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SHIRE RIVER BASIN MANAGEMENT PROGRAMME (PHASE I) PROJECT

CLIMATE RESILIENT LIVELIHOODS AND SUSTAINABLE NATURAL RESOURCE MANAGEMENT IN THE ELEPHANT MARSH, MALAWI

Sub-Study 3:
Ecosystem Services of the Elephant Marsh

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PREFACE AND ACKNOWLEDGEMENTS

This desktop study on ecosystem services forms part of a larger study on the Elephant Marsh, '**Climate resilient livelihoods and sustainable natural resources management in the Elephant Marsh, Malawi**'. This project aims to generate a thorough understanding of the functional ecology of the Elephant Marsh incorporating hydromorphology, ecosystem services, biodiversity, and local livelihoods in order to inform a management plan for the marshes and in order to prepare an application for Ramsar status as a wetland of international importance. The assignment also assesses the feasibility for designating the marsh as a community-managed protected area.

The study falls under the **Shire River Basin Management Program** (SRBMP), the goal of which is to increase sustainable social, economic and environmental benefits by effectively and collaboratively planning, developing and managing the Shire River Basin's natural resources. The SRBMP (Phase 1) is funded through a loan from the World Bank as well as grants by the International Development Association (IDA) of the World Bank with additional financial support from the Global Environmental Facility (GEF) and the Least Developed Countries Fund (LDCF).

The study was carried out by Katherine Forsythe and Jane Turpie of Anchor Environmental Consultants, and is informed by data collected by the Southern Waters team, the MRAG sociology team, as well as hydrodynamic modelling and expert opinions of Drew Birkhead.

This study provides a baseline description of ecosystem services provided by the Elephant Marsh. The findings of this study were then used in the development of a DRIFT model of the ecosystem in order to explore the potential implications of alternative future management scenarios.

The team wishes to thank the following people for their assistance with the study:

- Bastiaan Boon for help sourcing local information within Malawi,
- Samual Chihana for information on African Skimmers along the Shire River,
- Dr Julian Bayliss, for assistance with accessing literature, and
- Derek MacPherson for information on hunting safaris within the Elephant Marsh.

EXECUTIVE SUMMARY

Introduction

This desktop study on ecosystem services forms part of a larger study on the Elephant Marsh, 'Climate resilient livelihoods and sustainable natural resources management in the Elephant Marsh, Malawi'. This project aims to generate a thorough understanding of the functional ecology of the Elephant Marsh incorporating hydromorphology, ecosystem services, biodiversity, and local livelihoods in order to inform a management plan for the marshes and in order to prepare an application for Ramsar status as a wetland of international importance. The assignment also assesses the feasibility for designating the marsh as a community-managed protected area.

The objectives of the ecosystem services component were to:

1. Describe the ecosystem services provided by the Elephant Marsh in physical terms and provide desktop estimates of their economic and social value, including natural resources, flood control, carbon sequestration, sediment retention, water quality amelioration etc..
2. Draw comparisons with other wetlands in Africa of a similar nature;
3. Discuss how capacity of the system to deliver these services responds to hydromorphology how this has changed over time; and
4. Discuss the wetland's sensitivity and adaptive capacity to multiple pressures, with a description of those pressures.
5. Develop and analyse up to three different future management scenarios over the next 25 years.

The terms of reference for this component are in Appendix 1. This study was carried out as a desktop study based on literature available and previous studies conducted in the region or similar wetlands. This includes primary data collection and modelling by the hydromorphological and livelihoods components of this study. Limited modelling using parameters from literature was conducted to estimate the physical stocks and processes provided by the ecosystem.

Provisioning services

Ecosystems provide a number of living resources which are harvested for raw materials, food and medicine. Within the Elephant Marsh these resources are almost exclusively harvested by poorer households on a subsistence basis or to generate some cash income. The main harvested resources include fish, mammals, birds, papyrus, reeds, thatching grass and water lilies.

Fishing occurs throughout the Elephant Marsh, but is a particularly important livelihood activity in the eastern and southern parts of the marsh. Fish landings vary annually, and range between 2 000 and 12 000 tonnes per year. Given the most recent estimates of fish prices and estimated annual yields, the value of the fish caught from the marsh could be between US$1.5 – 8.8 Million per year. However, evidence suggests that the fish populations are somewhat depleted and that current exploitation is not sustainable.

While large mammals, including hippos, are now exceedingly rare in the wetland and little hunting of these animals occurs, various reptiles, birds and small mammals, or their eggs, are still hunted or collected. When the Elephant Marsh was still in a good condition, it is possible that it could have sustainably provided up to US$654 500 per year worth of ungulate and rodent meat. In its current condition, no sustainable off-take of mammals is possible due to the extirpated and depressed populations. Bird populations are still relatively health, and the sustainable yield is estimated to be in the order of 400 waterfowl per year sustainably (at a rate of 10% harvest), which would be worth about US$970/annum.

There is approximately 32.2 km^2 of papyrus and 166.2 km^2 of reeds within the Elephant Marsh, which means that it could potentially provide up to 483 tonnes of papyrus and 2160 tonnes of reeds per year. The total value of these harvested papyrus and reeds could be in the order of US$131 000/yr. It is, however, unlikely that the entre marsh is accessible to be harvested and so probably only a fraction of this actually used.

Grasses found in the 87 km^2 of uncultivated floodplains of the Elephant Marsh are widely collected, mainly for thatching. Based on a previous estimate for the area, the value of this resource could be in the order of US$2.6 million per year. Water lilies are abundant throughout the marsh and are harvested for food. Based on a previous estimate, the value of this resource could be about US$565 000 per year.

Regulating services

The Elephant Marsh provides regulating services in the form of flood attenuation, water quality amelioration, sediment retention, carbon sequestration and critical habitat for wildlife populations.

The value of the flood retention service offered by the Elephant Marsh was assessed by estimating the downstream damage related to floods with and without the effect of the marsh, which was estimated using a hydrodynamic model. It was estimated that the effect of there being no Elephant Marsh would effectively increase the Shire River peak flows by approximately 20%. This could make water levels at the Shire/Ruo River confluence rise by between 0.5 and 0.75 m for peak flows of ~1000 and 2000 m^3/s. This effect would be somewhat less in the wider floodplains further downstream of the confluence. A rise in water level of 0.5 m in a village near the confluence would conservatively be enough to move change the effect of a 1 in 5 year flood to that of a 1 in 10 year flood, and a 1 in 10 year flood to that of a one in 50 year flood. Beyond this however, the uncertainty is in the modelling and assumptions is too great to be able to estimate the change in depths. Therefore the increased damage cost that would be associated with the change from a 1 in 5 year return period flood if the Elephant Marsh was not present is estimated at approximately US$7.1 million and the increased damage cost associated with a 1 in 10 year flood would be in the order of US$19.4 million. Using a probability function based on the return periods, the annual value of the marsh in avoiding flood damage for 1 in 5 and 1 in 10 year floods is approximately US$3.3 million. These estimates are meant to be taken as ball-park figures given the lack of data available and uncertainty in the modelling.

The ability of wetlands to remove nutrients, wastes and sediment has been recognized since the 1970s. There are a number of different process through which wetlands remove nutrients and pollutants from the influent water including trapping sediment, absorption nitrogen and phosphorous through plant growth, denitrification of nitrogen as well as destroying pathogens by exposure to UV. Uptake rates by plants in papyrus wetlands have been estimated as being in the order of 475 kg N/ha/yr, while total phosphorus uptake was in the order of 77 kg P/ha/yr, with a further 1143 kg N/ha/yr and 63 kg N/ha/yr removed through other processes. Using only these estimates from plant uptake and applying this to the area of undisturbed papyrus marsh vegetation within the Elephant Marsh (~3500 ha) we get a potential removal rate of up to 1662 tonnes N/yr and 269 tonnes P/yr. There's a potential benefit from drinking water that has been polished by the Elephant Marsh in terms of nutrients and certain pathogens compared to the quality of the water without the additional treatment. However, it is likely that any benefit of such is outweighed by the risks associated with drinking water from the river including the contraction of Bilharzia and crocodile attacks while collecting the water.

The Shire River carries high sediment loads into the top of the Elephant Marsh. This sediment originates from the heavily deforested and degraded catchment. It was estimated that the average rates of sediment deposition was approximately 0.5 mm/yr in pre-anthropogenic times, however in the last 50 years has increased to between 10-34 mm/yr in the lower Elephant Marsh, while in the upper marsh was closer to 1 mm/yr. The current level of sedimentation equates to between approximately 144 kg/m^2/yr being deposited across the Elephant Marsh. The sediments trapped by the marsh are important for the planned resurrection of the river trade route between the Indian Ocean and Nsanje which has begun under the Shire-Zambezi Waterway Project. If the Elephant Marsh was not performing its sediment trapping service, additional sediment would need to be dredged each year to keep the transport channels open. In order to dredge the amount of sediment being deposited in the Elephant Marsh each year it could cost approximately US$252 million/yr.

Natural ecosystems make a significant contribution to global climate regulation through the sequestration and storage of carbon. When natural systems are degraded or cleared, much of this carbon is released into the atmosphere. Wetlands in general are known to be particularly efficient in storing and sequestering carbon. Papyrus wetlands in particular have been shown to have very high levels of primary production and potentially represent some of the most productive biological systems in the world. Considering above and below ground biomass, as well as peat accumulation, and the extent of undisturbed papyrus as well as undisturbed other natural vegetation the estimated standing stock of carbon in the major vegetation groups within the Elephant Marsh is approximately 0.6 million tonnes of carbon. Using the social cost of carbon which is equal to the damage avoided by not releasing the tonne of carbon into the atmosphere, we estimate that while the loss of the Elephant Marsh could generate global damages worth $20 million, the damage costs accruing to Malawi might only be $3596 per annum.

Animals which have large movements require habitats across their range for different purposes. Value may be derived from these animals at any point within their range, whether tourism value, biodiversity value or direct use value. Even if this value is not realised in one area, the fact that the animals rely on that area for habitat, some of the value derived elsewhere can also be attributed to that area. This is especially true for certain areas provide critical habitats for species that are globally threatened. The Elephant Marsh may provide an important stopover point for African Skimmers. While the Skimmer does not appear to breed within the Elephant Marsh, large flocks have been recorded more frequently in recent years (usually between 280- 600 individuals; see Turpie *et al.* 2016 for more details). African Skimmers are a sort after sighting for bird enthusiasts and in addition to being globally threatened, these birds are a drawing card for certain tourists, increasing the tourism and biodiversity value of areas like Liwonde National Park.

Cultural services

Tourism infrastructure is very underdeveloped in the Lower Shire Region and as a consequence there are not a great number of visitors to the region. There are only a few tourism establishments in the area which may attribute some of their annual turnover to the presence of the marsh. Nyala Lodge and Nchalo Sports club are the only tourism accommodation which may draw tourists interested in the Elephant Marsh. Using bed nights, rack rates and an estimate of the percentage of visitors visiting the marsh specifically, we estimate that approximately US$12500 of their annual turnover is attributable to the Marsh itself.

Recreational activities that occur within the marsh include trophy hunting in recent years as well as mokoro rides. While Trophy hunting is not currently operating, it is estimated that during its operations, up to $US50 000 in turnover was achieved annually, of which most is directly attributable to the Elephant Marsh. The value of day-trips on mokoros by nature and bird-watchers only equates approximately US$5000-7000 per annum.

Wetland disservices

Along the Shire River and its adjacent marshes, high rates of human-wildlife conflict are reported. The occurrence of these incidents stems from the large populations surrounds the waterways, and the high level of reliance on the river and marshes for fresh water and livelihoods. The two main problem causing animals along the Shire River and wetlands are crocodile and hippopotamus. Crocodiles have been known to take humans as they fish, wash clothes, bathe, fetch water or travel by canoe. They also destroy fishing gear and attack livestock. Hippopotamus graze on crops and can also cause harm to people as they try to protect their crops.

In addition to effects on crops and livestock, people living in the Elephant Marsh are also vulnerable to water-borne diseases, in particular malaria, bilharzia, filaria, cholera and diarrhoea. Many of these diseases seem to be somewhat connected with receding floodwaters in the marsh, as well as other artificial water bodies such as irrigation ponds and ditches. Improved sanitation, prevention and treatment could vastly decrease the prevalence of the diseases in and around the Elephant Marsh.

Opportunity costs

While ecosystems services are derived from the wetland in its natural state, we must also recognise that there is value in activities that derive benefit from the wetland in the short term, however ultimately degrade and transform the wetland. Examples of these include grazing domestic animals, abstracting water for irrigation and growing crops. Some of these activities are seasonal to some extent as during flooded periods, access to large parts of the marsh is limited, others may occur year round

The annual value associated with grazing cattle on the Lower Shire floodplains has previously been estimated at US$1.8 million per year. Previous estimates of the value of cultivation on the Shire River floodplains were in the order or US$17 million per annum. Note however, that the expansion of these activities in the marsh will be at the expense of the values described above.

Provision of water for irrigation was not considered to be an ecosystem service of the marsh, though water abstraction from the marsh does provide substantial value to the sugar cane industries in the Lower Shire. Over-abstraction of water from the Shire River and/or wetlands could have unintended consequences to the Elephant Marsh health.

Value of the Elephant Marsh in relation to other wetlands

The total annual provisioning value was estimated to be approximately US$5-12million per annum. Most of this value is from fish and thatching grass. Annual value of the regulating services offered by the Elephant Marsh was estimated between US$3 and 255 million. The high values, assume that this service will be demanded by the Shire Zambezi Waterway Project. The total tourism/recreation value is currently quite low at approximately US$17 500 per annum. These give a total value between US$8.5 million and US$268 million.

Previous estimates of the total value of the Elephant Marsh or Lower Shire wetlands were between US$3-98 million per year. These figures are therefore only ball park estimates, and only include the value of the Elephant Marsh provisioning services and eco-tourism, not regulating services. Comparison to other Malawian wetlands in which ecosystem services have been evaluated indicate that the Elephant Marsh is not markedly different from Lake Chilwa or Lake Chiuta in its provisioning services, with fishing being the main economic activity. Within the Zambezi Basin, however there are a number of larger wetlands that appear to provide a higher value of ecosystem services than the Elephant Marsh such as the Barotse and Liuwa plain wetlands as well as the Kafue flats.

Changes to ecosystem services under future scenarios

The links between biotic and abiotic components of the wetland system were explored in a linked study which used a rule-based model to explore the potential effects of future scenarios and/or management on the ecological condition of the Elephant Marsh. Here some of the results of that study have been used to estimate the likely effects on ecosystem services under the different scenarios modelled. The scenarios chosen examined the effects of decreased sediment load into the marsh as well as various iterations of restricting access to different parts of the marsh in isolation or combination. The effect of doubling population, through increasing the anthropogenic pressures on the ecosystem was also modelled. These different scenarios were then examined under maximum proposed water resource development and modelled climate change.

Changing the amount of sediment load coming into the marsh had little effect on the delivery of ecosystem services. Restricting access to combination of central, eastern and southern parts yielded the greatest increases in ecosystem service delivery. Increases in population had severely negative impacts on almost all of the ecosystem services. The maximum development and climate change scenarios in conjunction with different levels of protection had little effect, or a positive effect on most services. Water lilies however, seem to be negatively affected by maximum development and climate change. This is potentially to do with their reliance on certain aquatic habitats that may be limited under these scenarios. Human-wildlife conflict increased under most scenarios, possibly as a result of protection on increasing numbers of problem causing animals. The trade-offs between these alternate activities and the delivery of other ecosystem services can be clearly seen here as the opposite pattern to most goods and services is seen for grazing and cropping. Values decreased if the north or western portions of the marsh were protected as these are where most of the activities currently occur. The value of these activities would also increase with higher populations as more of the marsh would be exploited.

Conclusions and Recommendations

The total value of ecosystem services delivered by the Elephant Marsh was between USD$8-268 million per annum. The broad range of values is indicative of the complexity and uncertainties in measuring and estimating the value of regulating services. These important functions such as sediment retention and flood retention have the potential to have very high values, however these values will only be realised if the service is demanded by downstream users.

