Assessing social and economic outcomes from biodiversity 'no net loss' on infrastructure development

Using Natural Capital Accounting

-

A case study from Uganda

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Contents

Project team

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1. Introduction

Global spending on infrastructure development is expected to double between 2015 and 2030. This investment in transport, energy, utilities and other infrastructure is essential to grow national economies and keep pace with increasing populations (Bennett et al, 2017). However it is causing significant biodiversity loss where there are no requirements to design, build or operate infrastructure projects with 'no net loss' (NNL) or 'net gain' (NG) of biodiversity (Box 1).

Biodiversity loss from infrastructure projects has social and economic consequences because people use, and depend on, benefits from functioning ecosystems (Box 1). Yet these consequences are rarely quantified. As a result, mitigation efforts can fail to address these costs even when projects seek NNL of biodiversity. There is also a missed opportunity for NNL to generate wider benefits such as flood mitigation and climate regulation, as well as improving people's wellbeing.

Natural Capital Accounting can be used to quantify the social and economic outcomes from a project's biodiversity impact. Making these outcomes explicit enables infrastructure projects to fully adhere to the mitigation hierarchy (Box 1) and achieve NNL of biodiversity in ways that are fair and sustainable for local people, society and the economy.

1.1 This report

This report is for infrastructure projects seeking NNL of biodiversity

The report responds to calls from Uganda's government, investment and business sectors to operationalise the concept of Natural Capital Accounting for infrastructure projects seeking NNL. It is intended to support discussions by Uganda's government, investment and business sectors on establishing a Natural Capital Forum.

The report focuses only on biodiversity, as one component of natural capital. It describes how to produce Natural Capital Accounts of losses and gains in biodiversity from infrastructure projects, such as a new road, oil pipeline or dam. It illustrates these accounts using a fictitious case study of a sugarcane factory that aimed to achieve NNL with regards to its impact on wetlands. The report's chapters are:

2	**Natural Capital Accounts of No Net Loss**	Undertaking Natural Capital Accounts of infrastructure projects seeking NNL, and the benefits for governments, investors and businesses.
3	**Natural Capital Accounts by African countries**	The extent of Natural Capital Accounting of biodiversity by African countries, with a focus on Uganda.
4	**Contextual information to construct the Natural Capital Account**	Contextual information on Uganda's wetlands used to construct the Natural Capital Account case study, including stocks, flows of benefits, and the monetary values of these benefits.
5	**Natural Capital Account case study**	A Natural Capital Account of losses and 'offset' gains in wetlands from the construction of a sugar cane factory in Uganda.

Box 1. Key concepts

Biodiversity

Defined by the Convention on Biological Diversity as "the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems". In the case of NNL policies, biodiversity typically refers to a specific set of sub-components of total biodiversity.

No Net Loss

Governments, investors and businesses worldwide are increasingly adopting NNL or NG biodiversity targets for development projects. NNL is based on the concept that, after following the mitigation hierarchy, any unavoidable biodiversity loss is counterbalanced by equivalent gains elsewhere (Maron et al, 2018). This requires quantifying losses of biodiversity caused by a development project as well as any gains, in order to demonstrate that the gains are equal to, or greater than, the losses. Several publications exist on good practice for NNL (e.g. BBOP, 2012).

Mitigation hierarchy

A sequence of actions undertaken throughout a development project's life-cycle. The first action is to avoid negative impacts on biodiversity (e.g. re-locating a project to avoid sensitive habitats), then to minimise impacts that cannot be avoided (e.g. undertaking construction activities outside of breeding seasons). Where avoidance and minimisation are not feasible, the third action is to remediate damage and then finally to fully compensate for any unavoidable residual biodiversity loss, which can involve offsetting losses with gains elsewhere.

Biodiversity offsets

Measurable conservation outcomes resulting from actions designed to compensate for significant residual adverse biodiversity impacts from development projects after following the mitigation hierarchy. Offsets should aim to achieve NNL and preferably a NG of biodiversity (BBOP, 2012).

Ecosystem

An interacting system of both living components (e.g. plants, animals and microbes) and non-living components (e.g. soil, water and air).

Ecosystem services are the benefits people obtain from ecosystems (Millennium Ecosystem Assessment, 2005). They broadly comprise:

- Provisioning services e.g. food, fibre, fuel and water.
- Regulating services e.g. soil formation, climate control, flood regulation, disease control, water purification and pollination.
- Cultural services e.g. recreation, spiritual, educational and aesthetic value.
- Supporting services are necessary for all other ecosystem services, e.g. the cycling of water and nutrients. Some services are both supporting and regulating, such as erosion control.

2. Natural Capital Accounts of No Net Loss: what, why and how

2.1 What is Natural Capital?

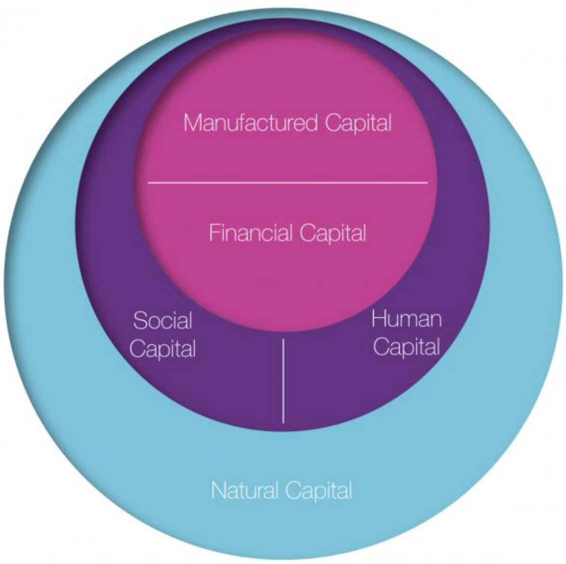
Natural capital is:

***"the elements of nature that directly and indirectly produce value or benefits to people, including ecosystems, species, freshwater, land, minerals, the air and oceans, as well as natural processes and functions*" (NCC, 2016).**

Natural capital underpins the wealth of a nation together with other types of capital including social and financial capital (Figure 2). While natural capital often underpins the other types of capital, it is the combination of all capitals that supports human well-being. On a farm for example:

- **Natural capital** provides the fertile soils, pollinating insects and flows of water needed to grow crops.
- **Social and human capital** provides the knowledge of farming techniques, labour and the institutions, such as cooperatives, to aid distribution.
- **Manufactured and financial capital** provides the equipment and materials needed for farming, such as tractors.

Figure 2: Forms of Capital



Source: IIRC, based on the Forum for the Future's five capital model

The concept of Natural Capital (Figure 3) can be considered in terms of:

Stocks

Natural capital can be assessed and quantified as 'stocks'. These stocks comprise biotic (living) elements such as forests, wetlands and grassland ecosystems, and the biodiversity they support. They also comprise abiotic (non-living) elements including minerals, fossil fuels and solar energy.

Flows of benefits

The biotic elements of Natural Capital generate flows called ecosystem services, which provide a range of benefits for people such as food, fibre, energy and clean water.

Value

The combination of stocks and the flows of benefits are valuable to local communities, societies, governments and businesses at local, national and international levels. These values can be described in qualitative terms, such as the joy of walking through woodland. Other values can be quantified and/or monetized, such as carbon storage. However, it is not always appropriate to assign monetary values.

Figure 3: Stocks and flows of Natural Capital

Source: Natural Capital Coalition Protocol, 2016

2.2 What is a Natural Capital Account of No Net Loss?

This report describes Natural Capital Accounts of - only - the ecosystem and biodiversity components of natural capital (hereafter collectively referred to as biodiversity). The purpose of these accounts is to:

Assess and quantify the social and economic outcomes from a project's biodiversity impact in order to design fair and sustainable No Net Loss measures

Based on the Corporate Natural Capital Accounting framework (eftec et al, 2015), the main stages of these Natural Capital Accounts (NCAs) are:

1. Assess and quantify the stocks

The first stage requires identifying the type and amount of biodiversity present, which is often based on habitat. Broad classifications of habitats can be used, such as simply referring to grassland, forest or wetland. Alternatively more detailed classifications can be used, for example identifying specific types of wetland such as swamps and swamp forests. Then for each habitat, the condition or quality is assessed and the area is measured.

2. Assess and measure the flows of benefits

The second stage is to identify the benefits (i.e. ecosystem services) that people obtain from each stock of biodiversity, and who realizes the benefits at local, national and international levels. Then benefits are measured using methods appropriate for the context. For example, to estimate firewood collection by local people from a forest reserve, the number of 'bundles' of firewood collected daily by each individual is used.

Measuring all benefits might not be possible, for example when data are limited or when measuring the benefit (such as people's cultural values associated with biodiversity) itself is not appropriate. In these situations, the NCA should contain a descriptive account of *all* benefits as far as possible. It should then measure benefits where possible, appropriate and most relevant for assessing the social and economic outcomes of the project's biodiversity impact.

3. Value the benefits

The final stage is to value the benefits that people obtain from the biodiversity stocks. Qualitative descriptions should be used first. Where possible and appropriate, monetary value of the benefits can be calculated. Note: *NCAs do not assign monetary values to biodiversity itself. Rather, they might involve calculating monetary values of the benefits that biodiversity provides to people (i.e. the ecosystem services) where appropriate to do so.*

2.3 Why undertake Natural Capital Accounts of No Net Loss?

International guidelines advocate that NNL projects should not make local people worse off (e.g. BBOP, 2012). Fulfilling this 'no worse off' principle can be challenging, as it requires a comprehensive understanding of how people are affected by losses and gains in biodiversity from an infrastructure project. It also requires demonstrating that people are indeed no worse off in the context of NNL (Griffiths et al, 2018).

NCAs can help to address these challenges. By quantifying the social and economic outcomes from a project's biodiversity impacts, they provide information to fully adhere to the mitigation hierarchy and to design NNL activities that are fair and sustainable for people. Also by illustrating a project's true costs and benefits, NCAs can address concerns that the value of biodiversity is not adequately reflected in traditional economic appraisals or Environmental and Social Impact Assessments (ESIAs) (TEEB, 2010). Other benefits of NCAs include:

Governments

Governments face the twin challenge of growing the nation's economy while protecting and enhancing biodiversity. NCAs make explicit biodiversity's contribution to the economy and the financial risks from losing this contribution. NCAs also show the multiple benefits and inter-dependencies between biodiversity, the economy and society. This is especially important where nationally-significant infrastructure development can adversely affect local livelihoods.

