ECONOMIC VALUATION OF MOEYUNGYI WETLAND, MYANMAR

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ACRONYMS AND ABBREVIATIONS

AGB	Above-ground biomass
ARIES	Artificial Intelligence for Ecosystem Services
BANCA	Biodiversity And Nature Conservation Association
BGB	Below-ground biomass
C	Carbon
CH_4	Methane
CO_2	Carbon dioxide
CO_2 eq	Carbon dioxide equivalent
ES	Ecosystem service
GIS	Geographical Information System
IBA	Important Bird and Biodiversity Area
InVEST	Integrated Valuation of Ecosystem Services and Tradeoffs
L	Litre
Mg	Metric tonne (1000 kilograms)
MOECAF	Ministry of Environmental Conservation and Forestry
N_2O	Nitrous oxide
NWCD	Nature and Wildlife Conservation Division
SOM	Soil organic matter
TESSA	Toolkit for Ecosystem Service Site-based Assessment
WWS	Wetland Wildlife Sanctuary

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EXECUTIVE SUMMARY

Over the past decade, several large-scale international studies, such as the Millennium Ecosystem Assessment and The Economics of Ecosystems and Biodiversity, have emphasised the importance of biodiversity conservation due to the benefits (known as ecosystem services) that nature provides to people. Through these and other studies, wetland ecosystems have often been highlighted for their important functional roles in providing clean water, reducing the risk of flooding and in supporting the livelihoods of numerous people worldwide. One global study estimated that the economic value of wetlands is \$3.4 billion yr^{-1} based on the variety of services these ecosystems provide for human well-being. Much of this value is over-looked when it comes to decision-making about land use in wetlands because these values do not appear in national financial accounts. Thus, over half of the world's wetlands have been degraded or destroyed in the last century, with Asia being one of the most impacted regions globally.

This report provides a summary of a rapid ecosystem services valuation of Moeyungyi Wetland Wildlife Sanctuary, Myanmar's only Ramsar site (wetland site designated due to its international importance for conservation and wise use). The purpose of this assessment is to raise awareness about the important economic and social values that wetlands, such as Moeyungyi, provide to people across all sectors and spatial scales. During a period of rapid developmental change in Myanmar, it is important that these non-market values are recognised and incorporated into decision-making.

Using a framework outlined in the Toolkit for Ecosystem Service Site-based Assessment (TESSA), the study identified that Moeyungyi Wetland Wildlife Sanctuary provides annual benefits of at least \$22 million (\$2,130 ha^{-1} y^{-1}) and that these benefits are received by local communities (c.12,000 households), downstream rice farms, and the international communities through global climate regulation and opportunities for tourism.

Given the likelihood that Myanmar will expand rice cultivation in the coming years, the impact of this on wetlands and the ecosystem services they provide needs to be addressed in order to make decisions that result in sustainable outcomes. In this preliminary study, an increase in water use for expanding agriculture in Bago town was not considered to have a dramatic effect on the benefits that the wetland currently provides because there is plentiful water supply into Moeyungyi lake from upstream dams. However, widespread rice cultivation could have more significant and detrimental impacts on: human health and wild species populations due to pollution from agro-chemicals; availability of water due to siltation and soil erosion; subsistence and livelihood incomes due to loss of habitat for species used traditionally by local people; and the potential to market wetlands as eco-tourism destinations. A full impact assessment at Moeyungyi Wetland Wildlife Sanctuary would require further exploration of the above factors and an analysis of the changing landscape across the catchment area.

Through Moeyungyi as a demonstration site, the results from this assessment provide information for local and national stakeholders on the broader importance of the conservation of wetlands for the benefit of people, due to the economic and social benefits they provide. By incorporating these ecosystem service values, sustainable management pathways for wetland sites across Myanmar could be achieved.

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1 INTRODUCTION

1.1 Wetland ecosystems

Wetlands are defined as areas of marsh, fen, peat land or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres (Ramsar, 2015). They are highly productive, complex, dynamic, ecologically sensitive and adaptive systems, supporting significant biological diversity.

Globally, wetlands cover approximately 12.8 million km^2 (8.5%) of the Earth's land area, of which inland wetlands cover at least 9.5 million km^2 (Finlayson et al. 1999). However, in the last century, it is estimated that almost half of the world's wetland area has been lost as a result of heavy pressure from human induced land use change through expansion of agriculture, increased demand for water use, infrastructure and urban development and intensive aquaculture (UNWWAP 2003). Although the rate of global wetland habitat loss has slowed, some geographic areas (especially East Asia) continue to convert large tracts of wetland habitat into other land uses.

Due to their complex nature, the functions that are lost when wetland areas are converted are often irreversible (Mitsch and Gosselink 2000). The continued degradation and conversion of wetlands to other land uses is not just impacting on biodiversity but also on the livelihoods of people living in and around wetlands and the wider human population. Action is needed both internationally and within nations to halt the loss of such a unique and important habitat for both biodiversity and people alike.

The Ramsar Convention

The Ramsar Convention on Wetlands of International Importance is an intergovernmental agreement that was established in 1971 in the town of Ramsar, Iran. It provides a framework for national and international action for the conservation of wetlands. As of 2015 there are 168 contracting parties that are committed to the Convention's mission of "*the conservation and wise use*[1] *of all wetlands through local and national actions and international cooperation, as a contribution towards achieving sustainable development throughout the world*". The objective of the Convention is thus to conserve wetlands for the benefits of people and nature.

Each contracting party must designate at least one site within its national jurisdiction for inclusion in the List of Wetlands of International Importance. Inclusion in this list requires the government to ensure conservation and wise use through maintaining the ecological character of the wetland, ensuring wetlands are included in planning decisions and providing adequate protection of their sites. There are over 2,186 Ramsar Sites currently designated covering more than 208 million hectares (Ramsar, 2015).

1.2 Ecosystem services from wetlands

Ecosystem services are the aspects of ecosystems that, actively or passively, produce human well-being (Fisher et al. 2009). These services are derived from ecological processes that occur within

[1] Wise use is defined as "the maintenance of their ecological character, achieved through the implementation of ecosystem approaches, within the context of sustainable development"

ecosystems such as nutrient cycling and soil formation (Figure 1), which when combined with some form of human input (such as labour or processing), result in benefits to people.

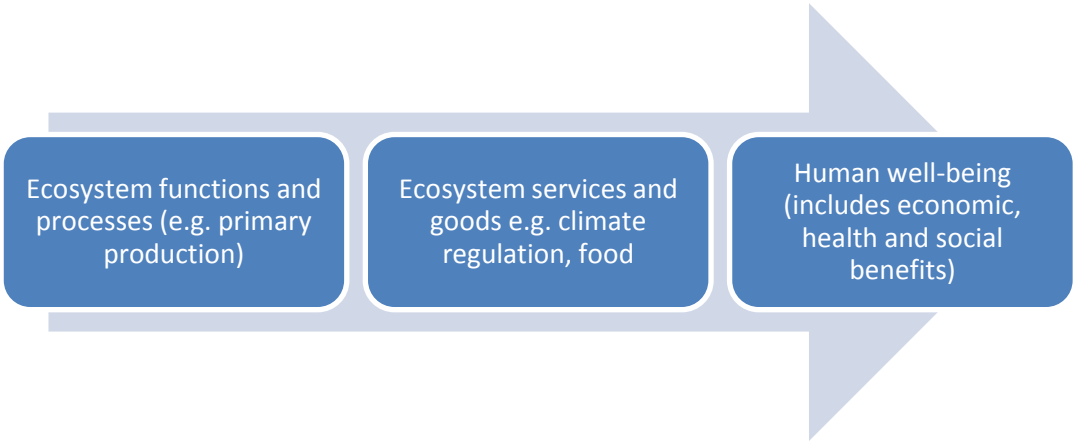

Figure 1. Conceptual framework of ecosystem services. Ecosystem services are produced as a result of ecosystem functions and processes and in turn provide goods and other benefits for human well-being. Ecosystem services represent non-use and non-material outputs from ecosystems (such as bequest values and spiritual values) as well as direct use values.

Many of these benefits that people derive from ecosystems are dependent on water and wetlands are integral to the global water cycle upon which all of life depends. The complex interactions of wetlands with the surrounding landscape underpin important ecosystem functions and processes. They provide, regulate and purify water so that it can be used for domestic purposes (drinking, cooking, cleaning etc.) and for industry. Wetlands also have an important role in the cultural identity of people and in spiritual practices and beliefs. They contribute to local climate control, erosion reduction and underpin a whole suite of economic industries such as inland fisheries, harvesting of raw materials, tourism and agricultural production which rely on the provision of water (Table 1).

Table 1. Inland wetland ecosystem services (adapted from Russi et al., 2013)

Ecosystem service	Role of wetland structure / function
Erosion control	Capture of sediments and soil retention
Flood protection	Regulation of the flow of water; water storage capacity
Water provision	Regular supply of water due to ability to store water in a reservoir; groundwater recharge
Water purification	Natural filtration through nutrient uptake; retention of particles and pollutants
Food	Habitat for fish, molluscs, other plants and animal species used for food
Raw materials (fibre, fuel)	Habitat for grasses, and other plants used for fibre and fuel
Spiritual / cultural values	Many cultures have spiritual values and religious practises associated with wetlands
Nature-based recreation and tourism	Aesthetic features of wetlands; open water; habitats for biodiversity
Carbon storage and sequestration	Vegetation and soils capture carbon dioxide and other greenhouse gases from the atmosphere

Local climate regulation	Water bodies are able to stabilise local temperatures. The microclimate at wetlands is often lower than surrounding areas

1.3 Why value wetlands?

Wetlands have an intrinsic value in that they exist as habitats for a wide range of fauna and flora. In addition to this, they have also been demonstrated to provide significant social and economic benefits to people. The economic benefit derived from the restoration of wetlands can rival the short-term economic benefits that people currently derive from the conversion of wetlands to other land uses (Hanley and Barbier 2009; Turpie 2010). The Economics of Ecosystems and Biodiversity (TEEB) estimated that 63 million hectares of wetlands around the world have an economic value of $3.4 billion per year with the highest benefits found in Asia (TEEB, 2010). However, the socio-economic benefits from wetlands have been over-looked and under-valued which has resulted in widespread modification, degradation, over-exploitation and conversion of wetlands habitats in favour of land uses that are more 'productive' yet in the long-term often lead to detrimental impacts and economic costs.

