4.1.1 Current provisioning services used by communities

The results from the respondents show a major use of water as a provisioning service than all the other service **Error! Reference source not found.**. This can be seen as more than half of the households (86%) acquire drinking water from Owabi followed by fuelwood (32%) and fishes (30%). The respondents value the Owabi dam and GWCL sees to it that they continuously provide them with drinking water. At the same time, the river provides them with fishes that are mostly harvested for home use. Although the communities are gradually getting urbanized, the response from the respondents shows the use of fuelwood as it is still the cheapest and easier source of energy for cooking and domestic use. The least used provisioning services include herbs, sand and snails. This can be understood as such services are not in line with the management plans of the Sanctuary. Therefore, the use of it is very limited.

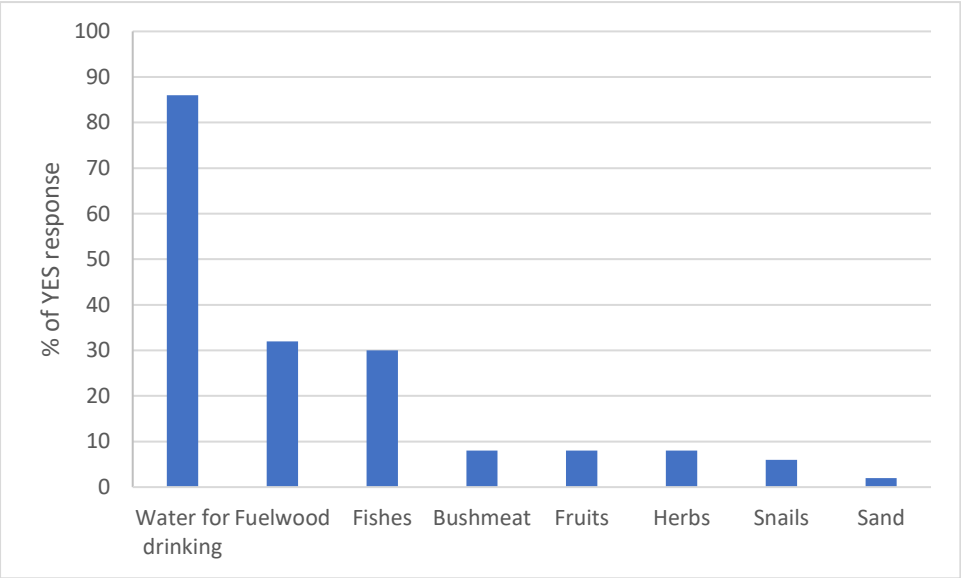

Figure 4: Current use of provisioning services by respondents

4.1.2 Frequency of use of provisioning services by the communities

With reference to the frequency of using provisioning services, respondents were asked to indicate how many times they use these specific services per month. This was then converted to the average annual usage of these provisioning services which is presented in Figure 1Figure

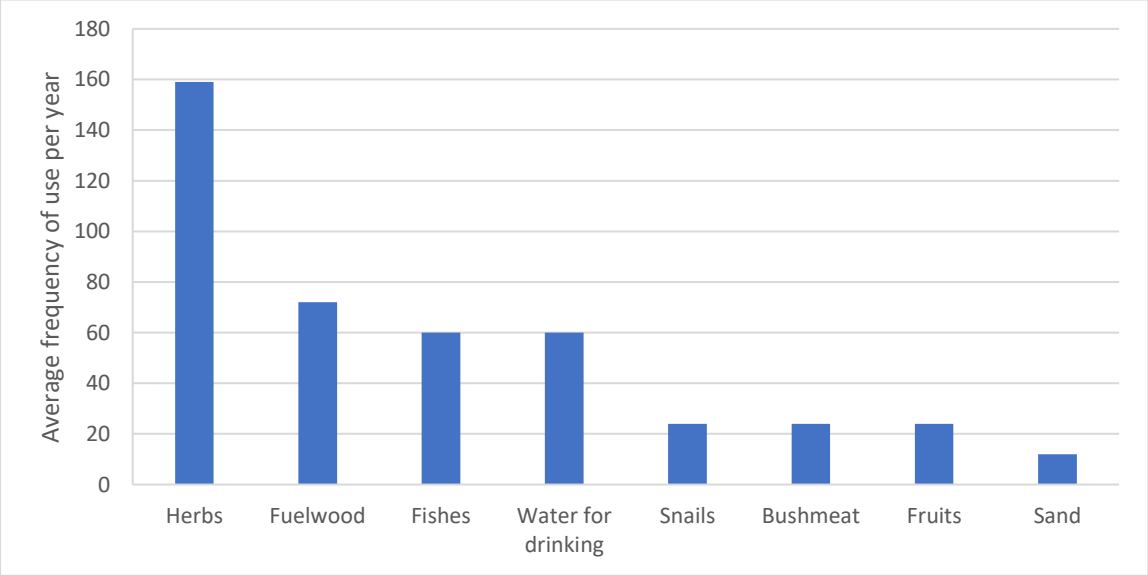

Figure 5: Average per year frequency use of provisioning services of respondents

5.

The result shows that herbs are the most frequently collected provisioning services representing a total of 159 times per year. Even though the number of people harvesting herbs is less than that of fuelwood, fishes and drinking water (*see* ***Error! Reference source not found.***), this is mostly because herbs are used in treating long-lasting illness (like chronic diseases) and also very cheap (in this case

free). It is possible that the frequency of acquiring and using of fresh herbs in treatment determines the healing of the person which in most cases takes a longer time hence the higher frequency of use. Other services like fish, fuelwood and drinking water are mostly collected and stored for a using period of time before collected again. The least frequent collected provisioning services include sand, fruits, bushmeat and snails. This is restricted to the season (fruits and snails) or the management policies of Owabi (bushmeat and sand).

4.1.3 Quantity and use level of provisioning services by communities

To present the use level and quantity for each provisioning services for the total number of household, the statistical analysis of the annual quantities used by the sampled households were calculated (*appendix 2f*). The percentage sampled households that uses a specific provisioning services was then used in calculating the quantity and use level for the total number of household in Owabi (*appendix 2g*). The unit value for the quantities were estimated by using the information developed by RMSC (*see appendix 3*). The minimum and maximum quantity of use services extracted by the total number of households from community is presented in Table 4. For easy explanation, drinking water have been assessed in m^3 and different from other seven provisioning services which was assessed in tons.

Table 4 : Quantity of provisioning services used by the total number of households per year

Provisioning services	Minimum quantity of use	Maximum quantity of use
Drinking water (m^3)	3,000	32,000
Fuelwood (ton)	150	1,500
Fishes (ton)	16	500
Fruits (ton)	13	21
Herbs (ton)	17	64
Bushmeat (ton)	21	26
Sand (ton)	0	53
Snails (ton)	0	10

The result shows that about 2000 ton per year of the seven provisioning services are maximumly extracted and also an annual of 32 000 m^3 drinking water are maximumly extracted from Owabi. This represents a maximum extraction of about 2.4 ton of the seven provisioning services and 8.5 m^3 drinking water per number of household in the communities annually (see appendix 2f). Among the eight provisioning services, drinking water had the highest contribution to the total amount being extracted (between 3000m^3 to 32,000m3). The service which is less used by the total number of households of Owabi is snails with an annual extraction of 10 ton(maximum).

4.2 Regulating Services and Current use

From the experts that were interviewed, the most important regulating services that were mentioned include wetland/watershed protection, and CO_2 regulation. However, this was seen differently according to the respondents' (see Table 6). The respondents recognize climate regulation as the most used regulating services. This can be explained as the majority of the

respondents are farmers (*see appendix 1d*), they expect conducive micro-climate influence from Owabi for their crops. Water purification was seen as the least regulating services. It is assumed that the dam and its waterworks built on the Owabi river is supposed to take care of the water purification and therefore the communities see no added significance of Owabi to take care of that.

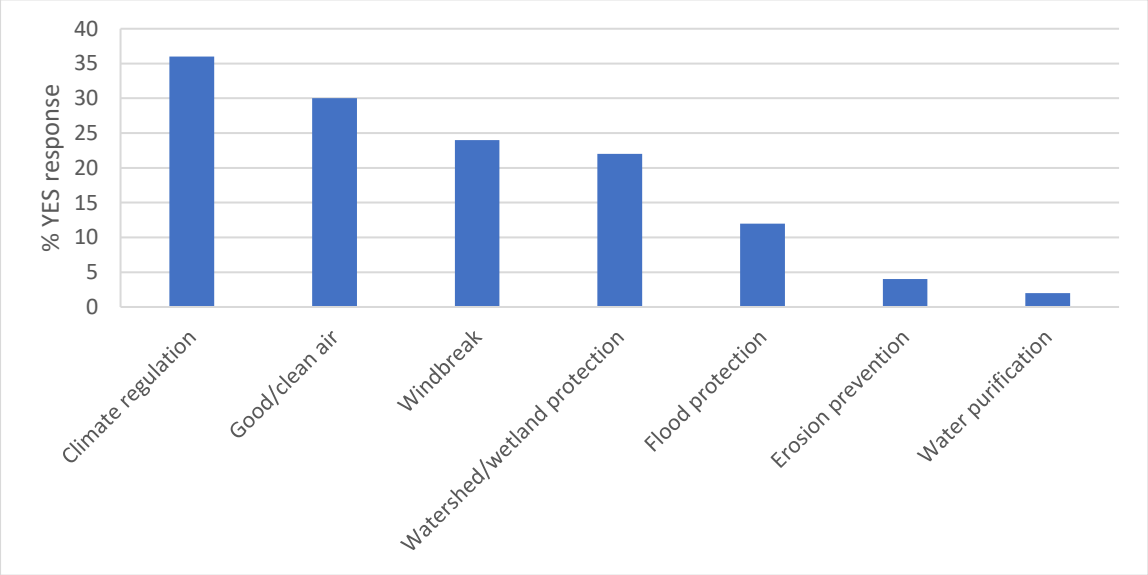

Figure 6: Current use regulating services of Owabi by respondents

4.3 Cultural Services and Current Use

Experts recognizes ecotourism and research center as the most significate cultural use of Owabi. There are regular visits by tourist from all around the world for bird watching, canoeing and camping as well as researchers and university students using the area for research purposes. Respondents from the communities also chose the current use of cultural services which was included in the questionnaires. The result was then presented in Figure 7.