Several governments are undertaking national NCAs using the System of Environmental-Economic Accounting Framework, see Chapter 3 (UN et al., 2014). These national accounts provide an important context for NCAs of individual infrastructure projects. For example, a national account shows that all of the country's wetlands are declining rapidly. An infrastructure project results in the loss of one wetland, which is identified as having severe consequences for economic growth and human well-being because it greatly exacerbates the national-level decline in wetlands.

Investors

Many investors have safeguard policies to minimise environmental and social impacts from their projects. By providing a more comprehensive understanding of the socio-economic costs from a project's impacts and dependencies on biodiversity, NCAs help investors to screen projects for compliance with their policies and to assess the sustainability of a project in the long-term.

Businesses

Businesses depend on natural capital, such as depending on clean water to produce tarmac for building a new road. Businesses can also affect natural capital positively, such as improving air quality, or negatively such as pollution. These dependencies and impacts generate costs and benefits not only for the business but also for society and the economy. NCAs provide a mechanism for understanding and quantifying dependencies and impacts on biodiversity, as well as the risks and opportunities. This enables more informed decisions when designing, constructing, operating and decommissioning infrastructure projects.

2.4 A check-list for Natural Capital Accounts of No Net Loss

NCAs can be undertaken as part of an ESIA or independently. NCAs can also incorporate measures of a development's losses and gains in biodiversity, which is typically from use of a biodiversity metric. As well as following natural capital accounting methods (e.g. eftec 2017), these NCAs should incorporate principles and methods for both NNL and ESIAs that include:

☐ **Undertake the NCA as early as possible**

Key decisions about an infrastructure project are often made during the early stages of its lifecycle, such as when a project's location is set during the feasibility stage. The earlier the NCA is undertaken, the more it can inform decision-making to generate commercial benefits. For example, avoiding biodiversity loss at a project's scoping stage can avoid costs on lengthy consent processes and extensive mitigation.

☐ **Clarify the purpose and scope at the start**

It is essential to clarify the purpose of the NCA, as well as how it will be used and who the intended users are. This will inform the scope of the account, which might be limited by practicalities such as access to data. An example statement on the purpose and scope of an NCA is:

This NCA is to inform the design of biodiversity NNL that is sustainable and fair for local people. It only regards the development project's direct and permanent impacts on biodiversity during construction and operation. It does not reflect any indirect, temporary or cumulative impacts on biodiversity, or the project's dependencies on biodiversity, as access to data was limited. Furthermore, monetary values in the NCA are only partial values that do not reflect the full value of biodiversity. The NCA is intended to be used with the project's biodiversity assessment, so that both inform application of the mitigation hierarchy and the design of NNL for biodiversity and people.

The Natural Capital Protocol contains guidance on defining the purpose and scope of NCAs.

☐ **Keep in impacts that are scoped-out from ESIAs**

ESIAs can involve scoping out impacts on biodiversity that are not deemed significant (significance is usually defined within national legalisation or ESIA guidelines e.g. IAIA). Whereas all impacts on biodiversity are incorporated into designs of NNL and should be included within NCAs, especially if the impacts generate adverse social or economic outcomes. For example, a public park that will be lost to a development project might have low biodiversity value but be cherished by local residents.

ESIAs are typically undertaken as an iterative process whereby the impact assessment informs the project's design. NCAs can, and should, be included in this iterative process, although any assumptions made during the early design stage should be clearly communicated.

☐ **Avoid impacts on irreplaceable features**

Development projects should avoid impacts on irreplaceable biodiversity features. Losses of these features cannot be offset to achieve NNL. Including irreplaceable features in the NCA can help to apply the mitigation hierarchy because the economic and social consequences of their loss will be explicitly clear (and often more so than traditional ESIAs).

Some biodiversity features are irreplaceable to people, for example where people place strong cultural values on a specific habitat in a specific place. Making explicit that these biodiversity features are irreplaceable to people is essential to apply the mitigation hierarchy.

☐ **Apply the mitigation hierarchy**

Biodiversity NNL and ESIAs are founded on the mitigation hierarchy. NCAs help to apply the mitigation hierarchy, especially by quantifying the costs to society and the economy from losses of biodiversity. For example, a new factory causes the loss of woodland. The NCA quantifies the resulting damaging impacts on air quality, climate regulation and flood mitigation, and the cost to the government (and ultimately tax payers) to address these impacts.

☐ **Define the geographical coverage**

ESIAs of infrastructure projects typically cover a 'zone / area of influence', which can be defined as the area over which ecological features may be subject to significant effects as a result of the project and its activities. The zone of influence can be used to construct the NCA, while making sure that direct, indirect and cumulative impacts on biodiversity from both the infrastructure project and any associated biodiversity offset are covered.

☐ **Clarify the baseline**

Baselines of NCAs should be considered extremely carefully because the choice affects the results.

ESIAs involve establishing a baseline of biodiversity before construction starts. Change in baseline conditions after the construction, operation and decommissioning stages are then determined. For biodiversity NNL, the baseline is used to evaluate whether NNL is achieved and can be:

- Static: status of biodiversity at a fixed point in time pre-works, which is compared to biodiversity after the development project.
- Dynamic: the anticipated rate of change in biodiversity without the development project i.e. the counterfactual* based on future projections and/or assumptions.

*Counterfactuals compare the development project's NNL with what would have happened to biodiversity without the development[1].

[1] For more discussion on counterfactuals and other frames of reference to evaluate NNL, see Bull et al, 2014. Also see Maron et al, 2018 for more discussion on reference scenarios for NNL.

☐ **Set timeframes**

The timeframes of the NCA should be clarified, for example whether completing accounts for each project lifecycle stage of construction, operation and decommission, and/or when the biodiversity NNL outcomes are fully realised e.g. on maturity of a biodiversity offset. The choice might depend on availability of data and other practicalities, but it should be justified with any implications for the NCA fully acknowledged.

☐ **Assess and value benefits, where appropriate**

NCAs should describe *all* benefits that people obtain from biodiversity affected by an infrastructure project, in qualitative terms as far as possible. NCAs then involve quantifying and assigning monetary values to the benefits. However, it is often not possible or appropriate to quantify or value all of the benefits, for example where people have strong cultural associations with biodiversity. So NCAs usually involve selecting benefits to quantify and value. This selection can be based on the significance of impacts from the infrastructure project, although it might depend on availability of data. Either way, it is important to justify the selection and ensure that benefits not quantified or valued are still represented in the NCA. It is also important to clarify the extent to which biodiversity is, and is not, represented in monetary valuations, as monetary values ascribed within NCAs are usually specific to situations and markets, and only cover part of the value generated by biodiversity.

☐ **Construct accounts for individual ecosystem services**

NCAs should comprise accounts for individual ecosystem services. Ecosystem services should not be grouped together to produce a single figure from which to make decisions. This is important for:

People affected by No Net Loss

NNL can affect different people in different ways. For example when people living near an infrastructure project are negatively affected from the loss of biodiversity, but people living further away benefit from ecosystem services generated by the project's biodiversity offset.

NCAs are incredibly useful to make explicit who is affected - and how - in terms of losses and gains in ecosystem service provision. But this relies on NCAs being constructed for individual ecosystem services.

It also requires NCAs being undertaken at an appropriate level of assessment. For example, assessing ecosystem service provision at the household level will detect impacts at the household level, whereas village level assessments will only detect impacts at the village level and not to individual households. These assessments should be undertaken at the level where significant impacts on people from biodiversity losses and gains occur (see Bull et al, 2018 for more details).

Avoiding trade-offs and securing win-wins

Infrastructure projects seeking NNL of biodiversity can generate win-wins when the project is built and operated with no overall loss of biodiversity or ecosystem service provision. But there can be trade-offs to avoid, such as not providing one ecosystem service at the expense of another. NCAs can help identify the trade-offs, but this relies on NCAs being constructed for individual ecosystem services and at an appropriate level of assessment.

☐ **Apply good practice principles to achieve NNL for both people and biodiversity**

Good practice principles for development projects to achieve NNL for both people and biodiversity have been published (Bull et al, 2018). NCAs can support application of these principles, thereby ensuring good practice to design, implement and maintain biodiversity NNL projects that are fair and sustainable to people. NCAs can also go beyond impacts on local people affected by a development project and be used to assess impacts at national and international levels, such as climate regulation

☐ **Incorporate well-being**

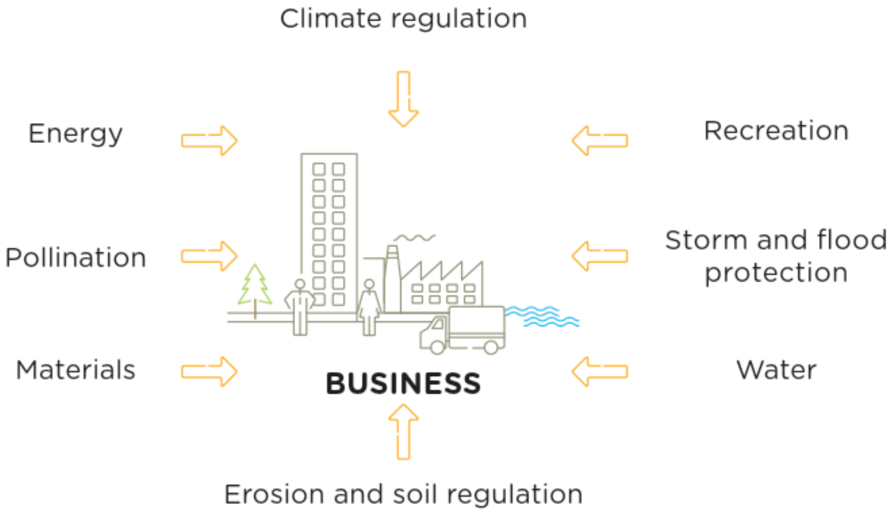
Monetary values cannot capture the cultural and social dimensions of people's relationships with biodiversity. Consequently, NCAs may miss how people are truly affected by NNL. This can be overcome by combining NCAs with assessments of human well-being. Assessing human well-being is part of the good practice principles for the social aspects of NNL (see above), which defines well-being as:

A positive physical, social and mental state that encompasses the objective, material aspects of people's lives (e.g. housing, income, livelihoods, health, and the environment), relational aspects (e.g. community networks and empowerment), and subjective components that capture individuals' assessments of their own circumstances (i.e. how happy they are with their current situation).