The most important provisioning service was that of the fish. This is not only an important economic activity for area, but also provides a food source for many occupants. Some of the other provision services such as hunting have a value of zero given that harvesting is considered unsustainable, despite being carried out by many local residents. Harvesting of wild plants, while not providing a large overall value, are also an important economic activity to many poor households.

This study highlights the importance in balancing pressures on the ecosystem with trying to maintain a healthy functioning ecosystem for future generations. Provisioning services rely on adequate stock of natural resources, which are easily depleted through over-harvesting. Maintaining areas of restricted access appears to be the best way to ensure stocks of natural resources are not completely depleted. This will potentially come at a cost to certain activities like grazing and hunting, however it will allow for some of the important regulating functions of the wetland to be maintained. If the marsh is allowed to become completely degraded and transformed, it will cease to provide the resources and services it currently does for so many households.

Some important findings from the DRIFT modelling in terms of ecosystem services were that:

- Changing the amount of sediment load coming into the marsh had little effect on the delivery of ecosystem services.
- Doubling the surrounding human population had severely negative impacts on almost all of the ecosystem services.
- The greatest increases in ecosystem service delivery were seen by restricting access to the marsh, in particular the combination of central, eastern and southern parts of the marsh.
- Including maximum water development and climate change in the future scenarios lowered the effectiveness of restricting access for some ecosystem services.

Cultural services such as tourism currently have a low value due to poor infrastructure, however birdlife is plentiful and offers potential for some bird-watching based tourism. In order to maximise the value of this ecosystem service, tourism access to the marsh would need to be improved. Investing in tourism infrastructure in the Elephant Marsh should however be done cautiously, as heat, humidity, as well as lack of large game and nearby attractions make it potentially a less desirable destination than other areas within Malawi.

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LIST OF ABBREVIATIONS

DNPW	Department of National Parks and Wildlife
EPA	Extension Planning Areas
GDP	Gross Domestic Product
MEA	Millennium Ecosystem Assessment
MK	Malawian Kwacha
N	Nitrogen
P	Phosphorous
US$	United States Dollar

1 INTRODUCTION

1.1 Background

This desktop study on ecosystem services forms part of a larger study on the Elephant Marsh, 'Climate resilient livelihoods and sustainable natural resources management in the Elephant Marsh, Malawi'. This project aims to generate a thorough understanding of the functional ecology of the Elephant Marsh incorporating hydromorphology, ecosystem services, biodiversity, and local livelihoods in order to inform a management plan for the marshes and in order to prepare an application for Ramsar status as a wetland of international importance (Figure 1). The assignment also assesses the feasibility for designating the marsh as a community-managed protected area.

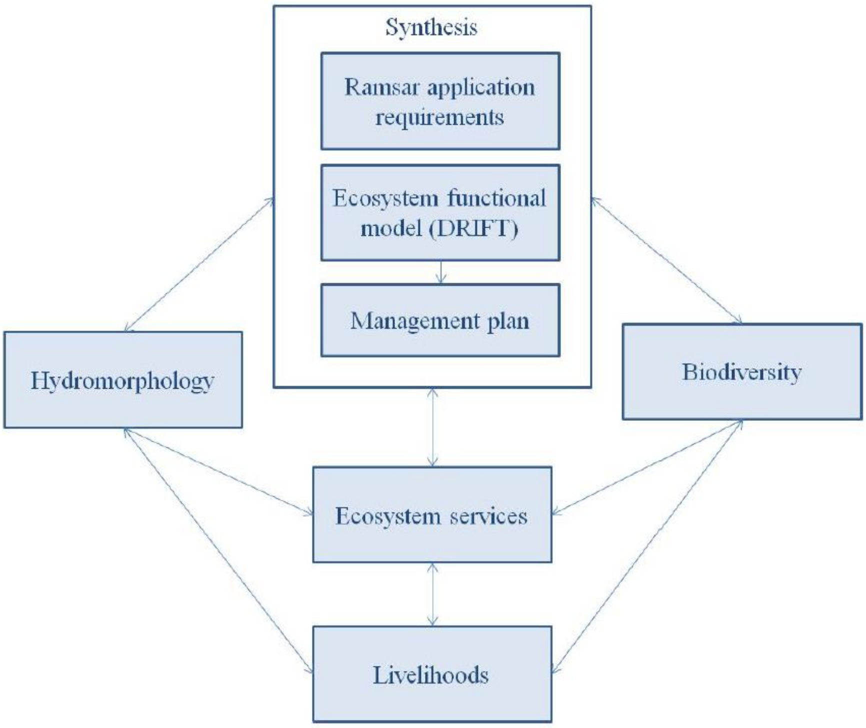


Figure 1. Components of the climate resilient livelihoods and sustainable natural resource management in the Elephant Marsh study.

The study is made up of four sub-studies; namely the Hydromorphology, Biodiversity, Livelihoods and Ecosystems Services which inform the Ramsar application, DRIFT modelling and overall synthesis and management plan. Different components will be referred to throughout the current report as the Livelihoods Report (Arthur & Hara 2016), Hydromorphology Report, Biodiversity Report (Turpie *et al.* 2016) and DRIFT Report to allow for ease in understanding the relationship to the current ecosystem services sub-study.

The objectives of the ecosystem services sub-study is to:

1. Describe the ecosystem services provided by the Elephant Marsh in physical terms and provide desktop estimates of their economic and social value, including natural resources, flood control, carbon sequestration, sediment retention, water quality amelioration etc..
2. Draw comparisons with other wetlands in Africa of a similar nature;

3. Discuss how capacity of the system to deliver these services responds to hydromorphology how this has changed over time; and
4. Discuss the wetland's sensitivity and adaptive capacity to multiple pressures, with a description of those pressures.
5. Develop and analyse up to three different future management scenarios over the next 25 years.

1.2 The Elephant Marsh

The Elephant Marsh lies within the floodplains of the Lower Shire River (S14°25'–17°50' and E35°15'–35°15'), extending from the south-eastern part of Illovo sugar estate at Chikwawa to the rail bridge and berm at Chiromo, and straddling the boundary between the two administrative districts of Chikwawa and Nsanje. The marsh habitats cover an average area of about 600 km^2 but the inundated area varies between approximately 2 700 km^2 in the wet season and 500 km^2 in the dry season (Kosamu 2014).

A major tributary of the Shire River, the Ruo River, enters the marsh in its south-eastern parts. Peak flows from the Ruo can rise above those of the Shire, causing flows to back upstream into the marsh, sometimes causing substantial flood damage and loss of life as was the case in 1950, 1991, 2001, 2011, 2012, and 2015 (Kosamu 2014).

The Elephant Marsh comprises a mosaic of rooted swamp vegetation (sudd), floating vegetation and open water with grassy margins. These habitats are interspersed with islands with saline soils and palm trees (Kosamu 2014). The northern margins are classified as 'semi-permanent' marshland inundated only during high water flows whereas the south resembles a small lake with islands and floating mats of vegetation. The marshes are known to trap sediment which would otherwise cause flooding downstream.

Named the Elephant Marsh by the explorer David Livingstone, this vast wetland area was once home to large numbers of game including herds of elephant, buffalo and antelope (Mitchell 1953). The Elephant Marsh was one of the first two Game Reserves gazetted in Malawi in 1897, but was subsequently deproclaimed in 1911 (Jawali 2015). Increasing human pressure and expanding agriculture have led to dramatic declines in remaining natural areas and wildlife numbers. The marsh now plays an important role in supporting livelihoods and helping local communities to cope with considerable climate variability.

1.3 Overview of ecosystem services

Ecosystems provide a range of 'goods' and 'services' and have 'attributes' that generate value and contribute to human welfare (Barbier 1994, 2011;Table 1). The concept of ecosystem goods and services stems from the perception of ecosystems as natural capital which contributes to economic production. Goods include harvested resources, such as fish, services are processes that contribute to economic production or save costs, such as water purification and attributes relate to the structure and organisation of biodiversity, such as beauty, rarity or diversity, and generate less tangible values such as spiritual, educational, cultural and recreational value. Goods, services and attributes are often referred to collectively as 'ecosystem services', or 'ecosystem goods and services'. More recently, the Millennium Ecosystem Assessment (MEA) (2003) defined ecosystem services as "the benefits people obtain from ecosystems" and categorized the services obtained from ecosystems into 'provisioning services such as food and water, 'regulating services' such as flood and disease control, 'cultural services such as spiritual, recreational, and cultural benefits, and 'supporting services', such as nutrient cycling, which maintain conditions for life on Earth. The first three align well with the definitions of goods, services and attributes described above. Supporting services, although necessary for the generation of final goods and services, are usually ignored in valuation studies to avoid double counting.

Table 1. Types of ecosystem services generated by natural systems

Ecological characteristics	Economic characteristics	Services
Stocks of resources	Goods	Grazing Fuel wood Woody raw materials (timber, poles etc.) Non-woody raw materials (e.g. thatching grass) Food and medicinal plants Animals and birds (hunting)
Ecological functions and processes	Services	Carbon sequestration and storage Regulation of hydrological flows (infiltration, flood attenuation) Amelioration of water quality Erosion control and sediment trapping Habitat for organisms useful in pollinating and controlling pests of croplands Refugia/critical habitat for organisms used consumptively or non-consumptively beyond forest areas
Ecosystem characteristics and biodiversity composition	Attributes (aesthetic qualities, biodiversity, rarity, physical features)	Spiritual and recreational values that manifest in property values and tourism as well as intangible value Cultural value Scientific and educational value

The values produced by ecosystem services are also categorised into different types. The Total Economic Value of an ecosystem comprises direct use, indirect, option and non-use values. Direct use values may be generated through the consumptive or non-consumptive use of resources. This includes both consumptive (e.g. resource harvesting) and non-consumptive (e.g. bird watching) activities, whether for income, subsistence or recreation. Indirect use values are values generated by outputs from the ecosystems in question that form inputs into production in other areas, or that contribute to net economic outputs in the economy by saving on costs. These outputs are derived from ecosystem functioning such as water purification and flood attenuation. Non-use values include the value of having the option to use the resources (e.g. genetic) of ecosystems in the future (option value), and the value of knowing that their biodiversity is protected (existence value). Although far less tangible than the above values, non-use values are reflected in society's willingness to pay to conserve these resources, sometimes expressed in the form of donations. The relationships between the concepts of ecosystem services and values are shown in Table 2.

Table 2. Broad relationships between the concepts of ecosystem services and values

Ecological descriptors	Ecosystem services		Total Economic Value
	Barbier 1994, 2011	Millennium Ecosystem Assessment 2005	
Natural resource stocks	Goods	Provisioning services	Consumptive use value
Ecological functioning	Services	Regulating and supporting services	Indirect use value
Ecosystem structure and organisation	Attributes	Cultural services	Non-consumptive use value
			Non-use value

Where there are markets for the services provided by ecosystems, the traded market good or service provides a basis for valuing them. Where markets prices are not available, estimates have to be obtained indirectly. This can be done by looking at related markets. For example, land which is more fertile will trade at a higher price. This price differential reflects the value of soil fertility. Alternatively, unpriced services can be valued by estimating how much it would cost to replace them, or the damages that might be incurred if they were removed. Depending on the purpose of the study, values can also be expressed in different ways.

1.4 Overall approach

This study was primarily a desktop study based on literature available and previous studies conducted in the region or similar wetlands. This includes some primary data collection and modelling by the hydromorphological and livelihoods components of this study. Limited modelling using parameters from literature was conducted to estimate the physical stocks and processes provided by the ecosystem. Methods and assumptions are described in more detail in the following sections, where appropriate.

2 PROVISIONING SERVICES

Ecosystems provide a number of living resources (e.g. firewood, fish, wild plants, grass) which are harvested for raw materials, food and medicine. Within the Elephant Marsh these resources are almost exclusively harvested by poorer households on a subsistence basis or to generate some cash income.

The provisioning value of the landscape is the value of the sustainable output of natural resources. Actual harvesting rates may or may not be sustainable. Where they are not, estimates based on harvesting rates can over- or underestimate the value of provisioning services, depending on the stage of exploitation and resulting condition of the resource base. Therefore, rather than ascertaining the current amounts harvested, which was not quantified in the broader study, this study takes the approach of valuing the sustainable yield based on broad resource characteristics, using available information from the study area or the literature on yields and prices, and simple models to estimate net private values derived from natural resource use.

Households living around the Elephant Marsh use the area for agriculture, fishing as well as collection of wild foods and raw materials for home consumption or for sale. The following descriptions and estimates are drawn from the literature as well as focus group discussions held with surrounding villagers.

Harvesting wild foods, either to consume directly or to sell, make important contributions to both income as well as food supply. For some of the poorest households, these coping strategies can be very important, especially in times of drought or poor harvests. Concern (2015) estimated that gathering, eating and selling wild foods contributed over 10% of total income for the poorest households within the Lower Shire during years of poor agricultural harvests.

2.1 Fisheries

While fishing occurs throughout the Elephant Marsh, it is particularly import for households in the east and southern parts of the marsh. Fishing households are sometimes among the wealthier households within mixed farming and fishing villages (Arthur & Hara 2016 - Livelihoods Report). A range of different types of fishing gear is used around the Elephant Marsh, including traps and scoop nets in the northern parts of the marsh and cast nets and gill nets in the more open-water areas in the south (Figure 2). Fish are often processed at landing sites and represent around 2-3% of food consumed within the average household around the Elephant Marsh (Figure 2, Concern 2015).

Fishers prepare to check their nets

Processing the catch at the landing site

Figure 2. Fishing activities at a landing site in the south-east Elephant Marsh.

The amount of fish landed within the Elephant Marsh is variable from year to year. For most years between 2006 and 2015 between 200 and 300 tonnes were landed at the few sampled landing sites, while in some years, significantly higher catches (~1 500 tonnes) were recorded. When extrapolated to the rest of the landing sites across the marsh, the total yield is estimated to be somewhere between 2 000 and 12 000 tonnes per year (Department of Fisheries in Arthur & Hara 2016). Previous estimates for the total catch of the Elephant Marsh has been around 8 500 tonnes (World Bank 2010 in Kosamu 2012) and between 1 600 and 11 000 tonnes (Turpie *et al.* 1999). The variation in the total yield of fish has been attributed to the flooding cycles.

Fishing is conducted all year round, with peaks in participation occurring between May and July (Turpie *et al.* 1999). Fishing generally takes place fairly close to the landing sites which are mainly located in the south, suggesting that fishing pressure may be lower within the central part of the marsh. There are more full-time fishers around the southern end of the marsh and it is considered to be more productive, especially on the eastern side. In this study, up to 30% of people in the southern area were estimated to be full-time fishers (Arthur & Hara 2016), whereas Turpie *et al.* (1999) estimated that over 50% of people across the entire marsh engaged in some kind of subsistence fishing. Kosamu (2012) estimated that the average catch per fisherman in the south was 11 kg/day. Of this catch, 1 kg was given to the village chief and the rest wither sold or consumed. The Department of Fisheries estimates that approximately 1 500 fishermen fish within the sections of the marsh that falls within the Chikwawa District. Numbers for the Nsanje District portions of the marsh were not available.

The average price per kg for fresh fish at landing beaches in the Chikwawa region of the Elephant Marsh in 2013 was MK530. It was slightly higher for *Mphende* Mozambique tilapia (MK595/kg) than other species like *Mlamba* catfish (MK535/kg) and *Kambuzi* small Haplochromine species (MK473/kg). Fish are usually sold to traders, usually women, at the landing sites. Some fishers will be sold fresh, while others will be processed prior to being sold. Most fish traders operate from the villages but some also come from Blantyre.

Turpie *et al.* (1999) valued the fishery at US$1.7 million/year based on the proportion of households engaging in fishing activities and the prices of fish at the time. Seyam (2001) valued the Elephant Marsh fishery at US$1.1 million/year based on regional per ha estimates of production of wetlands. Given the most recent estimates of fish prices and estimated annual catches, the value of the fish caught from the marsh could range between US$1.5 million and $8.8 million per year. Whether or not this level of fishing is sustainable, however, is unknown.

