Rapid ecosystem service assessment of a protected wetland in Myanmar, and implications for policy development and management

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ABSTRACT

Many of the world's wetlands have been degraded or destroyed, with Asia being one of the most impacted regions globally. Given the likelihood that Myanmar will increase rice production in the coming years, we assessed the impact of this on the Moeyungyi Wetland Wildlife Sanctuary in Myanmar, and the ecosystem services it provides. Using a framework outlined in the Toolkit for Ecosystem Service Site-based Assessment (TESSA), we estimated that sanctuary provides annual benefits of at least \$22 million y^{-1} (\$2,130 ha^{-1} y^{-1}; 2014 US dollars) and that these benefits are received by local communities (c.12,000 households), downstream rice farms, and the international communities. We show that an increase in water use for increasing rice production in nearby town was not considered to have a significant effect on the benefits that the wetland currently provides. However, our results are subject to methodological assumptions and limitations. Notwithstanding this, we found TESSA to be useful for providing information to local and national stakeholders on the broader importance of the conservation of wetlands. Our case study demonstrates how rapid ecosystem service assessments may pave the way to sustainable management of Myanmar's wetlands.

Keywords: Conservation; Cost-benefit assessment; Paddy; Rice production; TESSA

1. Introduction

Wetlands – 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 – are key ecosystems that cover approximately 12.8 million km^2 (8.5%) of the Earth's land surface (Finlayson et al. 1999; for a review of the estimates, see Hu et al. 2017). Inland wetlands, which exclude areas of marine water the depth of which at low tide does not exceed six metres, cover at least 9.5 million km^2 (Finlayson et al. 1999). These areas are highly productive and provide habitats for a wide range of fauna and flora. In addition, they have also been demonstrated to provide significant social and economic benefits to people (Russi et al. 2013). The Economics of Ecosystems and Biodiversity (TEEB; http://teebweb.org/) estimated that 63 million ha of wetlands around the world (approximately 5% of the global wetland area) have an economic value of $3.4 billion per year with the highest benefits found in Asia (Brander and Schuyt, 2010). However, most socio-economic benefits from wetlands have been over-looked and under-valued as they have not been traded in economic market nor integrated into decision-making (Gardner et al. 2015; Jiang et al. 2011; Russi et al. 2013). This has resulted in widespread modification, degradation, over-exploitation; and conversion of wetlands habitats in favour of 'development' yet in the long-term often led to detrimental impact and economic cost.

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 the expansion of agriculture, increased demand for water use, infrastructure and urban development and intensive aquaculture (United Nations World Water Assessment Programme 2003). Although the rate of wetland habitat conversion into other land uses has slowed in North America and Europe, Asia continues to lose large tracts of wetland habitats (Russi et al. 2013; Xu et al. 2019).

Due to their complex nature, the functions that are lost when ecologically sensitive 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. Given current trends in the loss of wetlands and the potentially huge ecological, social and economic impacts, it is becoming increasingly clear 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 the 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 (Merriman et al. 2018).

Assessing the impact of wetland conversion into other land uses in terms of ecosystem service benefits and costs to different stakeholder groups is currently limited by the tools available to local conservation practitioners and site managers that are restricted in capacity and resources (see Neugarten et al. 2018). At the current time, there is still limited guidance available on how to measure the real economic impact or benefits of maintaining a wetland for biodiversity conservation. Local conservation practitioners and site managers still need a yardstick, a “ready reckoner” that would allow them to account for these benefits provided by such complex, dynamic systems in both monetary and non-monetary ways.

At Moeyungyi Wetland Wildlife Sanctuary in Myanmar, the Irrigation Department releases water from the wetland to the downstream area around Bago for irrigation in December each year. This enables 16,520 ha of rice paddy to be cultivated in this area during the dry season. The flow of water into the wetland from the upstream catchment maintains the water level of the permanent Moeyungyi lake at 7.0 m. Given the aspiration of Myanmar to return being a major rice exporting nation (Pratruangkrai 2015) and the good market prospects to accommodate higher rice exports from Myanmar throughout this decade (World Bank Group 2014), the Irrigation Department has the intention to increase the release of water from Moeyungyi wetland for rice cultivation (Myint Soe, U., Irrigation Department, pers comm). It is likely that the water from Moeyungyi wetland used for supporting rice cultivation during dry season will be doubled in the near future. In order to elucidate the impact of increasing rice farm production, we used the Toolkit for Ecosystem Service Site-based Assessment (TESSA; Peh et al. 2013a) to carry out a comparative assessment of the ecosystem services provided by the Moeyungyi wetland and its future plausible alternative state should the water level of its permanent lake be dropped significantly due to an increased water use for rice irrigation. We then used the results of the assessment to support the implementation of the Ramsar Convention in Myanmar and to advocate for increasing the designation of Ramsar sites in Myanmar. Through this assessment, we aimed to demonstrate how the ecosystem services approach has been effectively institutionalised in wetland policy development and management in Myanmar.