☐ **Assess both impacts and dependencies**

ESIAs identify, evaluate and propose mitigation for impacts of development proposals before major planning decisions are made. NCAs should incorporate both impacts and dependencies on biodiversity. Dependencies are business activities that rely on biodiversity, such as those in Figure 4 and in Appendix D. Impacts and dependencies vary according to the life-cycle stage of an infrastructure project. In some situations, an NCA might focus primarily on impacts, for example under the Corporate Natural Capital Framework. However for NNL, including dependencies can be essential to avoid and then mitigate impacts on ecosystem services (Sonter et al., 2018).

Figure 4: Examples of business dependencies on natural capital



Source: Natural Capital Coalition Protocol, 2016

☐ **Consider a phased approach**

A phased approach starting with piloting NCAs can help companies to progress to comprehensive NCAs. For example a company pilots NCAs that only include direct impacts on biodiversity. It uses the learning to adopt more detailed NCAs that include direct, indirect, temporary and cumulative impacts on biodiversity, as well as project dependencies on biodiversity.

3. Natural Capital Accounts of biodiversity by African countries

3.1 African countries

The Gaborone Declaration for Sustainability of Africa (GDSA) was ratified by ten African Heads of State in 2012, and includes a commitment to explore the valuation and measurement of natural capital. In 2016, the GDSA commissioned a report on Natural Capital Accounting across the 10 GDSA countries, plus Uganda and Madagascar (two countries that, at that time, had not joined the GDSA). This report described each country's progress in Natural Capital Accounting and ecosystem valuation, focusing on public sector initiatives. It showed that many GDSA countries had started national or sub-national NCAs to quantify various natural capital stocks. Energy, forest/timber and water were the most common stocks being accounted for (Table 1). Some countries had undertaken NCAs of particular habitats and had valued a subset of the flows of benefits from these. For example, in 2009, Kenya produced an Environmental Economic Account for its forestry sector that focused on timber and non-timber forest products (Reuter et al, 2016).

While progress had been made at a national level, there was no evidence of NCAs of infrastructure projects.

Table 1. Past, current and planned national Natural Capital Accounting efforts in GDSA countries in 2016. Adapted from Reuter et al, 2016.

Country	Aquatic resources	Carbon	Ecosystem Accounts	Energy	Fisheries	Forest/Timber	Lakes/Rivers	Land	Minerals	Soil	Water	Wetlands	Wildlife
Botswana				Current				Current	Current		Current		Current
Gabon						Current							
Ghana	Future			Future		Current		Future	Future	Future	Future		
Kenya		Current	Current			Current							
Liberia													
Madagascar			Lower priority	Lower priority		Current							
Mozambique													
Namibia			Expressed interest	Past	Past	Past		Past	Past		Current		Past
Rwanda			Expressed interest	Lower priority		Lower priority	Current	Current	Current		Current	Current	
South Africa		Current		Current	Current			Current	Current		Current		
Tanzania													
Uganda			Current	Current	Current	Current		Current			Current		

Legend:

Past Efforts	Current Efforts	Future Efforts	Expressed interest at GDSA	Lower priority

3.2 Uganda

3.2.1 Uganda's requirements for NCA

Several strategic reports and plans by the Ugandan government stipulate the need for NCAs. For example:

- The **National Development Plan II** (NDP II) for Uganda (GoU 2015) emphasises the need for sustainable use and effective management of natural capital.

- The **Uganda Green Growth Development Strategy** 2017/18-2030/31 (UGGDS) identified five areas with the highest potential to achieve national development goals. Natural capital management is one of these and focuses on tourism development, sustainable forestry, wetlands and optimal water resource management. The UGGDS recommends that Uganda's government 'undertakes comprehensive environmental economic accounts across all sectors' and that 'the scope of NCAs should be wide, to capture socioeconomic activity and to support future policy and economic activity' (Uganda NPA, 2017).

In addition:

- The **State of the Environment Report** for Uganda (NEMA, 2016b), recommends innovative management approaches to ensure the environment continues to support human development and well-being.

- The **National Biodiversity Strategy and Action Plan** for Uganda (NBSAP II) (NEMA, 2016a) contains objectives on strengthening the management of biodiversity and promoting sustainable use.

3.2.2 Uganda's NCA

An initial set of ecosystem accounts at the national level has been completed for Uganda. These accounts quantified stocks for selected ecosystems using the System of Environmental-Economic Accounting – Experimental Ecosystem Accounting (SEEA-EEA) framework. The accounts provide a basis for assessing trends in the extent of ecosystems over time (UNEP-WCMC, 2016). However there is no evidence of NCAs of infrastructure projects.

Various studies have been undertaken to identify the benefits people attain from Uganda's biodiversity. Some studies have assigned monetary values to these benefits, for example, an economic valuation of Uganda's forest resources in 2010 showed that the forest sub-sector contributes 8.7% to Uganda's GDP. However, none of these studies were formally undertaken for a NCA but are independent and follow different methodologies. Nonetheless, they illustrate the range of benefits people attain from Uganda's biodiversity and possible monetary values of these.

4. Contextual information to construct the NCA case study

Chapter 5 presents a NCA of losses and gains in wetlands from the construction of a sugar cane factory in Uganda. This chapter summarises the contextual information that was used to construct the NCA – namely the stocks of Uganda's wetland, the benefits from these wetlands to people and the monetary values of these benefits. Further details are provided in Appendices A to D.

4.1 Stocks of Uganda's wetlands

Uganda's wetlands cover approximately 29,000 sq km, which equates to approximately 13% of the country. However, Uganda's wetlands have substantially declined with only 68% of wetlands remaining from wetland coverage in 1964. The greatest losses have occurred in East Central areas where only 35% of wetlands remain. Major causes of wetland decline include encroachment for agriculture; over-harvesting for domestic and commercial use (e.g. fishing, wetland plants, clay); and erosion from nearby farming practices.

4.2 Benefits from Uganda's wetlands

Uganda's wetlands provide benefits at international, national and local levels. Examples include climate regulation at the international level, and water purification and flood attenuation at the national level. At the local level, approximately 4,000,000 people live in and around Uganda's wetlands. Over 80% use wetland resources for their household food security needs. In addition, Uganda's wetlands are a principle supply of fresh water for human use and a major source of water for farming. Rural communities rely on wetlands for various subsistence needs (e.g. food and medicinal purposes) and for livelihood support (e.g. selling building materials).

4.4 Value of the benefits from Uganda's wetlands

Various studies have been undertaken on the monetary value of Uganda's wetlands. These represent ad-hoc independent studies on certain benefits (not all) using different methods to assign monetary values. Consequently the credibility of the studies cannot be assured. Nonetheless, they are useful illustrations of potential monetary values of Uganda's wetlands. Appendix B contains a selection of these studies, from which example values of Uganda's wetlands include:

- Fish spawning at US$363,815 per year.
- Livestock pastures at US$4.24 million per year.
- Domestic water use at US$34 million per year.
- Flood control at US$1.7 million per hectare per year.
- Crop farming ranging from US$4.2 million to US$25 million per year.

Note that certain benefits from Uganda's wetlands cannot be assigned monetary values, such as cultural values (Appendix A).

4.5 Impacts and dependencies on Uganda's wetlands

Various sectors of society and industry both affect and depend on Uganda's wetlands, such as the examples in Appendix D.

5. Natural Capital Account case study

This chapter presents a case study example of Natural Capital Accounting for an infrastructure project seeking No Net Loss of biodiversity. The case study is fictitious. It regards losses and gains in wetlands from the construction of a sugar cane factory in Uganda. It draws from research of wetlands in Uganda and elsewhere in Africa, and focuses on wetlands because of their importance to rural communities in Uganda. The NCA is based on the Corporate Natural Capital Accounting method (eftec et al., 2015).

5.1 The case study: sugar cane factory construction

In this case study, the developer Kapari Ltd is constructing a factory to process sugar cane. The factory's location is in rural Uganda near to Kapari's existing sugar cane plantations and to roads for transporting the processed product to market. The factory was subject to an ESIA. Initially factory construction resulted in substantial losses of the 'Leandro' Wetland. However after following the mitigation hierarchy, the factory was re-located to avoid as much wetland loss as possible in order to avoid and minimise both biodiversity and social impacts – biodiversity impacts from losses of this ecologically valuable habitat; and social impacts as local communities depend on the wetland for subsistence and livelihoods. The residual loss of wetland is 1500ha on the eastern side (out of a total wetland area of 10,000ha). Recommendations from the ESIA first included comprehensive measures to mitigate environmental and social impacts of factory construction and on-going operations. Then a specific recommendation was made for a biodiversity offset to achieve NNL of wetland habitat whilst ensuring that local communities are 'no worse off' as a result of NNL.

The ESIA contained an outline design of the wetland offset from a biodiversity perspective: the offset will be located on degraded grassland of extremely low ecological value on the western boundary of the wetland, and will be designed to be the same type of wetland, and to generate the same ecological functions, as that lost.

Regarding the size of the offset, at the time of this case study there is no Ugandan metric for measuring losses and gains in biodiversity from development in order to identify requirements for NNL. So the ESIA proposed that the offset be x4 the affected area, i.e. the permanent loss of 1500ha of wetland will be offset by the creation of 6000ha of wetland.