While there is a high level of variation in annual catches from the Elephant Marsh, the perception among locals is that fish availability, especially of larger fish, has decreased over time (Turpie *et al.* 1999). Although individual fishers may describe a decline in catches, they could be referring to their own catches rather than absolute changes in productivity for the area which is also dependent upon the number of fishermen in the system. Little consistent data has been collected on fish catches, however data from a few sampled landing beaches around the marsh from 2006-2015 do not indicate any obvious decline in catches during this period, but do show a high level of variability. The high level of variability in these floodplain fisheries make it extremely hard to identify a sustainable yield, as productivity is dependent upon flood regime, which is climatically driven (Mosepele 2008). Fish populations in these environments are however adapted to tough environments and have a high level of resilience. Given the past documented declines in fish production and apparent decrease in larger sized fish within the marsh, it is highly likely that the fish populations are somewhat degraded from previous conditions (Turpie *et al.* 2016 - Biodiversity Report) and thus current exploitation may not be sustainable.

2.2 Mammals, birds and reptiles

In 1998, 18% of household survey respondents in villages around the Elephant marsh stated that they hunted wild animals, which included hares, rats, doves, guineafowl and occasionally wild pigs, with 17% selling part of their catch (Turpie *et al.* 1999). Large wading birds were also reportedly netted or shot and smaller waterbirds like cormorants were reported to be a by-catch of gill netting. Considerable poaching of hippo was known to have taken place, with meat being sold in local markets. The demand for bushmeat was high, with only 70% of households regarding their intake of bushmeat as sufficient. In 1998, the market value of hunted animals was US$0.3 per bird and the net income (after costs of hunting) to households from hunting was estimated to be US$13 600.

Focus group discussions held during this study as well as observations by the biodiversity study team suggested that hunting is still exists in the area. While large mammals, including hippos, are now exceedingly rare in the wetland and little hunting of these animals occurs, various reptiles, birds and small mammals, or their eggs, are still hunted or collected. Of particular importance, during the livelihoods surveys, people mentioned hunting quelea-like grain eating birds as well as *tsekwe* (spur-winged goose) and *vuovuo* (another waterfowl species – probably some form of duck, likely the white-faced tree duck given its abundance). These birds are caught (using nets or poison) for both consumption and sale (Arthur & Hara 2016). The current off-takes across the marsh however could not be ascertained through these focus group discussions.

In Lake Chilwa, waterbird hunting is higher in years where fish catches are low and/or during periods of drought (Bhima 2006). Approximately 1.2 million birds were estimated to be caught on Lake Chilwa every year with a value of US$215 000 (US$0.2 /per bird Wilson 1999 cited in Bhima 2006). Turpie *et al.* (1999) estimated that within the Elephant Marsh area 18% of households hunted and on average caught 19 birds per year, which totals close to 200 000 birds per year for the entire marsh area. Not all of these birds will be waterbirds, with a large number of them being made up by small passerines such as queleas. The populations of these small-birds are unlikely to be threatened as they are known to be one of the most abundant wild bird species in Africa. These bird species are also not directly reliant on the wetland itself and are seen more as agricultural pests. The Elephant Marsh waterbirds however, appear to be somewhat depleted in numbers (Turpie *et al.* 2016). Waterfowl numbers were estimated at a minimum of about 4000, but it is likely actual populations exceed this. Assuming a similar number of birds are caught currently as in the 1998 survey, even if only 10% of the birds caught were waterfowl, this would place a significant pressure on the Elephant Marsh waterfowl population as often only 4-14 % of the population of different waterfowl species can be sustainably harvested (Cooke *et al.* 1995, Robinson & Bodmer 1999, Menu *et al.* 2002, Brook & Whitehead 2005). If a sustainable offtake is estimated at 10%, and using the current waterfowl population estimates, the Elephant Marsh could potentially yield at least 400 waterfowl per year. This estimate is based on waterfowl numbers as a whole, assuming hunting methods are not species specific. However if one species was targeted alone, especially one that is lower in numbers, it is unlikely such off-take numbers could be sustained.

The sustainable yield of an ecosystem is a function of the species-specific intrinsic rates of increase. Calculating this for every harvestable species within in ecosystem requires a vast amount of data, which is not readily available in this case. There are however, some estimates from literature for groups of species that allow estimates to be made. For instance, maximum sustainable yield of ungulates, primates and rodents combined for undisturbed ecosystems with rainfall equivalent to that in the Lower Shire are approximately 500-800kg/km^2 (Robinson & Bennett 2004). This biomass would mainly consist of ungulates and large herbivores and only about 0.1% (11 kg/km^2) of this biomass is likely rodents (Robinson & Bennett 2004). Large mammalian game species have been all but extirpated from the Elephant Marsh, and small mammal populations also seem depressed (Turpie *et al.* 2016). It is likely thus that most of the mammal populations have been harvested at an unsustainable rate. While no households reported hunting for venison in the 1998 survey (Turpie *et al.* 1999), it is unclear whether this is generally understood to be large mammals, or if it also includes smaller mammals like rodents. Considering hunting small mammals like rodents is prolific throughout rural Africa (see Avenant 2011), we assume these are not included in 'venison'.

In urban areas across Africa, bushmeat is often sold at a premium and only consumed by wealthier households, however in a rural setting bushmeat is often used as a substitute for other forms of meat and consumed mainly by poorer households (Brashares *et al.* 2011). When urban centres are over 100 km away, as it the case around the Elephant Marsh, the majority of wild-hunted meat is consumed locally where it costs about 70% the price of other meat alternatives (Brashares *et al.* 2011). Non-wild meet sources in Southern Malawi range from about US$1.7-2/kg for chicken or goat (B. Boon pers. communication).

Therefore, when the Elephant Marsh was in a pristine condition, it is possible that the marsh could have sustainably provided ungulate and rodent meat worth up to US$654 500 per year (assuming a 1000kg/km^2 yield and scaled current meat prices). However in its current condition, there is no sustainable off-take of mammals due to the extirpated and depressed populations. Waterfowl populations are somewhat less depleted than mammals (Turpie *et al.* 2016). With current waterfowl population estimates, the Elephant Marsh could potentially yield 400 waterfowl per year (at a rate of 10% harvest; but see caveats above). This would equate to a value of US$970/annum using the local price of a whole chicken (US$3.47; B. Boon pers. communication) and scaling to the lower cost of bush meat in rural areas. Without proper observation, it is hard to know if current off-takes exceed this number, however given the estimates for the number of households engaging in hunting birds during the late 1990s it is likely that rates exceed this and are therefore unsustainable and consequently have a ecosystem service value of zero.

While most harvesting of wild meat comes from mammals and birds, reptiles are known to form a small part (~10 % of species) of bush-meat trade and consumption in Africa (Taylor *et al.* 2015). In fact, worldwide, reptiles are harvested both for trade as well as subsistence needs (Klemens & Thorbjarnarson 1995). There is currently no data on consumption of reptiles within the Elephant Marsh. Similar to consumption of small mammals like rodents, people may be unwilling to offer information on the collection of these species. Current populations of most of the land-based reptiles are under threat mainly by habitat transformation and fires (Turpie *et al.* 2016) and are unlikely to be able to provide off-take at a sustainable rate. It is possible the crocodile population could withstand some harvesting of eggs and/or animals, however this then comes into competition with the commercial crocodile ranching which currently harvests approximately 5000 eggs per year (Turpie *et al.* 2016). This harvesting of wild crocodile eggs is also critical in supporting the crocodile ranching operations which have been running since 2008.

2.3 Wild plants

2.3.1 Papyrus & Reeds

During the survey in the late 1990s two thirds of the households surveyed reported having harvested reeds or papyrus (Turpie *et al.* 1999). Most of this harvesting is used within the households, with only 11% of households selling their harvest, and even then only about half of what they collected. The value of this activity was estimated at approximately US$283 755 per annum for the entire Elephant Marsh area in 1998 (Turpie *et al.* 1999).

Much of the reeds and papyrus is transformed in other goods that have higher value than the raw materials themselves. Papyrus culms are used for making sleeping mats and baskets (Figure 3), the flower heads are used for brooms, and the rhizomes once dried out can be used for charcoal. The net value added by papyrus mat making was estimated at US$371 509 per annum for the entire Elephant Marsh (Turpie *et al.* 1999).

There is currently estimated to be approximately 32.2 km^2 of papyrus and 166.2 km^2 of reeds within the Elephant Marsh (Brown *et al.* 2016 – DRIFT Report). Papyrus wetlands have also been shown to have potential as a bioenergy crop where a sustainable annual yield of up to 15 t ha^{-1} yr^{-1} (Jones

1982). About 20% of standing biomass of *Phragmites* reeds can also be harvested per year, which equates to approximately 13 t ha^{-1} yr^{-1} (McKean 2001).

Figure 3. Products made from reeds harvested being sold in a market near Sabvala village on the East side of the Elephant Marsh.

Given these sustainable yield estimates, the Elephant Marsh could potentially provide up to 483 tonnes of papyrus and 2160 tonnes of reeds per year. With an average bundle weight of 14 kg (McKean 2001) and a bundle price of approximately MK500/kg (inflating data on bundle price from Turpie *et al.* 1999) the total value of these harvested papyrus and reeds could be in the order of US$131 000/yr. It is, however, unlikely that the entre marsh is accessible to be harvested and so realistically, only a fraction of this realised sustainably in any one year.

2.3.2 Thatching grass

Within the Elephant Marsh there are several species of floodplain grasses which are harvested for use in thatching buildings and other structures as well as for making brooms and some other smaller products. Most of the harvesting of the grass species happens throughout the dry season June-September (Turpie *et al.* 1999). Up to 62% of households reported harvesting of grass, though this was mainly by poorer and middle income households. These natural products are harvested by people, especially at times when they need cash for food and are sold in local markets. Products are sold as raw materials or finished products, often to traders coming from Blantyre (Arthur & Hara 2016). These grassland species are likely found within the uncultivated floodplains of the Elephant Marsh, of which there is estimated to be approximately 87 km^2 of currently (Brown *et al.* 2016).

Figure 4. Thatching Grass being sold at market near Sabvala village on eastern side of the Elephant Marsh.

Turpie *et al.* (1999) estimated that the sales value of these products was in the order of US$1.8 million per year. Community members believed that this harvesting practice is sustainable as the grass regenerates fully the year following harvesting. While this may be the case, conversion of uncultivated floodplain to crops as well as uncontrolled burning of reeds and papyrus could decreased the ability of the floodplain to provide this natural product.

In the absence of any updated information of households utilising this wetland ecosystem good, the best estimate for the current value is based on the previous estimate. If the value of Turpie *et al.* (1999) is updated to 2016 US dollars, the current value would be in the order of US$2.6 million per year.

2.3.3 Water lilies

As well as cultivated crops and fruit trees, water lilies are important wild foods for both roots (*nyika*) and seeds (*chembereme*), particularly in years when water levels are low and households are unable to grow vegetables. Water lily roots are also boiled and sold, e.g. at Bangula and Ngabu markets. A number of other wild harvested plants including wild millet (*msinga*) bulbs, wild spices and seeds such as *Denje* and *thove* as well as plants with medicinal uses.

Harvesting of the wild staple foods occurs mainly at the end of the dry season and in years of bad agricultural harvests. This food is not considered favoured and only used when few alternatives are available. In the 1998 survey, 53% of households reported collecting wild plant foods with a total value of this activity estimated at US$385 882 per annum (Turpie *et al.* 1999).

The estimated area of extent of rooted aquatics was 21 km^2 across the entire marsh mainly in Central (6.5 km^2) and Southern (11 km^2). The vegetation report in the biodiversity sub-study estimated that *Nymphaea lotus* had about 25% coverage within these rooted aquatic environments. This yields a further estimate of 5.25 km^2 of water lily available within the Elephant Marsh. The main areas where water lily is accessible for harvesting are in the major lagoons in the south of the Elephant Marsh. This makes up about 2/3rd of the distribution of the aquatic plants.

Water lilies throughout the marsh are abundant and do not appear to be over-harvested. Many of the areas in which these species occur are not accessible to harvesting, and so it is unlikely that with current demand this resource could be over utilised. As such, the value of this resource at the sustainable yield would be an over-estimate of their actual value.

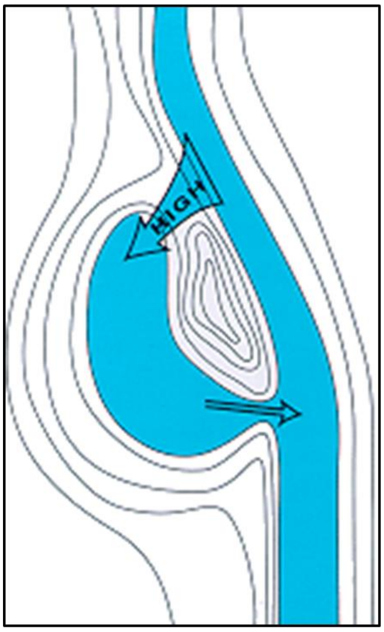
Again, in the absence of any updated information of households utilising this wetland ecosystem good, the best estimate for the current value is based on the previous estimate. If the value of Turpie *et al.* (1999) is updated to 2016 US dollars, the current value would be in the order of US$565 280 per year.

3 REGULATORY SERVICES

3.1 Flood attenuation

Large floods can qualify as natural disasters in many ways, leading to loss and damage of property, infrastructure, agricultural lands as well as potential injury and loss of life to local inhabitants. However, floods are a natural part of the hydrological cycle in many places. Flooding often occurs when heavy rainfall causes the flow to exceed that of the drainage natural drainage network. The rate at which a flood peak moves downstream is related to a number of different characteristics including the size and gradient of a channel, bed roughness, and presence of in-stream vegetation or obstructions as well as how braided the river is. The greater the roughness of the substrate or instream vegetation, the slower the water will move through the section of the river.

Attenuation refers to the loss of intensity of flux through a given medium. In the case of flood attenuation it refers to the slowing of water, or alteration of the downstream hydrograph along a river. Wetlands are often said to mediate this flow through groundwater recharge, storage and regulating base flow (MEA 2005). Wetlands and floodplains along the river can significantly increase the roughness of the area the flood wave come into contact with, through the presence of vegetation, slowing the water as it passes through the wetland. In addition, some wetlands and floodplain have areas that act as storage basins, either holding the water temporarily before discharging back into the river as the water level drops, or can decrease the overall volume of water through an increase in evaporative surface water, or by increasing infiltration and recharge of ground water (Williams *et al.* 2012; Figure 5). The extent to which wetlands can perform these services is highly dependent upon two main factors, namely the wetland storage capacity and how that stored water is then transferred either back to the main channel or via subsurface flow (Woltemade & Potter 1994). Other factors such as the topography, the soil, the antecedent rainfall and climate also have a strong influence.



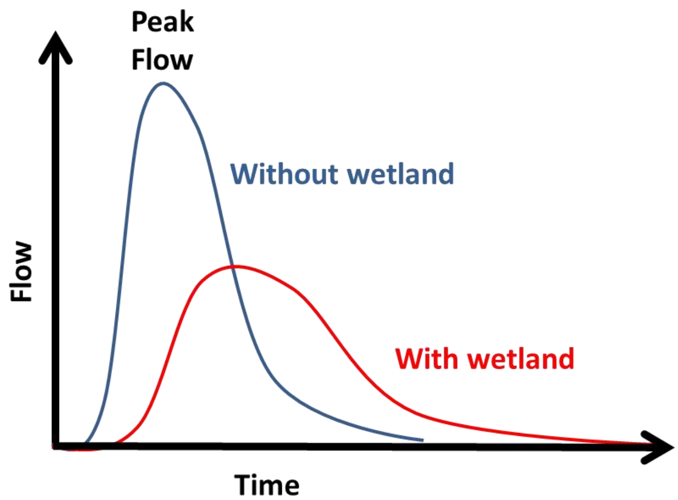


Figure 5. Example of how a wetland along a river way can store water and release slowly leading to an altered downstream hydrograph.