2. Methods

2.1. Study area

The Moeyungyi Wetland Wildlife Sanctuary (hereafter, Moeyungyi WWS or the wetland) is located in the administrative region of Bago in Myanmar (Fig.1; 17°32'57" N, 96°36'58" E), 25 km north-northeast of Bago town, east of the Yangon to Mandalay highway and 24 km west of the Sittuang river. It occupies 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). The wetland, approximately 10 m a.s.l., receives an average annual rainfall of 3,200 mm. The wet season lasts only from June to September, and most rain falls in July and August. At the end of the wet period, water covers the whole site and in the dry season it recedes again.

Moeyungyi lake is a man-made reservoir that was constructed in 1873-1878 under the British rule to store water for irrigation and to use as an embankment for flood protection. During the dry season, storage water from the 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 flows to downstream areas under rice cultivation. There are seven natural creeks flowing into Moeyungyi Lake during the wet season. In the dry season, the wetland is recharged with water from several upstream dams (Irrigation Department 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.

Moeyungyi wetland is surrounded by 17 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 the Biodiversity and Nature Conservation Association (BANCA) from eight of the villages (BANCA, 2014), most people derive their livelihoods from either fishing or agriculture (rice cultivation) directly associated with the wetland.

Moeyungyi WWS is managed by the Nature and Wildlife Conservation Division (NWCD) under the Ministry of Natural Resources and Environmental Conservation (MONREC). The wetland is an important habitat for resident and migratory birds, and qualifies as an Important Bird and Biodiversity Area (IBA) due to the presence of globally threatened bird species (Baer's Pochard, *Aythya baeri*; Sarus crane, *Grus antigone*; and Greater spotted eagle, *Aquila clanga*), and significant congregations of migratory species. The wetland was designated as a bird sanctuary in 1986 and declared a Ramsar status in 2004, the country's first Ramsar site (Davies et al. 2004).

Historically, there has been weak manpower capacity at Moeyungyi WWS, with 12 staff (one park warden and other support staff) currently assigned to the area. The wetland is under the jurisdiction of three government agencies: The Forest Department (overseeing the conservation of the site); the Fishery Department (managing the fisheries at the site); and the Irrigation Department (controlling the sluice gates) (Tun, 2018). 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. The proposed increase in rice production would double the use of water provided by the wetland to support two rice crop cycles instead of one during the dry months (from September to May). It is therefore timely for the project team (staff members from Moeyungyi WWS, NWCD and local conservation organisation BANCA) to consider the impact of increasing rice farming production could have on the communities around the wetland.

2.2. Ecosystem service assessment

To undertake this assessment, we used the Toolkit for Ecosystem Service Site-based Assessment version 1.2 (TESSA; Peh et al. 2013b) to estimate the biophysical and monetary values of ecosystem services provided by Moeyungyi WWS in its current state (i.e.

with the present irrigation regime). To elucidate the trade-offs under the “alternative irrigation regime” whereby there is an increased use of water for rice farming resulting in a drop of water level, we used the framework of TESSA for comparative assessment of the ecosystem service provision by the wetland in its current state and in its most plausible alternative state. 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. provisioning of water for irrigation and rice production). Whenever possible, data representative of this wetland area under the alternative state were collected from a nearby site that has undergone the plausible land-use change. For some ecosystem services (e.g. provisioning of water for irrigation), we gather the data from a scoping appraisal with key stakeholders or questionnaire surveys which were then calibrated for the alternative state.

This assessment was also built on available data from previous rapid assessments on the biological and socio-economic status of the Moeyungyi wetland (BANCA 2014), conducted by BANCA collaborating with researchers from Bago University, local villagers and staff from Moeyungyi, over the period from 24 February to 2 March 2014.