Consent for the sugar cane factory was granted because the factory will provide a substantial number of jobs for local communities and will boost economic activity within the region. But consent was granted with several conditions that Kapari Ltd has to discharge. These include the establishment of a Trust Fund to finance a 50-year wetland offset management plan, and approval by the regulators of a detailed design of the wetland offset that demonstrates NNL of wetland habitat will be achieved whilst ensuring that local communities are 'no worse off'.

5.2 Purpose and scope of the Natural Capital Account

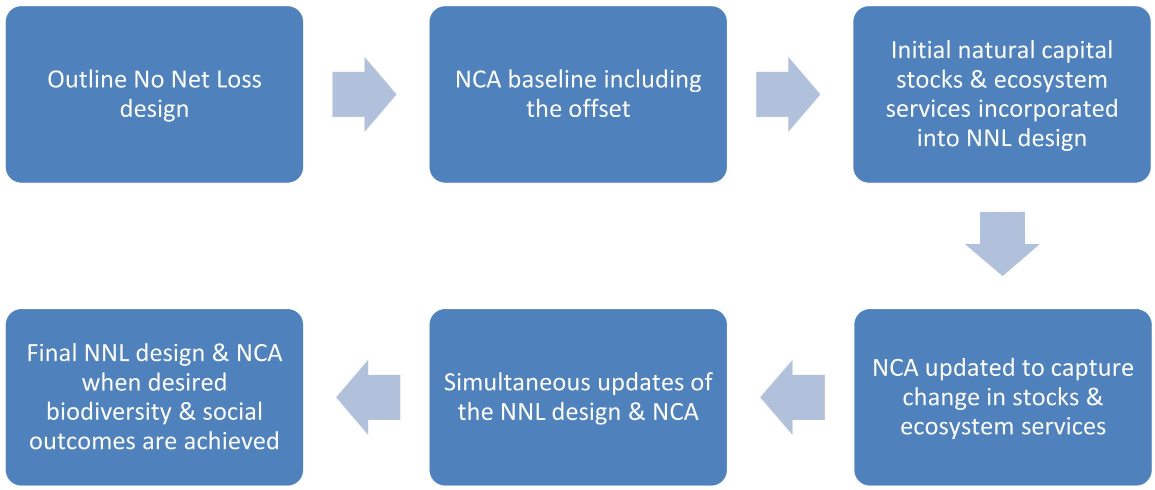
Kapari Ltd's immediate priorities are to discharge conditions of the consent so that factory construction can start. The ESIA team propose that they undertake a NCA to identify measures for ensuring that local communities are 'no worse off' from NNL. They also put forward that a NCA can improve management of natural assets for the whole lifecycle of the factory thereby decreasing operational risks over the long-term.

Kapari Ltd recognises the NCA will build on the ESIA by quantifying impacts of wetland loss on local communities – and that by informing the offset design, will help to discharge conditions of the consent. But they are uncertain of all benefits from a NCA, so only commission a NCA of losses in wetland from factory construction. Subsequently at this stage, the purpose of the NCA is to inform the design of the wetland offset so that local people are no worse off. The NCA will utilise qualitative social and ecological assessments in the ESIA including the outline design of the offset, but the scope excludes the full lifecycle of the factory as well as dependencies of factory operations on natural capital.

After completing this baseline NCA, the ESIA team propose to update the NCA as part of an iterative design process of the wetland offset. Kapari Ltd agree, so changes in ecosystem service provision resulting from the offset are fed back into the design to ensure that the offset achieves the desired biodiversity and social outcomes (Figure 5).

NOTE: in practice, NCAs are not yet mainstreamed within many industrial sectors and might be undertaken after the ESIA to inform the detailed design stage. This case study reflects this situation, while emphasising that, as noted in Section 2.4, the earlier a full NCA is undertaken of both impacts and dependencies, the greater its commercial advantages.

Figure 5. Possible iterative design process whereby Natural Capital Accounts inform a detailed design of Biodiversity No Net Loss for an infrastructure project



5.3 Baseline before factory construction

The ESIA team complete the following baseline NCA:

5.3.1 Natural Capital Stocks

The Leandro wetland is a swamp within rural Uganda. It is not within a protected area. Ecological surveys for the ESIA showed that the wetland provides habitat for various species including:

- Plants: including Papyrus species, Acacia species, Phoenix species, Phraganites species, Sorghastrum species and Cyperus species.
- Birds: globally endangered species including the Shoebill stork (*Balaeniceps* rex; IUCN conservation status is Vulnerable) and Fox's weaver (*Ploceus spekeoides*), also habitat for migratory water birds.
- Fish: including Tilapia, lungfish and catfish.
- Monkeys: including the red-tailed and black and white colobus monkeys.

The Leandro wetland is 10,000 hectares. The sugar cane factory will be located on its eastern side and will result in the permanent loss of 1500 hectares. The offset is to be located on degraded grassland of extremely low ecological value on the western boundary of the wetland (Table 2).

As part of the ESIA, local people were interviewed to assess social aspects of the wetland. This showed that the Leandro wetland is part of local folklore history with many people describing that a wetland has been present in that location for as long as they can remember, and that their community currently has a range of uses and values associated with the wetland including subsistence and livelihood needs, as well as cultural.

Table 2. Natural Capital Stocks Register

Stocks		Baseline
Leandrow wetland	Total wetland area	10,000 hectares
	Area of wetland permanently lost from factory construction	1500 hectares
Degraded grassland area proposed for the wetland offset		6000 hectares

5.3.2 Ecosystem service provision (benefits to people)

The area of wetland to be affected by factory construction is used by approximately 9000 households, bordering the eastern side of the wetland, for various subsistence and livelihood activities (Table 3). These include obtaining clean water for domestic use, food for subsistence, resources for agriculture and building materials, as well as visiting sacred sites within the wetland as part of long-standing cultural traditions. These households are rural farmers who depend on natural resources for subsistence and livelihoods. Constructing the NCA also identified various benefits the wetland provides for people at regional, national and international levels. These are shown in Table 3 and include:

At regional and national levels, natural resources derived from the wetland (including fish and building materials) are sold at town markets, stimulating economic activity. The wetland also provides flood control that protects farmsteads, infrastructure and buildings, as well as waste water treatment. By providing habitat for bird species of international conservation interest, the wetland is a key site for international tourism that boosts local and national economic activity.

At the international level, key benefits include carbon storage and providing habitat for bird species of international conservation interest.

Table 3. Key benefits to people generated by the wetland before factory construction

Ecosystem service	Key benefits	Benefits to people*		
		Locally	Regionally & nationally	Internationally
Provisioning	**Examples**			
Food	Fish, wild game, fruit, grains	✔✔	✔	
Fresh water	Storage & retention of water for domestic, industrial & agricultural use	✔✔	✔	
Materials & fuel	Logs, fuelwood, papyrus peat and fodder	✔✔	✔	
Regulating	**Examples**			
Climate Regulation	Source of & sink for greenhouse gases; influences local and regional temperature, precipitation & other climatic processes.	✔✔	✔✔	✔✔
Water Purification & Treatment	Retention, recovery & removal of excess nutrients and other pollutants.	✔✔	✔	
Nutrient cycling	Storage, recycling, processing and acquisition of nutrients	✔✔	✔	
Natural Hazard Regulation	Flood control and storm protection.	✔✔	✔	
Cultural	**Examples**			
Spiritual & Inspirational	Local spiritual sites	✔✔	✔	
Recreational	Opportunities for tourism that generates economic activities	✔	✔	✔✔

*Ticks indicate the relative importance of the benefits at each level of beneficiary (higher numbers = more important)

The area proposed for the biodiversity offset is degraded grassland that is of extremely limited use or benefit to local communities bordering the western side of the wetland (approximately 12,000 households), or to society at national and international levels.

5.3.3 Value of the benefits

As described above, the wetland generates various benefits for people at local, national and international levels. Several benefits are appropriate for assigning monetary values. For example, the local and national economic activity resulting from tourism; the income that local fishermen gain from selling fish to town traders as well as the income that town traders make from selling fish at markets; and the plants that local people use as building materials.

NOTE: when undertaking NCAs in practice, usually a selection is made of the benefits (i.e. ecosystem services) to assign monetary values. This selection can be based on significance to beneficiaries; whether appropriate to assign a monetary value; and, the availability of good quality, credible data for calculating monetary values.

Based on the data available from previous studies of Uganda's wetlands, the following ecosystem services were selected for monetary valuation:

- Climate regulation
- Flood control
- Clean water for local domestic use
- Pastures for cattle grazing
- Fish spawning grounds

NOTE: the monetary valuations below are only for illustrative purposes. They are <u>not</u> intended to represent the complete value of the wetland in the case study, especially given the variety of ecosystem services it generates (as is true for many wetlands within Uganda). Rather this section aims to illustrate the <u>potential</u> monetary values of specific ecosystem services – potential because the calculations are based on previous independent, ad-hoc studies of Uganda's wetlands that could not be assured (see the Appendices for details), whereas in practice, NCAs should be developed from both published literature and data gathered by field surveys.

Climate regulation and flood control

The wetland area to be affected by factory construction generates an annual benefit of approximately **US$397,500 in climate regulation.** This represents benefits provided by the wetland area in terms of carbon sequestration for local, national and international communities.

The wetland also generates an annual benefit of approximately **US$10 million in flood control**. This represents the wetland's properties as a natural 'sponge' that traps and slowly releases surface water, rain, groundwater and flood waters, as well as slowing the speed of flood waters and distributing them more slowly.

Monetary values of climate regulation and flood control were estimated from previous studies of Uganda's wetlands that used contingent valuation methods, including values derived from Karanja et al, 2001, as cited in Kakaru, 2013 (see the Appendices for details). The degraded grassland proposed for the wetland offset provides negligible climate regulation and flood control benefits (Table 4).

Table 4. Baseline monetary values of climate regulation and flood control

Stock	Benefit	US$ per ha per year	Baseline annual value US$
1500ha of wetland permanently lost from factory construction	Climate regulation	265	397,500
	Flood control	7240	10,860,000
6000ha proposed wetland offset on degraded grassland	Climate regulation	n/a	n/a
	Flood control	n/a	n/a

Clean water for local domestic use

The wetland area to be affected by factory construction provides clean water for local domestic use for approximately 9000 households bordering the eastern side of the wetland. These households depend on the wetland for domestic water, and this equates to an annual benefit of approximately **US$394,200**. This monetary value was estimated from previous studies (including Kakaru, 2013) that identified average household use of domestic water and price of water per m^3 (approximately US$2) (see the Appendices for details). The degraded grassland proposed for the wetland offset provides no clean water for domestic use (Table 5).