These wetland and floodplain areas, although becoming inundated themselves, provide a valuable service to areas downstream, by reduced the intensity and sometimes volume of flood water, resulting in less damage to infrastructure and property. This important value of wetlands and floodplains for flood attenuation has been understood for some time, for instance In the USA it was estimated that the flood reduction value of 3800 ha of floodplain storage along the Charles River avoids US$97 million (converted to 2016 prices) of flood damage downstream every year (US Corps of Engineers 1972). Indeed the mean flood attenuation value of wetlands was estimated at approximate US$1780/ha (converted to 2016 prices) across a number of different studies examining the value of wetlands (Woodward & Wui 2001).

Seasonal high river flows and flooding are a frequent occurrence in Malawi during the rainy period (December-April). Under natural land cover and conditions, much of the rainfall is intercepted by natural vegetation, slowed and often a large proportion is absorbed by the landscape and either slowly enters the river system through subsurface flow, or it utilised by the natural vegetation. The remainder of the rainwater reaches the river more quickly via surface run-off, and it is this proportion which contributes most directly to the peak flow which often causes rivers to flood. As is the case in Malawi, much of the natural vegetation within the river catchments has been cleared, which decreases infiltration and increases the proportion of surface flow, making the peak flow after a heavy rainstorm (and resultant flooding) greater than they would be otherwise. This type of flood attenuation is especially well documented for riparian floodplains (e.g. Acreman *et al.* 2003), however this is less well known for some other types of wetlands such as peat bogs and fens (Williams *et al.* 2012).

The Lower Shire, especially areas near the Elephant Marsh and the Ndinde Marsh are particularly flood prone and extensive natural floodplains exist. The edges of these floodplains have been heavily encroached by agriculture and settlements in some areas.

3.1.1 Damage costs of floods

In January 2015, Malawi received unusually high rainfall up to 400% higher than the long term mean. This resulted in flooding occurring in 15 different districts across Malawi, mostly concentrated in the Southern regions. The high rainfall caused the Shire River to reach its highest level in 30 years. Over 230 000 people were reportedly displaced and 106 killed. Close to 90 000 ha of crop land affected which in some areas meant that 90% of the inhabitants livelihoods were disrupted. There was also extensive damage to infrastructure such as roads, bridges, houses, schools, medical centres and fresh water and sanitation structures.

The Government of Malawi produced a Post Disaster Needs Assessment (PDNA) in response to the flooding which detailed the losses and damage cause by the 2015 floods as well as the costs involved in recovery and reconstruction (Government of Malawi 2015). This assessment was comprehensive and valued the cost incurred to number of different sectors as a result of the floods including, but not limited to, housing, agriculture, roads and education. The analysis was conducted at a district level and the data from the two districts in our study area, Chikwawa and Nsanje, are presented in Table 3.

Table 3. Damages and losses across various different sectors within Chikwawa and Nsanje districts as a result of the Jan 2015 floods (Government of Malawi 2015). All numbers are million Malawian Kwatcha (MK) except for the final row presented in million US$.

Sector	Damage cost per district	
	Chikwawa	Nsanje
Agricultural Sector	4644.00	7176.00
Industry & Trade Sector	115.90	481.60
Education Sector	908.73	758.55
Health Sector	702.48	1035.15
Nutrition Sector	21.67	4.63
Housing Sector	4564.00	3065.00
Roads & Transport Sector	6279.48	7609.90
Water, Sanitation & Hygiene Sector	1555.27	2359.83
Disaster Risk Management Sector	52.50	144.10
Employment & Livelihoods	3709.50	3631.40
Environmental Sector	75.00	284.30
Protection Sector	260.50	391.80
TOTAL (million MK)	**22889.03**	**26942.26**
TOTAL (million US$)	**52.62**	**61.94**

3.1.2 Value of flood attenuation to downstream communities

The January 2015 flood was rated as a 1 in 500 year event (Government of Malawi 2015). According to flood lines and flood hazard maps created by Atkins 2012, the number of separate villages within Nsanje district that are within the "Danger for all" category of flood hazard for different flood return periods are presented in Table 4 and Figure 6. If the Elephant Marsh was not present, there would be no retention of water within the marsh instead the water would just be transported via the main Shire River. This lack of retention of water within the marsh would lead to exacerbated flooding further downstream. In this study, we have only considered the downstream benefits within Malawi. However, in reality the settlements and agricultural areas across the border in Mozambique also benefit from this flood attenuation service.

Table 4. Relationship between Flood return period, number of villages at flood risk and damage costs for area downstream of Elephant Marsh, within Malawi. All numbers are presented in million 2015 US$.

Flood return period	No villages within "danger for all" category of flood risk	% villages in 1 in 500 flood	Adjusted damage cost (US$ million)
1 in 5	6	17%	10.6
1 in 10	10	29%	17.7
1 in 50	21	60%	37.1
1 in 100	23	66%	40.7
1 in 500	35	100%	61.9

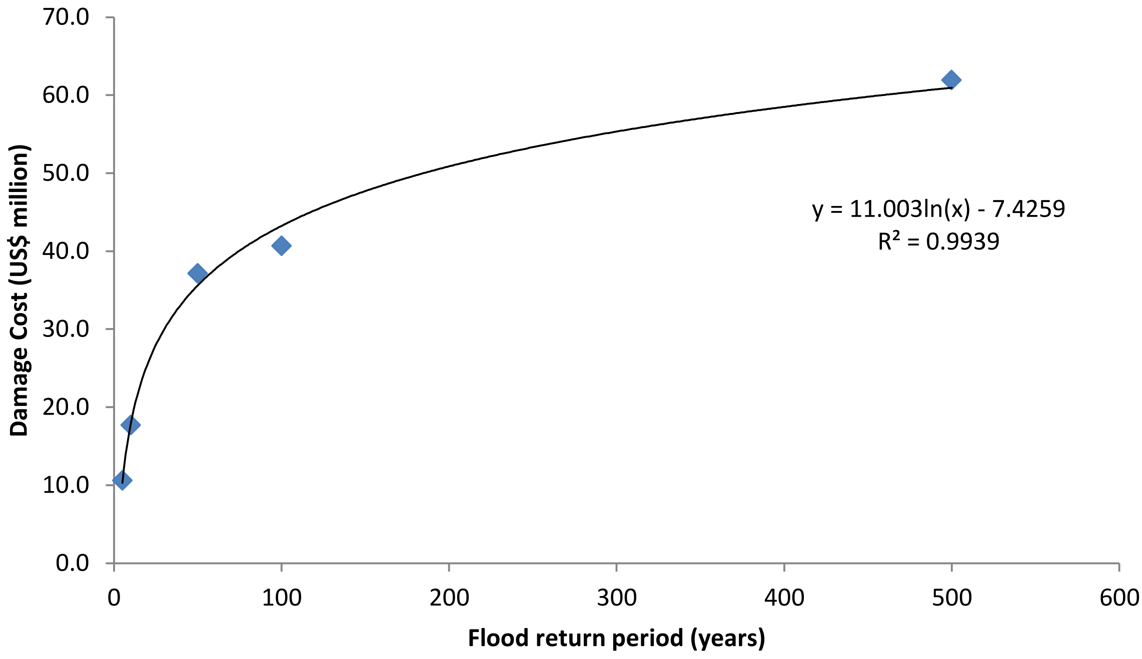


Figure 6. Relationship between estimated damage cost and flood return period for area downstream of Elephant Marsh, within Malawi

Based on the findings of the hydrodynamic model created under the Hydromorphology Report (Birkhead *et al.* 2016), it was estimated that the absence of the Elephant Marsh would effectively increase the Shire River peak flows by approximately 20%. This could make water levels at the Shire-Ruo River confluence rise by between 0.5 and 0.75 m for peak flows of ~1000 and 2000 m^3/s. This effect would be somewhat less in the wider floodplains further downstream of the confluence. The effect would also largely depend on whether or not the Ruo River is in flood at the same time as the Shire River. If both rivers were in flood, the attenuation effect of the marsh would be less (approximately three-quarters of the above effect).

Flood depths during a 1 in 500 year flood are between 0.98--3.98 for critical villages in the Nsanje District (Atkins 2012). A rise in water level of 0.5 m in a village near the confluence would conservatively be enough to move change the effect of a 1 in 5 year flood to that of a 1 in 10 year flood, and a 1 in 10 year flood to that of a one in 50 year flood. Beyond this however, the uncertainty is in the modelling and assumptions is too great to be able to estimate the change in depths.

Therefore using the relationship derived in Figure 6, the increased damage cost that would be associated with the change from a 1 in 5 year return period flood if the Elephant Marsh was not present is estimated at approximately US$7.1 million and the increased damage cost associated with a 1 in 10 year flood would be in the order of US$19.4 million. Using a probability function based on the return periods (i.e. the chance of any event occurring within a year), the summed annual value of the marsh in avoiding flood damage for 1 in 5 and 1 in 10 year floods, is approximately US$3.3 million. These estimates are meant to be taken as ball-park figures given the lack of data and uncertainty in the modelling.

3.2 Sediment retention and water quality amelioration

3.2.1 Nutrient and sediment removal by wetlands

The ability of wetlands to remove nutrients, wastes and sediment has been recognized since the 1970s. There are a number of different process through which wetlands remove nutrients and pollutants from the influent water (Figure 7).

Sediment deposition in wetlands depends upon a number of factors including water velocity, flooding regimes, vegetated area of the wetland, and water retention time (Gilliam 1994; Johnston 1991). Sediment deposition in wetlands prevents a source of turbidity from entering downstream ecosystems and prevents siltation of rivers downstream. Typically wetland vegetation can trap up to 80-90% of sediment coming from the runoff of the catchment (Gilliam 1994; Johnston 1991).

Nutrients that are introduced in dissolved form can be taken up directly by plants and incorporated into plant tissue as they grow. Most of the phosphorous that is introduced to wetlands is attached to sediment and settles to the bottom, where it can remain inactive (Brinson 2000). Because phosphate is associated with sediments (Brinson 2000), much of the load may enter the wetland during large flood events (McKee *et al.* 2000). These loads often become a permanent part of the bottom sediments, and wetlands with clay soils are particularly efficient at retaining phosphorus, even at low loading rates. Thus phosphate removal is expected to be higher in wetlands with low water velocities and high hydraulic roughness. Macrophytes also contribute to total phosphorus retention by enhancing sedimentation.

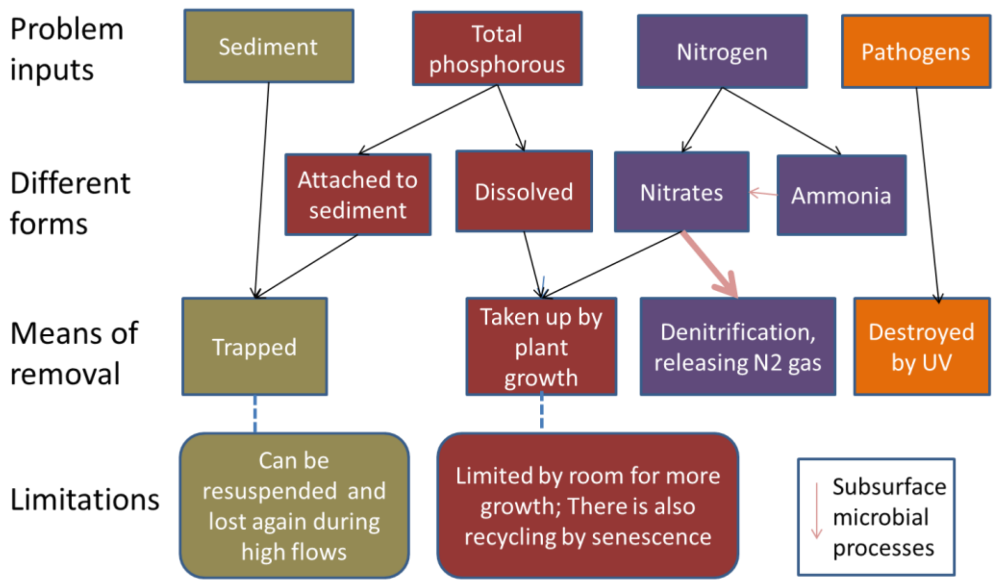


Figure 7. Summary of water quality amelioration services by natural systems (Source: Turpie 2015)

However, if sediments are stirred up then some of this phosphorous can go back into solution and become available for use by aquatic plants. The uptake of dissolved phosphorous will continue as long as there is room for further plant growth (in terms of space, oxygen or plant size limits), after which the system will reach some kind of equilibrium in which the uptake is balanced by the senescence, death and rotting of plant material which reintroduces nutrients into the water column (remineralisation). At this point there would be no further net uptake of nutrients by the wetland unless nutrients are being exported out of the system (e.g. by harvesting plants or dredging and removal of sediments), or unless there is a natural process of peat formation, which does occur in many, but not all, wetlands. High vegetative productivity and long water retention times allow long-term phosphorus storage through the accumulation of litter and peat (Mitsch & Gosselink 2000). Adsorption of dissolved phosphorus to soil and sediments is the main retention processes in wetlands. Sediment-litter is the ultimate sink for phosphorus (Faulkner & Richardson 1989).

Phosphorus may be taken up in the wetland by plankton and periphyton, but this storage pool is small with rapid turnover (Richardson 1985). Macrophytic production may account for measurable phosphorus uptake, however approximately 30-75% of the nutrient is seasonally released back to the water column during senescence, with some permanent storage as peat and litter (Richardson & Craft 1993).

Nitrogen enters wetlands in the form of ammonia (e.g. from animal wastes) or nitrates (e.g. from fertilisers), and is removed by the nitrification–denitrification process (Saunders & Kalff 2001). Nitrification is the microbially-mediated oxidation of ammonium (NH_4) to nitrite (NO_2) and then nitrate (NO_3). This process consumes oxygen and thus occurs in aerobic areas of the wetland. Nitrate then diffuses to anaerobic areas of the wetland where it may be denitrified. In the denitrification process nitrate (NO_3) is reduced to gaseous nitrous oxide (N_2O) and nitrogen gas (N_2), which are then released to the atmosphere (Mitsch & Gosselink 1993). This occurs mainly in sediments with abundant organic matter that provides a carbon source for denitrifying bacteria. Inputs with low nitrate loads (e.g. from natural catchments) will require both aerobic and anaerobic conditions to nitrify and denitrify nitrogen inputs. In this situation, nitrification is enhanced in wetlands where soil moisture contents fluctuate repeatedly (Patrick & Mahapatra 1968, Ponnamperuma 1972). On the other hand, wetlands receiving fertilizer runoff or other sources associated with high nitrate levels will reduce nitrogen loads most efficiently when they are anaerobic and when input nitrate concentrations are high. Wetlands that are more or less permanently inundated promote reducing conditions. Nitrogen, in any form, is also taken up from the soil by growing plants. Bacteria concentrations are reduced in wetlands by exposure to UV-light. The degree to which this occurs is linked to the duration of water retention within the system.

The ability of wetlands to perform water quality amelioration services depends on their area and type of vegetation as well as to their overall health and management. Hydraulic efficiency, which is the degree to which a wetland disperses inflow over its area, is also important (Jordan *et al.* 2003). This maximizes contact area and it can be assumed that it serves to increase detention time as well. There is an upper limit to the amount of pollution that a wetland can remove, as well as to the amount of pollution that can be added to a wetland without having a significant impact on its functioning and biodiversity. At high phosphorus loading rates wetlands may eventually become a phosphorus source rather than a sink (Tilton & Kadlec 1979, Forbes *et al.* 2004). This also varies seasonally. Wetlands are thought to be better at removing total suspended solids, phosphorus and ammonia during high flow periods (when sediment loads entering the wetland increase), but better at removing nitrates during low flow periods (Johnston *et al.* 1990, McKee *et al.* 2000).