2.3. Preliminary scoping appraisal

Preparatory meetings were held from 18 to 22 December 2014. During these meetings, existing information and data was collated and the feasibility of this assessment was discussed. A preliminary scoping workshop of key stakeholders involved at the wetland was then convened on 6 and 7 February 2015. The participants included government staff from the Environmental Conservation Department (2), Irrigation Department (1), Department of Agriculture (1), Department of Fisheries (1), Moeyungyi WWS Park Warden Office (4), NWCD of the Forest Department (4), the Township Administrative Office of Bago (2) and Waw Township (1) 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 wetland. This scoping exercise, using the free-listing method, identified the important ecosystem services provided by Moeyungyi WWS to the stakeholder groups as (1) global climate regulation; (2) nature-based recreation; (3) flood protection; (4) provisioning of water for domestic use and irrigation; (5) provisioning of wild goods, such as fish, aquatic plants for buffalo grazing, molluscs and lotus stalks; (6) rice production during the dry season; and (7) biodiversity. All identified ecosystem services – bar biodiversity which TESSA defined as an important part of ecosystems or an important component of natural capital, and is therefore not considered as an ecosystem service – were covered in TESSA (version 1.2) methodology. General information on fishing activities (see Appendix S1) and rice cultivation (Appendix S2), as well as details about the wetland in terms of habitats, management and current threats were gathered as participants had good local knowledge of the site.

Using a topographic map of Moeyungyi WWS, the workshop participants estimated how the land use within the wetland would change if the water from the wetland used for irrigating the rice paddies of 16,500 ha were to be doubled during the dry season to support two crop cycles (i.e. participatory mapping). They reported that 1,100 ha of the newly-exposed marshland caused by the drop in water level would be converted to rice paddy (Table 1). The estimated amount of water in Moeyungyi lake needed for supporting one crop cycle of dry season paddy and the resultant water level were deduced from an observation in 2013 when there was no replenishment of irrigated water (i.e. no recharge) in the lake during dry season due to the blockage of major in-flow canals caused by soil erosion in the upstream area. The stakeholder groups predicted that the plausible alternative irrigation regime would affect the following services provided by the wetland: (1) global climate regulation in terms of carbon greenhouse gases emission; (2) provisioning of water for irrigation; and (3) rice production during the dry season. Conversely, the water level during the dry season under the alternative state would still be high enough to support the other ecosystem services.

The preliminary scoping appraisal did not consider water quality to be an immediate concern for the current water use, even though fertilisers and pesticides were applied to the paddy fields within the wetland, for three reasons. First, chemical run-off from paddies within the wetland was localised and not of significant level as fertilisers and pesticides were applied only during low precipitation period (dry season). Second, the concentrations of chemicals in water were not observed to have negative impact on biodiversity, human health or deterioration of water quality in the wetland (i.e., no eutrophication; Nesheim et al. 2018). Last, the large volume of water entering and leaving Moeyungyi WWS (i.e., sufficient water flow) had pollution dilution effects within the wetland (Nesheim et al. 2018).

2.4. Measuring ecosystem services

We measured six ecosystem services: global climate regulation (carbon storage and greenhouse gas flux), water provision (for domestic use and irrigation), flood mitigation, harvested wild goods (such as fish, lotus stalks, molluscs for duck feeding and aquatic plants for buffalo grazing), nature-based recreation and cultivated good (rice). We also included in our assessment services that were likely not impacted by the alternative irrigation regime (such as water provisioning for domestic use, flood mitigation, harvested wild goods and nature-based recreation) so that we could estimate the total economic value of the wetland under the current irrigation regime. This knowledge could promote awareness of the importance of the wetland when we communicated the results of the assessment to local and national stakeholders and decision-makers.

Moeyungyi WWS ecosystem services values under the alternative irrigation regime were also quantitatively assessed in order to show the differences between the amount of the ecosystem services provided by the wetland in its current state compared to the alternative state. Data gathered from the immediately adjacent rice paddy was used to estimate what the rice cultivation value of this wetland area would be under the alternative state. However, it was not always necessary to collect data representative of the alternative state from a nearby site. For example, we collected data from a scoping appraisal with key stakeholders for assessing water provisioning for irrigation under the alternative state.

We conducted field surveys over a five-day period in February 2015 to measure the value of these ecosystem services. In consultation with staff members from Moeyungyi WWS Park Warden Office, 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. All interviews were conducted in Burmese language by staff members from BANCA, Moeyungyi WWS, and NWCD. We converted local units into metric units if necessary and all values were estimated in 2014 US dollars using an exchange rate of 1000 Myanmar Kyat = 1 USD.