Table 5. Baseline monetary values of cleaned water for local domestic use

Stock	Benefit	Baseline value
1500ha of wetland permanently lost from factory construction	Average domestic water use per household (m^3/year)	197,100
	Market price of water per m^3	US$2
	Gross annual value of clean water for domestic use by 9000 households	US$394,200
6000ha proposed wetland offset on degraded grassland	Clean water for local domestic use	n/a

Pastures for cattle grazing

Households bordering the eastern side of the wetland regularly graze cattle within fringes of the wetland area to be affected by factory construction. An estimated 3300 cattle graze within the wetland, which equates to approximately a total annual benefit of **US$40,900**. This was calculated using the cost of leafy feeds that farmers would have to buy if the wetland pastures were not available for cattle grazing, which was estimated to be US 0.2 per animal per day from previous studies (see the Appendices for details). The degraded grassland proposed for the wetland offset provides negligible provision for cattle grazing (Table 6).

Table 6. Baseline monetary values of cattle grazing

Stock	Benefit	Baseline value
1500ha of wetland permanently lost from factory construction	Cattle grazing within wetland fringes by local communities	3300
	Market price of leafy feeds	US$0.2 per cattle per day
	Value per day for all cattle	US$660
	Gross annual value of wetland pastures for cattle grazing	US$240,900
6000ha proposed wetland offset on degraded grassland	Cattle grazing provision	n/a

Fish spawning grounds

The wetland area to be affected by factory construction contains fish spawning grounds up to an estimated 500ha. Households bordering the eastern side of the wetland primarily use this as a source of food for subsistence. There are several ways to estimate the monetary value of the fish spawning grounds, for example by the market price of fish caught. The approach adopted here was to estimate the monetary value of 1 hectare of fish spawning ground from previous research, which was US$6.3/ha (see the Appendices for details). Hence, the 500ha of fish spawning grounds equates to an approximate annual value of **US$3150**. The degraded grassland proposed for the wetland offset provides no fish spawning grounds (Table 7).

Table 7: Baseline monetary value of fish spawning grounds

Stock	Benefit	Baseline value
1500ha of wetland permanently lost from factory construction	Fish spawning ground	500ha
	Fish spawning ground per hectare	US$6.3
	Gross annual value of wetland fish spawning grounds	US$3150
6000ha proposed wetland offset on degraded grassland	Fish spawning grounds	n/a

Local cultural values

Local cultural values of the wetland were assessed as part of the NCA, building on the assessment in the ESIA. The ESIA revealed that local people place strong cultural attachments on the wetland area to be affected by factory construction, as there is a sacred site where water spirits are present. The water spirits are worshipped by local people who take offerings to ask the spirits for various aspects such as a good harvest, rainfall and a prosperous life. Local people also bathe in water nearby as they believe this washes away bad luck, and some mix water with medicinal herbs to treat illnesses. These cultural values were included in the NCA and the loss of the sacred site was addressed as part of the factory development (Box 1).

Box 1. Addressing the loss of a sacred site
Factory construction will cause the permanent loss of a sacred site of local cultural value within the wetland. Consultations for the ESIA with various local community members (to avoid consultations with only local elites) revealed that local people felt that relocating the spirits was acceptable to address this loss. The consultations also revealed that relocating spirits is an extremely sensitive activity, requiring the relocation site to be nearby where the people who were visiting the original sacred site can access, and to be directed by the local spiritual leader. Kapiri Ltd commissioned the ESIA team to undertake a series of consultations over an extended period of time, with various local community members (including poor, vulnerable and marginalised groups) to produce a fully comprehensive plan to relocate the spirits <u>that local communities accept</u>. Kapiri Ltd also committed funds to implement the relocation and to protect the relocation site from construction activities and on-going factory operations.

Baseline Natural Capital Account

The wetland area to be affected by factory construction provides ecosystem services at local, national and international levels. Five ecosystem services generate over US$11 million in benefits per year. As these were only five out of all ecosystem services provided by the wetland, the actual monetary value of the wetland will be substantially higher. In addition, local communities bordering the affected wetland area place strong cultural values on sacred sites within the wetland. In contrast, the degraded grassland proposed for the wetland offset is not of ecological value nor does it generate any significant ecosystem services (Table 8).

Table 8. Summary of baseline Natural Capital Account of selected ecosystem services generated by the wetland area affected by factory construction

Natural Capital Stocks	Local people affected	Benefits	Annual Monetary Value (US$)
1500ha of wetland permanently lost from factory construction	9000 households bordering the eastern wetland side	Climate regulation	397,500
		Flood control	10,860,000
		Clean water for domestic use	394,200
		Cattle grazing provision	240,900
		Fish spawning ground	3150
		Local cultural value	High cultural value on scared site of water spirits
6000ha wetland offset on degraded grassland	12,000 households bordering the western wetland side	All of the above	Negligible

5.4 Designing No Net Loss of Biodiversity using Natural Capital Accounting

With the baseline NCA, the ESIA team now commence the detailed design of the wetland offset. They anticipate that the offset will take 20 years to be of a similar ecological status to the wetland cleared for factory construction, where it achieves NNL of wetland habitat. So that offset planting starts before losses of wetland are incurred, the planned timescale is:

- 2018: wetland baseline established
- 2019: offset implementation commences
- 2021: wetland cleared for factory construction
- 2039: offset reaches maturity
- 2069: completion of the 50 year wetland offset management plan

The next steps are to update the NCA as the offset design progresses, so that changes in wetland stocks and ecosystem service provision resulting from the offset are incorporated into the offset design. In practice this requires a detailed, careful approach. For illustrative purposes only, key considerations include[2]:

- **Set the timescales**

This stage of the NCA requires estimating ecosystem service provision, and the associated monetary values, in 2039 when the wetland offset reaches maturity (i.e. is assumed to generate similar levels of ecosystem services as the wetland cleared for factory construction), and in 2069 on completion of the wetland offset management plan (i.e. after which protection of the offset is uncertain).

[2] For a full list of considerations when constructing NCAs, please see 'Developing Corporate Natural Capital Accounts' (eftct et al, 2015).

In practice there will be some level of ecosystem service provision as the wetland offset establishes (i.e. in the years from 2019 up to 2039). Predicting such incremental increases might be possible as the detailed offset design progresses. But when information is limited, it could be reasonable to only consider the two time periods of 2039 and 2069.

Whichever time period is chosen, identifying who benefits from the offset's ecosystem services in comparison with who suffered from loss of wetland from factory construction is vital - see below the section on "benefit the people who are affected".

- **Account for change in monetary values and for time-lags**

Calculating monetary values of ecosystem services in 2039 and 2069 will account for any likely change in the baseline monetary values over those timescales. For example, whether international trading in carbon credits would increase or decrease carbon sequestration values, or whether food prices could increase for rural communities in Uganda. Coupled with this is the need to account for time-lags. There is a time-lag of 20 years before the wetland offset stocks are providing similar levels of ecosystem services to the wetland cleared for factory construction. This time-lag should be factored into the NCA, so that it is reflected in the final monetary values of 2039 and 2069.

Discounting can be used to determine future monetary values and to compare benefits across time. It can also account for risks that ecosystem service provision does not arise as anticipated. The advantage of discounting is that it is widely used by governments and in the private sector. Also it has been used to construct NCAs. For example for the UK's national-level natural capital account, a 100-year asset life was assumed with a declining discount rate of 3.5% up to 30 years, 3% for 31 to 75% years and 2.5% for 76 to 100 years (Office of National Statistics, 2017). If discounting is applied to NCAs, the multipliers applied and the time-scales used should be carefully chosen based on credible published literature and fully justified.

- **Benefit the people who are affected**

Households on the eastern side of the wetland will suffer from losses of wetland, whereas households on the western side could benefit from the wetland offset. The balance sheet of the NCA will make explicit who loses and who gains from changes in ecosystem services. Illustrating losses and gains in ecosystem services to specific groups of people is essential to identify measures for local people to be 'no worse off' (and to demonstrate that the 'no worse off' principle will be achieved). Furthermore, Uganda's population is projected to increase at an annual 3.1% growth rate. The NCA will account for population increases when predicting changes in ecosystem service provision over the 2039 and 2069 periods.

- **Account for liability costs**

In some NCAs, the costs of creating, enhancing and/or maintaining natural capital stocks are factored into the monetary accounts under 'liability costs' (for example see eftec & Forest Trends, 2017). This requires gathering credible information on likely costs, which for the case study would be to create and maintain the wetland offset over a 50-year period. Then the final balance sheet shows both the value of natural capital stocks and costs of generating and maintaining that value.

- **Account for dependencies**

The initial scope of the NCA was only wetland loss from factory construction. However, full NCAs regard both impacts and dependencies of economic development on natural capital stocks. Making explicit these dependencies captures the 'private' values accruing to the developer, as well as the risks to their business – from which they can reduce these operational risks by improving management of their natural capital asset. The final NCA balance sheet can reflect both private values and external values (i.e. values accruing to society in general) that together represent the full value of natural capital (for more information see eftec et al, 2015).

5.5 In summary

Natural Capital Accounts can assess and quantify the economic and social outcomes of NNL of biodiversity for infrastructure development. This is incredibly useful to ensure (and demonstrate) local people are 'no worse off' as a result of NNL. This case study illustrates key considerations when constructing such NCAs, especially to make explicit which groups of people suffer and which groups benefit from change in ecosystem service provision. However it is important to acknowledge that full NCAs regard both impacts and dependencies of economic development on natural capital. It is also important to acknowledge that, while the case study focuses on social and economic outcomes of No Net Loss in biodiversity, ultimately the role of natural capital accounting is to document an organisation's ownership, liability and assets relating to natural capital in the format of a typical financial balance sheet. Constructing NCAs will help companies to improve the management of their natural capital assets, to the benefit of their business as well as society.