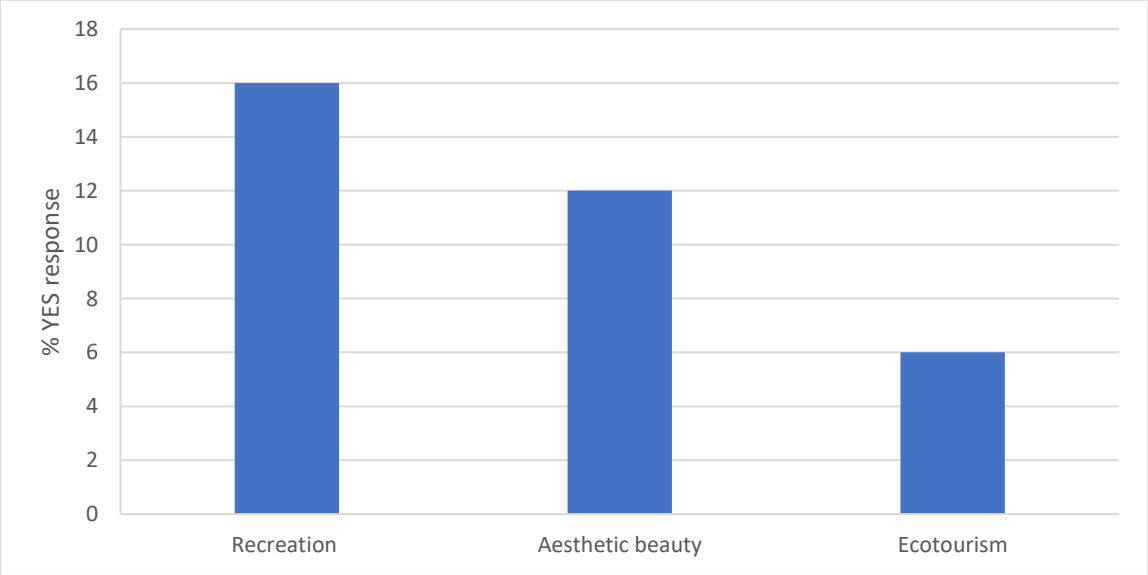

Figure 7: Current use cultural services of Owabi by respondents

The result shows a majority of the respondents involving themselves in recreational activities followed by aesthetic beauty and ecotourism. Most of the time they go for a walk, recreational fishing (with hook and line), and also enjoying the serene environment.

4.4 Habitat Services

Maintenance of life cycle of migratory birds and maintenance of genetic diversity of both flora and fauna are the habitat use services that were mentioned by the experts. This is very important and mandatory for Owabi establishment. Owabi provides gene pool resources (wildlife) for ex-situ (Kumasi zoo) management to prevent wildlife extinction. All communities recognize this habitat uses and conform with its mandatory.

The habitat services protect flora species of high conservation status which is considered as vulnerable under IUCN red list including *Nauclea diderrichii, Entandrophragma angolense, Entandrophragma utile, Pterygota macrocarpa* and *Albizia ferruginea.* Till date there are 193 species of vascular plant which includes 91 trees, 18 shrubs, 37 herbs and 14 grass species, 1 epiphyte, 6 ferns and 26 climbers (Forestry, 2014).

The habitat also harbours the *Manis tricuspis* (tree pangolin) which is considered as vulnerable with decreasing population status in the IUCN red list. Although quantitative data on animals are not available, the spot-nose, Mona and the green monkey has been recorded in 1988. There are footprint traces of wild animals such as bushbuck (*Tragelaphus scriptus*) and black duiker throughout the area. The area also consists of birds species with 13 families listed in Appendix II of the Convention on International trade in Endangered Species (CITES) (Badu-Boateng & Poku, 2009).

5 Carrying capacity and Sustainable use level of Ecosystem services of Owabi

To arrive at the performance/sustainable use of all the eight provision services from Owabi, The maximum productivity and Net Primary Production (NPP) of each service was generated wherever possible (*see appendix 4*). This value for sustainable use represent the maximum value of each services that can be used without degradation (De Groot et al., 2010a, b and UNEP-WCMC, 2011) . The maximum productivity and NPP were derived from both expert advice and literature search. However to obtain the NPP of each service was difficult due to limited information for such a specific area. In the case of such an obstacle, benefit transfers and assumptions were made (appendix 4). Sustainable extraction of Owabi ecosystem services by the fringe communities were then generated by using only 10% of NPP i.e. the maximum productivity (see Table 5).

Table 5: Performance/Sustainable use of the eight provisioning services from Owabi by total households of fringing communities

Provisioning services (per yr)	Maximum Current used (per yr)	Maximum Productivity (per yr)	Ratio of used/produced Per year	Performance/Sustainable use indicator (10% of NPP or maximum productivity in per yr)
Drinking water (m^3)	32000.00	2000	16	200.00
Fuelwood (ton)	2000.00	33000.00	0.06	3300.00
Fishes (ton)	500.00	2.50	2000.00	25.00
Sand (ton)	53.00	1000.00	0.05	100.00
*Fruits (ton)	21.00			
Bushmeat (ton)	26.00	2.20	12.00	0.22
Herbs (ton)	65.00	0.02	0.004	1500.00
Snails (ton)	10.00	520.00	0.02	52.00

Services with (*) were not able to assess

The result shows that all the provisioning services with the exception of fuelwood, sand, herbs and snails are being extracted more than their maximum productivity annually. For easy understanding, the details of the analysis have been grouped into drinking water, sand and biological resources which is further explained in the subsections.

5.1 Drinking water

The maximum amount of drinking water being used by the communities amounts more greater than what is being produced. The ratio between used and produced shows a value of sixteen times more than what is being produced. About 32,000m^3 of drinking water per year compared to 2,000 m^3 that can be produced per year (expert advice). With such an indication, it can be said that the amount being used by the total number of households fringing Owabi is not sustainable. This can however jeopardize service function of the Owabi dam and communities may not enjoy such service in a long run. It was however confirmed during community interviews. Respondents complaining of the occasional shortage of drinking water. Drinking water sometimes may not be available through the pipe borne for about weeks. To improve the

sustainable use of this services, an amount of 200m^3/year can be sustainably used by the communities representing 10% of what is being produced.

Gap analysis

The total number of households fringing Owabi as well as the amount of water being extracted from the dam is known. Although through expert advice the amount of drinking water that can be produced was known, there is the need for proper assessment of the productivity function of the Owabi dam. To be able to get a clearer picture of how much can be used without over-exploitation, the amount of water that can be maximumly produced must be known exactly.

5.2 Sand

About 53 tons of sand is being extracted from the Owabi river annually. This indicates about 5% of the yearly produced sand (sedimentation) being extracted annually. With that amount of what is being extracted it could be said that the amount extracted is sustainable compared to the 10% of what can be used from the maximum productivity. For a sustainable harvest, communities can extract about 100 tons of sand yearly to ensure the sustainable harvest annually. This activities was explain by experts during interview that it is more beneficial for the dam since the depth of the dam has reduced by eroded sand.

Gap analysis

There is the need for impact assessment of sand winning in Owabi dam to ensure that such services do not have an impact on other services like the drinking water or fishes extraction. Also, a more detailed assessment of sand sedimentation in Owabi dam needs to be assess to know the exact quantities of sand being produced.

5.3 Biological resources

The biological resource includes fuelwood, fishes, fruits, bushmeat and herbs.

The amount of fuelwood used by the communities is about 6% of the yearly production. This shows about 2,000 tons of fuelwood out of about 32,000 tons produced are being harvested annually. The amount harvested is within the sustainable usage thus i.e. not more than the 10% of what is being produced (about 3,000 tons/yr). However it should be known that not all woods can be harvested in the area especially that of timber and other endangered species. Mostly dead woods and overpopulated tree can be used in this case.

With fishes and bushmeat provisioning services, the amount being extracted is 2000 and 12 times more than what is being produced respectively. This is considered as unsustainable. To harvest both fishes and bushmeat sustainably an amount of 2.5 and 0.2 tons can be respectively harvested annually.

The use of herbs by the communities were within the sustainable usage indicator. They only use about 0.4% of what is annually produced.