2.4.1. Global climate regulation

Global climate regulation was estimated based on changes in carbon stocks and greenhouse gases flux between the two states (current irrigation regime; alternative irrigation regime). 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' (Intergovernmental Panel on Climate Change 2013) and their unit value for carbon stocks was from the Intergovernmental Panel on Climate Change (IPCC) tier 1 database (Intergovernmental Panel on Climate Change 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).

Greenhouse gases emissions (carbon dioxide, CO_2; methane, CH_4; and nitrous oxide, N_2O) for all habitat within 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.

We estimated the potential range in monetary values of the carbon stock and overall greenhouse gas fluxes using six estimates of the price of carbon, adjusted to 2014 prices based on the GDP deflator index given by the International Monetary Fund (2015) (Table 2).

2.4.2. Water provisioning for domestic use

Previous surveys conducted by BANCA (2014) found that 52% of the households in eight 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 four villages (Kapin, Saitisu, Tar-son and Thoneeainsu) to gather data on the quantity of water from the wetland used directly for domestic purposes (for interview questions see Appendix S3). Based on the 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 participating households were randomly chosen by the village chiefs. The respondents were asked about their main water uses from the wetland in the wet and dry seasons; what quantity they used per day on average; and whether the household used less water during the dry season. The water from wetland for domestic use was priced at $0.04 per gallon, based on the water sold in the villages.

2.4.3. Irrigation

An important function of the Moeyungyi WWS is to store water for the irrigation of rice paddies around the region. During the dry period each year under the current irrigation regime, the wetland supports one crop cycle of rice farming in 16,520 ha of paddies, whereas under the alternative irrigation regime, the wetland would support two crop cycles of rice in the same paddies during the dry season, doubling the amount of water used in irrigation. In addition, the wetland also irrigates the rice paddies within the site (800 ha) during the dry period. We estimated its value as the cost for irrigating these paddies if the water from the wetland were not available.

2.4.4. 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). No property would be directly affected by flood damage as houses are built on stilts or above flood water level. We estimated the economic value of flood mitigation provided by the wetland by interviewing a staff from the Irrigation Department at the preliminary scoping workshop to find out the total area of wet season paddies the wetland protected from flooding and the costs of annual maintenance of the embankments. The total annual value of flood protection benefit was estimated as the annual value of the avoided damage to wet season rice paddies. 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 to estimate the net annual flood protection benefit.

2.4.5. Harvested wild goods

At the preliminary scoping workshop, the village representatives identified fish as the most important wild product harvested from Moeyungyi WWS at community level. Thirty-three household questionnaires (for the interview questions see Appendix S4) were conducted across two villages (Kapin and Pyin Pon Gyi) to gather data on the quantity and annual 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 annual net value per household for fishing was calculated, with the wages of hired labour and costs of equipment, transporting and marketing accounted for, 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. Information on other harvested wild goods (lotus harvesting, molluscs and buffalo grazing) – such as average amount harvested per day; the total number of harvesting days and 2014 prices of the products at a local market – was provided by the Park Warden Office.

2.4.6. 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 wetland on four days (5 – 8 February 2015) during dry season. We used a questionnaire survey to obtain information on the distance travelled, mode of transport, accommodation, and expenditure in the shop and restaurant (for interview questions see online Appendix 6). Our method would likely yield 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. Nevertheless, our estimates could reveal how nature-based recreation at Moeyungyi WWS impact on local economy and indicate how local communities benefited economically from recreational visitor spending (Wai Soe Zin et al. 2019).

2.4.7. 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 online Appendix 7) were conducted in Pyin Pon Gyi village to gather data on the quantity and net value of harvest from one crop season (typical number of crop cycle in the region) for the paddy adjacent to the wetland. The respondents from these farming households were randomly selected by the village chief. Sample size was determined by plotting a running mean of the net economic benefit per household. 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. The mean annual net value of rice per hectare was calculated and applied to the total area under cultivation in the current and alternative states.

2.4.8. Moeyungyi WWS management costs

We obtained information on annual management costs of Moeyungyi WWS from the Park Warden Office. The annual management costs included salaries, equipment as well as road and building maintenance.