A number of studies have been carried out on the water quality amelioration function in natural and created aquatic habitats (e.g. Jordan *et al.* 2003, Peltier *et al.* 2003, Thullen *et al.* 2005, Batty *et al.* 2005, Kansiime & Nalubega 1999), but most research has been carried out in treatment wetlands. In South Africa there are data on the capacity of artificial wetlands to treat wastewater (e.g. one ha wetland can treat about 272 m^3 of wastewater per day – Rogers *et al.* 1985), but little data exists on natural systems, which are likely to be less efficient. However, while removal rates in natural wetlands may be lower than in man-made wetlands, they are often more permanent, because of the loss to peat. Most constructed treatment wetlands have to be 'reset' every few years by removing the accumulated biomass, and often soil as well, as they become saturated.

In treatment wetlands, absolute removal rates are often proportional to concentration, and the percentage of N and P influx removed tends to increase as the hydraulic loading rate decreases and the detention time increases (Jordan *et al.* 2003).

3.2.2 Water quality amelioration within the Elephant Marsh

Monthly water quality samples taken at a number of locations within the elephant marsh indicated that the marsh had an average monthly Phosphorus concentration of between 0.005 and 0.113 mg/l, between 0.1 and 0.28 mg/l of Ammonium and between 0.0075 and 0.36 mg/l of Nitrate. While these samples were only taken from a small number of locations, they do give an indication of the state of water quality within the marsh. These levels correspond with a trophic state in the range of mesotrophic to eutrophic, which indicates only a moderate effect of anthropogenic inputs on water quality. The phosphorous levels are more of a concern that the nitrogen levels, as freshwater systems tend to be phosphorous-limited rather than nitrogen-limited.

Kansiime & Nalubega (1999) showed that natural *Cyperus papyrus*-dominated wetland in the Nakivubo wetlands was resilient against, and indeed apparently actively thrived, in conditions exposed to through-flows of waste water. These authors cited uptake rates by indigenous plants of total nitrogen by this wetland as being in the order of 475 kg N/ha/yr, while total phosphorus uptake was in the order of 77 kg P/ha/yr. Nutrient uptake rates in *Cyperus papyrus* wetland were highest in wetlands with high oxygenation, with the high rate of uptake associated with high plant productivity. Other processes such as sedimentation, dilution and nitrification with the lake waters at the edge of the wetlands approximately contributed to a further removal of 1143 kg N/ha/yr and 63 kg N/ha/yr. Using only these estimates from plant uptake and applying this to the area of undisturbed papyrus marsh vegetation within the Elephant Marsh (~3500 ha) we get a potential removal rate of up to 1662 tonnes N/yr and 269 tonnes P/yr. While the inflowing water into the marsh is not have as high a nutrient concentration as that in the Kansiime & Nalubega (1999), the area of papyrus is an underestimate because it does not include the more disturbed areas of papyrus, as such this estimate is likely to be relatively realistic.

People who draw water directly from the Shire River face health risks associated with water-borne diseases and poor water quality. As such there has been a lot of investment in creating boreholes around the Elephant Marsh to provide people with safe, clean drinking water. In recent years however, the rising salinity of the water produced has resulted in people abandoning boreholes, forcing people to once again rely on water directly from the Shire River (See the project's Arthur &

Hara 2016, and Grimason *et al.* 2013). While the Elephant Marsh may have reduced nutrients and certain pathogens to some extent, it is likely that this would not be sufficient to eliminate the risks associated with drinking water from the river, including the contraction of Bilharzia and crocodile attacks while collecting the water.

Another potential benefit of the decreased nutrients in the outflowing water of the Elephant Marsh is that fewer nutrients are made available downstream. Downstream of the Elephant Marsh, the growth of aquatic weeds such as water hyacinth and water lettuce cause problems by blocking the passage of vessels. Using the estimated amount of Nitrogen absorbed by the marsh vegetation, and the average annual inflow of water, this equates to a drop in nutrient levels of approximately 0.0003 mg/l. A relationship between the growth of water hyacinth and water Nitrogen concentration is given by Wilson *et al.* (2005). According to this relationship, this change in concentration is unlikely to have any noticeable effect on water hyacinth growth rates.

3.2.3 Sediment removal within the Elephant Marsh

The Shire River carries high sediment loads into the top of the Elephant Marsh. This sediment originates from the poorly-managed and heavily deforested slopes of the catchment, where most of the natural vegetation has been removed, and erosion and loss of topsoil are a major problem. Water quality monitoring data from between July 2015 and July 2016 indicated that the sediment concentration was between 20 and 831 mg/l at Chikwawa Bridge prior to entering the marsh. The highest loads were recorded between January and April.

While monitoring was also conducted at the lower end of the marsh, it was hard to separate the waters flowing from the Shire in the north vs those flowing from the Ruo River which recently changed its course is also brings high levels of sediment into the bottom half of the Elephant Marsh.

Photos taken during microlight flights as part of the Biodiversity Study clearly show clear streams flowing out from vegetated areas mixing with the turbid water of the main channels and distributaries (Figure 8). This change in water clarity was also noted during aquatic invertebrate sampling whereby the clear streams had a visual clarity of over 120 cm, whereas the main channel had a clarity of <2 cm.

Using cores that extended 5 m and carbon dating a selection of sections of the core, it was estimated that the average rates of sediment deposition was approximately 0.5 mm/yr in pre-anthropogenic times, however in the last 50 years has increased to between 10 and 34 mm/yr in the lower Elephant Marsh, while in the upper marsh was closer to 1 mm/yr (see Hydromorphology Report for details on sedimentation processes in the Elephant Marsh).

The current level of sedimentation equates to between approximately 144 kg/m^2/yr being deposited across the Elephant Marsh. This value is at the upper end of the range of deposition rates given by Kansiime and Nalubega (1999) in a papyrus swamp in Uganda (range 11-158.8 kg/m^2/yr). If we take the area of the marsh where we estimate sedimentation to occur as approximately 300 km^2, this would equate to approximately 43 million tonnes (or 45 million m^3) of sediment per year being prevented from travelling further down the Shire River.

Figure 8. Clear water from small streams (on far right) that pass through vegetated areas mixing with turbid waters of the main channels (bottom left). Photo taken above Elephant Marsh during microlight flight.

Downstream of the Elephant Marsh, the town of Nsanje (formerly Port Herald) lies on the banks of the Shire River. Up until the 1970s, the town was a port that received ships that had transported goods from the Indian Ocean up the Zambezi and Shire. A railway line then transported goods from Nsanje to Blantyre. The transportation was halted and the closed due to the civil war in Mozambique hindering transport up the Zambezi.

A resurrection of this trade route has begun under the Shire-Zambezi Waterway Project. Thus far a new port at Nsanje has been built, the road to Nsanje tarred, a feasibility study has been carried out and negotiations between Malawi, Zambia and Mozambique are in progress. Mozambique is currently holding up the process amid concerns over the feasibility and environmental impact of the project. Mozambique is also less committed as they are already committing resources to other ports such as Beira, whereas Zambia and Malawi are landlocked and so would benefit from the project greatly.

The three-year, technical feasibility study funded by the African Development Bank and carried out by German consulting company Hydroplan concluded that the project was in fact feasible. In addition to port building costs it would require US$18 million of initial dredging (1-33.5 million m^3) and US$50 million of clearing of the alien water hyacinth plant (235 km^2). An additional US$30 million would reportedly be required for dredging per year to keep the channel open and deep enough for the passage of ships. Despite these high input costs, the project is expected to be more economically viable for Malawi than continued road transport of imported foods, especially if all three governments buy in to the project.

The cost of dredging from the literature places the average cost of dredging inland waters at about US$5.6 /$m^3$ (Bortone & Palumbo 2007). In order to dredge the amount of sediment being deposited in the Elephant Marsh each year it would therefore cost approximately US$252 million/yr using the average price of dredging.

3.3 Carbon storage

There is more carbon stored in the earths' biomass, soil and ecosystems than there is in the atmosphere (Lal 2002). Natural systems can therefore make a significant contribution to global climate regulation through the sequestration and storage of carbon. When natural systems are degraded or cleared, much this carbon is released into the atmosphere. These emissions contribute to global climate change, which is expected to lead to changes in biodiversity and ecosystem functioning, changes in water availability, more frequent and severe droughts and floods, increases in heat-related illness, and impacts on agriculture and energy production (IPCC 2007). These impacts will affect economies and human wellbeing on a global scale.

Carbon is stored in ecosystems in a number of different pools including above-ground biomass, below-ground biomass, in sediments and standing dead carbon (Figure 9). In addition to these pools, some ecosystems also help to accumulate carbon, adding to these carbon pools over time, this process is called carbon sequestration. It can often be easier to estimate the carbon storage of an ecosystem as estimating carbon sequestration requires knowledge about rate of accumulation over time which often requires a greater understanding of the ecosystem and multiple years of field work. For a desk-based assessment such as this, taking literature estimates for carbon pools will have a much lower degree of uncertainty than rates of sequestration which have been studies much less.

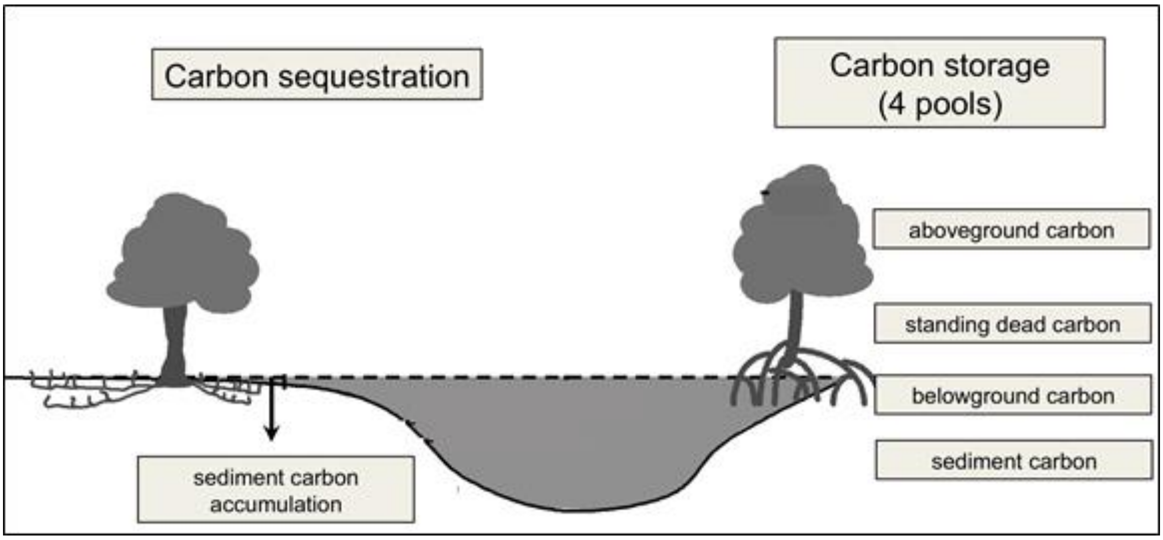


Figure 9. Difference between carbon sequestration and storage, as well as the different carbon pools (Source: Natural Capital Project).

Wetlands in general are known to be particularly efficient in storing and sequestering carbon. Papyrus wetlands in particular have been shown to have very high levels of primary production and potentially represent some of the most productive biological systems in the world (Saunders *et al.* 2014). Other emergent macrophytes in wetlands also have rates of net primary production that rival that of tropical rainforests and intensive agriculture, due to their high rates of carbon use efficiency (Rocha & Goulden 2009).

Saunders *et al.* (2014) estimated the standing above and below ground stock of papyrus wetlands to be approximately 41 tC/ha. They also estimated that peat forming under papyrus mats. Using a conservative estimate of 0.25 m peat depth and density and carbon content parameters from Saunders *et al.* (2014) we calculate that approximately 123.5 t/C is potentially stored in addition to standing stocks within the papyrus vegetation within the Elephant Marsh. Maqbool & Khan (2013) estimated the standing above- and below-ground biomass for *Phragmities* and *Typha* in wetlands were similar, at about 7.4 tC/ha. Using these carbon densities and the extent of undisturbed papyrus as well as undisturbed other natural vegetation the estimated standing stock of carbon in the major vegetation groups is approximately 0.6 million tonnes of carbon.

Thus the benefits of carbon storage can be valued in one of two ways depending on the analytical context: based on the social cost of carbon emissions, or based on market prices. In an ideal world, these values would be similar. Since the Kyoto Protocol, the development of emissions trading on a global scale has spawned markets for carbon sequestration and storage. In recent years, this has extended to markets for carbon that is secured or sequestered as a result of reduction of deforestation and degradation of forests. This has created opportunities for obtaining more tangible benefits from biodiversity and habitat conservation that can potentially offset the benefits gained from damaging activities.

We use the method of calculating the social cost of carbon, as in the case of the Elephant Marsh, it is unlikely there is any market for the stored carbon. The social value of a tonne of carbon is equal to the damage avoided by not releasing the tonne of carbon into the atmosphere. Estimates of the social cost of carbon are based on the impacts of climate change on country GDP outputs aggregated at a global scale. A recent estimate puts this value at $29.60 per tonne of carbon in 2015, and this is expected to rise at about 2% per year (Tol 2012). These impacts are not evenly shared across the globe. While developed countries emit more carbon, developing countries are expected to incur proportionally greater costs in terms of percentage of GDP.

The IPCC (1996) estimated damages to be in the order of 1% of GDP for developed countries, whereas developing countries were expected to suffer larger percentage damages, so that mean global losses would be 1.5 to 3.5% of world GDP. Given that Malawi's GDP amounts to 0.025% of the GDP of low and middle income countries, this means that Malawi's share of the global costs due to climate change of a tonne of carbon emitted would be less than 0.018%. Thus, while the loss of the Elephant Marsh could generate global damages worth $20 million, very little of this damage would actually occur within Malawi and so the damage costs accruing to Malawi might only be as little $3596 per annum. From Malawi's perspective, there is relatively little economic incentive to prevent the degradation of the Elephant Marsh on the grounds of mitigating climate change damages. Nevertheless, it should be borne in mind that the social impacts that are not reflected in GDP figures would be far more serious in developing countries, where people rely on land and natural resources for their livelihoods and where governments lack the resources to provide social welfare or to adapt to climate change through early warning systems and infrastructure.

3.4 Habitat/refugia

Animals which have large movements require habitats across their range for different purposes. Value may be derived from these animals at any point within their range, whether tourism value, biodiversity value or direct use value. Even if this value is not realised in one area, the fact that the animals rely on that area for habitat, some of the value derived elsewhere can also be attributed to that area. This is especially true for certain areas provide critical habitats for species that are globally threatened.

3.4.1 The African Skimmer

The Elephant Marsh may provide an important stopover point for African Skimmers. While the Skimmer does not appear to breed within the Elephant Marsh, large flocks have been recorded more frequently in recent years (usually between 280- 600 individuals; see Turpie *et al.* 2016 for more details). Large flocks of up to 300 also frequently occur at Liwonde National Park further about 150 km upstream on the Shire River, however they do not breed in this habitat either (S. Chihana Pers. Comm).

In order to breed, African Skimmers require relatively undisturbed sand banks. Breeding often occurs in the dry season when river levels are lowest and sandbanks are exposed. In the region, this occurs between July-Nov. It is likely that breeding occurs further south along the Zambezi River where there are more sandbanks between the braided channels.

In the non-breeding season they requires large expanses of relatively calm water for feeding where they skim the surface of the water for fish prey species. African Skimmers are quite susceptible to disturbance by humans, either in their breeding grounds, or in their foraging areas. Liwonde provides one of the least disturbed suitable habitats between the Zambezi and Lake Malawi. Sections of the Elephant Marsh also provide relatively undisturbed large expanses of habitat that might be used as a stopover between the Zambezi and Liwonde.

African Skimmers are a sort after sighting for bird enthusiasts and in addition to being globally threatened, these birds are a drawing card for certain tourists, increasing the tourism and biodiversity value of areas like Liwonde National Park.

4 CULTURAL SERVICES

4.1 Tourism/recreational value

Tourism infrastructure is very underdeveloped in the Lower Shire Region and as a consequence there are not a great number of visitors to the area. The Elephant Marsh is also not on any major travelling route for tourists and few tourists drive through Mozambique to Malawi or vice versa through the Marka Border Post on the M1. There are not a great number of other tourist destinations nearby (Figure 10).