Gap analysis

To extract the biological resources of Owabi sustainably, a clear assessment of the potential yield of the various services needs to be done. Producing such assessment can provide valuable data input for computation of the exact amount of these services that can be harvest without

exceeding their potential productivity. Assessment should be done on what types of wood e.g. bamboo can be extracted as fuelwood. Also assessment should be done on type of bushmeat that can be permitted for extraction e.g. rodents. Introduction of new fish species should be introduced to improve their sustainable harvest. Fruits tree should also be assessed in the area to know the types of fruits available and their productivity to ensure a sustainable harvest.

6 Stakeholders associated with ecosystem services of Owabi

This section presents the various stakeholders involved in the ecosystem services of Owabi. This was assessed following the method described in the framework developed (see Figure 2). A list of stakeholders was created and grouped according to spatial scale. Also, the interest and influence matrix of these stakeholders were analyzed. The fringe communities perceive stakeholders with different power and influence level which was also analyzed in this section. Finally, the potential conflicts and synergies among communities and other users of the ecosystem service of Owabi was further analyzed.

Stakeholder involvement within Owabi can be distinguished at the local, national/region and global level. At the local level, it includes fringe communities who depend on the area for food, fuelwood and water for consumption. At the national level, Owabi houses the Owabi river which was dammed by the GWCL. GWCL provides treatment of Owabi water and distributes drinkable water to the people of Kumasi (Ameyaw & Dapaah, 2017). At the international level, Owabi ecological resources have been recognized by Wildlife Society. This is a Non-profit making organization representing Birdlife International partner in Ghana. Known from experts' interview, Wildlife Society provides conservational programmes and education for the sustainability of the ecological resources of Owabi. Details of the different stakeholders can be seen in Table 6 below.

Table 6: Stakeholders involvement in Owabi ecosystem services

INSTITUTION	SCALE		
	LOCAL	**NATIONAL/REGINAL**	**INTERNATIONAL**
Individuals	Fringe communities	Kumasi environs	Global community
Public sector	District Assembly, Chiefs	WD, GWCL, WRC	
NGO			Wildlife Society
Research organization		KNUST	

6.1 Interest and influence matrix of stakeholders of Owabi

Following another categorization of stakeholders of Owabi, an interest and influence matrix was drawn. This is the measure of the degree of interest (on the vertical axis) and influence (on the horizontal axis) on the use and management of ecosystem services of Owabi. This was adapted from several studies (Ackermann & Eden, 2011, De Lopez, 2001 and Reed et al., 2009). The four quadrants of the grid shows distinctively four categories ('subject, players, crowd and context setters') of stakeholder in Owabi with different degree of interest and influence (Figure 8). Stakeholders belonging to the 'Subject' quadrant have high interest but less influential on intervention. They can be influential by forming alliances with other involved stakeholders. Stakeholders belonging to the 'Players' quadrant are those with the most interest and influence which needs to be groomed. Stakeholders belonging to the 'Context Setters' quadrant are the one with a high degree of influence but less interest on the outcome of Owabi in the future. And the 'Crowd' quadrant exhibits stakeholders with either low or no

influence on or interest in strategy outcome. This categorization is subjective and based on researchers' knowledge of stakeholders. In addition, the use of knowledge in defining stakeholders on the grid was also drawn from Table 6 with the help of expert knowledge.

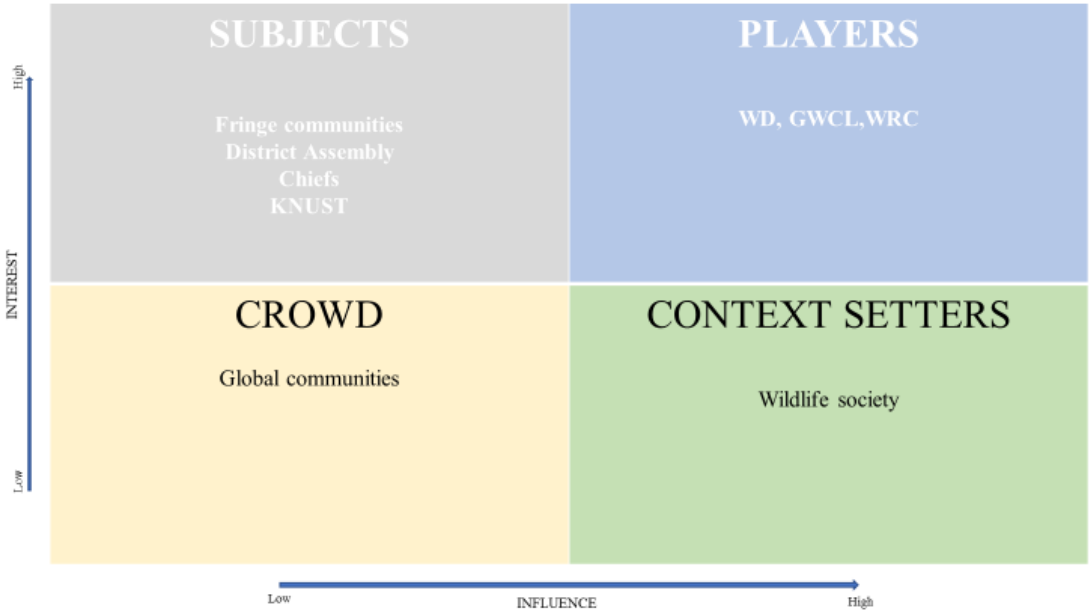

Figure 8: Interest and influence grid for the stakeholders of Owabi

Subjects

Stakeholders belonging to this category exhibit high interest but low influence. They include stakeholders such as chiefs, Kwame Nkrumah University of Science and Technology (KNUST) and fringe communities (e.g. farmers, fishermen). They are mostly affected by the outcome of the interventions proposed on the area. They are marginal stakeholders that any development of interventions must seek to empower. A particular attention needs to be given to these stakeholders. Their interests need to be consulted and protected in order to be included in proposed policy intervention.

Players

Stakeholders in this category showcase high levels of interest and influence. They are mostly government institutions such as Wildlife Division, Ghana Water Company Limited and Water Resource. They are mostly policy and decision makers of Owabi and can initiate any policy interventions that may positively or negatively impact Owabi. It is relevant to maintain good relations with these stakeholders for the success of any management intervention for Owabi.

Crowd

This category of stakeholders like global communities has low interest in and low influence on the proposed intervention for Owabi. Less attention or priority can be given to such stakeholders in developing management intervention for Owabi. However, their interest and influence change over time and the impact of such change can be considered when necessary.

Context settlers

Stakeholders in this category have a high influence but low interest which consist of Wildlife Society. Their high influence is as a result of providing assistance in terms of funding, training and education which is necessary and important for the sustainability of Owabi. These stakeholders with little interest may be a significant risk and therefore need to be monitored and managed since they can influence policy interventions.

6.2 Power and influence level of stakeholders by communities

The power and influence level is a tool to further analyse the relationship of communities and other stakeholders in relation to usage of Owabi ecosystem services. These two level were assessed by using the household questionnaires. Respondents were asked to indicate among the list of stakeholders provided, who was significant in terms of influence on the management and use of Owabi ecosystem services.

The results obtained was not surprising as all the respondents (100%) indicated that the government and its associated institutions were the most significant entity. This coincides with the "Players" category on the interest and influence grid (Figure 8). This shows that communities recognise WD, GWCL and WRC as the government institutions that have the mandate to manage and to help by improving interventions for Owabi.

6.3 Potential conflicts and synergies to communities use of services

The respondents from the communities were asked to indicate which stakeholder has conflicts or is more collaborative in terms of them using services from Owabi. This was presented in Figure 9. The conflicts in this case can be actions, policies or measures that may prevent communities from using services. The synergies here can be defined as any supporting measures for using Owabi services. This is a very important relationship to know among communities and other stakeholders in order to predict any source of conflicting issues or any collaborative involvement.

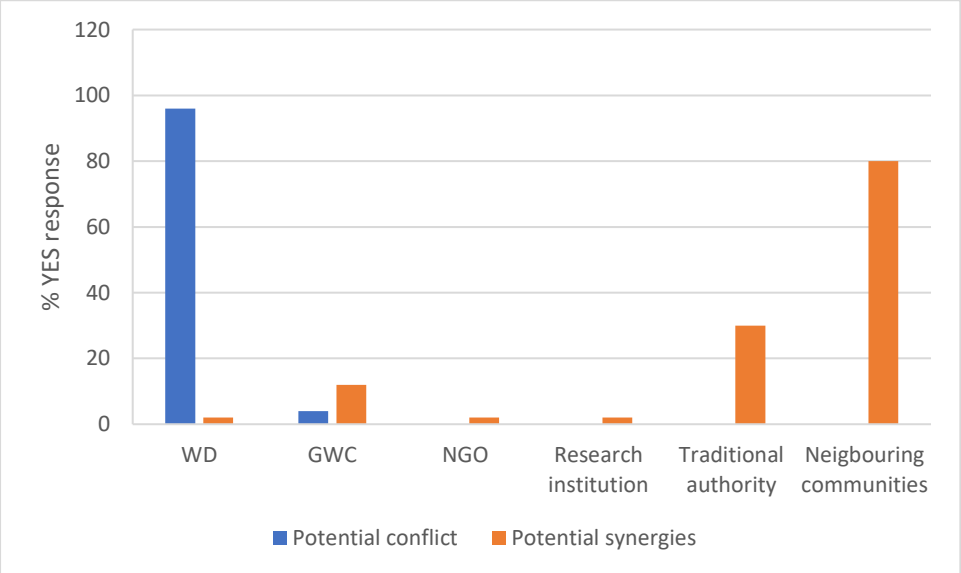

Figure 9: Potential conflicts and synergies to communities in relation of using services from Owabi

The result shows that almost all communities perceive the WD (96%) as a potential threat for them using Owabi ecosystem services. This is not surprising as WD as a government body, has the mandate in terms of policy-making and taking action when necessary to protect Owabi. With such a mandate, all the communities recognise the governments significance (see sub section 6.2). Communities are either stop from going into the area to harvest resources or resources harvested are at times ceased.