Given current trends in the loss of wetlands and the potentially huge ecological, social and economic impacts, it is becoming increasingly realised that the diverse values of wetlands need to be better understood, communicated and incorporated into decision-making. Combining improved understanding of biophysical interactions, socio-economic dependencies and valuation of the benefits that wetlands provide to people can help demonstrate the importance of wetlands to society and the economy and thereby help argue for their protection, wise use and restoration.

1.4 Economic valuation

Valuation is simply a process to aid decision-making because it involves trading off the worth of something against another. Hence, economic value is measured by what someone is willing to give up in other goods and services in order to obtain a good, service, or state of the world. Currently, most decisions are made on the basis of measures of manufactured and financial capital (a proxy for value) and overlook the other forms of capital, most importantly, natural capital[2] which is the foundation of all other types of capital (Figure 2). Informed decision-making therefore needs to incorporate the contribution of natural capital and ecosystem services to human well-being. The economic valuation of ecosystems is an approach that enables the values of ecosystems and biodiversity to be presented in an accessible and policy-relevant way.

[2] Natural capital is defined as the world's stocks of natural assets which include geology, soil, air, water and all living things. It is from this natural capital that humans derive ecosystem services, which support all human life.

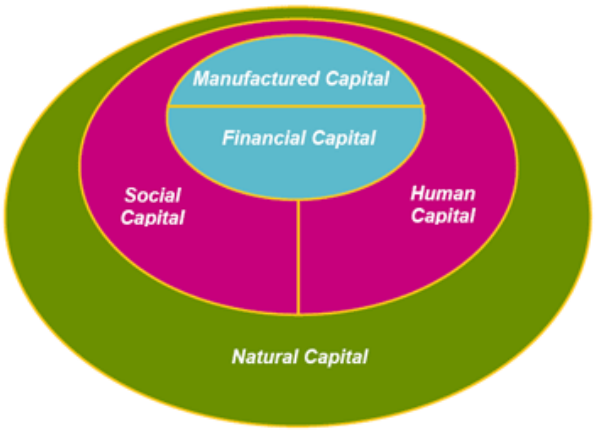

Figure 2. The five capitals model. There are five types of sustainable capital from where we derive the goods and services we need to improve the quality of our lives. Natural capital underpins all other forms of capital from which we derive our well-being. (Source: **Forum for the Future)**

However, this type of valuation can only capture part of the total value of ecosystems (Figure 3). Although economic valuation can be a useful metric, care should be taken not to overlook other important values to society that cannot be quantified or measured in this way. For example, ecosystems provide important livelihood benefits to communities, which may or may not be substantial in terms of financial rewards, but which are vital to sustaining their way of life such as ethical, cultural and other traditional values. It is arguable that these benefits cannot be adequately captured in an economic framework. However, with appropriate caveats an economic approach serves to increase the visibility of many - otherwise overlooked –values of nature and presents them for inclusion in decision-making about land use change and its impacts on people.

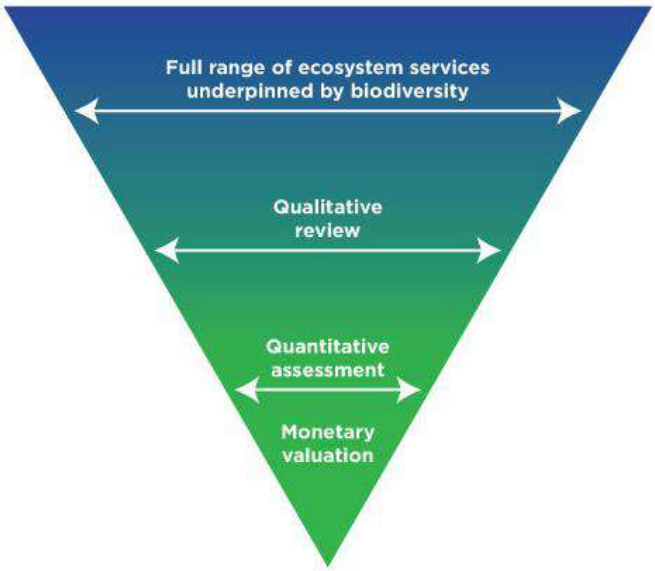

Figure 3. The limitations to measuring ecosystem services. It is important to use a range of methods to assess the value and importance of the full range of ecosystem services underpinned by biodiversity.

1.5 Objective of the study

The objective of this study was to undertake a pilot assessment of the economic value of the Moeyungyi Wetland in Myanmar to demonstrate the range of benefits that Moeyungyi wetland provides to people. The purpose of this is to promote awareness of the importance of the wetland by communicating the results of the assessment to local stakeholders and decision-makers. The results of the assessment will also be used to support the implementation of the Ramsar Convention in Myanmar and to advocate for increasing the designation of Ramsar sites in Myanmar.

2 SITE OVERVIEW

2.1 Location and characteristics

Moeyungyi Wetland Wildlife Sanctuary (WWS) is located in the administrative region of Bago in Myanmar (Figure 4), 25 km north-northeast of Bago town, east of the Yangon to Mandalay highway and 24 km west of the Sittuang river. The site is c. 10 m asl and the average annual rainfall is 3,200 mm and the wet months are June to September (though most rain falls in July and August). The Sanctuary covers 10,360 ha, 82% of which is freshwater marshes, 10% is permanently covered by the lake and 8% is cultivated land in the dry season (rice paddies). At the end of the wet season, water covers the whole site and in the dry season it recedes again.

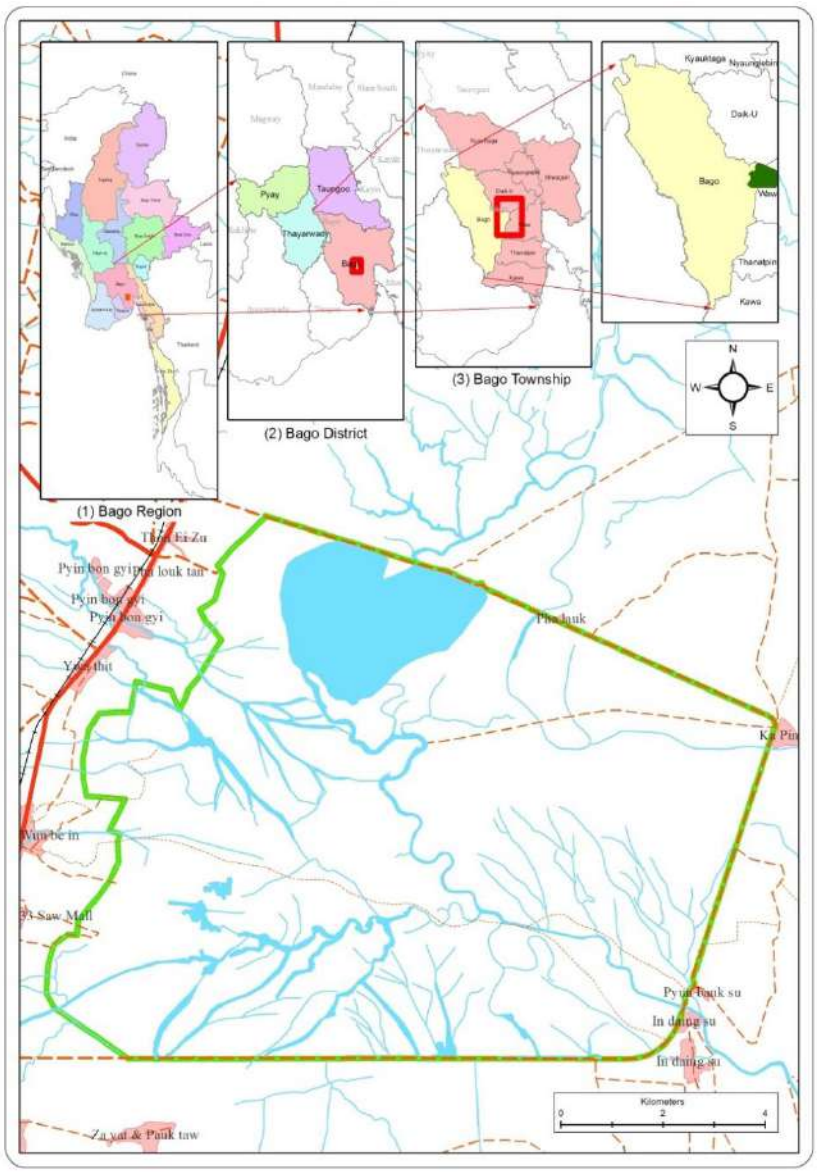

Figure 4. Location map of Moeyungyi Wetland Wildlife Sanctuary (MWWS)

Moeyungyi lake is a man-made reservoir that was constructed in 1873-1878 under management of the British Government to store water for irrigation and to use as an embankment for flood protection. During the dry season, storage water from Moeyungyi wetland was fed into Bago-Sittaung Canal not only for transportation (mainly of timber) but also for irrigating seasonal paddy fields. During the wet season, the lake serves as flood protection (Irrigation Department, Bago Region, 2014). Its main function now is to provide water

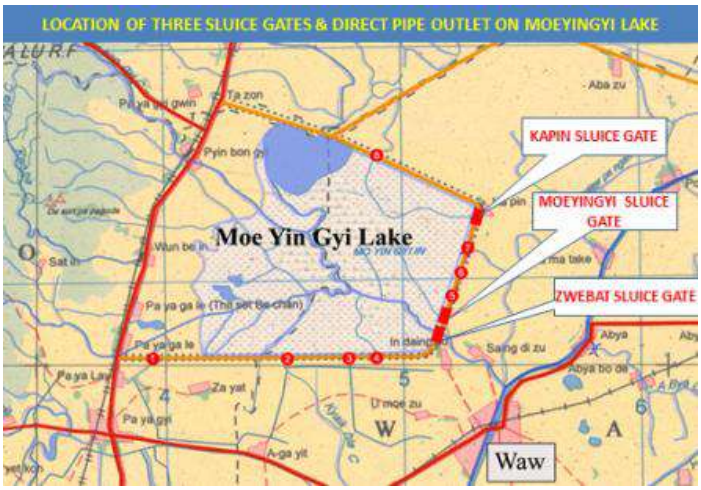

Figure 5. Location of the sluice gates at Moeyungyi WWS

flows to downstream areas under rice cultivation. There are seven natural creeks flowing into Moeyungyi Lake during the wet season. In the dry season Moeyungyi wetland is recharged with water from several upstream dams (Irrigation Department, Bago Region, 2014).There are three major outflows with three sluices (Zwebat sluice gate, Moeyungyi sluice gate and Kabin sluice gate) in the eastern bund that drain water downstream to the Sittaung river.