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Appendix A: Contextual information for the NCA case study

This Appendix builds on Chapter 4 by providing more details on contextual information for the NCA case study.

Stocks of Uganda's wetlands

Uganda's wetlands (Box A1) cover approximately 29,000 sq km, which equates to approximately 13% of the country. The wetlands are swamp (8,832 sq. km), swamp forest (365 sq. km) and sites with impeded drainage 20,392 sq. km (NEMA, 2016a). Uganda has 11 wetland RAMSAR sites that support habitats for birds, including breeding grounds for the crested crane.

Box A1. Definition of wetlands in Uganda

Uganda's National Policy for the Conservation and Management of Wetland Resources (1995) defines wetlands as an area where plants and animals have become adapted to temporary or permanent flooding by saline, brackish or fresh water. These include permanently flooded areas with sedge or grass swamp, swamp forest or high altitude mountain bog, as well as seasonal flood plains and depressions without flow ('Mbuga' or Dambos).

In 2016, UNEP-WCMC and IDEAA produced the first ecosystem service accounts for Uganda (UNEP-WCMC; IDEEA, 2017). These accounts quantified natural capital stocks for a national-level NCA based on the following elements of biodiversity: land cover, vegetation class and selected species. For wetlands, the accounts quantified the extent, type and coverage of three main wetland types:

- Communities on sites with impeded drainage
- Swamps
- Swamp forests

The accounts showed substantial reductions in the extent of Uganda's wetlands. Compared with the first map of wetland coverage in Uganda (in 1964 by Langdale-Brown et al.), overall there was only 68% of coverage remaining. The largest losses in absolute terms occurred in Teso (61% of the 1964 coverage of 382,000 ha remained), Central (70% of the 1964 coverage of 420,000ha remained) and East Central (35% of the 1964 coverage of 180,000ha remained) (Table A1).

Table A1. Quantification of ecosystem extent, including wetlands, in Uganda (UNEP-WCMC: IDEAA, 2017)

Sum of Area (ha) Subregion	Langdale-Brown Biomes Dry Savannahs			Forest			Moist Savannah			Wetlands		
	Original Extent*	Current Extent (2015)	% of Original	Original Extent	Current Extent (2015)	% of Original	Original Extent	Current Extent (2015)	% of Original	Original Extent	Current Extent (2015)	% of Original
ACHOLI	777,655	457,035	59%	27,477	26,579	97%	1,842,369	692,643	38%	146,303	87,862	60%
CENTRAL 1	757,532	333,267	44%	497,487	109,714	22%	103,541	18,690	18%	188,594	145,146	77%
CENTRAL 2	976,599	564,238	58%	718,102	114,927	16%	219,705	70,466	32%	420,039	205,535	70%
EAST CENTRAL	164,458	13, 059	8%	399,695	14,673	4%	191,083	11,431	6%	179,920	62,926	35%
ELGON	113,229	39,415	35%	204,421	103,307	51%	71,027	3,141	4%	109,084	58,041	53%
KARAMOJA	1,837,976	1,605,141	87%	103,573	94,740	91%	163,994	126,439	77%	622,503	564,141	91%
LANGO	144,467	27,233	19%	-	-	-	937,189	151,436	16%	170,877	76,616	45%
SOUTH WESTERN	1,090,973	619,838	57%	445,458	189,706	43%	211,473	64,112	30%	77,573	52,122	67%
TESO	273,045	46,786	17%	17,864	505	3%	637,940	80,155	13%	382,301	232,519	61%
WEST NILE	601,940	275,405	46%	4,711	2,315	49%	607,074	255,894	42%	113,654	76,436	67%
WESTERN	935,502	555,097	59%	1,201,317	409,230	34%	622,890	306,318	49%	178,378	98,219	55%
Grand Total	**7,673,376**	**4,536,514**	**59%**	**3,620,105**	**1,065,696**	**20%**	**5,608,285**	**1,780,725**	**32%**	**2,589,226**	**1,749,563**	**68%**

* This is the original extent mapped by Langdale-Brown et al. (1964).

Drivers of wetland loss in Uganda

The State of the Environment Report (2014) attributes Uganda's loss of wetlands to conversion for agriculture, human settlement and industrial development. Specific causes of the decline and degradation of Uganda's wetlands include:

- **Encroachment** from demand for land for grazing and agriculture such as rice, dairy farming and vegetables and pastoral land, as well as industrial development. This is most common in rural and sub-urban areas.
- **Drainage** driven by urban expansion or development.
- **Pollution** especially in urban places from discharging untreated industrial and municipal waste, while in rural areas from large agricultural farms and mining.

- **Overharvesting** or over-exploitation which includes fishing, harvesting wetland plants for domestic and commercial use, and harvesting materials including clay, sand, firewood, timbre, papyrus and ornaments.
- **Siltation** from poor farming methods that cause erosion.

Benefits from Uganda's wetlands

Uganda's wetlands provide benefits for people at international, national and local levels. Appendix B lists these benefits according to type of ecosystem service. It also indicates whether the primary beneficiaries are local, national or international communities. Examples of benefits from Uganda's wetlands include:

International

As wetlands store carbon dioxide, they benefit the international community by regulating climate (Akwetaireho, 2010). Uganda's wetlands also provide opportunities for international tourism. For example, Bigodi Wetland Sanctuary in western Uganda is home to approximately 200 bird species, including the Papyrus Gonolek, Great Blue Turaco, the snowy-headed Robin-Chat, the Black-and-White Casqued Hornbill and the Emerald Cuckoo. Guided tourism walks through the sanctuary have been developed with the aim of assisting community development projects (UNDP-UNEP-PEI, 2009).

National

Wetlands have been identified as a national priority. In 2017 in response to a Presidential Initiative on Wetlands, the Government of Uganda and United Nations Development Programme (UNDP) initiated a project on "Building community resilience, wetlands ecosystems and associated catchments in Uganda." This project is intended to restore degraded wetlands, improve ecosystems, and strengthen climate information and early warning systems (UNDP Climate Change Adaptation, accessed Feb 2018 - http://adaptation-undp.org/node/3540).

Uganda's wetlands provide a range of benefits at the national level. These include water treatment and purification. Large amounts of water enter the wetlands with waste that includes detergents, oil, acids, nitrates, phosphates and heavy metals. The wetlands treat and purify this water before it flows into lakes and rivers (Schuyt, 2005). Uganda's wetlands provide other national-level benefits such as water flow and storage, flood attenuation and micro-climate regulation.

Local

Approximately 4,000,000 people live in and around Uganda's wetlands. Over 80% use wetland resources for their household food security needs (UNDP Climate Change Adaptation, accessed Feb 2018 http://adaptation-undp.org/node/3540).

Uganda's wetlands are a principle supply of fresh water for human use (NEMA, 2007). They are also a source of water for farming (both livestock and crop cultivation), are used for fish farming, and deposit sediments and nutrients that maintain soil fertility.

People harvest a variety of plants from wetlands for subsistence use and for sale in local markets. For example, people harvest papyrus from wetlands to sell to artisans such as thatch and mat makers, or to make products to sell at local markets. In addition, there are various species of edible plants in wetlands and many wetland plants are used for medicinal purposes (NEMA, 2007). See Box A2 for other examples.

Box A2. Examples of benefits from Uganda's wetlands to local communities

Research showed that the Nakivubo wetlands near Kampala, Uganda, supported local people via subsistence and income-generating activities. The main uses were small-scale cultivation, papyrus harvesting, brick making and fish farming (Emerton et. al, 1999)

Studies of the Mabamba Bay wetlands, near Lake Victoria, showed that water supply, sand mining, fishing and agriculture were the main benefits it provided to local communities. Of these, the provision of drinking water for local people and the extraction of sand for construction purposes were most important. This study also noted the importance of Uganda's wetlands to national (e.g. tourism) and international communities (e.g. carbon storage) (Akwetaireho and Getzner, 2010).

Value of the benefits from Uganda's wetlands

Certain benefits from Uganda's wetlands cannot be assigned monetary values, such as cultural values (see Appendix B). For benefits from Uganda's wetlands that can be assigned monetary values, various studies have been undertaken. Appendix C contains a selection of these, which are summarised in Table A2. The studies were not formally undertaken for a NCA. Rather, they represent ad-hoc independent studies on certain benefits (not all) using different methods to assign monetary values. Consequently the credibility of the studies cannot be assessed. Nonetheless, they are useful illustrations of potential monetary values of Uganda's wetlands.

Table A2. Examples of the monetary values of Uganda's wetlands*

Study	Monetary values of Uganda's wetlands
Wetlands in three of Uganda's five agro-ecological zones	• Fish spawning was valued at approximately US$363,815 per year. • Livestock pastures at US$4.24 million per year. • Domestic water use at US$34 million per year. • Flood control at US$1.7million per hectare per year. • Monetary value to crop farming ranged from US$417,536 to US$25 million per year. • Gross annual value of domestic water supply was US$13.9 million (wetlands were the sole source of domestic water in these areas).
Nakivubo wetlands near Kampala (NEMA, 2007)	• Monetary values of wastewater purification and nutrient retention varied from US$1 million a year (using replacement cost methods) to US$1.75 million a year (using mitigation expenditure methods), whereas a sewage treatment plant would cost over US$2 million dollars to maintain each year. • Other monetary values of this wetland included: - Crop cultivation at US$60,000 per year. - Papyrus harvesting at US$10,000 per year. - Brick making at US$17,000 per year. - Fish farming at US$3000 per year.

Wetlands in the Bushenyi district (IUCN,2004)	Values of local benefits in Ugandan Shillings (UGX) included: • Milk production was valued at UGX 435,600,000 per year. • Domestic water supply at UGX 9,088,500 per year. • Provision of water for livestock at UGX 654,080,000 per year. Values of international and national benefits in Ugandan Schillings included: • Climate regulation at UGX 8438,130,00 per year. • Food control UGX 230,536,080,000 per year.
Wetlands in the Pallisa District (IUCN, 2001)	• Wetland grass for thatching houses was valued at UGX 3 billion per year. • Fishery at UGX 875,385,000 per year. • Water transport value at UGX 250 million per year.