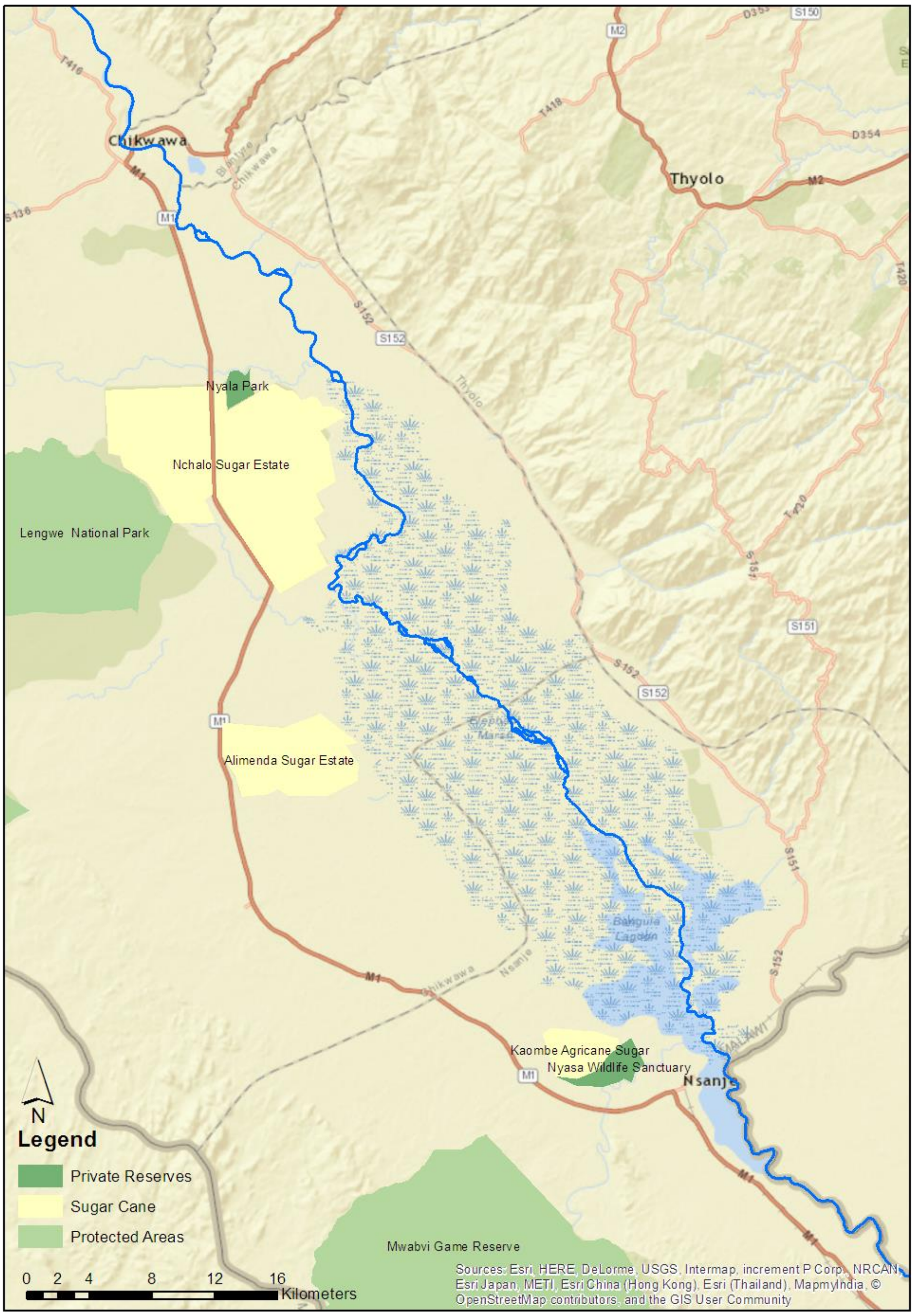


Figure 10. Location of National Parks, Games reserves and Private Reserves around the Elephant Marsh.

The area is known for being very hot during summer months; however, water-based activities are very limited given that most of the water is heavily sedimented and it is also inhabited by crocodiles and occasionally hippo. Much of the area surrounding the Elephant Marsh is rather inaccessible, making gaining access to the marsh itself difficult. There are only a few points where motor boats can be launched and few places accessible by car where there are mokoro polers who could take tourists out onto the marsh. With exception to the M1 running along the west bank of the marsh, most roads are in poor condition, especially after rain. Guide books and internet blogs suggest the fishing village of M'chaha James near Chiromo is the best place to hire a mokoro and poler and have a day trip out on the marsh. This area is no longer accessible by car since the January 2015 floods, as the bridge and road to Chiromo were swept away.

4.1.1 Tourism destinations and accommodation nearby the Elephant Marsh

Majete Game Reserve is situated just north-west of Chikwawa and the Elephant Marsh along the Banks of the Shire River stretching westwards. The park is close to 700 km^2 and its' vegetation is a mix of moist miombo woodland in the west, dry savannah in the east with and riparian thickets along the Shire river banks. While this park was devoid of most wildlife before African Parks took over management of the park in 2003. It has now been restocked with many animals including all of the Big Five species. African Parks has also upgraded park roads and infrastructure to also easier access and attract tourists. There are three different accommodation options available to tourists in Majete including the upmarket Mkulumadzi Lodge in a private concession held by Robin Pope Safaris, the Thawale tented lodge as well as a community run campsite. This is the largest tourist attraction in the Lower Shire, however is not associated with the Elephant Marsh and only peripherally associated with the Shire River. As such, none of its tourism value is attributable to the Elephant Marsh.

Mwabvi Game Reserve is situated directly south of the Elephant Marsh to the south-west of the town of Bangula. It is Malawi's smallest wildlife reserve at 135 km^2 but was once home to a range of rare animals including Malawi's last Black Rhino. The park is hilly and consists mainly mopane and acacia woodland. This reserve has suffered from an extremely high level of poaching and as a result no longer has higher numbers of animals nor big game species. A non-profit UK-based organisation Project African Wilderness (PAW) took over management of the park in 2007. Roads were extended and a lodge was opened for tourists as well as a lion rehabilitation project. In 2012 the project sponsors ran into financial difficulty and the project had to be dismantled. Since the withdrawal of PAW, the park has once again been under the management of DNPW. During this period it seems the roads and infrastructure within the park have not been well maintained and the park is once again suffering from heavy poaching and currently does not have accommodation options.

Situated near Bangula town and close to the edge of Bangula lagoons on the Kaombe Ranch is another small privately owned reserve. This reserve, Nyasa Sanctuary, is approximately 700 hectares and was previously land under grazing and/or cultivation before being fenced and protected. The vegetation is secondary growth dry woodland. It also houses a range of large game species such as buffalo and Nyala. While there are currently no accommodation and very few roads, there are plans to make this area more accessible to tourists in the future.

Lengwe National Park is situated west of Nchalo and is mainly dry deciduous forest. While Lengwe only contains two of the Big Five, it is home to the Nyala antelope indigenous to this part of Malawi as well as a broad range of bird species. While the park is around 900 km^2, only 90 km^2 have accessible roads. Jambo Africa manages the accommodation available within the park at Nyala Lodge. Here there are both chalets and camping options available to tourists. The annual turnover of the accommodation at the Nyala Lodge is estimated at less than US$50 000 (Table 6). If 5% of the visitors were staying in order to see the Elephant Marsh, which is likely an overestimate, then less than US$2 500 can be attributed to the marsh itself.

Table 5. Calculation of annual turnover at Lengwe Nyala Lodge assuming a 25% unit occupancy rate and an average price of 70% the rack rate.

Accommodation Type	No. units	Rack Rate per unit per night (US$)	Estimated Turnover (US$)
Chalet (4 person)	5	122.00	39 000
Camping Chalet (2 person)	2	35.00	4 500
Camping	10	7.50	4 800

Within the Illovo Sugar estate there is a small (~400 ha) reserve called Nyala Park. This reserve houses large games species like zebra, giraffe, buffalo, wildebeest and Nyala, some of which are introduced and not necessarily naturally occurring in the area. The Park is open to visitors and has good road access. There is no accommodation offered in the park, but picnic facilities are available. It is mainly utilised by Illovo staff members and visitors to the Illovo Estate. The Illovo estate also has accommodation available on the river's edge at the Nchalo Sports Club. While the accommodation is mainly utilised by Illovo consultants, the bar, pool and restaurant are regularly frequented by staff members and people who live locally. The annual turnover of the accommodation at the Illovo Sports club is estimated at less than US$200 000 (Table 6). If 5% of the visitors were staying in order to see the Elephant Marsh, which is likely an overestimate. Then less than US$10 000 can be attributed to the marsh itself.

Table 6. Estimate of annual turnover at Illovo Sports Club assuming a 75% unit occupancy rate and an average price of 70% the rack rate.

Accommodation Type	Rooms	Rack Rate per unit per night (US$)	Estimated Turnover (US$)
Rooms	20	50.00	192 000

4.1.2 Recreational activities on the Elephant Marsh

For many years, Malawi had a ban on hunting, however between 2010 and 2013 trial hunting was permitted by Cluny Safaris within the Elephant Marsh. This meant setting up a seasonal camp for three years within the Southern end of the Marsh. Clients (mainly from Europe) were brought in to specifically hunt crocodiles, hippopotami, ducks and geese. This hunting experience was marketed as a unique and challenging hunting safari for only the most intrepid hunter.

In 2013 a hunting safari from Europe to the Elephant Marsh including all flights, government fees, outfitting, professional hunter, in country transport and accommodation was in the order of US$11 000 for 6-9 days hunting with additional days were priced at approximately US$550 per day. Even an estimate of only four clients a year this would equate to a turnover of close to US$50 000 per annum, of which most is directly attributable to the Elephant Marsh.

The only other recreational activity that takes place on the marsh is the occasional bird-watching or sight-seeing tour from a mokoro. Guide books and internet blogs suggest the fishing village of M'chaha James near Chiromo is the best place to hire a mokoro and poler and have a day trip out on the marsh. This area is no longer accessible by car since the January 2015 floods as the bridge and road to Chiromo were swept away. There are a few alterative places like most fishing landing zones, where a tourist could potentially hire a mokoro and poler. Prices are variable for mokoro rides, but a few hours paddling will cost approximately US$10-15. Panoramio photos on Google Earth across the marsh consist of handful of photos from only three different photographers, again indicating the scare number of visitors to the Elephant Marsh. If 200 recreational mokoro trips were made each year (more than this is unlikely), this would equate to a value of US$5000-7000 per annum.

4.1.3 Current tourism/recreational value and potential for growth

The current tourism/recreational value of the Elephant Marsh in 2016 is in the order of approximately US$17 500 per annum. During the period where the hunting was taking place, this value would have been much higher. However, it is not clear how sustainable the hunting practices were. In addition there were concerns around safety considering the large number of fishermen and other local inhabitants that also use the marsh (D. Macpherson Pers. Comm.).

There are a number of ways in which the tourism value of the Elephant Marsh could be increased. These include making the area more accessible, especially the more scenic southern end. M'chaha James and Chiromo allow for easier access into the marsh, and rebuilding of the road and bridge to Chiromo would facilitate the utilization of these access points.

The building of tourist facilities within the Nyasa Sanctuary would provide accommodation in close proximity to the marsh, as well as provide tourists with some game viewing opportunities within the sanctuary. The nearby scenic Bangula Lagoon can also be accessed from the Koambe Estate pump house facilities. With the right infrastructure, this location could be a good place to offer boat rides into the marsh.

It should be kept in mind, for any expansion of the tourism facilities in and around the Elephant Marsh, that the area is unlikely to hold great potential due to its lack of endemic or interesting species and large game and lack of easy access. In addition, not being situated on a major tourism route, along with the heat and humidity makes the Elephant Marsh an unlikely choice for most travellers.

5 WETLAND DISSERVICES

Wetlands provide a number of beneficial services to people, however having a large wetland in close proximity to people also comes with a number of disadvantages or risks. These disservices can be detrimental to human health as well as livelihoods. In understanding the total value of the Elephant Marsh, these disserves must be weighed against the beneficial services offered by the wetland.

5.1 Human-wildlife conflict – attacks and crop damage by wildlife

Along the Shire River and its adjacent marshes there have been high rates of human-wildlife conflict reported. The occurrence of these incidents stems from the large populations surrounds the waterways, and the high level of reliance on the river and marshes for fresh water and livelihoods. While there are indeed a high number of incidents, it appears that some of these reports are over-exaggerated in the media (Kalokekamo 2000). Some media sources reported up to 200 attacks and close to 60 deaths per year along the Lower Shire, while Kalokekamo (2000) confirmed that the number was closer to 30 per year in the late 1990s. More recently, reports for Chikwawa District hospital alone were only of six cases of crocodile bite in 2014 and eight in 2015, however this is not for the entire marsh area.

The two main problem-causing animals along the Shire River and wetlands are the crocodile and hippopotamus. The crocodile has been known to take humans as they fish, wash clothes, bathe, fetch water or travel by canoe. They are also known to destroy fishing gears and attacking livestock. Hippopotamus graze on crops and can also cause harm to people as they try to protect their crops.

People have tried to reduce the extent of human-wildlife conflict by erecting fences and placing scarecrows along the riverbanks to discourage hippopotami from entering their crop fields (Figure 11). People also erect small temporary huts deep in the marsh in which a person will stay to try and chase away any hippopotami that try to graze within the crop field. Collection of water from the river is often done via bucket on a pole or role from a height about the river bank rather than having to enter the water. In the 1980s the course of the Shire River in the Elephant Marsh was supposedly narrowed and blocked to reduce the incidence of crocodile attacks on the western edge of the marsh. While it is not sure how successful this was at reducing crocodile attacks, it did lead to expansion of cultivation further into the marsh, which may have placed people once again in closer proximity to damage causing animals.

Figure 11. Fences (top) and scarecrows (bottom) to try and protect crops from Hippopotamilong the banks of the Shire River within the Elephant Marsh.

The Department of National Parks and Wildlife (DNPW) have a number of officers on call to deal with problem animals in and around the Elephant Marsh. Data from the DNPW suggests that there have been up to around 120 reports of problem animals a year (Figure 12). In response to these reports, DPNW officers have killed or injured around 30 animals a year in recent years (Figure 13). The DPNW is allowed to sell the meat of the animals killed and use the income to fund activities. It has been suggested in interviews that this tends to affect the response by DPNW in that they are more likely to respond and address calls related to (valuable) problem hippos than crocodiles, which are not valuable but cause considerable levels of injury and death in communities within and around the Marsh (Arthur & Hara 2016). This indicates that the removal of problem animals may not be based purely on the damages but rather the benefit of their culling. This can easily lead to over harvesting of hippopotamus, of which there are only a small number remaining in the marsh (Turpie *et al.* 2016).

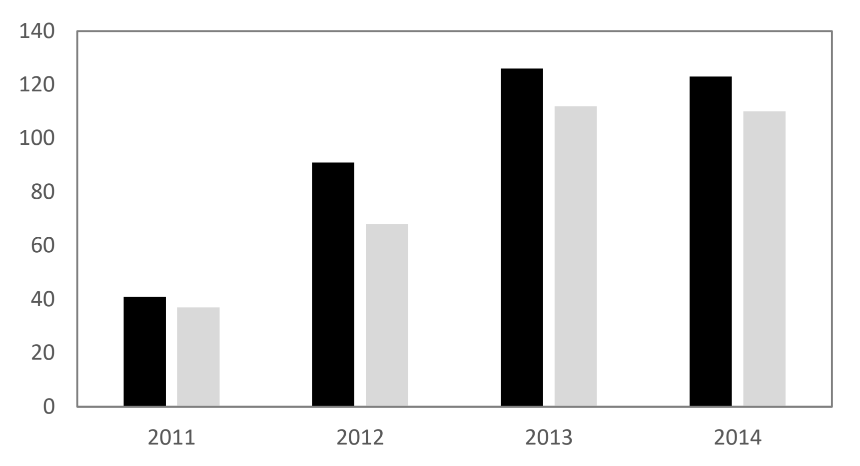


Figure 12. Reports received by DNPW of problem animals (Black) and reports attended (Grey; Data Source: DNPW).