2.2 Biodiversity

The Sanctuary is an important site for a wide range of wildlife including many resident and migratory bird species. Moeyungyi WWS qualifies as an Important Bird and Biodiversity Area (IBA) due to the presence of critically endangered birds species and significant congregations of migratory species (Table 2). Waterfowl censuses have taken place at the site since 1987 providing useful long-term data on the trends of bird populations. In 2014, a rapid survey found 133 species of birds with a total population count of 18,364 (BANCA, 2014). Herpetofauna, mammals, insects and fish are other important animal taxa found within the site with a high diversity of plant species also being present. As a result of the wetland's important fauna and flora, it is an interesting place for researchers from different academic fields.

Table 2. Populations of IBA trigger species

Species	IUCN category
Baer's Pochard *Aythya baeri*	CR
Lesser Whistling-duck *Dendrocygna javanica*	LC
Cotton Pygmy-goose *Nettapus coromandelianus*	LC
Spot-billed Pelican *Pelecanus philippensis*	NT
Greater Spotted Eagle *Clanga clanga*	VU
Sarus Crane *Antigone antigone*	VU
A4iii *Species group - waterbirds*	

Antigone antigone (Sarus crane, listed as vulnerable by IUCN) (Thet Win, BANCA)

Morenia occellata (Myanmar eyed turtle, an endemic turtle listed as vulnerable by IUCN) (BANCA)

2.3 Socio-economic overview

The wetland is surrounded by seventeen villages with an estimated population of 65,000 people in 12,000 households (Bago and Waw Township Administrative Offices, 2014). According to previous survey data collected by BANCA from eight of the villages (BANCA, 2014), most people derive their livelihoods from either fishing or agriculture (rice cultivation) directly associated with the Moeyungyi WWS. Fish is the main protein source for local people. The average daily household income is 3001 – 6000 MMK (US $3-6) and 77% of the population is reported to be directly dependent on the wetland for their livelihood (BANCA, 2014). According to the interview survey of BANCA, in some villages, drinking water is predominately taken directly from the lake without treatment. Many socio-economic activities occur on the lake and around it, including fishing, water buffalo and cattle grazing, cultivation of rice for subsistence use, harvesting of the padoma lotus and duck-rearing.

Small scale industry is also an important component of the communities' livelihood. It includes, rice milling, and industry for Ngapi (shrimp paste), cheroot (tobacco), lotus textiles and dried stalks of pein (Taro, *Colocasia esculenta)*.

Fishing on Moeyungyi lake (BANCA)

Cleaning the harvested lotus stalks (BANCA)

2.4 Management history

MOEYUNGYI WWS is managed by the Nature and Wildlife Conservation Division (NWCD) under the Ministry of Environmental Conservation and Forestry (MOECAF). The wetland was designated as a bird sanctuary in 1986 and was given Ramsar status in 2004. Moeyungyi WWS is still the only Ramsar site in Myanmar, despite there being a further 18 wetland sites that qualify (Davies et al. 2004).

Historically there has been weak capacity at the site, with 12 staff (one park warden and other support staff) currently assigned to the site. The Forest Department are developing a five year management plan though at the present time there are limited ongoing conservation activities. Patrolling, law enforcement and awareness raising programmes are undertaken to stop illegal fishing, hunting poaching and limit the extension of agriculture land. In recent years a boardwalk has been constructed through the site for visitors.

The boardwalk at Moeyungyi WWS (BirdLife)

Children viewing the wildlife (BANCA)

Conflict over resource use occurs when the water is slowly drained at the end of the wet season by the Irrigation Department. The resulting shallow waters encourage illegal electric shock fishing and encroachment of rice paddies.

2.5 Key threats

Despite conservation action at the site by the park warden and NGOs such as the Biodiversity And Nature Conservation Association (BANCA) the condition of the wetland is very unfavourable and threats remain high (BirdLife International, 2015). The most serious threats to the wetland at the present time are bird hunting and trapping with nets; electric shock fishing (which has reduced fish stocks considerably); trading of species and land encroachment by paddy fields (BANCA, 2014). Other reported high threats are invasive species (such as *Mimosa pigra*), pollution from use of fertilisers and pesticides, livestock raising, water use and population growth (see Table 3).

Table 3. Ranking of threats undertaken as part of the Biodiversity and Socio-Economic Assessment on Moeyungyi Wetland Wildlife Sanctuary (BANCA, 2014).

Very High	High	Moderate	Low
Bird hunting / trapping	Invasive species	Insect catching using nets	Trapping of small mammals for food
Electric shock fishing	Use of fertilisers/pesticides	Poor waste disposal	Infrastructure development (tourism)
Trade of species	Livestock raising	Flooding	
Agricultural expansion	Use of water	Fuelwood collection	
	Population growth		

3 METHODS

3.1 TESSA

3.1.1 Rapid ES assessment

In this study, methods from the Toolkit for Ecosystem Service Site-based Assessment (TESSA; Peh et al 2014) were used to estimate the biophysical and monetary values of ecosystem services provided by Moeyungyi WWS, and to compare such values with those of the most plausible alternative state

(see Section 3.1.3). This toolkit was chosen for its relatively simple methods, which enable rapid collection of locally-relevant, site-scale data – relevant to decisions being made regarding the management of the wetland (such as by the Irrigation Department of the Ministry of Agriculture and Irrigation and the MOECAF). TESSA is ideal for rapid ES assessment as it can be applied without substantial investment of staff time, and without having to rely on modelling or GIS specialists to run the currently available tools such as InVEST (Tallis et al. 2013) or ARIES (Bagstad et al. 2011).

The MOEYUNGYI WWS ecosystem services values were first identified and then quantitatively assessed under the current management regime. The data from the immediately adjacent rice paddy was used to estimate what the ecosystem service value of this wetland area would be if further expansion of rice cultivation were to occur (the plausible alternative state). This study built on available data from previous rapid assessment studies on the biological and socio-economic status of the Moeyungyi Wetland, conducted by teams of scientists from BANCA collaborating with researchers from Bago University, local villagers and staff from Moeyungyi, over the period from 24th February to 2nd March 2014.

3.1.2 Preliminary scoping

Preparatory meetings were held from 18 to 22 December 2014. During the meetings, existing information and data was collated and the feasibility of this assessment was discussed. In order to collect the necessary information for this assessment under the restricted circumstances, two scoping workshops and two group interviews were designed. A preliminary scoping workshop of key stakeholders involved at Moeyungyi WWS was then convened on 6 and 7 February 2015. The participants included government staff from the Environmental Conservation Department, Irrigation Department, Department of Agriculture, Department of Fisheries, Moeyungyi Park Warden Office (under management of the NWCD of the Forest Department, the Township Administrative Office of Bago and Waw Township and representatives from eight of the 17 villages (including Pyi-bon-gyi, Wunbeinn, Tarsone, Thone-eain-su from Bago Township and Pha-lauk-tan, Saitisu, Pyune Su and Kapin Waw townships) around Moeyungyi WWS. This scoping exercise identified the main ecosystem services provided by Moeyungyi WWS as (1) global climate change mitigation in terms of carbon storage; (2) nature-based recreation; (3) flood protection; (4) provisioning of water; (5) provisioning of wild goods; and (6) rice production during the dry season. General information on fishing activities (Appendix 1) and rice cultivation (Appendix 2) was then gathered as participants had good local knowledge of these activities.

Preliminary scoping workshop (BirdLife)

3.1.3 Alternative state

To understand the benefit that Moeyungyi WWS provides through ecosystems services it is necessary to compare these services to those that would be provided if the WWS was somehow different. This can be referred to as the 'plausible alternative state' and is specific to the local situation at the site.

At Moeyungyi WWS, the Irrigation Department releases water from the wetland to the downstream area around Bago for irrigation in December each year (Figure 6). This enables 16,520 ha of rice paddy to be cultivated in this area during the dry season. The flow of water into Moeyungyi WWS from the upstream catchment maintains the water level of the permanent Moeyungyi lake at 7.0 m.

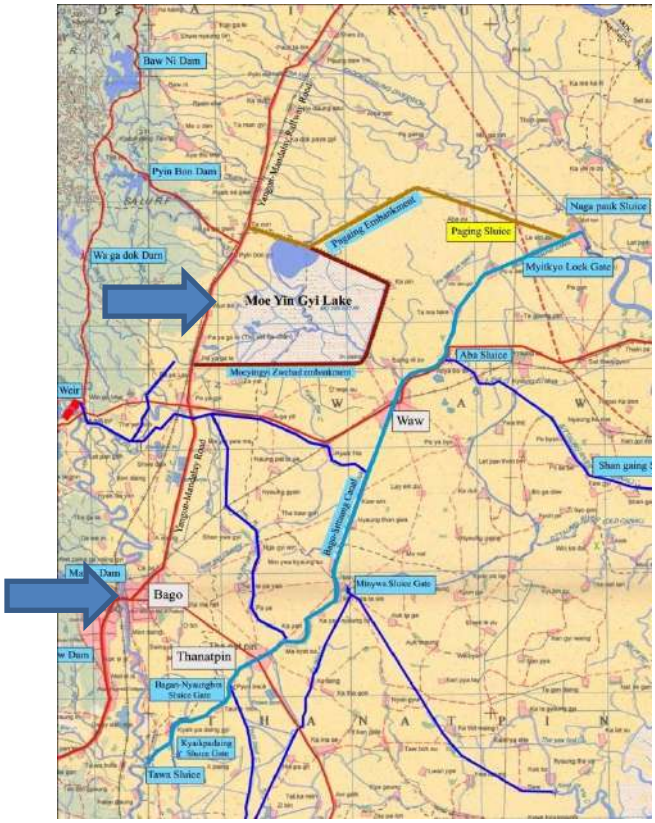

Figure 6. Location of Bago town in relation to the Moeyungyi WWS. Water is released in December each year via the Bago-Sittuang canal.