When using services provided by Owabi, communities perceive co-existence among some stakeholders of which they do not feel threatened but are rather allies. This is because none of these human activities pose an effect on each other. Communities see such relationship as more of a synergy. Neighbouring communities (80%), and traditional authority (30%) are the most popular parties to form allies in terms of the use of services from Owabi. NGOs are seen as the least popular organisations to form allies. This is because NGO like Wildlife society mostly deals with government bodies directly (e.g. providing funding) and not directly to the fringe communities .

7 Management and Sustainability of Owabi

7.1 Communities support of measure to ensure Owabi sustainability

Communities support some measures to improve the sustainable use of Owabi ecosystem services. These measures are to ensure the performance/sustainable use of Owabi ecosystem services (Table 5). Communities were asked to rate from zero to five (0 indicating no support and 5 indicating the highest support) among the measures that were developed with experts (see appendix 5). The mean ratings of these measures were calculated and presented in Figure 10. The outcome was used in providing some of the recommendations that will improve the sustainability of Owabi.

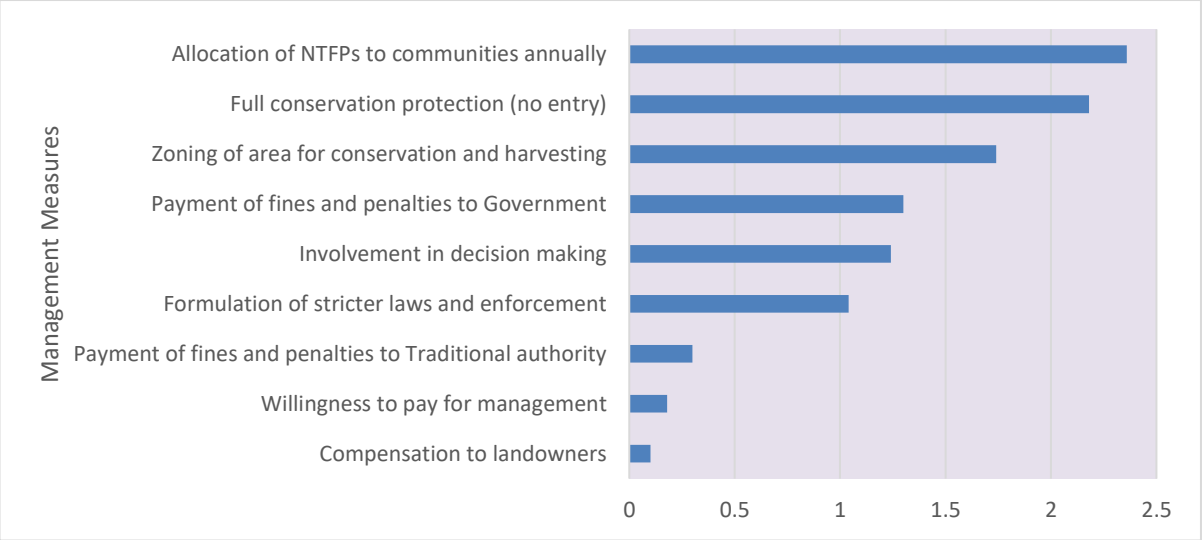

Figure 10:Measures supporting sustainability of Owabi by fringe communities

The result shows that communities favour the allocation of NTFPs annually the most. This is understandable when communities derive benefit from the area and want to maintain. This measure can proved to be sustainable if allocations are based on the performance/sustainable indicator derived for Owabi services (*see Table 5*). However, full conservation protection (no entry) was second highly favoured. This was quite surprising as this could prevent communities from getting some benefits from the area. This can only be explained by the fact that the area was established partly for supplying drinking water, hence communities cannot supplement their source of water by degrading the area. They would prefer maintaining their source of drinking water if it prevents them from entering the area hence full conservation protection is supported. Zoning of the area for conservation and harvesting as well as involving communities in decision making were fairly favoured. The least favoured measure is the compensation to landowners. From the communities' point of view, they recognize that the government representing bodies have full control of the area and as such they have more authorities than the landowners. They assume the government has the power to protect the area by virtue however policy-makers should be able to get landowners involved and necessary payment should be done. This can prevent landowners from allocating Owabi areas for developmental work like housings.

7.2 Implications for the sustainability of ecosystem services of Owabi

This section explains the implication of the supporting measures on the ecosystem of the Owabi. This depicts the sustainability of the Owabi in the future. It further provides the necessary recommendations that favours the sustainability of these measures on the ecosystem services of Owabi.

7.2.1 Allocation of NTFPs to communities annually

This measure seeks to allocate the amount of NTFPs including all the eight provisioning services obtained from Owabi annually. This allocation can be based on the performance and sustainable indicators obtained for Owabi in Table 5. Since this measure is highly accepted by the communities, its implementation will as well be supported by them. With such measure taken, all the provisioning services being harvested by the communities then turns out to stabilize (→) in the near future as only 10% of what is produced is being harvested. This gives the resources time for regeneration and begins to increase (↑) in the long term. This will moreover prevent or decrease the declining value of the ecosystem services of Owabi as well as increase the value of other services.

7.2.2 Full conservation protection (no entry)

This is the second most favoured measure by the communities of Owabi. It basically result in the whole protection of Owabi and prevents any entry from fringing communities. The Owabi establishment is to provide potable water for surrounding communities as well as wildlife protection. Because of these two main services it seems that any measure to ensure these services rendered is very much supported by the communities, even if it prevents them from exploiting the area. With the full protection of the area, all degradation will cease and the ecosystem services provided by the area will gradually improve and increase (↑) in the future.

7.2.3 Zoning the area for conservation and harvesting

This measure basically divides the area into protection zones and harvesting zones, which is the third measure being supported by the communities. It designates areas where communities can harvest NTFPs and areas where habitats, wildlife etc can be protected from extraction. With this measure, the current harvesting of NTFPs continue but in a smaller area zone for harvesting. However the amount of harvesting is the same and therefore provisioning services decrease (↓) in time. Nevertheless the measure ensures the improvement of ecosystem services that is unextractable like the cultural, regulating and habitat service and hence these services increase (↑) in the future.

7.2.4 Payments of fines and penalty to Government

This measure allocates fines and penalties to offenders from the communities in relation to the use of Owabi ecosystem services. In this case the Government (WD and GWCL) may set fines and penalties e.g. payment of a set amount of money or arrest any person who over-exploit these ecosystem services unsustainably or causes damages to the area. This will stabilizes (→) the unsustainable use of Owabi resources in the future. However, this measure is fairly supported by only some of the communities. This means that the implementation of this measure will be difficult to be accepted by the whole communities fringing Owabi.

7.2.5 Involvement of communities in decision making

This measure stabilizes (→) the ecosystem services of Owabi in the future as communities are involved in the management activities of the area. This means their needs and local knowledge are brought on board to sustainably manage the area which is fairly supported by some communities.

7.2.6 Formulation of stricter law and enforcement

This measure had a low acceptance by communities even though helps to stabilize (→) the ecosystem services in the future. Communities perceive that new and more stricter laws enforcement may prevent them from benefiting from Owabi ecosystem services and therefore its acceptance is minimal. Stricter law and enforcement here could be arresting and jailing offenders of using Owabi ecosystem services unsustainably.

7.2.7 Payment of fines and penalties to Traditional authorities

This measure falls among the least favoured measures by the communities. Communities do not consider the traditional authorities as the mandatory authority to manage Owabi, therefore any measures to pay fine or penalties to traditional authorities are not highly favoured. This implies that the current decline on Owabi ecosystem services will continue decreasing (↓) with this measure in place.

7.2.8 Willingness to pay for management by communities

This measure implies that, communities are willing to pay for the use of Owabi ecosystem services and its management. This measure surely will render Owabi services more sustainable as money obtained can be used in managing the area. This will help stabilize (→) benefits obtained in the area in the long run. However, communities do not fully support this measure as they will have to pay for everything. In such cases more illegal activities are likely to happen and can cause a decrease in the ecosystem services.

7.2.9 Compensation to Landowners

This measure has to do with the establishment of Owabi where the government pays compensations to the landowner for their land. With this measure, all illegal allocation of areas and exploitation in the Sanctuary by landowners will cease. This will help stabilize (→) the services being rendered by the area. Communities have the least support of this measure since they perceive the government to have the command control and not landowners.