3. Results

3.1. Global climate regulation

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). 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. Based on monetary values in the sensitivity analysis range from \$24.09 Mg^{-1} C (2011 Verified Emissions Reductions [VER] market price) to \$338.12 Mg^{-1} C (2011 UK Government social carbon price), the alternative irrigation regime would result in a loss of stored carbon estimated at between \$434,000 and \$6.09 million. However, the estimates of carbon stocks for the current and alternative states were subject to wide nominal errors (Table 3), and the broad estimate ranges do not point to the significance of the change. Therefore, no benefit of avoided carbon loss was conservatively assumed under the current state; and the value of the stored carbon at the wetland was estimated at $91.6 million based on the more conservative social carbon cost (i.e. the US Government social cost value of carbon; Table 2).

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; Table 3). In the alternative state, net emissions of greenhouse gases would increase by an estimated 0.5%. Our sensitivity analysis shows a range of carbon prices from \$ 6.56 Mg^{-1} CO_2eq (2011 Verified Emissions Reductions [VER] market price) to \$92.13 Mg^{-1} CO_2eq (2011 UK Government social carbon price), resulting in an avoided carbon loss estimated at between \$4,080 y^{-1} and \$ 57,300 y^{-1} under the current irrigation regime. Given the wide nominal errors of the estimates of net greenhouse gases emissions for both states (Table 3), it was conservatively assumed that there was no benefit of avoided greenhouse gases emissions under the current state, and the cost of greenhouse gas emissions of the wetland was estimated at 3.14 million y^{-1} (based on the US Government social cost value of carbon; Table 2).

3.2. Water provisioning for domestic use

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. 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 did not expect the alternative irrigation scheme to have a significant impact on the current water supply from the wetland and its value for domestic use.

3.3. Irrigation

Based on the price of water for irrigation from a nearby dam ($4.82 per crop cycle ha), we estimated the annual net benefit of irrigation as $83,400. Under the alternative state with an expansion of rice paddies within the wetland (i.e. an increase from 800 ha in the current state to 1,100 ha) and an increase from only one crop cycle of dry season paddies to two crop cycles outside the wetland (16,500 ha), the annual net benefit was estimated to be $164,000.

3.4. Flood mitigation

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 costs of annual maintenance of the embankments was estimated at $32,000 annually. Hence, we estimated the net annual flood protection benefit as $458,000. The alternative state of the wetland would provide the same flood protection benefit.

3.5. Harvested wild goods

The mean annual net value of fish per household was estimated as $3,360 (± 300). The mean annual net value of fish per household was not significantly different between the two villages. Based on data obtained from Moeyungyi WWS Park Warden Office, there were 4577 households around the wetland 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.

Each day over a period of nine months a year, 20 people are allowed to harvest lotus stalks in the wetland; this takes place from July to March. 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.

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.

Buffalo grazing is carried out in Moeyungyi WWS for eight months from October to May. 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.

3.6. Nature-based recreation

We interviewed 47 individuals and counted a total of 274 visitors over the survey period. 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 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 $73,500 with the majority of the annual revenue (74%) from the international tourists. The annual recreational visitor spending remained unchanged under the alternative irrigation regime because the change in water level would not affect the visitors' experiences and the area affected by the paddy encroachment during the dry season was relatively small and remote from the visitor centre.

3.7. Rice cultivation

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 annual net value of rice cultivation adjacent to the wetland was estimated as \$548 (±114) ha^{-1}. 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 irrigation regime was estimated as \$438,000 whilst that under the alternative irrigation regime was \$603,000.

3.8. Moeyungyi WWS 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}.

3.9. Overall summary of results

The overall net benefit generated from annual ecosystem service flows at Moeyungyi WWS, minus management costs, is estimated at \$22.1 million (\$2,130 ha^{-1}). The carbon stock is estimated at \$91.6 million (\$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}; Table 4). 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; Table 5) or global beneficiaries (no significant change in greenhouse gases emissions and carbon storage; Table 5). Furthermore, an increase in the export of water outside the wetland would be likely to benefit the local and regional population (rice farming; Table 5).

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 5). 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 small sample size 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.

4. Discussion

A great deal of literature on wetland ecosystem service assessment has been published since the Millennium Ecosystem Assessment in 2005. However, a recent systematic review conducted by Xu et al. (2020) reveals that wetland ecosystem service research has mainly focused on temperate countries (>74% of the total publications) and natural wetlands (>73%); and are predominantly non-economic assessments that used biophysical, qualitative or social sciences methods (>91%). Therefore, our study contributes to the minority cases that addressed human-made wetlands in tropical countries. In fact, it is likely one of the few – if not the only – ecosystem service assessment of a human-made reservoir that used economic valuation methods (see Xu et al. 2020). Among the economic valuation studies on wetland ecosystem services, willingness to pay (choice experiments and the contingent valuation methods) was the main approach (40%); benefit transfer methods and multiple economic valuation methods (like this case study) only constituted 19% and 18%, respectively (Xu et al. 2020).