Given the aspiration of Myanmar to become a major rice exporting nation (Pratruangkrai 2015), the Irrigation Department has the intention to increase the export of water from Moeyungyi WWS for rice cultivation (Myint Soe, U., Irrigation Department, pers comm). It is likely that the area of paddy supported by the water from Moeyungyi WWS will be doubled in the near future. In consultation with local stakeholders, we therefore anticipate that the most plausible alternative state for the WWS would be the increase in area of paddy cultivation downstream at Bago by 100% (i.e. to 33,040 ha).

Assuming a constant in-flow from upstream, the level of the Moeyungyi Lake would be likely to decrease under this alternative state. This is based on an event which occurred in 2013, when a major in-flow canal was blocked by soil erosion, leading to a fall of water levels to 5.8 m while the Irrigation Department maintained the annual supply of water for irrigation outside Moeyungyi WWS

during that year. Some conservation practitioners and staff from the Nature and Wildlife Conservation Division have raised their concern that the newly-exposed marshland aggravated by the reduction of water is likely to attract further rice paddy cultivation. Therefore, a comparative assessment of the ecosystem services provided by Moeyungyi WWS in its current state and in its most likely alternative state was carried out, in order to elucidate the trade-offs between the increased provisioning of water for irrigation downstream and the current management regime.

3.1.4 Field work and data collection

Based on the expert opinion of BANCA staff and the preliminary scoping workshop, harvested wild goods (fish, aquatic plants for buffalo grazing, molluscs and lotus stalks), water provision (for domestic use and irrigation), flood protection, nature-based recreation and global climate change mitigation in terms of carbon storage were identified as key ecosystem services to measure. These services delivered by Moeyungyi WWS in its current state (i.e. with the present irrigation regime, see Table 4) and in its alternative state with more water use for irrigation (referred to as 'alternative irrigation regime') were assessed by using TESSA. Thus, the evaluation of the alternative state includes all ecosystem services measured in the current state, as well as significant increase in some services that the alternative would provide (e.g. use of water for irrigation and rice production). All values were estimated in 2014 US dollars using an exchange rate of 1000 Burmese Kyat = 1 USD.

Using a topographic map of Moeyungyi WWS, stakeholders estimated how the land use within the wetland would change if the rice paddies irrigated by the water from the wetland were to be doubled, from 16,520 ha to 33,040 ha, during the dry season (Table 4). They reported that 1,100 ha of the newly-exposed marshland caused by the drop in water levels would be converted to rice paddy. To measure the rice production that would be delivered under this alternative state, paddies around the wetland were selected, as they best represented the paddies within the wetland. In consultation with BANCA, two villages were selected for the household surveys to gather data on the quantity and net value of fish and rice harvest: (1) Pyin Pon Gyi, located northwest of Moeyungyi WWS and (2) Kapin, northeast of Moeyungyi WWS. These villages – where a majority of households either harvest fish from the wetland or grow rice – reflected the socio-economic characteristics of all 17 villages around the wetland. Information on other harvested wild goods (buffalo grazing, molluscs and lotus harvesting) was provided by staff of NWCD.

Table 4. Land cover change. Estimated land cover under the current (present irrigation regime) and alternative (future irrigation regime) states of Moeyungyi wetland at the driest and the wettest period of the year.

	Area under current irrigation regime (ha)	Area under alternative irrigation regime (ha)
	Dry season	
Paddy	800	1100
Marshes	8524	8224
Open water body	1036	1036
Total	**10360**	**10360**
	Wet season	
Paddy	0	0
Marshes	7252	7252
Open water body	3108	3108
Total	**10360**	**10360**

Gathering of villagers for household questionnaire survey (BirdLife)

Reporting of results from the focus group discussions (BirdLife)

4 ECONOMIC VALUATION

4.1 Global climate change mitigation

Global climate change mitigation was estimated based on changes in carbon stocks between the two states (current irrigation regime; alternative irrigation regime). The total areas of different habitat types in both the current and alternative state were identified through consultation with local experts (see Table 4). Estimates of carbon stocks in the above-ground biomass, below-ground biomass, litter and dead wood for paddy and marshes were taken from Anderson-Teixeira and DeLucia (2010). The substrate at the bottom of the open water body and the soils of paddy and marshes were considered as inland wetland mineral soils, 'gleysols' (IPCC, 2013) and their unit value for carbon stocks was from the Intergovernmental Panel on Climate Change (IPCC) tier 1 database (IPCC, 2013). The total carbon stock of the wetland was estimated to be the weighted average of the values between the dry (eight months) and the wet seasons (four months). The overall economic value of these carbon stocks and how it differed between states was estimated using the US Government social cost value of carbon from 2007 (Greenspan Bell and Callan 2011) at \$88.50 $Mg^{-1}C$, converted from $\$Mg^{-1}CO_2$ to $\$Mg^{-1}C$, and adjusted to 2014 prices based on the GDP deflator index given by the International Monetary Fund (2015) (Appendix 1).

Carbon storage in the current state is estimated at over 1.03 million tonnes (Mg) for Moeyungyi WWS (based on weighted average between dry and wet seasons; for these values see Appendix 2). As a result of conversion of marshes to paddy in the alternative state, carbon storage would decrease by an estimated 2% to 1.02 million Mg which results in the potential loss in stock value of \$1.60 million. Nevertheless, the estimates of carbon stocks for the current and alternative states were subject to wide nominal errors (Appendix 2), and the broad estimate ranges do not indicate the significance of the change. Therefore, no benefit of avoided carbon loss is assumed under the current state.

4.2 Greenhouse gases emission costs

Greenhouse gases emissions (carbon dioxide, CO_2; methane, CH_4; and nitrous oxide, N_2O) for the wetland under the current and alternative irrigation regimes were assessed based on unit values

from Anderson-Teixeira and DeLucia (2010), Kemenes *et al*. (2011) and Soumis *et al*. (2004). The net emission of each gas (in tonnes ha^{-1} y^{-1}) was converted to tonnes CO_2 equivalents (CO_{2eq}) ha^{-1} y^{-1}. The sum of all CO_2, CH_4 and N_2O emitted by the wetland and CH_4 from buffalo in the wetland gave a net global warming potential (over 100 years – GWP_{100}) ha^{-1} y^{-1} under each state. These values are also expressed as a total value of tonnes CO_{2eq} y^{-1} for the whole wetland. The standard convention of positive values indicating net atmospheric warming was applied. A monetary value of overall greenhouse gas fluxes was then estimated using a range of carbon values and presented here using the US Government social cost value of carbon from 2007 (Greenspan Bell and Callan 2011) at \$88.50 $Mg^{-1}C$, converted from \$$Mg^{-1}CO_2$ to \$$Mg^{-1}C$, adjusted to 2014 prices based on the GDP deflator index given by the International Monetary Fund (2015) (Appendix 1).

Net greenhouse gases emitted in the current state are estimated at 130,000 Mg CO_{2eq} annually (based on weighted average between dry and wet seasons; for these values see Appendix 2). In the alternative state, net emissions of greenhouse gases would increase by an estimated 0.5%. Given the wide nominal errors of the estimates of net greenhouse gases emissions for both states, it is conservatively assumed that there was no benefit of avoided greenhouse gases emissions under the current state.

4.3 Water provision

4.3.1 Domestic use

Previous surveys conducted by BANCA (2014) found that 52% of the households in 8 villages around the wetland used the water directly from Moeyungyi WWS for domestic purposes. Therefore it was estimated that 6,240 households around Moeyungyi WWS rely on the water from the wetland. Household questionnaires were conducted across two villages to gather data on the quantity of water from the wetland used directly for domestic purposes (for interview questions see Appendix 3). Based on variance in the amount of water from the wetland used in the first ten interviews, we used a power analysis to calculate the minimum sample size need to estimate the annual value of water from the wetland used to a precision level of ±15 % (n=21). As a result 22 interviews were conducted.

The annual amount of water from Moeyungyi WWS collected by an average household for domestic use was estimated at 145,513 (±24,938) L. The mean annual value of this benefit was calculated as \$1,280 (± 219) per household, based on the price of water sold in the village (\$0.04 per gallon). Hence the annual net economic value of water from the wetland for domestic use was estimated to be \$7.99 million. All respondents reported that water from the wetland is abundant throughout the year, and that they have never experienced any shortage of this resource. Therefore, based on our assumptions, we don't expect the alternative irrigation scheme to have a significant impact on the current water supply from the wetland and its value for domestic use.

4.3.2 Irrigation

An important function of Moeyungyi WWS is to store water for the irrigation of rice paddies around the region. During the dry period each year, the wetland supports one season of rice farming in 16,520 ha of paddies. In addition, the wetland also irrigates the rice paddies within the site (800 ha). We estimated its value as the cost for irrigating these paddies if the water from the wetland were not available.

Based on the price of water for irrigation from a nearby dam, we estimated the annual net benefit of irrigation as $83,400. With an expansion of rice paddies both within (1,100 ha) and outside the wetland (33,039 ha), the annual net benefit was estimated to be $164,000 under the alternative state.

4.4 Flood mitigation

The low-lying paddies adjacent to Moeyungyi WWS are at risk of serious floods if the embankments fail during the wet season from June to September. Rice paddies have no flood storage capacity but the wetland was built with a storage capacity of 17.3 million m^3 (Irrigation Department, 2015). According to the Irrigation Department, the flood storage capacity of Moeyungyi WWS has the potential to protect 16,200 ha of rice paddies in the area. The total annual value of flood protection benefit was estimated as the annual value of the avoided damage to wet season rice paddies. No property would be directly affected by flood damage as houses are built on stilts or above flood water level. Hence we multiplied the mean net value per ha for one season of rice cultivation by the total area protected from floods used for wet season paddy and deducted the costs of annual maintenance of the embankments ($32,000 annually according to staff from the Irrigation Department) to estimate the net annual flood protection benefit as $458,000. The alternative state of the wetland would provide the same flood protection benefit.

4.5 Harvested wild goods

4.5.1 Fishing

At the preliminary scoping workshop, the village representatives identified fish as the most important wild product harvested from the wetland at community level. Thirty-three household questionnaires (for the interview questions see Appendix 4 & 5) were conducted across two villages to gather data on the quantity and net value of harvest from fishing activities. The participating households with income derived mainly from fishing activities within the wetland were randomly chosen by the village chiefs. Sample size was determined by plotting a running mean of net economic benefit per household. The mean net value per household for fishing was calculated, and then applied to the estimated total number of households that harvest fish from the wetland. The opportunity cost of family labour was valued at 'market rate' since there was a high seasonal demand for labour.