7.3 Recommendations for management by the Government

All the measures described above seek the sustainability of Owabi ecosystem services, with a greater chance of success when the communities are in support of it. These measures can be integrated to form a more robust measure to improve the area. Below are some recommendations for the government who has control of the area and interested non-governmental parties;

1. The area has be zoned into protection zone and harvesting zone and apply the annual allocation of NTFPs for fringing communities (with their carrying capacity)

2. There should be a clear management responsibilities and collaboration between WD and GWCL especially at the catchment area in order to prevent over-exploitation and degradation.

3. Restore affected and degraded areas by plant trees which can support NTFPs extraction by the communities.

4. Implement alternative livelihood programmes in fringing communities to reduce pressure on Owabi resources in the case of full protection (no entry).

5. Involve the local communities to bring their needs on board and also to predict their area of conflict in order to minimise them.

8 Discussion

1 Ecosystem services assessment: comparison with literature

This thesis is the first study to provide a comprehensive list of ecosystem services of Owabi aside its management plan in 2014. It covers sixteen out of twenty-two categories of TEEB's services and twenty-three specific examples of these services. Other studies in Owabi either reveal the distribution of a specific ecosystem services or a combination of two or three specific services in Owabi. Nunoo et al (2012) studied fish fauna in the Owabi dam and revealed nineteen specific fish species present in the reservoir. Amuquandoh (2011) revealed seven different ecotourism experiences of international visitors to Owabi Wildlife Sanctuary. Also, Ameyaw & Dapaah (2017) studied the effect of encroachment on ecosystem services provided by Owabi wetland and revealed sand winning, timber logging, fishing and water quality as an impact on the communities encroachment. All these studies provide at least one specific ecosystem services that is being derived from Owabi.

In comparison to the Forestry Commission management plan in 2014, based on studies relating to the Sanctuary's physical and biological features, the socio-economic context of the local people, Wildlife Division policy and the management objectives for the Sanctuary, this thesis was more detailed. The management plan generally identified services that can be grouped under sixteen service categories but twenty specific services. This is because in the plan, interviews were conducted in fringe villages regarding human activities related to wildlife conservation like hunting, farming and bushmeat trading, while in my interviews the focus was on all ecosystem services being used in fringe communities. This thesis revealed eight specific provisioning services including sand, fruit and snails. These were not found in the previous plan. The thesis also quantified the provisioning services and its contributions to the larger population of all the households fringing Owabi. Moreover, the thesis studied fifteen additional specific services examples from the regulating, cultural and habitat which communities also valued. This was very explicit compared to the previous plan. Although the thesis did not assess all the ecosystem services of Owabi, it provides the basis for accounting ecosystem services of Owabi to different actors and ensuring its sustainability.

2 Involvement of stakeholders in ecosystem assessment

The thesis has incorporated key but specific stakeholders from different scale and institutions associated with Owabi. Different ecosystem users at different scales and institutions present different perception on the importance of ecosystem services of Owabi. Experts and NGOs mostly put relevance on endangered species of Owabi which has the national or global concern. This is because these services need protection rather than extracting. Community involvement also brings out relevant issues associated with Owabi ecosystem services. These services are attached to their livelihood at the local level and greater importance is placed on their extractions. Involving key stakeholders in ecosystem assessment helps to provide a quality management plan to manage the Owabi ecosystem services. This analysis is consistent with the findings of Brody & Brody (2003) and Hein et al (2006). Brody & Brody (2003) reported that the presence of specific stakeholders to develop an 'ecosystem plan' has a significate increase in its quality. Hein et al (2006) also confirms that stakeholders have different interest at different spatial scales. Most of the time stakeholders that are classified as "subject" in this

thesis often lack influence on the intervention of Owabi. they are very close to the area and therefore decision makers need to draw their input during the planning process of any intervention.

3 Lack of data for carrying capacity and sustainable use of ecosystem services:

The state condition of Owabi can be related to the extraction level of the provisioning services by the communities. There is a need for more information on that and this thesis quantified the amount of provisioning services used in the area. However, this thesis could not quantified other services (regulating, cultural and habitat) due to the lack of data. Nevertheless it provided a qualitative information on the regulating, cultural and habitat services for future research. The information provided by this thesis on the provisioning services reveals the use quantities (flow) of Owabi ecosystem services which is important for sustainable management decision making. This thesis also defined the carrying capacity of the eight provisioning services identified from Owabi. Three out of the eight provisioning services including drinking water, fishes and bushmeat were unsustainably being harvested. This diminishes the quality and quantity of these services being produced in Owabi and hence policymakers can use the performance indicators derived from this thesis to provide intervention for community extractions. This conforms with Roy Haines-Young et al (2006) study on defining and identifying environmental limits for sustainable development. They revealed that environmental limits are usefully defined in relation to a range of situations, above which benefit gotten from natural resources are unacceptable or not sufficient. In addition, it is stated that environmental limit can be useful in justifying areas where management targets should be set. This is also consistent with the findings of Jacobs (1991) study on green economy. The research revealed that, the harvest or use-rate of renewable resources should not exceed the regeneration rate and for non-renewables the demand should be relative to maintaining the stock level.

There were data lacking in computing the exact carrying capacity for the provision services especially with that of their maximum productivity or net primary productivity. This was because there were no assessment or literature on the maximum productivity or the net primary productivity for Owabi resources. Defining such assessment would be out of the scope for this thesis. My research however, provided some basis for assessing the productivity of the eight provisioning services in Owabi in order to determine their sustainable usage whiles not exceeding their carrying capacity. Most of the data used were based on benefit transfer and assumptions. Further research could be done to determine the productivity or stock level of these services obtained from Owabi. This can be compared with that of the findings in this thesis.

4 Influence of Stakeholder selection and analysis

There are different methods for stakeholder analysis in resource management. The thesis performed stakeholder analysis based on the following four steps (Kurtz, 2012) including 1. creating a list of stakeholders 2. deciding on important and influential stakeholders 3. creating an influence/important matrix and 4. deciding on the method to consult stakeholders. Some studies follow either the first step by identifying stakeholders by different approaches (Colvin et al., 2016) or a combination of the first three steps, referring to those steps as identification,

categorisation and relationship investigation of stakeholders (Reed, 2008; Reed et al., 2009). Other studies go beyond these four steps by including stakeholders evaluation to see their impact on the outcome of a project (Luyet et al., 2012). However, reaching out to all the stakeholders for evaluation on their impact to the project outcome was not the point of interest in this study, therefore the method used in this thesis by creating a list of stakeholder was through experts advice and it is consistent with other literature (e.g Chevalier & Buckles, 2008).

I further classified stakeholders by an analytical categorisation called a top-down approach. This method of categorisation includes deciding on important and influential stakeholders and the use of an interest and influence matrix to classify stakeholders into 'key players, context setters, subjects and crowd'. This approach was based on my knowledge and observation of the system after a careful analysis of literature and the previous management plan to understand the links and functions of each stakeholder (Reed et al., 2009; Hare & Pahl-Wostl, 2002). A popular method 'bottom up' is used in other studies to allow stakeholders to categorise other stakeholders themselves (Dryzek & Berejikian, 1993). I partly used this where I allowed communities of Owabi to classify other stakeholder in terms of the power and influence level relationship and their potential conflicts and synergies.

5 Questionnaire approach to ecosystem assessment

There are different approaches to assess the ecosystem of any landscape especially when they are susceptible to trade-offs. Some literature employs the use of mapping and modelling approach (Petz et al., 2014) while others use the approach of dynamic simulations (Vidal-Legaz et al., 2013). This thesis used the questionnaire based approach in assessing the ecosystem of Owabi. Even though this approach is not a commonly used tool for such an assessment, it is consistent with recent literature (Santos et al., 2017; Pranovi et al., 2016). Santos et al. (2017), used a questionnaire-based approach to carry out the socio-ecological assessment to characterise the use of mangrove fisheries by the local population. The study revealed that the local population explores different types of fishes, crabs, mollusks and shrimps.

Most times, it is convenient to use other approaches in assessing ecosystem services at the national, regional or even global. In many cases there are limited spatial data for developing countries. Available data sometimes lack the accuracy in estimates. This is usually not localized and make assessment difficult. In the instance where the above situation exists, questionnaire-based approach may play a vital role in helping decision makers to assess the changes in the services and prioritize interventions. Questionnaire approach was used in my study to provide first hand data on a localised area. In using this approach, the questionnaires designed for assessment need to be tested and refined before the actual assessment. This test illustrates the shortfalls and clarifies the questionnaires which need to be re-adjusted. A more detailed report on the challenges of using questionnaire surveys in ecosystem assessment and ecological valuation can be more helpful in designing appropriate questionnaires (Luyet et al., 2012).

8.6 Limitations and uncertainties related to data collection and interpretation

Through the completion of this thesis, limitations on the data collection, quantifications and uncertainties in the computed carrying capacity emerged.

Firstly, fifty households out of about four thousand households were interviewed. A larger sample size could be employed to have a better representation of the total number of households in Owabi. However, random sampling was employed in selecting these households in other to have a representative of the fringe communities. Also the minimum and maximum quantities used by total number of households were derived to show the least and the highest amount of services they extract. The average quantity used can fall within the minimum and maximum quantities being used. Therefore the findings of this thesis still represent the views from the total number of households in Owabi.