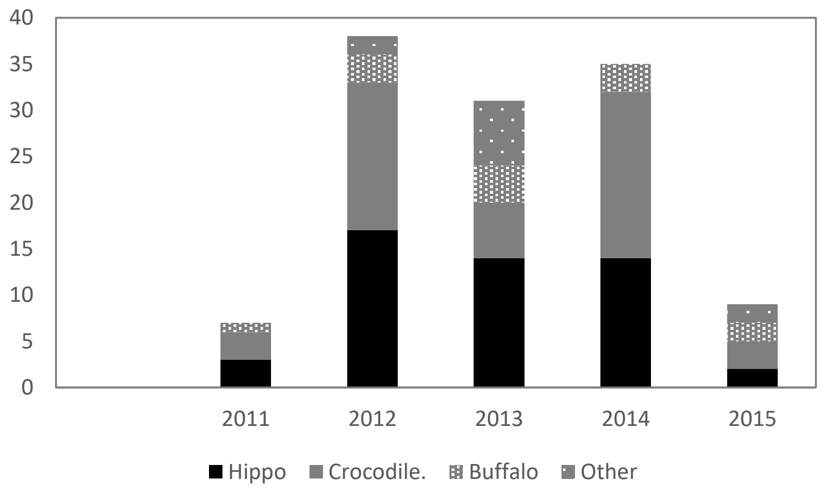


Figure 13. Problem animals killed or injured over time. Other includes elephant, monkey and baboon (Data Source: DNPW).

5.2 Waterborne diseases

In addition to effects on crops and livestock, people living in the Elephant Marsh are also vulnerable to water-borne diseases, in particular Malaria, Bilharzia, Filaria, Cholera and diarrhoea. Many of these diseases seem to be somewhat connected with receding floodwaters in the marsh, as well as other artificial water bodies such as irrigation ponds and ditches. Improved sanitation, prevention and treatment could vastly decrease the prevalence of the diseases in and around the Elephant Marsh.

Malaria transmission is perennial, with seasonal increases after rains during November–April (Bennet *et al.* 2013). The most abundant malaria vector in the region is *Anopheles arabiensis* which breeds predominately in larger water bodies surrounding villages such as rice paddies and irrigation pools (Spiers *et al.* 2002). While most of the breeding grounds are a result of rainwaters and/or irrigation projects, some of the habitats can be caused by receding floodwaters of the marsh.

Bilharzia, or Schistosomiasis, is another water-associated disease that occurs in the Lower Shire region. Schistosomiasis is contracted though water contact and requires aquatic intermediate snail hosts to complete their lifecycle. A recent study found that fishing, farming and working in gardens along the Shire River were potential risk factors associated with the disease (Chipeta *et al.* 2013). Prevalence rates of up to 94% for urogenital schistosomiases and 25% for intestinal schistosomiasis were found in mothers within the Chikwawa district (Poole *et al.* 2014). No populations of the intermediate snail host of intestinal schistosomiasis were found during surveys, so it is hypothesised that transmission either happens elsewhere or that populations are washed down from upstream during flood events and transmission occurs intermittently (Poole *et al.* 2014). The host for urogenital schistosomiasis, however, was found to be present in a number of sampled locations near Chikwawa (Poole *et al.* 2014).

The Lower Shire is also known to be a hotspot for lymphatic filariasis (Nielsen *et al.* 2002) which as another mosquito transmitted disease. Prevalence of the disease in adults living around the Elephant Marsh is as high as 60% in Chikwawa District and 77% in Nsanje District (Nielsen *et al.* 2002). Similar to transmission of malaria, villages close to water bodies such as marshes, the river and irrigation ponds had highest rates of infection.

Cholera and diarrhoea are related to poor access to clean water and sanitation that is attributable to limited maintenance of existing water facilities and spatial coverage of permanent latrines combined with flooding and siltation, theft and vandalism of water facility infrastructure and equipment. According to the district health officials, cholera outbreaks can occur in both drought and flood conditions (although mainly in flood). For the first half of 2015 Chikwawa reported 357 cases and five deaths from Cholera. The majority of these were attributed to unsafe water and contaminated food or water (Chikwawa Heath Department), although they believe there is also an association with eating foods obtained from the wild in the Elephant Marsh.

It is important to note, however, that the presence of these problems is linked to the combination of a marsh habitat with a populated area in which there is inadequate sanitation and management of behaviours that affect the risk of exposure to diseases such as malaria and cholera. The wetland is not the primary cause of these problems, but can exacerbate them under these circumstances. Removal of the wetland would not eliminate these problems.

6 OPPORTUNITY COSTS (VALUE OF ALTERNATIVE USES)

While ecosystems services are derived from the wetland in its natural state, we must also recognise that there is value in activities that derive benefit from the wetland in the short term, however ultimately degrade and transform the wetland. Examples of these include grazing domestic animals, growing crops and abstracting water for irrigation. These activities are seasonal to some extent as during flooded periods, access to large parts of the marsh is limited.

The marshes not only provide areas for cropping and grazing, particularly in dry periods, but the opportunities for fishing and harvesting plants and animals, also constitute an important safety net for many households.

6.1 Grazing (seasonal)

The Lower Shire region contributes to approximately 70% of the livestock meat production within Malawi (Kalowekamo 2000). Cattle are grazed in both the upland areas as well as the lower-lying floodplain areas. Most people living within the Elephant Marsh area have their cattle grazing in the uplands from December through to June while July through November most have cattle grazing within the floodplain (Turpie *et al.* 1999). Dry season grazing on the wetland is often conducted on crop residues after crops have been harvested. Cattle are then moved off the wetland during peak floods and also during planting season to avoid damage to crops.

Turpie *et al.* (1999) found that between 5-40% of people own cattle, with a higher percentage of richer households owning cattle poorer households. Richer households also own a higher number of cattle than poor households (14 vs. 2). It was estimated that approximately 100 000 cattle were grazed on the floodplain during the non-flood season and that the entire herd spends on average seven months a year on the floodplain. Similarly Kalowekamo (2000) estimated that between 76 000 cattle and 156 000 are grazed within the Lower Shire.

Grazing on the wetland during the dry season coincides with the breeding seasons for crocodiles, which often make then more active and aggressive, leading to higher incidents of livestock being taken or injured (Kalowekamo 2000). This reality of grazing within the wetland can lower the value of livestock production associated with the marsh.

Although, much of the grazing occurs on crop residues, natural floodplain grasses are also grazed. These floodplain habitats should be quite resilient to seasonal grazing as the marsh used to support large herd of ungulates in the past (Jawali 2015). Grazing however, does help open up areas and access which may allow further cultivation of the marsh. The effect of grazing on the overall marsh health, and its ability to deliver other goods and services should however be considered when evaluating the benefit of grazing.

The annual value associated with grazing cattle on the Lower Shire floodplains was estimated at US$1.8 million per year (Turpie *et al.* 1999). This value however, does not take into account any degradation to the wetland caused by the livestock, not does it take into account any negative values associated with losing livestock to crocodile attacks.

6.2 Crops (seasonal)

Malawi's economy is largely based on agriculture, mostly from rural smallholder farmers (Figure 14). The Lower Shire is almost entirely customary land under smallholder farming with only a few larger sugar estates. Crops grown in the Lower Shire are predominately maize, sorghum, millet, beans, rice, cotton, cassava as well as Irish and sweet potatoes (Turpie *et al.* 1999). Almost all inhabitants within the Lower Shire are involved in some kind of subsistence agriculture, however, only about 54% of the cultivation was found to occur within the wetland floodplains, with the remainder happening in the uplands (Turpie *et al.* 1999).

Figure 14. Vegetable and rice crops being grown on the floodplain of the eastern side of the Elephant Marsh.

Both the area cultivated and the crop yield varies from year to year. Many farmers experience have experienced crop failure in recent years and mainly attribute this to climatic factors such as rainfall, temperature and flood extents as the main reason for crop failure (Arthur & Hara 2016). It was estimated that Shire Valley maize production between 1984 and 1993 varied from 20 500-60 811 ha under cultivation with production between 7 939-44 635 tonnes (Ngongola & Kapwepwe 1994). More recently, agricultural production figures were sourced from the Agricultural Development Division in Ngabu and the various Extension Planning Areas (EPAs) that cover the Elephant Marsh. Based on the production figures provided, the total production of staple crops for the Elephant Marsh was in the region of 255 000 tonnes, of which 132 000 tonnes was produced in the winter season[1].

Cultivation of the marsh is largely driven by accessibility to the marsh. Accessibility to the marsh is driven by the wetness and extent of flooding within the marsh, i.e. in drier years it is easier to traverse the marsh and access new areas, where as the opposite it true in wetter years. Access is also influenced by the surrounding human population. This relationship is backed up by evidence suggesting higher levels of cultivation of the marsh during prolonged dry periods the extent of cultivation was greater than during wetter or current conditions (see Brown *et al.* 2016).

[1] Note that the EPA areas do not exactly correspond to the area of the Elephant Marsh. The totals are likely to be an overestimate, particularly for the summer crop. Figures are for 2014/15 with the exception of Southern/Central where figures for 2010/11 were the only ones currently available. Given the flood and drought in 2015/16, these figures are again going to be an overestimate of recent production from the Elephant Marsh.

Croplands are generally transformed from either uncultivated floodplain grass land, or from areas that were previously reeds and papyrus. These habitats tend to be fairly resilient in terms of vegetation, and can recover fairly quickly from being cultivated if the fields are abandoned as they sprout rapidly and more densely in response to being cut or burnt (Turpie *et al.* 2016). This however is not always the same case for the native fauna which is often killed or displaced during the cultivation process (Turpie *et al.* 2016).

Cultivation within the marsh benefits from the higher water content during flood recession as well as nutrient additions through sediment deposition. As a result, the inputs needed (such as fertiliser and water through irrigation) are less than in upstream areas. Turpie *et al.* (1999) estimated that the cultivation on the Shire River floodplains was in the order or US$17 million per annum. Again, this value does not take into account any degradation to the wetland or impact on its ability to deliver other goods and services.

6.3 Abstraction of water for irrigation

Water used for agricultural purposes comes from one of two different water resources, 'blue' and 'green' water (Figure 15). These two water sources are not completely distinct and do interrelate. For example increased plant cover leading to increased infiltration (green water resources) which can increase ground water recharge and thus the blue water resources and irrigation can convert blue water resources to green water through plant uptake and evapotranspiration. However, separating the two in this simplistic scheme helps understand which parts of the overall water cycle can be attributable to natural ecosystems and therefore can be considered ecosystem services.

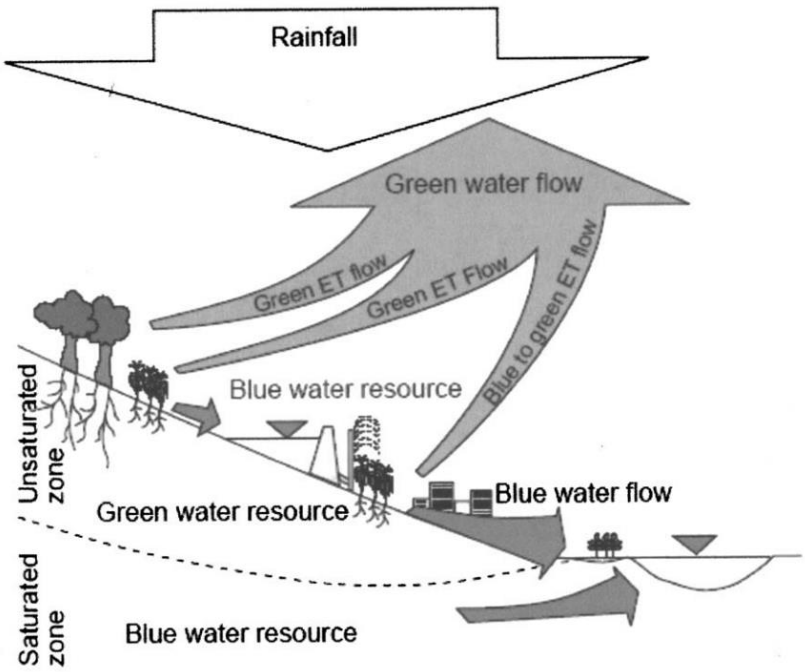


Figure 15. Blue and Green water cycles. Green water cycles include soil moisture and water used by plants, returned to the atmosphere by evapotranspiration. Blue water cycle include surface and ground water flows as well as water in lakes and reservoirs (from).

Green water is water stored in soil moisture is often regulated by local rainfall, vegetation cover, soil organic matter as well as the biological communities living within the soil. Green water is used in plant processes and is returned to atmosphere through plant evapotranspiration. Water supplied through these processes are generally considered to be ecosystem services.

Blue water includes surface water flows through rivers as well as water stored in lakes and groundwater flows. This store of water is reliant on rainfall and run-off in upstream catchments and can be somewhat independent of quality of surrounding ecological systems. This part of the water cycle is more a result of physical properties of the catchment than the ecological components within it. In some systems, however the timing, quality and total yield of surface flows and the recharging of groundwater systems are related to the vegetation cover within the catchments. Water within this part of the cycle is returned to atmosphere through evaporation from water and ground surfaces, or becomes part of the green cycle through irrigation and uptake from crops.

There are a number of current irrigation schemes that exist adjacent to the Elephant Marsh, the main ones being the Illovo Sugar Estate near Nchalo, and the Kaombe Agricane Estate in the south neat Bangula. These enterprises represent some of the biggest formal employers within the Lower Shire Valley.

The provision of water for irrigation by the Shire River mainly forms part of this blue water cycle, and while it can be important for many people’s livelihoods and food security, it cannot strictly be considered an ecosystem service at the scale of the Elephant Marsh. The amount of water in the system is determined by the balance between rainfall in the catchments, as well as amount of water is taken up by plants (both natural and crops), people, soil infiltration as well as evaporation in the catchment. Much of the Shire River catchment is already heavily degraded/transformed and contains few intact natural ecosystems which might assist in water infiltration. Any additional water yield due to naturally vegetated areas would be attributed back to those catchment areas, not ecosystems near the abstraction point. Thus the supply of this water is not related to the existence of the Elephant Marsh. Rather, abstraction of water upstream of the marsh, or within the marsh and is in fact traded-off with the wetland health, as the more water that is abstracted from the river for irrigation, the less water is available to maintain the current ecosystem. The exact balance between these two uses (irrigation or natural function of the ecosystem) could only be determined through a dedicated environmental flow assessment.

7 VALUE OF THE ELEPHANT MARSH IN RELATION TO OTHER WETLANDS

The total annual provisioning value estimated in this current study is approximately US$5 million assuming that the lower end estimate of fisheries is used and up to US$12 million if the higher estimate is used, this assumes both are sustainable. Most of this value stems from the fisheries and the provision of thatching grass. The total tourism/recreation value is probably only in the order of US$17 500 per annum. This would be higher if the hunting safari company was still operating, however the sustainability of their operations has not been demonstrated.

Attributing an annual value to the regulating services offered by the Elephant Marsh is difficult given the uncertainties and lack of data in modelling. Flood retention values could only be estimated for certain return flood periods, while these values themselves are quite high, floods do not occur every year and the estimated annual value of US$3.3 million is more realistic. Estimated values for sediment retention are very high (US$252 million per year), however, they completely contingent on a plan to develop the Shire Zambezi Waterway Project. Carbon storage values were estimated to be low based on the social cost to Malawi (US$3596), however, if the global social cost is considered (i.e. the cost of climate change that is realised in countries other than Malawi) the estimate is much higher (US$20 million). Further work is required to properly estimate the value of regulating services provided by the Elephant Marsh.

Within Malawi, there are few other large river floodplain wetlands with which to compare, however the wetlands surrounding Lake Chilwa and Lake Chiuta are similar in many ways and provide another useful comparison. Most research on these systems considers only provisioning values and not on the harder to estimate regulating or cultural services.