The mean net value of fish per household was estimated as $3,360 (± 300). The mean net value of fish per household was not significantly different between the two villages. Based on Park Warden Office data, there were 4577 households around Moeyungyi WWS harvesting fish at the wetland. Hence the annual net economic benefit from fish harvesting was estimated as $15.4 million. The annual net benefit of fish harvesting under the alternative state is assumed to remain the same as the drop in water level is unlikely to be significant enough to change the fish population.

4.5.2 Lotus harvesting

Each day over a period of nine months a year, a total of 20 people are allowed to harvest lotus stalks in Moeyungyi WWS; this takes place from July to March. Data on the annual net value of harvest was gathered from staff of Moeyungyi WWS Park Warden Office. We estimated that 4.86 million lotus stalks were harvested annually from the wetland. As the harvesting method is simple and the stalks

are processed locally, the costs of harvesting and transport were valued at zero. The annual net benefit of lotus harvesting was estimated as $19,400 for both current and alternative states.

4.5.3 Molluscs

Based on the data from Park Warden Office, a total of 34,200 ducks are allowed to feed on the molluscs in Moeyungyi WWS throughout the year. We estimated its value as the annual cost of the molluscs consumed by these ducks. Based on information of the total amount of molluscs (expressed in terms of bags) required by 1,000 ducks per day and the cost per bag from the same source, the annual net benefit of duck feeding on the wetland was estimated as $74,900. There is no difference in the annual net benefit provided by the molluscs in the wetland for the alternative state.

4.5.4 Buffalo grazing

Buffalo grazing is carried out in Moeyungyi WWS for eight months from October to May. Based on data from the Park Warden Office, a total of 5,375 buffalo grazed on the wetland annually. We estimated its value as the annual cost of the grass consumed by these buffalo. Based on information from Moeyungyi staff, the amount of grass (expressed in terms of bundles) a buffalo consumes daily and the cost per bundle, the annual net benefit of grazing on the wetland was estimated as $774,000. The same annual net benefit of buffalo grazing was also associated with the alternative state as the number of grazing buffalo allowed to graze into the wetland would be maintained.

Duck rearing on the lake (BirdLife)

Buffalo inside the wetland (BANCA)

4.6 Nature-based recreation

The opportunity to view wetland birds, to walk on the board walk in the marshes and to take a boat ride into the open lake attracts domestic visitors and international tourists to Moeyungyi WWS. The annual value of nature-based recreation was estimated from the direct expenditure by visitors to the site and the 2012-2013 records of visitor numbers from the Park Warden Office. We carried out a field survey at the entrance of the sanctuary on four days (5 – 8 February 2015) during dry season. We used a questionnaire survey to obtain information on distance travelled, mode of transport, accommodation, and expenditure in the shop and restaurant (for interview questions see Appendix 6).

We interviewed 47 individuals and counted a total of 274 visitors. Most of the visitors (97%) were domestic day-trippers from within the region and international tourists represented 3% only. Based

on the data from the Moeyungyi WWS Park Warden Office, a total of 7,334 people visited Moeyungyi WWS in 2012-2013 (7,031 domestic visitors; 303 international tourists).

From the total reported expenditure on travel, food and drinks, the annual recreation revenue from the national visitors was estimated to be $19,300; based on variance in expenditure reported in the first ten interviews, the precision level of this estimate was at ±32%. The annual recreation revenue from the international tourists was estimated as $54,200. The overall annual recreation revenue was estimated at $74,000 with the majority of the annual revenue (74%) from the international tourists. Note that this is likely to be a conservative estimate of the actual tourism value of the wetland as we did not include a willingness-to-pay survey in this assessment which would identify the additional value (beyond actual amount of money spent) that people attribute to the site for the benefit of nature-based recreation. It was assumed that all respondents would visit the area if it was under the alternative state – as the area affected by the paddy encroachment was relatively small and remote.

Board walk in the marshes (BirdLife)

Spot-billed Pelican (Near Threatened species) (BANCA)

4.7 Rice cultivation

At the preliminary scoping workshop, rice was identified to be the only cultivated product in the area. Twelve household questionnaires (for the interview questions, see Appendix 7 & 8) were conducted across two villages to gather data on the quantity and net value of harvest for the paddy adjacent to the wetland. The respondents from these farming households were randomly selected by the village chiefs. Sample size was determined by plotting a running mean of the net economic benefit per household. The mean net value for rice was calculated and applied to the total harvested area in the current state and the expected harvested area in the alternative state. Costs for water, equipment and processing were subtracted from the total and the opportunity cost of family labour was valued at 'market rate' since there was a high seasonal demand for labour.

Based on a previous survey conducted by BANCA (BANCA, 2014), it was estimated that 27% (weighted mean of eight villages) of the households farm paddies. The mean net value of rice cultivation adjacent to the wetland was estimated as $548 (± 114) per ha. The areas within the wetland encroached by rice paddies during dry season under the current and alternative states were estimated as 800 ha and 1,100 ha, respectively. The annual net economic benefit from rice cultivation within the wetland under the current management regime was estimated as $438,000

whilst the annual net benefit of farming rice within the wetland under the alternative management regime was $603,000.

Rice cultivation is the main livelihood activity for 27% of villagers living around the wetland (BirdLife/BANCA)

4.8 Management costs

Information on annual management costs of Moeyungyi WWS which included salaries for 12 full-time and three part-time staff, and operational costs was obtained from Moeyungyi WWS Park Warden Office. This on-going management cost of the wetland was estimated to be a total of $22,300 y^{-1}.

4.9 Summary of economic value

The overall net benefit generated from annual ecosystem service flows at Moeyungyi WWS, minus management costs, is estimated at $22,100,000 ($2,130 ha^{-1}). The carbon stock is estimated at $91,600,000 ($8,840 ha^{-1}). The overall net benefit generated from annual ecosystem service flows (water for irrigation and rice production) associated with an increase in water use for irrigation, minus the management costs, was $245,000 ($24 ha^{-1}; see Table 5). According to our estimates, and the limited scope of this study, the alternative irrigation regime would not reduce benefits to local people (no change in domestic use of water, flood protection, harvested wild goods and nature-based recreation) or global beneficiaries (no significant change in greenhouse gases emissions and carbon storage). However, an increase in the export of water outside the wetland would be likely to benefit the local and regional population (rice farming; Table 6).

Table 5. Net values of all services (for which economic values were available) resulting from an alternative irrigation regime (i.e. increase in water export for rice paddies)

	Current irrigation regime ($) (10,360 ha)	Alternative irrigation regime ($) (10,360 ha)	Difference ($) (10,360 ha)	Difference ($ ha^{-1} y^{-1})
Service (flow) ($ y^{-1})				
Water for irrigation	83,420	164,431	81,012	8
Rice production	438,400	602,800	164,400	16
Management cost	-22,300	-22,300	0	
Net annual benefit ($ y^{-1})	544,120	789,531	245,412	24
Net annual benefit ($ y^{-1} ha^{-1})	53	76	24	

Table 6. Magnitude of change in delivery of different services under the alternative irrigation regime (i.e. exporting more water from wetland to Bago township), shown for beneficiaries at the local, (villagers living around Moeyungyi wetland only), regional (includes people from nearby towns and cities) and global scale (includes foreign tourists).

Ecosystem service	Location of beneficiaries			Level of confidence
	Local	Regional	Global	
Change in annual flows				
Water for irrigation	↑	↑↑	=	High
Water for domestic use	=	=	=	Medium
Flood protection	=	=	=	High
Harvested wild goods	=	=	=	Medium
Nature-based recreation	=	=	=	Low
Rice production	↑	↑↑	=	Medium
Change in stock				
Carbon storage	=	=	=	Low

4.10 Limitations

Given that rapid nature of this study, there are several limitations of the study. The use of TESSA involved a trade-off between cost (time, resources), simplicity, utility versus in-depth analysis and inclusion of complex factors (e.g. discount rate, landscape impacts).

Firstly, it should be noted that the overall valuation of the ecosystem services of Moeyungyi WWS will be conservative. We have included only a limited range of services that could be easily measured and that are included in the current version of TESSA. Therefore we had to omit benefits such as those relating to health, or cultural services (exception of recreation) that are likely to be provided by Moeyungyi WWS simply because we could not measure them.

One of the most significant omissions is the evaluation of water quality. Local rice farmers apply fertilisers and pesticides to their paddy fields within the wetland in order to increase the productivity of the crop. The input of agrochemicals to the surface water at Moeyungyi WWS is likely to be impacting on the overall water quality of the wetland, though we were unable to explore this because the wetland has numerous tributaries upstream which makes water quality studies complex to undertake when there are time and budget limitations. As the vast majority of people living in some villages depend on untreated wetland water for drinking, cooking and bathing and other domestic purposes, the risk of health issues from pollution is evident. There may also be negative impacts on the biodiversity of lake, resulting in reduced fish catches, mollusc populations etc. In terms of effects downstream, the wetland may be able to naturally reduce the nitrogen loadings that occur downstream (to the population of Bago) through storage and nutrient cycling, but again, since this has not been measured, the impact of agrochemicals on the wider beneficiaries of the lake is currently unknown.

We were also unable to make an assessment of the sustainability of the current rate of harvesting of wild goods from the wetland. Although data from BANCA's assessment in 2014 suggests that overall biodiversity is relatively stable, this has not been directly assessed in terms of the quantity and quality of harvested goods over time. Additionally, illegal harvesting methods – such as electric shock fishing – are reported to be having devastating effects on certain populations (BANCA, 2014).

The valuation of nature-based recreation is a conservative estimate as we looked only at the actual spend of visitors (revealed preference) and did not include a willingness to pay survey (which would provide information on additional value not currently captured). It is also possible that the value of nature-based recreation will increase over time due to the increasing number of tourists visiting Myanmar in recent years and constant improvements in the on-site facilitates at Moeyungyi (e.g. opening of education centre in 2014 and installation of electricity generators in 2015) attracting more visitors. However, with the increased benefits may also come some costs as uncontrolled tourism can have negative impacts on habitats and species. Our study did not assess this aspect of change over time.