Also, questionnaires developed for the community interview were translated into the local dialect for the better understanding of the local people. This translation of the concept of ecosystem services and other scientific terminology may innate limitations that may affect the responses of communities interviewed. Nonetheless translation was done by me with knowledge on local dialect. Translation was therefore done to the best of my understanding which do not have influence on the findings. Again interviews with expert were recorded with pen and field note rather than the earlier intention of recording with tape and transcribing later. This was as a result of the choice made by expert as to not record the interview. Although recording on tape and transcribing give the advantage of playing back in exact word, all other methods like writing in field book as used in this thesis also offer possibilities that others do not like impressions, emotions and contextual details (Tessier, 2012). All this was factored during the interview and should not be misinterpreted. A combination of different methods can be used wherever possible to achieve a better data.

Secondly, the study was focused on determining the ecosystem services of Owabi and the amount of these services used by the fringe communities but not necessarily focused on quantifying all the ecosystem services of Owabi. All provisioning services were analysed quantitatively and other services (like cultural, regulating and habitat) were more analysed qualitatively. To quantify other services used by the communities would be more time consuming for a master study and basically out of scope for this thesis. Most importantly a comprehensive list of all the ecosystem services was provided and therefore further research can be done to quantify all.

Thirdly, to estimate the carrying capacity for the various provisioning services of Owabi was mostly based on benefit transfer, assumptions and expert advice as said earlier. Wherever possible benefit transfer, expert advice and assumptions were. Benefit transfer values used in this thesis were critically analysis to the best fit of Owabi in terms of their characteristics or similarities with that of Owabi. Further research can be done to assess the exact quantity on the productivity or the net primary productivity of Owabi provisioning services to refine the carrying capacity. This can be compared with the result of this thesis.

Lastly, upon all this limitations and uncertainties that the study came across, the assessment performed in this thesis represent a vital information on Owabi ecosystem assessment to contribute to new sustainable management plan. This is important for decision makers, communities and other involved stakeholders to appreciate the connection of a semi-natural environment in providing service and benefit.

9 Conclusions

9.1 Previous Management measures and activities of the local people (RQ1)

Owabi Wildlife Sanctuary was established for the purpose of wildlife protection and the provision of drinking water for the people depending on it. This thesis has reviewed the previous management plan and elaborated the activities of the fringing communities of Owabi including the use of Owabi ecosystem services. Although the thesis reveals the use of some services which are opposed by the previous management plan e.g. harvesting of bushmeat, cutting of tress for fuelwood and illegal harvesting of fish, it shows the use of such services in Owabi. Most management measure usually includes patrolling and removing snares.

Communities involve in various activities that put pressure on Owabi resources. This includes agriculture, bead making, fish farming and demand for drinking water. Also the community interviews confirmed some activities like harvesting of goods, hunting, tourism, having leisure, farming and swimming in Owabi. The area faces different management challenges of which this thesis offers relevant information and has provided recommendations to contribute to the development of a new management plan.

9.2 ecosystem services and the amount being harvested by communities (RQ2)

Both the experts and the fringing communities have placed importance on Owabi ecosystem. The communities acknowledge the use of some provisioning services that include fishes, fruits, snails, drinking water, fuelwoods, bushmeats, herbs and sand for construction. The communities use about 35 million kilogram of the eight provisioning services are extracted annually. This shows about 11 thousand kilogram per number of households in the community. They extract these services for their basic subsistence e.g. they use fuelwood as their energy source for cooking, water for drinking and harvest fish, snail and bushmeat to supplement their protein source. The experts recognize the regulating services of Owabi. They place important value on the wetland/watershed protection and CO^2 regulation. The Sanctuary protects the Owabi river for which was dammed to provide drinking water to communities. On the other hand, communities recognize climate regulation (micro) as the most used regulating services. This is because the majority of them are farmers and depend on the conducive climate for their crops. Also, experts recognize ecotourism and research centre as the most significate cultural use of Owabi. This is because Owabi provides an avenue for bird watching, canoeing, camping as well as centre for research purposes for tourist all over the world. From the communities perspective, recreation is the most used cultural service. Some of the communities just go for walks, relaxation, recreational fishing (hook and line) and just enjoy the serene environment. Nonetheless, both experts and communities acknowledge the maintenance of the life cycle of migratory birds and maintenance of genetic diversity as the most important habitat services. This is because Owabi harbour thirteen families of birds species that is listed in Appendix II of CITE. It also protects flora and fauna species that is recognise under IUCN red list. Moreover, it provides gene pool resources for ex-situ (Kumasi zoo) management.

9.3 Carrying capacity of ecosystem services and sustainability of the use level (RQ 3)

Using of the provision services of Owabi by the fringing communities pose threats to the status of Owabi. To ensure the sustainability of Owabi, the thesis performed analyses on the carrying

capacity of these provisioning services used by the communities. Out of the eight provisioning services extracted, three namely fishes, bushmeat and drinking water were unsustainably harvested. This was because the amount being harvested annually is more than their productivity per year. To ensure their sustainable use without degrading the status of Owabi, ten percent of their productivity can be annually harvested.

9.4 Main users of Owabi ecosystem services and the potential synergies and conflict among communities and other users (RQ 4)

There are different stakeholders that are involved in the use of Owabi ecosystem services. All provisioning services are mostly used by communities near Owabi and services like watershed protection, CO^2 regulation, ecotourism, research and habitat functions are mostly used by people near and far from Owabi. These users are grouped into local, national or regional and international. The main users includes fringe communities, Kumasi environs, chiefs, district assemblies, WD, GWCL, WRC, KNUST, Wildlife Society and global community.

Communities may have potential conflict with the WD in terms of using the provision services. From the communities perspective, WD may put measures that prevent them from extracting from Owabi. On the other hand, communities perceive allies with their neighbouring communities and traditional authority (e.g. chiefs) because their activities are seen as not to affect them from extracting Owabi services.

9.5 Management and sustainability of Owabi (RQ5)

Communities support some measures generated by experts to improve the management and sustainability of Owabi ecosystem services. These measures generated by experts include allocation of NTFPs to communities annually, full conservation protection (no entry), zoning of area for conservation and harvesting, payment of fines and penalties to government, involvement in decision making, formulation of stricter laws and enforcement, payment of fines and penalties to traditional authority and willingness to pay for management and compensation to landowners. With all these measures the communities supported the allocation of NTFPs annually the most. The allocation is based on the carrying capacity of the provisioning services obtained in this thesis. This measure stabilizes the provisioning services currently used by the communities because only 10% of their productivity can be extracted. Moreover, it improves the value of other ecosystem services (regulating, cultural and habitat).

However the thesis provides a more integrated recommendation that, zoning the whole area (both inner and catchment site) into protection zone and harvesting zone and applying the annual allocation of NTFPs to fringing communities will be the best fit for Owabi and also most appealing to communities. This integrated measure assures the stability in the quality and quantity of provisioning, regulating, cultural and habitat services. However, to implement this measure requires policy change in the institutions and regulations in terms of the management of Owabi. The re-zoning and sustainable allocation of NTFPs annually need to be integrated with the current management of Owabi. It requires the WD and GWCL to enact on new policies, have clear policy guidelines and the feel of management responsibilities to zone and allocate resources (based on their carrying capacity) in the entire area. This will inform communities on which area of Owabi they can have their activities going on sustainably and

also inform decision-makers on the communities impact on these ecosystem services. This is useful to control degradation such as depletion of game and wildlife, deforestation, erosion etc. This thesis has provided some basics for re-zoning purposes by giving out a detailed list of ecosystem services (regulating, cultural, and habitat) of Owabi. This can further be assessed and zone for their protection or harvesting from/by the communities. Also, necessary dialogue should be ensured between GWCL and landowner to curb for arrest payments in the acquisition of land for the Owabi establishment and also to prevent illegal allocation of areas in the Sanctuary for local development. Moreover, degraded areas in Owabi should follow a restoration programme to improve the health of Owabi.

In the case where full conservation protection (no entry) is necessary which will appeal to decision makers because it ceases the total decline of resources (harvesting) in the area and increases the quality and quantity of ecosystem service in the future. With such measure, the government has to compensate communities by developing alternative livelihood programmes for their subsistence.

In conclusion, this thesis performed an ecosystem assessment to all the ecosystem services of Owabi which helped in achieving the set out objectives. It provided a comprehensive list of all the ecosystem services Owabi for future developments. It provided adequate information on the provisioning services of which decision makers and involved stakeholders can make use of and produce a sustainable management plan for the whole area of Owabi.