* See Appendix B for details (figures and currencies used are taken directly from the literature sources)

Impacts and dependencies on Uganda's wetlands

Various sectors of society and industry affect wetlands in Uganda, for example by over-extraction of water or by over-harvesting wetland plants. These activities can degrade the extent and condition of wetlands, which in turn can affect those who depend on wetlands. For example, degradation of a wetland reduces its capacity to capture storm run-off from surrounding areas. This results in flooding that damages road infrastructure, which in turn disrupts transport and results in a cost to undertake the necessary repairs. (UNDP-UNEP PEI 2009). Examples of dependencies and impacts on Uganda's wetlands by various sectors are listed in Appendix D.

Appendix B: Benefits from Uganda's wetlands at international, national and local levels

Table B.1 lists benefits provided by Uganda's wetlands, as described by the Ministry of Natural Resources (Government of Uganda, 1995). It categorizes the benefits according to type of ecosystem service, lists examples from the literature and indicates whether the primary beneficiaries are people at local, national or international levels.

Table B.1: Benefits provided by Uganda's Wetlands to local communities, nationally within Uganda and internationally

Key:

- ✔ indicate the relative importance of ecosystem service benefit
- Locally: benefits local communities in areas surrounding wetlands
- Nationally: benefits Uganda nationally
- Internationally: benefits the international community

ECOSYSTEM SERVICES	EXAMPLES	SELECTED EXAMPLES FROM LITERATURE*	PROVIDES BENEFITS AT THESE SCALES		
			LOCALLY	NATIONALLY	INTERNATIONALLY
Provisioning ecosystem services					
Food	Production of fish, wild game, fruits and grains.	Fish such as tilapia, lungfish and catfish; food for livestock (Akwetaireho & Getzner, 2010); crops such as yams & rice (UNDP-UNEP PEI 2009).	✔✔	✔	
Fresh water	Storage and retention of water for domestic, industrial and agricultural use.	Water for domestic use; Water for crop cultivation; Water for livestock	✔✔	✔	
Fibre and fuel	Production of logs, fuelwood, peat and fodder.	Fuelwood which provides energy for cooking, heating and lighting (Akwetaireho, 2010); sand for construction; fibre for construction (UNDP-UNEP PEI 2009); papyrus for thatch and mat (NEMA 2007); brick making (NEMA 2007).	✔✔	✔	
Biochemicals	Extraction of medicines and other materials from biota.	Many plants are used for medicines (NEMA 2016a).	✔	✔	✔

ECOSYSTEM SERVICES	EXAMPLES	SELECTED EXAMPLES FROM LITERATURE*	PROVIDES BENEFITS AT THESE SCALES		
			LOCALLY	NATIONALLY	INTERNATIONALLY
Genetic materials	Genes for resistance to plant pathogens, ornamental species, etc.	Provision of gene pool research material (UNDP-UNEP PEI 2009).		✔	✔
Regulating Ecosystem Services					
Climate Regulation	Source of and sink for greenhouse gases; influences local and regional temperature, precipitation, and other climatic processes.	Sink for storing carbon dioxide (Akwetaireho & Getzner,, 2010); micro-climate regulation (NEMA 2016a)	✔✔	✔✔	✔✔
Water Regulation (Hydrological Flows)	Ground water re-charge and discharge retention.	Ground water re-charge and discharge retention (UNDP-UNEP PEI 2009).	✔	✔	
Water Purification and Water Treatment	Retention, recovery and removal of excess nutrients and other pollutants.	Purification of wastes, such as detergents, oil, acids, nitrates, phosphates and heavy metals (NEMA 2016a).	✔	✔	
Natural Hazard Regulation	Flood control and storm protection.	Flood control (UNDP-UNEP PEI 2009).	✔✔	✔✔	
Pollination	Habitat for pollinators.	Munyuli (2011) identifies wetlands to be very good foraging and nesting habitats for pollinators, notably for the Meliponini bee group. Together with forests, wetlands harbour not only specialist but also generalist bee species.	✔	✔	✔
Cultural Ecosystem Services					
Spiritual and Inspirational	Sources of inspiration; many religions attach spiritual and religious values to aspects of wetland ecosystems.	For example the Grey-crowned crane which is the national symbol of Uganda. (NEMA, 2015) (Pomeroy, 2017).	✔✔	✔	
Recreational	Opportunities for recreational activities, including sports and ecotourism.	Recreation (NEMA 2016a); tourism (UNDP-UNEP PEI 2009), for example bird-watching.	✔	✔✔	✔✔

ECOSYSTEM SERVICES	EXAMPLES	SELECTED EXAMPLES FROM LITERATURE*	PROVIDES BENEFITS AT THESE SCALES		
			LOCALLY	NATIONALLY	INTERNATIONALLY
Aesthetics	Wetland ecosystems and their resources are a source of beauty.				
Educational	Opportunities for formal and informal education and training.	Opportunities to learn about animals and plants (UNDP-UNEP PEI 2009).	✔	✔✔	✔✔
Supporting					
Soil Formation	Sediment retention and accumulation of organic matter.	Fertility replenishment from sediment trapping, settling of silt particles and rotting of organic matter from vegetation (Kakaru, 2013).	✔	✔	
Nutrient Cycling	Storage, recycling, processing and acquisition of nutrients.	Depositing sediments and nutrients that maintain soil fertility (NEMA 2007).	✔	✔	

**Note these references provide examples, but do not necessarily distinguish between benefits provided at local/national/international level*

Appendix C: Example literature on monetary values of the benefits from Uganda's wetlands

Economic valuation of wetlands in Lake Victoria, Southwestern farmlands and Kyoga plains – 2013 (Kakaru, 2013)

The study was conducted in eight wetland systems located in areas that represent three of the five agroecological zones of Uganda. The zones were:

- the Lake Victoria crescent agroecological zone, represented by the Nangabo, Mabamba, and Mende in Wakiso district wetlands
- Southwestern farmlands, represented by the wetlands Rucece in Mbarara and Lake Nakivale in Isingiro
- The Kyogo plains agroecological zone represented by the wetlands Limoto and Gogonyo in Pallisa and Kibuku Districts

This study identifies the following benefits from these three zones:

<u>Provisioning services:</u>

Food from:

- Fish, breeding ground, paddy rice, vegetables, yams/taro, sugar cane, livestock grazing, livestock watering, hunting (bush meat), grass for mulching, wild fruits and vegetables wetlands in these three zones

Fibre from:

- Papyrus, crafts, sand, clay, grass for thatching

Fresh water for:

- Industrial/urban water supply, domestic water supply

<u>Regulating services:</u>

- Flood control
- Weather modification
- Carbon sequestration

<u>Cultural services:</u>

- Recreation for tourists

The study applied three methods for quantifying the monetary values of wetland ecosystem services: the market price method, the productivity method and the contingent valuation method. The market prices method was applied to quantify direct use values, by estimating the price in commercial markets for such wetland resources as papyrus products, pastures, and fish. The respondents made an estimate of the value of nonmarket goods by utilising direct surveys to solicit responses that reflect each individual resource user's valuation of a nonmarket good. The productivity method was used to quantify the use of water. The contingent valuation method was used for non-use values such as flood attenuation, water recharge and supply, and habitat and breeding.

In summary, selected benefits from these wetlands were valued as follows:

The per capita value of fish was approximately US$ 0.49 person. Fish spawning was valued at approximately US$ 363,815 per year, livestock pastures at US$ 4.24 million, domestic water use at US$34 million per year, and the gross annual value added by wetlands to milk production at US$ 1.22 million. Flood control was valued at approximately US$ 1,702,934,880 per hectare per year and water regulation and recharge at US$ 7,056,360 per hectare per year. Through provision of grass for mulching, wetlands were estimated to contribute to US$ 8.65 million annually. The annual contribution of non-use values was estimated in the range of US$ 7.1 million for water recharge and regulation and to US$ 1.7 billion for flood control.

Wetland resources contributed to food security by:

- providing food (fish, crops, game meat) and income from the sale of these
- providing income from the sale of materials and products made from e.g. fibre, sand, clay;
- contributing to increased crop and livestock yields by providing water, silt and via climate regulation

The study concluded that wetlands provide ecosystem benefits that contribute to income and food security in Uganda, and thus resource investment in wetlands conservation is economically justified.

Crop farming

The study calculated the monetary value of these wetlands from crop farming by estimating the total farming area in each of the three agro-ecological zones and the area of wetlands under crop production from the district inventory reports. Data was collected on the yields and the number of harvests per year for the key crops grown in the wetlands. Table C.1 shows the results. In summary, the economic value of wetlands to crop farming in these areas ranged from US$ 417, 536 to $25,090,560 per year. Local communities stated that yields from wetland crops were higher than those grown in other areas, due to the guaranteed water supply, even during drought periods. Wetlands are fertile areas for growing crops, due to the ecosystem services provided by those wetlands such as sediment trapping and silt formation.

Table C.1 Monetary value of wetlands in terms of crop farming in the three study areas.

Variable	Southwestern farmlands	Lake Victoria crescent	Kyoga plains
Major crop grown in wetlands	Maize	Vegetables (Nakatti)	Rice
Total farming area in wetlands (ha)*	932	3,065	16,355
Area of wetland under crops (ha)	746	2,452	13,068

Yield per hectare (per season) tonnes	4	8	2
Number of harvest per year	2	3	2
Total harvest per year	5,219	55,170	52,272
Price per tonne (US$)	80	60	480
Gross annual value of harvest at farm gate prices (US$ per year)	**417,536**	**3,310,200**	**25,090,560**

Domestic water supply

The study calculated the monetary value of wetlands for water storage and supply by estimating the number of households dependent on wetlands for water supply and annual water use for all the households. Table C.2 shows the results. In summary, the gross annual value of domestic water supply from these areas was US$13.9 million. Wetlands were the sole source of domestic water in these areas.

Table C.2: Monetary value of wetlands for domestic water supply in the three study areas.