Finally, the results have varying levels of uncertainty related to the accuracy and precision of the data. We used a simple scale of 'high', medium' and 'low' to assess the degree of error, as recommended in TESSA (Table 6). Based on these standards, our confidence is rated 'high' for services related to irrigation and flood protection; 'medium' for values of water for domestic use, harvested wild goods and rice production; and 'low' for nature-based recreation and carbon storage. The reason for a low confidence in nature-based recreation is because the range of values obtained from the sample (n=47) was high, suggesting a high error around the mean values used to calculate the total. More surveys would improve this estimate. For carbon, look-up values were used from the published literature which generally implies a lower confidence in the results than if they were locally obtained on site through appropriate survey methods. Nevertheless, errors should be the same for both the current and alternative states.

5 DISCUSSION

This is the first study to estimate some of the economic values provided by the Moeyungyi wetland and perhaps the first such assessment of a wetland in Myanmar. It demonstrates the vital importance of conserving this wetland for the 12,000 households that derive direct benefits from it (food, fibre, irrigation water, free grazing land), the users downstream to whom water is released in the dry season for rice paddy cultivation, and the global community in terms of its role in contributing to global climate regulation and the tourism and recreation values associated with viewing the unique biodiversity.

Our estimation of the economic value of ecosystem services of Moeyungyi WWS at $22.1 million y^{-1} is a conservative estimate due to the limitations of this study as outlined above. However, it demonstrates that there are important values that need to be incorporated into any future decision-making about the wetland and wider landscape development activities that may impact upon it.

In order to put this value in context, we compared the net benefits provided by Moeyungyi WWS under the current irrigation regime with the net benefits that would be obtained if more water was released to irrigate twice the current area of rice paddies downstream. Given the resulting change in land use within the WWS would be relatively small, we estimated that the overall impact on those ecosystem services that we were able to measure is small, with benefits being $24 ha^{-1} y^{-1} greater under the alternative (increased) irrigation regime, suggesting that the economic value of this wetland could be enhanced if more water from the wetland is exported for irrigation.

However, this initial result should be considered with caution due to a number of impacts that could occur outside of the wetland and the limitation mentioned in Section 4.10. The recharge of the water in Moeyungyi depends on the constant in-flow of water from natural creeks and upstream dams. Land use change upstream, such as logging, could cause siltation in the tributaries upstream; which in turn would reduce the in-flow rate. If more water is being extracted for irrigation downstream, it will be challenging to maintain the water level. Similarly, land clearing upstream also causes serious soil erosion that could block the major in-flow canal, as happened in 2013. If this were to occur again under the alternative irrigation regime, the water could drop to an unprecedented low level which may be harmful to the flora and fauna. There would also be a significant increase in carbon emissions resulting from the expansion of rice cultivation downstream in Bago township. Since we were just looking at the economic valuation of the WWS this impact was not included as part of the study, but is an important consideration from a landscape perspective.

As mentioned in the limitations, we were unable to measure water quality within the WWS. Water quality may deteriorate with increasing paddy cultivation through the input of more agrochemicals to the surface water. This has important health implications for the villagers who depend on the wetland for their potable water. During the BANCA study in 2014 it was realized that the use of chemical fertilizers and pesticides could be a serious threat for the water quality not only for the aquatic life but also for those depending on the water from the wetlands.

Therefore, the broader implications of the potential to increase withdrawal of water from Moeyungyi WWS associated with agro-irrigation need to be assessed in relation to land use management in the wider landscape and more intensive studies of those aspects that were beyond the scope of this study.

The beneficiaries of Moeyungyi's wetland values are found across sectors and spatial scales. The immediate benefits that the wetland provides are received by the local communities who are directly dependent on the wetlands for their livelihoods. These people are able to access water supplies, harvest food, lotus stalks and other products from which they derive an income and subsistence benefits for free. Without access to these benefits, the communities would have to find alternative sources of income. Thus it is essential that the biodiversity status of the wetland is secured. Raising awareness among the local community, management authorities and wider beneficiaries of the wetland (including regional and global beneficiaries) could foster greater participation and investment in sustainable management of the WWS.

Given the development plans for the country, there may be an opportunity for innovative financing to support the continued conservation of Moeyungyi wetland and its users. For example, if rice cultivation is to expand nationally (as is anticipated based on recent reports), this is likely to impact more and more on Myanmar's important wetlands and the subsistence livelihoods that people derive from them. Particularly if foreign companies are interested to invest in large-scale agriculture development in Myanmar, there may be scope for the establishment of financing mechanisms or benefit-sharing schemes to ensure that the beneficiaries (downstream rice farmers) compensate the suppliers (local people and park management authorities) who ensure the continued provision of these services.

6 CONCLUSIONS

The results of this study should be viewed as a rapid, preliminary assessment only. The overall objective was to highlight the benefits that the Moeyungyi WWS provides to people for the purposes of raising awareness about the importance of the wetland. It is clear that continued conservation of the wetland is vital for supporting the livelihoods of the large population living around it and that the wetland provide a whole range of socio-economic benefits that are currently under-valued and often excluded when it comes to decision-making.

The important implication of this study is that it raises awareness of the benefits that wetlands provide and their ability to support resilient livelihoods to people whilst continuing to support good populations of species. In this period of change for Myanmar, with expanding development opportunities on the horizon, wetland conservation values should be incorporated into land use planning through integrated management approaches so as to retain the important biodiversity and ecosystem functions of wetlands so that they can continue to provide benefits to people into the future. The challenge for wetland management is to simultaneously achieve multiple objectives (e.g. ensuring water, food and energy security, mitigating and adapting to climate change, alleviating poverty and conserving biodiversity and our natural capital) and to deal with the synergies and trade-offs among them.

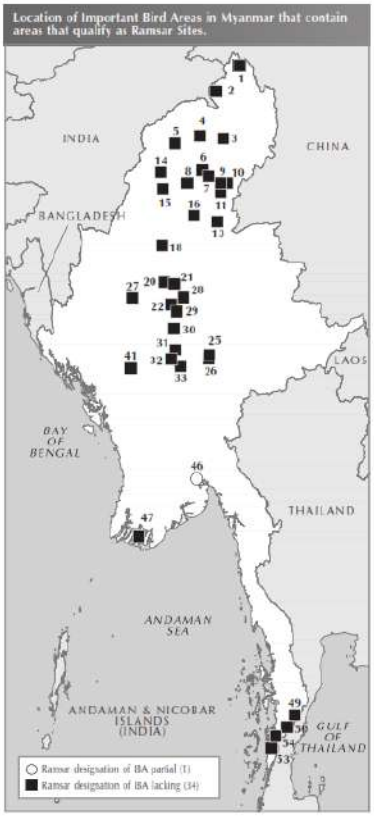

Figure 7. Important Bird and Biodiversity Areas in Myanmar that quality as Ramsar sites (BirdLife International, 2005)

One of the main points that this study has highlighted is the need to look at wetland values in the landscape context (e.g. upstream impacts from siltation/soil erosion and downstream impacts e.g. increasing rice cultivation, greenhouse gas emissions and demand for water).

This study can be viewed as a pilot assessment which would be applicable across all of Myanmar's wetland sites. BirdLife International has identified 34 further wetlands in the country that would qualify as Ramsar sites according to the criteria (BirdLife International 2005) and are likely to provide substantial benefits to people. These wetlands are already IBAs with little or no protected status. By demonstrating the important benefits that these sites provide to people across all sectors, better decisions can be made that incorporate the values of nature so that more equitable and sustainable outcomes can be achieved.

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APPENDICES

Appendix 1. Economic valuation of carbon storage and greenhouse gases emissions

Sensitivity analysis of (A) carbon storage and (B) greenhouse gases emission valuation. Carbon prices were adjusted to 2014 based on IMF (2015) inflation rates. Prices are expressed in US dollars.

(A)

Source	$ Mg C	C storage $	
	(adjusted to 2014)	Current irrigation regime	Alternative irrigation regime
EU Emission Trading Scheme (Point Carbon, 2012)	59.49	61,551,134	60,480,286
US Government (Greenspan Bell and Callan, 2011)	88.53	91,595,228	90,001,683
UK Governent (Greenspan Bell and Calan, 2011)	338.12	349,822,714	343,736,606
Tol (2010)	125.04	129,368,885	127,118,165
Stern et al. (2006)	368.60	381,361,056	374,726,254
Verified Emission Reductions (Peters-Stanley et al., 2011)	24.09	24,925,998	24,492,343

(B)

Source	$ Mg $CO_{2\,eq}^{-1}$	Greenhouse gases emission $ y^{-1}	
	(adjusted to 2014)	Current irrigation regime	Alternative irrigation regime
EU Emission Trading Scheme (Point Carbon, 2012)	16.21	2,107,608	2,117,689
US Government (Greenspan Bell and Callan, 2011)	24.12	3,136,365	3,151,367
UK Governent (Greenspan Bell and Calan, 2011)	92.13	11,978,482	12,035,779
Tol (2010)	34.07	4,429,795	4,450,984
Stern et al. (2006)	100.44	13,058,404	13,120,867
Verified Emission Reductions (Peters-Stanley et al., 2011)	6.56	853,506	857,588

Appendix 2. Carbon storage and greenhouse gases emissions

Mean C storage by habitat type at Moeyungyi WWS under current and alternative state. AGB, BGB, SOM, CO_2, CH_4 and N_2O denote above-ground biomass, below-ground biomass, soil organic matter, carbon dioxide, methane and nitrous oxide, respectively. The estimates of AGB, BGB and litter were from Anderson-Teixeira and DeLucia (2010); and SOM were from IPCC (2013). Estimates for dead wood are not given. All greenhouse gases emission estimates were from Anderson-Teixeira and DeLucia (2010), except those of open water body which were from Kemenes et al (2011) for CO_2 and Soumis et al (2004) for CH_4. IPCC guidelines suggest a nominal error of ±90%. No errors were given for the estimates from Anderson-Teixeira and DeLucia (2010), so we assume 90%.