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Appendices

Appendix 1. Community characteristics (demographic and socio-economic) of respondents

a. Gender distribution of respondents from house

Gender	**Number of respondents**
Male	29
Female	21
Total	**50**

b. Age distribution of respondents

Age	**Number of respondents**
Under 20	0
21-30	16
31-40	13
41-50	11
Above 50	10
Total	**50**

c. Education level of respondents

Education level	**Number of respondents**
Basic	37
Secondary	11
Tertiary	1
No education/illiterate	1
Total	**50**

d. Occupation of respondents

Occupation	**Number of respondents**
Baker	1
Bar keeper	1
Beads maker	1
Carpenter	2
Charcoal Vendor	1
Driver	1
Farmer	15
Fisherman	1
Food Vendor	4
mason	4
Pastor	1
Seamstress	4
Shoe maker	2

Occupation	Number of respondents
Shop keeper	6
Student	1
Teacher	1
Unemployed	1
Welder	3
Total	**50**

e. Household composition of respondents

Number of family members	Number of households
1	3
2	4
3	8
4	10
5	2
6	6
7	4
8	5
9	2
11	1
12	3
21	1
26	1
Total 301	**50**

I. Average person in household = 6
II. Total population = 26567
III. Number of household = Total population of fringe community divided by average persons in household =26567/6 = 4428

f. Activities carried on in Owabi

Activities	Number of household	percentage
Farming	8	16
Harvesting of goods	18	36
Hunting	1	2
Leisure	16	32
Tourism	17	34

Appendix 2. Provisioning Services, Current and Frequent Use, Use level and Quantities

a. Current use of provisioning services by household (N=50)

Provisioning Services	Number of households	Percentage of households
Water for drinking	43	86
fuelwood	16	32
Fishes	15	30
Fruits	4	8
Herbs	4	8
Bushmeat	4	8
Snails	3	6
Sand	1	2

b. Frequent use of provisioning services of respondents

Provisioning Services	Average use by respondents/month
Herbs	13
Fuelwood	6
Fishes	5
Water for drinking	5
Snails	2
Bushmeat	2
Fruits	2
Sand	1

c. Current use of regulating services by household

Regulating services	Number of households	Percentage of households
Climate regulation	18	36
Good/clean air	15	30
Windbreak	12	24
Watershed/wetland protection	11	22
Flood protection	6	12
Erosion prevention	2	4
Water purification	1	2

d. Current use of cultural services by households

Cultural services	Number of households	Percentage of households
Recreation	8	16
Aesthetic beauty	6	12
Ecotourism	3	6

e. Statistical analysis of central tendency and variation for the eight provisioning services per number of households per month

Provisioning services	**Number of households using services**	**Percentage (%) of household using services**	**average frequency of using services per month**	**Average quantity of using services per month**	**Five average minimum quantity per month**	**Five average maximum quantity per month**
Drinking water L	43	86	5	266.56	68	707
Fuelwood (kg)	16	32	6	9.50	9	90
Fishes (kg)	15	30	5	2.62	1	30
Fruits (kg)	4	8	2	0.32	3	5
Herbs (kg)	4	8	13	0.72	4	15
Bushmeat (kg)	4	8	2	0.35	5	6
Snails (kg)	3	6	2	0.16	0	3
Sand (kg)	1	2	1	1.00	0	50

f. Average, maximum and minimum quantity of the eight provisioning services per number of household per year

Provisioning services	**Average quantity of use**	**Minimum quantity of use**	**Maximum quantity of use**
Drinking water L	3199	816	8484
Fuelwood (kg)	114	108	1080
Fishes (kg)	31	12	360
Fruits (kg)	4	36	60
Herbs (kg)	9	48	180
Bushmeat (kg)	4	60	72
Snails (kg)	2	0	36
Sand (kg)	12	0	600
Total	**3375**	**1080**	**10872**

g. Average, maximum and minimum quantity of the eight provisioning services per total number of households per year

Provisioning services	**Total number of households using services**	**Average quantity of use**	**Minimum quantity of use**	**Maximum quantity of use**
Drinking water L	3809	12184991	3108144	32315556
Fuelwood (kg)	1417	161538	153036	1530360
Fishes (kg)	1328	41168	15936	478080
Fruits (kg)	354	1416	12744	21240
Herbs (kg)	354	3186	16992	63720
Bushmeat (kg)	354	1416	21240	25488
Snails (kg)	266	532	0	9576
Sand (kg)	89	1068	0	53400
Total		**12,395,315**	**3,328,092**	**34,497,420**

h. Selling of benefits from Owabi

Response	Number of households	Percentage of household
No	44	88
Yes	6	12

Appendix 3. Unit value for estimating the quantities of ecosystem services used by communities from Owabi.

Class	Name of product harvested	Local unit	Conversion of local unit to metric
Non-timber Forest Product	Snails	Paint rubber	1 Paint rubber = 2.5 kg
Bushmeat	Maxwell's Duiker	Full grown	1 Full grown = 30 kg
Non-timber Forest Product	Herbal medicine	Jute sack	1 Jute sack = 15 kg
Bushmeat	Pel's flying squirrel	Full grown	1 Full grown = 1.5 kg
Bushmeat	Giant Pouched Rat	Full grown	1 Full grown = 1.2 kg
Bushmeat	Pangolin	Full grown	1 Full grown = 2 kg
Bushmeat	Grasscutter	Full grown	1 Full grown = 5.5 kg
Bushmeat	Bushbuck	Full grown	1 Full grown = 42 kg
Bushmeat	Brush Tailed Porcupine	Full grown	1 Full grown = 4.5kg
Bushmeat	Giant Pouched Rat	Full grown	1 Full grown = 1.2 kg
Non-timber Forest Product	Drinking water	Big aluminium bucket	1 big bucket= 34 litres
Non-timber Forest Product	Drinking water	Big barrel	1 big barrel = 8 big buckets= 272 litres
Non-timber Forest Product	Sand	Cement paper bag	1 cement paper bag=50kg
Non-timber Forest Product	Firewood	Bundle	1 Bundle = 5 Kg
Non-timber Forest Product	Fishes (Tilapia)	Small rubber bucket	1 bucket= 5kg
Non-timber forest Product	Fruits	Polythene bag	1 polythene bag =1kg

Appendix 4: Maximum productivity or NPP of the eight provisioning ecosystem services from Owabi

Provisioning services	**Maximum productivity/Net Primary Production of Owabi (kg/yr)**	**Assumptions**	**Source**
Drinking water	2,000,000	Expert assumes such amount can be produced due to the impact on the dam from human activities	Expert from GWCL
Fuelwood	32,449,250	The NPP of Kade tropical forest (25000kg/ha/yr) with similar characteristics was used. This was then computed for the whole area of Owabi excluding the reservoir area. This includes the above and below ground biomass, litterfall, standing litter crop and nutrient content data.	(Nye & Greenland, 1998)
Fishes	250	We assumed that the fishery potential of Barekese (located at the same district) can be used for Owabi. However, the computed NPP for Owabi was calculated using size of Owabi dam.	(Addison et al., 2008)
Sand	1,139,670	The volume of water in Owabi dam is 134,000 m^3 with an area of 2 ha and a depth of 6,7 m (Nunoo et al., 2012) The sedimentation rate calculated for different waters in Ghana is 0,63 (mass-%/m^3/yr) also represent the storage loss for water as the a certain volume is replaced by sand. The water volume loss in the dam per year is then 844.2 m^3 (134,000 m^3 * 0,0063) Assuming that the relative density of the sediment is 1.35 tons/m^3 (also according to the article), the potential yield of sand in the dam will be 844.2 m^3/yr * 1350 kg/m^3 = 1139670 kg/yr	(Icold, 2009)
Fruits			
Bushmeat	2,200	The average productivity of bushmeat of the Congo basin was used (1.7kg/ha/yr). It was assumed that the only bushmeat harvested were mainly small rodents specifically duikers which can as well be found in Owabi	(Wilkie & Carpenter, 1999)
Herbs	14,900,000	The NPP (11.5t/ha/yr) from the dry tropical forest of in the Manhan range of East Mirzapur Forest Division, India was used.	(Singh & Singh, 1991)
Snails	520,000	The NPP (40g/m^2/yr) from the tropical pond of India was used. It is assumed that the type of snails harvested is (P. globose). This was then calculated for the whole area of Owabi.	(Haniffa, 1978)

Appendix 5. Measures supporting sustainability of Owabi by fringe communities

		Willingness to pay for management	Full conservation protection (no entry)	Compensation to landowners	Zoning of are for conservation and harvesting	Payment of fines and penalties to Traditional authority	Payment of fines and penalties to Government	Formulation of stricter laws and enforcement	Involvement in decision making	Allocation of NTFPs to communities annually
N	Valid	50	50	50	50	50	50	50	50	50
	Missing	0	0	0	0	0	0	0	0	0
Mean		.18	2.18	.10	1.74	.30	1.30	1.04	1.24	2.36
Sum		9	109	5	87	15	65	52	62	118

Appendix 6. Questionnaires used for expert and community interviews

Part A

Questionnaires for Expert Interview

Introduction

This questionnaire is designed to assess the ecosystem services provided Owabi Wildlife Sanctuary (including the catchment area) and also assessing the maximum use limit of these services to help develop sustainable management plan of the area in accordance to the Master of Science (MSc) in Environmental Science (Wageningen University). The aspect of sustainability entails the continuous use of these ecosystem services without jeopardizing the ability of the area to provide such services in the future. The study will help to assess the different usage of the services, its current and future use, synergies and conflicts among users of these services to ensure limited challenges among users. For the purpose and use of this research, all the information will be treated as confidential. This would take about 10 minutes proximately and would be grateful if you can spend such time to fill this questionnaire for the study.

Interview No:
Date of interview:
Name:
Institution:

A. Ecosystem Services Assessment/carrying capacity
   1. What are the benefits that are being provided by Owabi? For fringe community and for the larger population?
   2. Which of the benefits do you regard as important? (as an organization or person)
   3. What is the state or health condition of Owabi in providing the benefit to meet societal demand in your opinion?
   4. What is the performance indicator (e.g. Kg/ha/year) for these benefits that support sustainability usage without degrading Owabi?