Variable	Southwestern farmlands	Lake Victoria crescent	Kyoga plains	Overall
Midyear human population projections (2012)*	865,800	1,371,600	544,300	2,781,700
Number of households	123,686	195,943	77,757	397,386
Households dependent on wetlands for water supply**	98,949	156,754	62,206	317,909
Average use of water (20 litre jerry cans)	3	3	3	3
Water use for all households per year (m^3)	2,166,974	3,432,919	1,362,305	6,962,198
Market price per m^3 (US$)***	2	2	2	2
Gross annual value of water for domestic consumption (US$)	**4,333,947**	**6,865,838**	**2,724,610**	**13,924,395**

*Human population projections were based on midyear values of 2012
**Estimated at 80% from Wetlands Management Department et al. (2009)
***Computed based on the price of a 20 litre jerry can at US$ 0.04

Economic valuation of selected benefits from the Nakivubo wetland in the Kampala area, 2007

This study used economic valuation of the ecosystem services benefits to people from the Nakivubo wetland, to support decision-making regarding the potential construction of a sewage and water treatment plant on the wetland. The results of the evaluation showed that the wastewater purification and nutrient retention ecosystem services of Nakivubo Swamp have a high economic value between US$ 1 million a year (using replacement cost methods) and US $1.75 million a year (using mitigation expenditures methods) (Emerton, 2003). Furthermore, the Wetlands Inspectorate Division and the IUCN showed that a sewage treatment plant would cost over US $2 million dollars to maintain each year (Emerton et al, 1999). Not only was the cost of expanding the sewage treatment plant greater than the value of the wetland, there were associated costs to livelihoods.

The water, land, soils, plants, hydrological and ecological characteristics of Nakivubo wetland directly support economic activities in terms of wetland resources and services. Nakivubo wetland resources support various subsistence and income-generating activities of the residents of the low-cost settlements that directly border the wetland. The most significant uses of the wetland resources by the surrounding population are small-scale cultivation, papyrus harvesting, brick making and fish farming (Almack, 2010).

The Greater City of Kampala benefits from the ecological services provided by the Nakivubo wetland. It maintains the quality of urban water supplies by treating and purifying domestic and industrial wastes and effluents. At the same time the Nakivubo swamp supports small-scale income activities for slum dwellers such as papyrus harvesting, brick making, and fish farming (Emerton et al, 1999).

The values of the ecosystem services are shown in Table C.3.

Table C.3: Economic value of Nakivubo urban wetland in Kampala.

Wetland Benefit	Economic Value (US$/year)
Crop cultivation	60,000
Papyrus harvesting	10,000
Brick making	17,000
Fish farming	3,000
Water treatment & purification	7000,000 – 1,300, 000

Source: NEMA 2007

Two methods were used: the "avoided costs of replacing natural wetland functions with manmade alternatives", and the "expenditures on mitigating the effects of wetland loss" (Emerton, 2003). The cost of developing the wetland was calculated by looking at the investment and recurrent costs of a sewage and water treatment, and the cost per household for sanitation infrastructure. The additional capital and recurrent expenditures of the expansion of the sewage treatment plant had already been calculated by the National Water and Sewerage Corporation. The cost to livelihoods of adjacent dwellings was calculated based on income per person and returns to labour from using the wetland.

Economic valuation of selected wetlands benefits in Bushenyi District (Kaggwa/UNDP-UNEP PEI, 2009)

This study carried out economic valuation of selected ecosystem service benefits from wetlands in Bushenyi District in 2004. It valued milk production at UGX 435,600,000 per year, domestic water supply at UGX 9,088,500 per year and provision of water for livestock at UGX654,080,000 per year. Various regulating ecosystem services were also valued, for example climate regulation (UGX 8438,130,00 per year) and flood control (UGX 230,536,080,000 per year). Table B.4 shows more detail.

Milk production

The total milk production in the Bushenyi District is estimated at 126,000 litres a month. It is estimated that 10 percent of the total production in the district originates from grazing in wetlands, implying that monthly productivity levels of 126,000 litres are wetland-supported. The gross annual values added to wetland pasture through gate price of UGX300/litre is UGX 435,600,000

Water reservoir and purification

A GIS model of household dependence on wetland-based water sources per year estimated that at least 83,000 households in Bushenyi District depend on wetlands for their domestic water supplies. The study further established that, on average, each such household uses 60 litres of water per day. These households therefore consume 1,817,700,000 litres (1,817,700 M^3) of water per annum, implying a wetland gross value of water provision of UGX 9,088,500 per year.

Water provision for livestock production

Livestock obtain their water requirements from the wetlands. Through interviews with farmers, it was found that each cow consumes on average about 40 litres of water per day, or an annual water consumption of around 130,816,000 litres. The gross value associated with the provision of water was UGX654,080,000 per annum in 2004

Regulating and Cultural Ecosystem Services Benefits

Various regulating and cultural ecosystem service benefits were values, as shown in Table C.5.

Table C.5 Monetary value of Regulating and Cultural Ecosystem Service Benefits of Wetlands in Bushenyi.

Wetland Function	Economic Value (US$/ha/year)	Equivalent in UGX*	Total value in UGX for the 18,300 ha of wetlands
Micro-climate regulation	265,000	461,100	8,438,130,00
Flood control	7,240,000	12,597,600	230,536,080,000
Water regulation/recharge	30,000	52,200	955,260,000

Habitat/refugia	439,00	763,860	13,978,638,000
Recreation/aesthetic	491,00	854,340	15,634,422,000
Cultural	1,761,00	3,064,140	56,073,762,000
Total	**10,226,00**	**17,793,240**	**325,616,292,000**

* The exchange rate is UGX 1,740 = US $1, as at 2004

Economic valuation of selected benefits of Pallisa wetlands, 2001

This study carried out economic valuation of selected ecosystem service benefits from wetlands in the Pallisa District in 2001. It valued wetland grass use for thatching houses at close to UGX 3 billion per year, fishery at UGX 875,385,000 per year and water transport value at UGX 250 million per year. As sources of livelihoods, the Pallisa wetlands are particularly threatened by agricultural conversion to rice fields. The wetlands contribute greatly towards poverty eradication by providing sources of water, grazing of livestock, fuel wood and raw materials for handicrafts. Water transport via wetlands is very important in this region since the road network is not well developed.

Value of wetland grass in Pallisa District

The population of Pallisa District is estimated at 474,000. The average household has 5.4 persons; 83.6 percent of them use grass for roof thatching. A standard house requires about 50 bundles of grass, which costs an average of UGX 750. The roof thatch is replaced every year. Based on these figures, the wetland grass resources of Pallisa District are worth close to UGX3 billion.

Wetland fishery value in Pallisa District

There are nine gazetted landing sites in Pallisa District on the nine small lakes of Lemwa, Kawi, Gigati, Nakuwa, Meito, Geme, Nyaguo, Komunuo and Nyasala. There are a total of 147 fishing boats; 99 percent of the fresh fish is caught and sold at Pallisa town market. The total annual net value of fish from the wetlands in Pallisa District is UGX 875,385,000 (IUCN, 2001). Although fishing is carried out in wetlands is mainly for domestic purposes, it also contributes cash income to several fisher groups. Due to the lack of processing facilities in Pallisa District, much revenue is foregone.

Water transport value of Pallisa wetlands

Since the road network in Iganga and Kumi Districts bordering Pallisa District is not well developed, water transport is very important, especially to the neighbouring districts, which are separated from Pallisa District by huge wetlands and water bodies. An economic case study on Kasodo wetland was conducted based on five boats that ferry 16–20 people up to three trips a day. A net economic value of water transport is estimated at UGX 250 million.

Appendix D: Examples of dependencies and impacts on Uganda's wetlands by various sectors

Dependencies and impacts on wetlands from various sectors in Uganda (adapted from UNDP-UNEP PEI 2009: Enhancing Wetland Contribution to Growth):

Sector	Example dependencies	Example impacts
Agriculture, livestock and fisheries	Wetlands provide: • Water for agricultural production, including milk production. • Grazing and fodder for livestock such as cattle. • Fish and fishing opportunities. • A mode of transport for agricultural produce to markets. Wetlands contribute: • Directly to Uganda's agricultural production. • Climatic stabilisation, thus facilitating agricultural production. • Flood control by trapping and holding excess storm water and releasing it gradually and systematically into the lake systems.	• Over-extraction of water. • Pollution e.g. through agrochemicals. • Silt loading, reducing the area of wetlands. • Overgrazing. • Seasonal burning of wetlands for grazing, fishing and cultivation.
Water availability and purification for human consumption	• Wetlands purify water, making it clean for consumption. • Wetlands recharge water sources, thus making water available for people.	• Dumping of waste water.
Energy	• Wetlands supply fuel wood for local domestic purposes e.g. wood and papyrus.	• Overharvesting of wetland fuel wood resources.
Transport	• Boats facilitate the movement of goods and merchandise, enabling access to markets and services. • Wetlands provide flood protection for road infrastructure.	• Use of motorised boats may lead to oil spillages and pollution.
Health	• Wetlands provide medicinal herbs used for medication for over 80% of Uganda's population.	• Poor waste management e.g. dumping of hazardous waste.

Examples of dependencies on wetlands from Uganda's construction sector (adapted from the spreadsheet ""NCFA_D1 Sector dependencies_Construction" of the UNEP-WCMC and the Natural Capital Finance Alliance and the Advancing Environmental Risk Management project)

Components of wetlands	**Construction sector dependency**
Surface and Ground water	Water is used for settling soil and dust, cleaning etc.
Filtration by organisms and ecosystems	Water quality is important for use on sites.
Mediation of sensory impacts	Green infrastructure to mediate noise and dust impacts.
Mass stabilisation and erosion control	Erosion control to protect infrastructure.
Buffering and attenuation of mass flows	Erosion control to protect infrastructure.
Water flow maintenance	Maintenance of water flow for construction activities.
Flood and storm protection	Green infrastructure for protection against natural hazards.
Ventilation	Maintenance of air quality.
Pest control	Natural pest control of invasive species is a dependency.
Weathering processes	To maintain a stable soil environment for building.