Regime	Season	Habitat type	Habitat coverage (%)	Carbon storage (Mg)						Greenhouse gases emissions (Mg CO_2 eq y^{-1})				
				AGB	BGB	Litter	SOM	Total	Potential range	CO_2	CH_4	N_2O	Total	Potential range
Current irrigation regime	Dry	Paddy	8	4000	800	2400	17600	24800		0	7360	1017	8377	
(current state)		Marshes	82	639300	80978	123598	187528	1031404		-426	55917	7265	62756	
		Open water body	10	0	0	0	22792	22792		34723	1172	0	35895	
		Total		643300	81778	125998	227920	1078996	107900 - 2050092	34297	64450	8282	107029	10703 - 203355
	Wet	Paddy	0	0	0	0	0	0		0	0	0	0	
		Marshes	70	543900	68894	105154	159544	877492		-363	47573	6181	53391	
		Open water body	30	0	0	0	68376	68376		104170	3517	0	107686	
		Total		543900	68894	105154	227920	945868	94587 - 18897149	103807	51090	6181	161078	16108 - 306048
Alternative irrigation regime	Dry	Paddy	11	5500	1100	3300	24200	34100		0	10120	1399	11519	
(Alternative state)		Marshes	79	616800	78128	119248	180928	995104		-411	53949	7009	60547	
		Open water body	10	0	0	0	22792	22792		34723	1172	0	35895	
		Total		622300	79228	122548	227920	1051996	105200 - 1998792	34312	65242	8408	107962	10796 - 205128
	Wet	Paddy	0	0	0	0	0	0		0	0	0	0	
		Marshes	70	543900	68894	105154	159544	877492		-363	47573	6181	53391	
		Open water body	30	0	0	0	68376	68376		104170	3517	0	107686	
		Total		543900	68894	105154	227920	945868	94587 - 18897149	103807	51090	6181	161078	16108 - 306048

Appendix 3. Household questionnaire for domestic water use from Moeyungyi WWS

1. Personal information												
Occupation:	Age:											
Gender:	Number of people in household: adults ____ children_____											
2. Source, use and importance of freshwater												
2.1) What is your most important water supply source Note: Answer will tell us if water used by the Household (HH) comes from wetland Note: Main reason is crucial. E.g. a source can be important because there is no alternative supply	*[Respondent to name one and its main reason* *From springs, well, borehole* *From a piped supply or tap* *From rainwater pond* *From the wetland (lake, river, etc)* *Other (please specify)*											
Determine here, using the information supplied in 2.1, whether the source of water used at the HH is from the site	☐ water is supplied by the wetland ☐ water is not supplied by the wetland* *Do not continue with the questionnaire if this is the case											
2.2) For water supplied by the wetland only, what are the main uses?	***Main uses (tick all that apply)***	***Wet season (Jun to Sep)***	***Dry season (Feb to May)***									
	Irrigation of crops											
	Water for livestock											
	Drinking (domestic use)											
	Cooking & washing (domestic use)											
	Sanitation (domestic use)											
	Other uses (please specify)											
2.3) How does the provision of	***Jan***	***Feb***	***Mar***	***Apr***	***May***	***Jun***	***Jul***	***Aug***	***Sep***	***Oct***	***Nov***	***Dec***

water by the wetland meet your demand on a month by month basis? Use the following keys: + more water than is needed – not enough water O about right												

2.4) If the water runs dry or becomes unavailable, what are the alternative sources of supply? (State 'none' if this is the case) Note: Refer to question 2.2 for regular sources of supply in wet and dry season	***Main uses (tick all that apply)***	***Alternative sources (In wet season)***	***Alternative sources (In dry season)***
	Irrigation of crops		
	Water for livestock		
	Drinking (domestic use)		
	Cooking & washing (domestic use)		
	Sanitation (domestic use)		
	Other uses (please specify) *……*		

3. Freshwater quantity and seasonal use	
3.1) How many buckets or containers do you use <u>PER DAY</u> for each of the domestic use listed above (<u>WET SEASON ONLY</u>)? **What size are these buckets or containers? Or indicate the actual amount (e.g. in litre or other units if known)**	Drinking: Cooking & washing: Sanitation:
3.2) How much time do you spend collecting water each time?	
3.3) Does your household use less water in dry seasons? If yes, how much less?	o Yes, we use.... *[enter an actual proportion or percentage]* o No

4. Land use change and resulting impacts on water-related ecosystem services	
4.1) Have you ever had problems of too little water since living in this area? e.g. drought **In your opinion, what was the cause?** **What was the impact of this?**	*[describe when – year, month, duration – cause and effect]*
4.2) Have you ever had problems of too much water since living in this area? e.g. flooding **In your opinion, what was the cause?** **What was the impact of this?**	*[describe when – year, month, duration – cause and effect]*
4.3) If the amount of water supplied by the wetland was to increase, how would this affect you? **Indicate whether there are any increased expenditures or increased time spent; and if possible, quantify how much.**	
4.4) Have you ever had problems with the water quality of your drinking water supply since living here? **In your opinion, what was the cause?** **What was the impact of this? Indicate whether there are any increased expenditures or increased time spent; and if possible, quantify how much.**	Odour / Taste / Illness *Others (please specify).....* *[describe when – year, month, duration – cause and effect]*
4.5) Have you noticed any change in the colour or amount of sediment in the water during	*[Increased, no change or decreased]* *[describe when – year, month, duration – cause and effect]*

the time you have lived here? **In your opinion, what was the cause?** **What was the impact of this? Indicate whether there are any increased expenditures or increased time spent; and if possible, quantify how much.**	
4.6) Have you noticed any change in the water availability in the time you have lived here? **In your opinion, what was the cause?** **What was the impact of this? Indicate whether there are any increased expenditures, or increased time spent, and if possible, quantify how much.**	*In wet season: Increased, no change or decreased* *In dry season: Increased, no change or decreased*

Name of interviewer:..... Date:.....
Location:.....

Appendix 4. Harvested Wild Goods – Fish only

Questions for the workshop participants

Description of the harvesters

1. Approximately how many people in your village harvest fish from the site?
2. What percentage of the harvest is by:
    - local rural people
    - non-local rural people
    - urban people
    - people from other countries
3. Do the people who harvest fish come from any particular socio-economic group, and if so, what is it (e.g. specific ethnic groups, women, landless people, people with inherited rights to harvest fish)?
4. Are any harvesters particularly dependent on fishing for their livelihood?
5. Are harvesters organised in any way – for example is there a harvesters' organisation or cooperative? Give details.

Description of the harvested fish

6. What is the harvested fish mainly used for?
7. What units are used locally to quantify the harvested fish (e.g. bundles, tins, head-loads, baskets)
8. What is the conversion rate between this unit and the relevant metric unit? (e.g. 1 bundle = 50 kilograms)
9. Does the availability of fish vary during the year (is the availability seasonal)? Explain.
10. Where within the site is it harvested?
11. Are there costs associated with harvesting fish (e.g. buying nets, boat, baskets or other equipment)? Are these one-off costs or regular/annual costs?

Users and marketing

12. Out of 100 units of the harvested fish, how many units are typically used for subsistence (i.e. by the harvester and his/her household) and how many are sold? The answer should range between 0 and 100.
13. If it is sold, who uses it?

14. Is the harvested fish processed by the harvesters before it is sold, or do they sell the raw fish? Give details.

15. If the harvested fish is processed, are there any costs associated with processing? Explain and describe.

16. Where is the harvested fish usually sold – locally, in a nearby market town, in the nearest city?

17. How many points of sale are there for the harvested fish that has been collected from the site?

18. Do harvesters tend to take the harvested fish to market themselves or is there a 'middle-man' who comes to villages to purchase the fish? Give details.

19. What is the current market price per unit of the harvested fish:

    - Where the harvesters live
    - In the nearest market
    - In the nearest city.

20. Does the price vary very much (seasonal variation) during the year? Explain and describe.

Non-marketed goods

21. If the fish is not sold in any market, and you were not able to harvest it, what effect would this have on your livelihood?

22. If you could no longer harvest the fish and had to replace it, what product would you need to buy and what would it cost for an equivalent amount?

Hired labour

23. Does a legal minimum wage exist? If so, what is it?

24. What is the typical daily wage rate in the area (for the kind of work needed to harvest fish)? Do rates fluctuate seasonally? Describe.

25. Is there much unemployment in the area? What are the probabilities of an individual getting a day of paid work if they wanted it?

26. Is there much seasonality in the demand for labour and levels of unemployment? Describe.

These questions are designed to help determine what value should be given to family labour used for harvesting wild goods (Wild Goods Method 2 – questionnaire survey). As a general rule:

- If levels of unemployment are high throughout the year, value any family labour at zero.
- If there are periods of high seasonal demand for labour (but high unemployment at other times of year) find out family labour inputs during those peak periods, and value it at the 'market rate'.
- If there is a high demand for labour throughout the year, value annual inputs of family labour at relevant market rates.

Sustainability

Answers to the following questions may help to indicate the level of sustainability of the harvested wild goods. If a user group exists then records kept by its members relating to past and present harvesting levels can be used to provide a more accurate account and to substantiate information collected at the stakeholder meeting.

27. How has availability of the harvested wild good at the site changed in the past 20 years (or other chosen period)? (Declined a lot; declined a little; about the same; increased slightly; increased a lot).

28. Has the time spent harvesting changed in the past 20 years? (Declined a lot; declined a little; about the same; increased slightly; increased a lot).

29. If the availability of the harvested wild good has changed (or time spent harvesting has changed), what do you think are the reasons for this?

Rules for harvesting fish

30. Are there formal or informal rules on accessing, processing or selling fish, which affect how much is harvested? Give details.

31. Are there restrictions on harvesting fish in regard to the quantity that can be harvested?

32. If there are restrictions as specified above, how is the total quantity to be harvested or used during a year decided?