B. Stakeholder Assessment (conflicts and synergies)
   1. Who are the main stakeholders considering the usage and management of the benefits mentioned above?
   2. What are the potential conflicts among users of these benefits? Like which benefits have competing usage.
   3. Do you think competition of one benefit affects the other in your opinion?
   4. What are the potential synergies among the benefits to ensure sustainable use of the area?

C. Management and Sustainability of Owabi
   1. What are the actual needs of the primary stakeholders with regard to the benefits of Owabi?
   2. How can the needs be met sustainably without degrading Owabi?
   3. In your opinion, is the current management sufficient to support the sustainable use of the benefits? (specify the benefit) Why?
   4. What measures can be put in place to ensure sustainable usage of the benefits from Owabi?
   5. Who needs to implement the above measures and with which stakeholders?

Thank you for your time and support.

Part B

Household questionnaire

ECOSYSTEM SERVICES ASSESSMENT AND SUSTAINABILITY ANALYSIS OF OWABI

INTRODUCTION

Dear Respondent

This is to fulfill my Master of Science (MSc) in Environmental Science (Wageningen University & Research, The Netherlands). This study is to analyze the ecosystem services (benefits) that is provided by Owabi Sanctuary (including catchment area) in order to sustainably manage the area for continuous benefit in the future without destroying the ability to provide these services. This study will therefore assess the main ecosystem services, the users of these services, relationship among users and the choice of measure for sustainable development from fringe communities. The information obtained will be handled confidentially for purpose of the research use.

Please tick wherever appropriate.

Date		Interview No:			
A: Demographic and Socioeconomic characteristics					
A1	Sex	Male [ ]	Female [ ]		
A2	Age (years)				
		Under 20			
		21-30			
		31-40			
		41-50			
		Above 50			
A3	Occupation				
A4	Income level	Annual [ ]	Monthly [ ]	Daily [ ]	Other [ ]
A5	Education level	basic [ ]	Secondary [ ]	Tertiary [ ]	Illiterate [ ]
B: House composition					
B1	Number of family members in the house	Total [ ]			
C: Benefits of Owabi					
C1	What are the activities you carry out in Owabi				
	activity				
C1/1	Swimming				
C1/2	Harvesting of goods				
C1/3	Farming				
C1/4	Spiritual				
C1/5	Leisure				
C1/6	Tourism				
C1/7	Hunting				
C1/8	Other (please specify)				

C2: **Services provided by Owabi**											
C2	**Provisioning**	**Current use**	**Would want to use**	**Quantity (Kg)**	**Frequency (per month)**	**C3**	**Cultural/Amenity**	**Current use**	**Would want to use**	**Quantity (kg)**	**Frequency (per month)**
C2/1	Timber					C3/1	Festivals and rites				
C2/2	Fuelwood					C3/2	Sacred groves				
C2/3	Bushmeat					C3/3	Ecotourism				
C2/4	mushroom					C3/4	Recreation				
C2/5	Fishes					C3/5	Aesthetic beauty				
C2/6	Sand					C3/6	Research				
C2/7	land					C3/7	Others (specify)				
C2/8	Wood for kiln (beads)										
C2/9	Snails					C4	Habitat				
C2/10	Fruits					C4/1	Intrinsic value				
C2/11	Herbs					C4/2	Maintenance of life cycles of migratory birds				
C2/12	Spices					C4/3	Gene pool protection				
C2/13	Wood for mortar					C4/4	Other (specify)				
C2/14	Pestle										
C2/15	cane					C5	Regulating				
C2/16	Twine					C5/1	Watershed/wetland protection				
C2/17	Sponge					C5/2	Erosion prevention				
C2/18	Chewing stick					C5/3	Water purification				
C2/19	Construction poles					C5/4	Windbreak				
C2/20	Wrapping leaves					C5/5	Good/clean air				
C2/21	Honey					C5/6	Climate regulation				
C2/22	Water for drinking					C5/7	Others (specify)				
C2/23	Water for irrigation										
C2/24	Other (specify)										

C6	Do you sell any of the benefits from Owabi?		
C6/1	Yes [ ] No [ ]		
C6	If yes for C6/1, how much (in Ghc) do you get from selling it?		
C6/2	Benefit	Amount (GHc)	
C6/3	how far do you travel to collect these goods/services	Distance (km or mile) [ ]	
C6/4	Distance from house to market place	Distance (km or mile) [ ]	
C6/5	Has benefits been declined from the past 3years	Yes	No

D: **CONFLICT AND SYNERGIES**

The wildlife Division (WD) and Ghana Water Company (GWC) are the state institutions in charge of the management of the Owabi Sanctuary and the catchment area respectively. These are institutions responsible for implementing regulations, law and policies for Owabi to manage its services/benefits. This section seeks to understand the challenges and collaborations that the various users of Owabi services encounter in accessing those benefits and how to address it.

D1: regarding stakeholders and use of benefits of Owabi				
	Stakeholder	Significance	Potential threat of using services	Potential collaboration/friend in using of services

D1/1	Government (WD, GWC, FC etc)			
D1/2	Research Institution (eg. NGO etc)			
D1/3	Traditional Authority (chiefs etc)			
D1/4	Neighboring community			
D1/5	Illegal timber operators			
D1/6	Timber companies			
D1/7	Sand winning operators			
D1/8	Building contractors			
D1/9	Landowners			
D1/10	Educational institution (universities etc)			
D1/11	Others (specify			

E: Favorable measures to enhance the sustainable management of Owabi to continuous benefiting

	Measures	Rate (0=lowest 5=highest)				
E1/1	Allocation of NTFPs to communities annually					
E1/2	Involvement in the decision-making processes in the use of Owabi services					
E1/3	Formulation of stricter laws and enforcement					
E1/4	Payment of fines and penalties to Government					
E1/5	Payment of fines and penalties to Traditional authority					
E1/6	Zoning of area for conservation and harvesting					
E1/7	Compensation to landowners					
E1/8	Full conservation protection (no entry)					
E1/9	Willingness to pay for management					

Thank you for participating in the study

Appendix 7: Recorded expert interviews

Question	Expert 1	Expert 2
A: Ecosystem Services Assessment and carrying capacity		
1	Owabi provides avenue for hunting, logging, fishing, farming and extract ting drinking water. It also protect and maintain migratory birds.	There are so many benefits derived from Owabi. They include herbs, medicine, fuelwood for home use, purifies the earth (take CO^2 from the earth), tourism (patronage of community products), used as research center, shelter for dam (provide portable water for fringe communities) and ecotourism, provide resources for Kumasi zoo.
2	Portable drinking water because that is what we work on.	Research center and ecotourism
3	The state of Owabi in providing benefit especially drinking water is in a bad state. There are defecating activities that leave the dam in bad condition. It requires lots work in its management. The depth of the dam has decreased from the past years by erosion.	When we talk about the inner area, although there are traces of human activities, it is somehow in good state considering its management. With the catchment area the development around it serves as a threat.
4	Considering the state of the dam at the moment, we can produce 30% of what we initially produced. That is 2 million liters of drinking water annually.	It is difficult to tell the maximum quantity that can be used in terms of the benefit mentioned earlier. This is because there are no assessment on the quantities that can be harvested. With the fuelwood, it is more beneficial to us when extracted because it reduces over-population and provides more open for patrolling in the sanctuary.
B: Stakeholder Assessment (conflict and synergies)		
1	GWCL, WD, FC, WRC	NGO (Wildlife Society), Communities (personal use), District Assembly
2	There are potential conflicts between management authorities and hunter, chiefs, chainsaw operators, farmers.	Hunters and poachers may be individuals that may have a potential conflict with WD. This is because their activities are mostly out of Owabi's management.

3	Yes. With activities like sand winning, cutting of trees, bad farming practices affect the production of water.	Yes. Hunting or over-exploitation of Owabi resources affect the protective status of the fauna and flora species.
4	There could be potential synergies between management authorities and chiefs in the communities in terms of the Owabi land-use.	Between WD and GWCL there are many synergies that can exist. This can be in relations to the management responsibilities both in the catchment area and the inner site. Both institution can work hand in hand to ensure the sustainability of the Sanctuary.
C: Management and Sustainability of Owabi		
1	NTFPs.	NTFPs, Timbers, Lands (for development).
2	Stop entry. This will help not damage the dam to continuously provide drinking water. Zone area into protection and harvesting.	Develop alternative livelihood, Plant trees for fuelwood use
3	No because many people do not get enough water.	For the inner site yes because it is fully protected and exploitation is under control. The use of some benefits are not allowed. Like hunting of bushmeat, cutting down of trees etc. But for the catchment area WD has no control of it and therefore current management may not be sufficient.
4	Allocation of NTFPs to communities annually Full conservation protection (Stop entry), Willingness to pay for management (pay realistic tariff), Formulation of stricter law and enforcement, Payment of fines and penalties to traditional authorities like Chiefs.	Involvement in decision making (especially between communities, chiefs and GWCL, Paying of royalties to landowners, Payments of fines and penalty to government.
5	Public Utility Regulation Commission (PURC), Land Commission. WD,	WRC, GWCL Environmental Protection Agency (EPA)