Assessments of the Lake Chilwa wetland estimated that the direct and indirect use value was in the order of US$41.3 million (updated to 2015 US$; Schuyt 2005). One study estimates that the value of goods harvested and produced in Lake Chiuta totalled approximately US$16.6 million (updated to 2015 US$; Zuze 2013). Similar to the case in the Elephant Marsh, the value of the fisheries and crop production at both lakes were the main contributor to the overall values, making up over 90% of the value in both cases (Schuyt 2005; Zuze 2013). Other harvested resources such as plant products made significant contributions to local livelihoods, however the total value of these services was not significant (Zuze 2013). Despite the heavy reliance of households on goods and services derived from these wetlands, Zuze (2013) estimated that the willingness to pay for conservation of biodiversity of Lake Chiuta by local residents was only in order to US$12.1 million (updated to 2015 US$), much lower than the realised value from resource extraction.

The per hectare values calculated in this current study for provisioning value were between US$89-214 per ha, which was between the value calculated in the Lake Chilwa and Lake Chuita studies (US$172 and US$529 per ha; Schuyt 2005 and Zuze 2013). It is difficult to directly compare these values, however, given the different methodologies. All of these values for the other Malawian wetlands include crop production and grazing, do not take into account the sustainability of provision services. Discussion of the major threats to both of these lake ecosystems suggest that resources may be being over harvested, the catchments degraded and water being over abstracted

(Schuyt 2005; IUCN 2009; and Zuze 2013). These threats indicate that some of the direct-use values of both of these wetland systems are likely unsustainable. As such, the direct-use values present in these other studies may represent an over estimate of the actual value of these ecosystem services.

Constanza *et al.* (1997) provided global estimates for the value of different ecosystem types. He estimated a value per hectare of US$14 785, which would equate to over US$700 million for the Elephant Marsh. These values are orders of magnitude great than those provided in this current study and other studies focused on the area. While these values have often been transferred to many different types of systems globally, there are a couple of important caveats that must be understood prior to doing so. The global estimates are often derived from small wetlands, often surrounded by developed areas, and in developed countries. This often inflates the value of habitats when transferred into rural environments and into less developed countries and often therefore are not appropriate to be used.

A number of studies have examined the value of wetlands within the Zambezi Basin, which are much more comparable to the current study (Table 8). While exact numbers of different studies will vary widely depending upon which attributes and services are considered, putting the value of the Elephant Marsh into the context of similar wetlands within Africa is essential in order to understand the importance of this wetland at a regional scale. Previous estimate for both provision services (direct use) and regulating services (indirect use) estimated by Turpie (1999) were within the lower and upper estimates of the current study (Table 8). The value of natural products estimated by Seyam (2001) were lower than the current estimate, cultural/tourism values were similar. It should be kept mind when comparing these numbers that not the same extent, techniques nor categories are considered in each study.

Table 7. Comparison of current estimated values of ecosystem services within the Elephant Marsh with other values from literature. Note: not all the same categories were measured in each study, nor were the extents considered the same in each study. Values presented in 2015 US$.

	Current Study		Turpie (1999)		Seyam (2001)	
	Lower	Upper				
Provisioning[1]	5.17	12.46	**Direct Use**[4]	10.81	**Natural Products**[6]	2.96
Regulating[2]	3.30	255.30	**Indirect Use**[5]	87.44		
Cultural[3]	0.02	0.07	**Tourism**	0	**Eco-tourism**	0.02
Total	**8.49**	**267.84**	**Total**	**98.24**	**Total**	**2.98**

1- Upper bound estimate includes higher estimate for fishery.
2- Upper bound includes value of sediment retention assuming project goes ahead.
3 - Upper bound includes value of safari hunting.
4 - Includes fish, wild animals, wild plants and clay.
5 - Includes flood attenuation, groundwater, sediment retention, water purification and carbon sequestration.
6 - Includes fish, wildlife and natural products and medicine.

In the late 1990s Turpie et al (1999) evaluated the Barotse floodplain, the Chobe-Caprivi wetlands, the Zambezi Delta and the Lower Shire wetlands in terms of their economic value. This study examined the direct and indirect uses of the wetlands including livestock, crops, fish and other wild animals, tourism, flood attenuation, groundwater recharge, water purification and carbon sequestration. The Zambezi Delta provided the largest overall economic value compared with the other wetlands. The Lower Shire Wetlands provided the largest value in terms of direct use value, however this was almost entirely due to high values of the crops produced rather than any of the other provisioning services. When considering these values relative to other wetlands it is important to remember that population density is an order of magnitude higher in the Lower Shire than the other wetlands considered which increases the value of direct use as more people are using the wetland. Financial returns per person are however, much higher in the other areas than in the Lower Shire. The Zambezi Delta and Barotse Floodplain provided the highest values in terms of indirect use values, however the Lower Shire wetlands had high values in terms of water purification and groundwater recharge.

Seyam (2001) valued the overall ecosystem services of the Elephant Marsh to be in the order to US$4 million per year (updated to 2015 US$). This value was less than 2% of the estimated value of the major wetlands within the Zambezi Basin. This valuation was based on a simplified rapid assessment method which used per ha values derived from one or two wetlands in the region and applied to other wetlands based on size. These figures are therefore only ball park estimates, and only include the value of the Elephant Marsh provisioning services and eco-tourism, not regulating services. They do however indicate that within the Zambezi Basin, there are a number of larger wetlands that appear to provide a higher value of ecosystem services than the Elephant Marsh such as the Barotse and Liuwa plain wetlands as well as the Kafue flats to mention a few.

8 CHANGES TO ECOSYSTEM SERVICES UNDER FUTURE SCENARIOS

The delivery of ecosystem services is directly linked to a number of different biotic components such as the area of certain habitats or the number of individuals of certain species. In wetland systems many of these attributes are closely linked to the flow of freshwater through this system as well as the pressures placed on these habitats and species humans.

In the DRIFT Report (Brown *et al.* 2016)) compiled as part of the larger study, the links between biotic and abiotic components of the wetland system were explored using a rule-based model of the system, created in a platform called "DRIFT". This model was used to explore the potential effects of future scenarios and/or management on the ecological condition of the Elephant Marsh. Here some of the results of the DRIFT modelling have been used to estimate the likely effects on ecosystem services under the different scenarios modelled. The scenarios chosen examined the effects of decreased sediment load into the marsh as well as various iterations of restricting access to different parts of the marsh in isolation or combination. The effect of doubling population, through increasing the anthropogenic pressures on the ecosystem was also modelled. These different iterations were then examined under maximum proposed water resource development and modelled climate change. Full explanations of the model and scenarios can be found in Brown *et al.* 2016.

Brown *et al.* 2016 gives percentage change for a number of indicators on which ecosystem services are based. Other factors such as prices, demands, access to alternative goods and services may also change over the same time as the scenarios, so estimating the exact value of the ecosystem services in the future is likely to be inaccurate. Instead we indicate the likely direction and magnitude of change for each of the ecosystem services that are linked to modelled indicators such as area of different habitats or abundance of groups of taxa. For a number of ecosystem services, no estimate could be made as they are either not closely linked to flow, or are complex and there is not sufficient data to allow a reasonable estimate to be made.

Changing the amount of sediment load coming into the marsh had little effect on the delivery of ecosystem services. Restricting access to parts of the marsh had positive effects on the ability of the marsh to deliver provisioning services and regulating services (Table 8). Restricting access to combination of central, eastern and southern parts had the greatest increases in ecosystem service delivery. Increases in population had severely negative impacts on almost all of the ecosystem services. The maximum development and climate change scenarios in conjunction with different levels of protection had little effect, or a positive effect on most services. Water lilies however, seem to be negatively affected by maximum development and climate change. This is potentially to do with their reliance on certain aquatic habitats that may be limited under these scenarios. Human-wildlife conflict increased under most scenarios, possibly as a result of protection on increasing numbers of problem causing animals.

While not included in the DRIFT modelling, the value of the area in terms of its bird-tourism potential would be expected to respond similarly to mammal, birds and reptiles provision service as well as the habitat/refugia service. As such the highest tourism potential would be under maximum restriction and worst with increased population, development and climate change. While we might expect the eco-tourism potential to be related to the health of wildlife and birding areas, the realised tourism value will depend more on infrastructure and making the marsh accessible to tourists. Depending on what types of infrastructure is developed and where it is developed, there could be potential trade-offs with other marsh extractive uses.

Modelling the flood retention value of the Elephant Marsh is difficult given the lack of data and complexity of the system. While some basic hydraulic modelling was done to estimate ball-park figures for the current value, incorporating future scenarios requires further information and time beyond the scope of this current modelling exercise. Similar to sediment retention, most processes that would change the underlying ability of the marsh to retain water or sediment are unlikely to change over the short time frame considered in this modelling. As such we do not expect any sizeable change in flood retention in the given scenarios. Factors that would be likely to change flood and sediment retention over a longer period of time include man-made alterations to channels, building or removal of bridges, dams or barrages.

The trade-offs between these alternate activities and the delivery of other ecosystem services can be clearly seen here as the opposite pattern to most goods and services is seen for grazing and cropping. Values decreased if the north or western portions of the marsh were protected as these are where most of the activities currently occur. The value of these activities would also increase with higher populations as more of the marsh would be exploited.

Table 8. Likely changes in ecosystem services offered by the Elephant Marsh under different future scenarios. Scenario 1 includes baseline conditions with only 20% of the current sediment input, scenarios 2-7 restrict human access to parts of the north, east, central, west and south sections of the marsh, scenario 7 keeps baseline conditions but double the human population surrounding the marsh. Scenarios 9-15 repeat scenarios 2-8 but adding the effects of maximum development of water resources and climate change over the next 30 years. Full descriptions of the models used to generate scenario outcomes for indicators on which ecosystem services are based on can be found in Brown *et al.* 2016. Water borne diseases, flood attenuation, tourism were not able to be estimated under future scenarios as they are too reliant on other factors not related to the flow of water through the wetland or the relationships are too complicated and unable to be modelled given insufficient data. Where little change is expected a – symbol is used, ↑ or ↓ indicate a small increase or decrease in service, whereas ↑↓ or ↓↓ indicate a larger proportional change in the service.

Ecosystem Service		Future Scenarios														
		1. 20% Sediment input	2. Restrict 100% N	3. Restrict 100% E	4. Restrict 100% C	5. Restrict 100%W	6. Restrict 100% S	7. Restrict 100% C, 50% E & S	8. Double population	9. DevCC + Restrict 100% N	10. DevCC + Restrict 100% E	11. DevCC + Restrict 100% C	12. DevCC + Restrict 100%W	13. DevCC + Restrict 100% S	14. DevCC + Restrict 100% C, 50% E & S	15. DevCC + Double Population
Provisioning Services	Fisheries	-	↑	↑	↑	↑	-	↑↑	↓↓	-	-	-	↑	-	↑	↓↓
	Mammals, Birds & Reptiles	↑	↑	↑	-	↑	-	↑	↓↓	-	↑	↑	↑	-	↑	↓↓
	Papyrus & Reeds	-	-	↑	↑	-	-	↑↑	↓↓	-	↑	↑	-	-	↑↑	↓↓
	Thatching Grass	-	-		↑	↑	-	↑↑	↓	-	↑	↑	-	-	↑↑	↓
	Water lilies	-	-	-	↑	-	↑	↑	↓	↓↓	↓↓	↓↓	↓↓	↓↓	↓	↓↓
Regulatory Services	Sediment retention	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Water quality	-	-	↑	↑	-	-	↑↑	↓↓	-	↑	↑	-	-	↑↑	↓↓
	Carbon storage	-	-	↑	↑	-	-	↑↑	↓↓	-	↑	↑	-	-	↑↑	↓↓
	Habitat/refugia	↑	-	↑	↑	↑	↑	↑↑	↓↓	-	-	-	-	-	↑	↓↓
Wetland disservices	Human-wildlife conflict	-	↑	↑	-	↑	-	↑	-	↑	↑	↑	↑	↑	↑	-
Opportunity costs	Grazing	-	↓	-	-	↓	-	-	↑	-	-	-	↓	-	-	↑
	Crops	-	↓	-	-	↓	-	-	↑	-	-	-	↓	-	-	↑

9 CONCLUSIONS AND RECCOMENDATIONS

The total value of ecosystem services delivered by the Elephant Marsh was between USD$8-268 million. The broad range of values is indicative of the complexity and uncertainties in measuring and estimating the value of regulating services. These important functions such as sediment retention and flood retention have the potential to have very high values, however these values will only be realised if the service is demanded by downstream users.

The most important provisioning service was that of the fish. This is not only an important economic activity for area, but also provides a food source for many occupants. Some of the other provision services such as hunting have a value of zero given that harvesting is considered unsustainable, despite being carried out by many local residents. Harvesting of wild plants, while not providing a large overall value, are also an important economic activity to many poor households.

The Elephant Marsh values determined here do not markedly differ from other wetlands in Malawi that have been valued in terms of ecosystem services such as Lake Chilwa and Lake Chiuta. The value of the Elephant Marsh is not, however, particularly high when compared to other large floodplain wetlands in the Zambezi Basin such as the Barotse, Liuwa and Kafue wetlands.

This study highlights the importance in balancing pressures on the ecosystem with trying to maintain a healthy functioning ecosystem for future generations. Provisioning services rely on adequate stock of natural resources, which are easily depleted through over-harvesting. Maintaining areas of restricted access appears to be the best way to ensure stocks of natural resources are not completely depleted. This will potentially come at a cost to certain activities like grazing and hunting, however it will allow for some of the important regulating functions of the wetland to be maintained. If the marsh is allowed to become completely degraded and transformed, it will cease to provide the resources and services it currently does for so many households.

Some important findings from the DRIFT modelling in terms of ecosystem services were that:

- Changing the amount of sediment load coming into the marsh had little effect on the delivery of ecosystem services.
- Doubling the surrounding human population had severely negative impacts on almost all of the ecosystem services.
- The greatest increases in ecosystem service delivery were seen by restricting access to the marsh, in particular the combination of central, eastern and southern parts of the marsh.
- Including maximum water development and climate change in the future scenarios lowered the effectiveness of restricting access for some ecosystem services.

Cultural services such as tourism currently have a low value due to poor infrastructure, however birdlife is plentiful and offers potential for some bird-watching based tourism. In order to maximise the value of this ecosystem service, tourism access to the marsh would need to be improved. Investing in tourism infrastructure in the Elephant Marsh should however be done cautiously, as heat, humidity, as well as lack of large game and nearby attractions make it potentially a less desirable destination than other areas within Malawi.

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11 APPENDIX 1: TERMS OF REFERENCE FOR COMPONENT 3: ECOSYSTEM SERVICES

- A description of the wetland biophysical and social ecosystem services is required to understand the economic and social value of the Marshes to the region and the wider catchment.
- Quantification of these services in terms of production, flow, use and value and provide an assessment of the resilience of these services to environmental changes. These will include the role the Marshes play in flood control, the extractive use of ecosystem services, carbon sequestration, and how the Marshes affect the rest of the Shire River Catchment above and below the Marshes.
- Due to unavailability of data for the elephant marsh wetlands, local/expert knowledge should be used where available to complement those collected through contemporary scientific means.
- The firm will be expected to conduct a valuation of Ecosystem Services which must also be linked to the hydromorphology and how these have changed over time
- The Firm will also determine the wetland's sensitivity and adaptive capacity to multiple pressures, involving a description of those pressures and the development of plausible future changes. For example focusing on 3 different future management scenarios over the next 25 years – business as usual, best practice, and a worst case scenario. The welfare and functional resilience of the Elephant Marshes affects the whole of the lower Shire River system and models should be produced that reflect this. Comparisons will be made with other wetlands in Africa of a similar nature.
- The firm will determine the economic importance of the Marsh ecosystem and how it affects the whole of the Shire River Catchment at different times of year

The deliverables will be a report of the above assessments that include an account of the ecosystem services, a valuation of those services, future scenario modeling to reflect management regimes and how this affects these ecosystem services, and the importance of the Elephant Marshes to the functioning of the Shire River Catchment.