33. How are any rules monitored and enforced?

Appendix 5. Household questionnaire for the use of fish harvested from the Moeyungyi WWS

Name/number of respondent			
Date			
Location/name of village			
Name of product (*if more than 3 products, use additional forms)*	**1.**	**2.**	**3.**
Quantity and value of product			
Do you harvest this product from the site? (Y/N)			
a. Total days harvesting per year			
b. On average, total harvest per day over that period			
c. Estimated total quantity collected **from the site** per year*			
d. Unit			
e. Percentage for own use			
f. Percentage sold/ bartered			
g. Average price obtained per unit**			
Family labour			
h. Annual time taken by respondent and family members (unpaid) to harvest and process the product (person days)*			
Hired labour			
i. Annual input of hired labour for harvesting and processing (person days)*			
j. Typical daily wage rate paid for hired labour			
Equipment costs* **			
k. What capital items (tools, materials, equipment) do you need for harvesting and processing this product?			

l. How long do you expect each of these tools etc. to last?			
m. How much did each item cost to buy?			
Transport and marketing costs			
n. What are the annual costs of transporting and marketing this product?*			
* If respondents find it difficult to recall accurately the harvest for the past 12 months, then break these questions down. For example, ask for the harvest on a monthly basis (and then add these figures up yourself, to get an annual total). Do the same for each of these questions (price, inputs of labour, costs of equipment and other inputs, etc.).			
****** If the individual respondent does not sell the product they gather, but others do, then apply the mean price recorded from other respondents.			
*** If any tools or equipment have a lifetime of more than one year, divide the initial purchase cost by their expected lifetime and add typical repair/maintenance costs. If tools are not specifically used/purchased for this product but are for general use, apply a sensible percentage of their cost/maintenance.			

Appendix 6. Questionnaire for domestic visitors and international tourists

Site name/Location interviewed:	
Date/Time:	
Respondent number:	
1. Mode of Transport: Walk/Car/Bus/Motorcycle/Bicycle/Others(please specify)	
2. Type: National day-tripper/Domestic tourist/International tourist	
3. If applicable, how many persons in the travel group?	Number of adults Number of children (under 5)
4. Where are you from?	**For national day-trippers and domestic tourists**: Indicate which town/city: Within 10 km of this site □ Within 25 km of this site □ More than 25 km of this site □ **For international tourists**: Indicate which country:
5. Did you pay an entrance fee/permit to enter this site? (state currency)	Yes □ No □ If yes, how much _____ (indicate per person or for the whole group)
6. How much have you spent/do you expect to spend **in relation to this trip**? For each: - state currency - indicate per person or for the whole group - indicate whether the suppliers are local (< 10 km) or no-local (> 10 km). For example, a taxi/bus ride from Yangon is non-local, but the food/drinks bought at the stall outside the wetland is local	Transport (e.g. petrol cost, bus fares etc; include return trip) _____ Food/drinks _____ Travel guides _____ Souvenirs _____ Others (please specify) _____
Questions 7 – 10 for **International tourists and domestic tourists** only	
7. How many nights will you spend away from home whilst **on this whole trip**?	
8. Have you spent/do you plan to spend any nights at or near (less than 10 km) this site?	Yes □ No □ If Yes, state: (1) Number of nights at or near this site: (2) How much is the room rate per night: (3) How much is the guesthouse meal arrangement per person:
9. In total, how much money do you expect to spend **during your whole trip** (state currency)	Estimate _____ (indicate per person or for the whole group)
10. How many days will you spend at this site **during your whole trip**?	
11. Please indicate what proportion of your reason for visiting this site is for the following: Try to split the reasons into the following groups, using percentage to score the relative importance of each reason, e.g. wildlife was 60%; time with friends was 40%; total must be 100)	Landscape, nature or wildlife _____% Cultural, spiritual (visiting religious or spiritual sites, museums, etc.) _____% Exercise, sports or hobbies _____% Time with family or friends _____% Other (please specify) _____%
13. Would you come for these activities when most of the area is covered by water (e.g. during wet season)?	Yes □ No □ 'Don't know' □ If yes, would you visit the wetland as often? Less □ More □ No change □
12. Would you come for these activities **if the marshy areas (exposed as the water recedes during the dry season) are used for rice farming**? Describe the alternative state (accompany with a photograph representing this state) The paddy fields near the entrance of the site can represent the alternative state.	Yes □ No □ 'Don't know' □ If yes, would you visit the wetland as often? Less □ More □ No change □

Appendix 7. Cultivated Goods - rice

Questions for the workshop participants (17 village representatives)

Description of the cultivators

1. Approximately how many households or businesses in the area cultivate rice?
2. What percentage of the cultivation is by:
    - local rural people?
    - non-local rural people?
    - urban people?
    - people from other countries?
3. Do the people who cultivate rice come from any particular socio-economic group, and if so what is it (e.g. specific ethnic groups, women, landless people, people with inherited rights to harvest the product)?
4. Are any of these people particularly dependent on rice for their livelihood?
5. Are the cultivators organised in any way – for example is there a producers/farmers organisation or cooperative? Give details, and contact information where available.

Description of the cultivated good

6. How long does the crop take to grow (from planting to harvest)? How many times is the crop harvested in one year?
7. What units are used locally to quantify the product (e.g. bundles, tins, head-loads, baskets)?
8. What is the conversion between these units and the relevant metric unit (e.g. 1 bundle = 50 kilograms)?

Users and marketing

9. Out of 100 units of the product, how many units are used for subsistence (i.e. by the farmer and his/her household) and how many are sold? The answer should range between 0 and 100.
10. If it is sold, what percentage of the users are:
    - local rural people?
    - non-local rural people?
    - urban people?
    - foreigners?
11. Is the rice processed by the farmer before it is sold, or do they sell the raw product? Give details.
12. If the rice is processed, are there any costs associated with processing? Explain and provide the cost.

13. Where is the rice usually sold – locally, in a nearby market town, in the nearest city?
14. Do farmers tend to take the rice to market themselves or is there a 'middle-man' who comes to villages to purchase the product? Give details.
15. If the rice is sold through traders, how many points of sale are there for the product that has been collected from the site?
16. What is the current market price for a local unit of rice:
    - where the cultivators live?
    - in the nearest market?
    - in the nearest city?
17. If the rice is not sold in any market, and you were not able to cultivate it, what effect would this have on your livelihood?
18. If you could no longer cultivate rice and had to replace it, what product would you need to buy and what would it cost for an equivalent amount?

Sustainable use

19. Looking over the past five years, have the yields of rice (per unit area), the inputs needed to produce it, or the price paid for it noticeably changed? Give details.

This question is designed to identify cases where cultivation is unsustainable even over the short-term, and to shed light on important drivers of change (such as changing markets or demand). It may not detect longer-term unsustainability, which is a shortcoming in that it may cause you to overestimate the long-term value of cultivation.

Hired labour costs

20. Does a legal minimum wage exist? If so, what is it?
21. What is the typical daily wage rate for agricultural labour in the area? Do rates fluctuate seasonally? Describe.
22. Is there much unemployment in the area? What are the probabilities of an individual getting a day of paid work if they wanted it?
23. Is there much seasonality in the demand for labour and levels of unemployment? Describe.

These questions are designed to help determine what value should be given to family labour used on the farm. As a general rule:

- If levels of unemployment are high throughout the year, value any family labour at zero.
- If there are periods of high seasonal demand for labour (but high unemployment at other times of year) find out family labour inputs during those peak periods, and value it at the 'market rate'.

- If there is a high demand for labour throughout the year, value annual inputs of family labour at relevant market rates.

Appendix 8. Household questionnaire for rice cultivation

1. General information	
Name/number of respondent (household)	
Date	
Location/name of village	

2. Rice		
Do you grow rice?	Yes	No
If NO, do you intend to farm rice at the site in the future? (Yes/No)		
If YES, what is your **total** size of the land you farm in the area (use local units of area if appropriate):		
Do you intend to expand your farm in the area in the future? If yes, by how much?		
Unit of measurement for that crop		
Last year, how much rice did you produce?		
Last year, what was the average price obtained per unit**?		
Percentage for own use	**%**	
Percentage sold/bartered	**%**	
Did you, or family members, spend (unpaid) time cultivating/ harvesting/ processing this crop? (Yes/No)		
If yes, how many person-days did you or your family spend cultivating/ harvesting/ processing this crop last year*?		
Did you hire people to cultivate/harvest/process this crop? (Yes/No)		
If yes, how many person-days did hired people spend cultivating/ harvesting/ processing this crop last year*?		
What is the average daily wage rate you paid these hired people (outside of any reciprocal arrangements)?		
What is the cost of other inputs for this crop (seed, fertiliser, pesticide, water, fuel for machinery)*?		
What capital items (tools, materials or equipment) do you need for cultivating/ harvesting/ processing this crop? (e.g. tools, machinery)?		
How long do you expect each of these tools / machines to last (years)***?		
How much did each tool / machine cost to buy?		
Last year, what was spent on transporting and marketing this crop*?		

3. Livestock****			
It is important to find out the value of livestock as a contribution to cultivated goods. The value of the service that the land provides to livestock is determined from the value of all the feed it provides them.			
Do you have any livestock?	**Yes**		**No**
If yes, what?	**1.Buffalo**	**2. Cattle**	**3. Duck**
How many animals do you own on average last year*?			
What percentage of the total feed needed last year* obtained from wild harvest at the site*****? Think about all the food they ate (including grass, fodders, mollusc for duck etc.)	%	%	%
What is the estimated value of that feed? (i.e. how much would it cost you to replace that feed if you had to buy it from someone else, or if you had to replace it with another kind of animal feed?)			

* If respondents find it difficult to recall cultivation details accurately for the past 12 months or for all the land they farm in the area, then break these questions down. For example, ask about the harvest on a monthly basis, and ask how many months the harvest lasts (and then add these figures up yourself, to get an annual total). If necessary you could do the same for each field the cultivator uses, and then add the answers up to get a total for their entire farm.
** If the individual respondent does not sell what they cultivate but others do, then apply the mean price recorded from other respondents.
*** If any tools or equipment have a lifetime of more than one year, divide the initial purchase cost by their expected lifetime and add typical repair/maintenance costs. If tools are not specifically used/purchased for producing this particular good but are for general use, apply a sensible percentage to their purchase and maintenance cost.
**** Only complete this section for livestock whose feed is identified as among the top 5 most important cultivated goods. Complete a separate column for each form of livestock which is among these top 5.
***** Here you are asking the respondent about <u>all</u> the animal feed they obtain from the current area or the alternative state that you are studying, i.e. not just from their farm. This may include cultivated feed crops, crop residues, pasture, browse cut from hedgerows and field margins.

4. Fertiliser and pesticide			
	Natural fertiliser	Chemical fertiliser	Pesticide
Did you use any of these? (Yes/No)			
If yes, total amount you used for **an acre** last year			
Unit of measurement (e.g. bag, bottle, etc. but also find out the weight of the bag or the volume of the bottle)			