We followed the methodology in TESSA for our ecosystem service assessment. This toolkit was chosen for its relatively simple methods, which enable rapid collection of locally-relevant, site-scale data – relevant to decisions regarding the management of the wetland (such as by the Irrigation Department of the Ministry of Agriculture and Irrigation and the MONREC). Given the capacity of the project team in Myanmar, TESSA was ideal for a rapid assessment without substantial investment of staff time, and without having to rely on modelling or GIS specialists to run the publicly-available computer-based modelling tools such as ARIES, InVEST or MIMES (Neugarten et al. 2018). There are indeed other rapid assessment tools (e.g. the Protected Areas Benefits Assessment tools) available that would take less time than TESSA. However, these approaches collect only qualitative data using participatory methods (Neugarten et al. 2018). Compared to all available tools, a unique feature of TESSA is that it enables gathering of empirical data on quantity, value and distribution of selected priority services through field surveys, in addition to a qualitative assessment of all the ecosystem services provided by the site.

4.1. Net consequences of an alternative irrigation regime

This is the first study to estimate some of the economic values provided by the Moeyungyi WWS and 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 (see Section 4.2). 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 twice the amount of water was released to irrigate 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. This also implies that it might be possible to both protect the wetland and pursue economic growth activities.

However, this initial result should be considered with caution due to a number of impacts that could occur outside of the wetland. 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 canals, as happened in 2013. If this were to occur again under the alternative irrigation regime, and combined with low precipitation as happened in 2019, 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 greenhouse gases emissions resulting from the increase in rice production downstream in Bago Township. Since we were just looking at the economic valuation of Moeyungyi WWS, this impact was not included as part of the study, but is an important consideration from a landscape perspective.

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. 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.

Given the development plans for the country, there may be an opportunity for innovative financing to support the continued conservation of Moeyungyi WWS 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.

4.2. Limitations and caveats

Given the rapid nature of this study, there are several limitations. 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, the overall valuation of the ecosystem services of Moeyungyi WWS would be conservative. We assessed only a limited range of services that could be easily measured and that were included in TESSA version 1.2. Therefore, we had to omit benefits such as those relating to health, or cultural services (with the exception of recreation) that are likely to be provided by Moeyungyi WWS simply because rapid protocols for measuring them were not available when this study was conducted in 2015. However, the latest version of TESSA (version 2.0) has incorporated three additional ecosystem services (coastal protection services, pollination services and cultural services) since 2017, while all methods from the earlier version used in this study remains valid. This provides conservation practitioners with tools for measuring cultural services for the future wetland ecosystem service assessment in Myanmar.

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) and we did not factor illegal fishing into the calculations.

One of the most significant omissions is the evaluation of water quality. The quality of water is undoubtedly compromised when local rice farmers apply fertilisers and pesticides to their paddy fields within Moeyungyi WWS during the dry season in order to increase the productivity of the crop. The run-off of agrochemicals could affect the overall water quality of the wetland. However, based on our preliminary scoping appraisal, the water quality is not yet an immediate concern for the current water use. An independent water quality survey conducted at the wetland in the same year as this study has also reached the same conclusion (Nesheim et al. 2018). Nevertheless, given the vast majority of people living in some villages depend on untreated wetland water for drinking, cooking, bathing and other domestic purposes, it may deem necessary to monitor water quality in the future.

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. Arrival of water from upstream and through rainfall also has impacts on pollution dilution effects within the wetland. Admittedly, this service is difficult to assess due to the lack of point-source outlets for measuring these effects within the wetland. In this study, we were unable to explore this because the wetland has numerous tributaries upstream which makes water quality studies complex to undertake under time and budget limitations. Therefore, there is still a need to assess the broader implications of the potential to increase withdrawal of water from Moeyungyi WWS associated with agro-irrigation in relation to land use management in the wider landscape.

4.3. Impact on wetland policy development and management in Myanmar

Given the rapid nature of TESSA, we cannot draw a clear conclusion on the overall impact of increasing rice production on the benefits provided by Moeyungyi WWS. Our study, nevertheless, has raised awareness – at the national level in Myanmar– of the benefits that wetlands provide and their ability to support resilient livelihoods to people whilst continuing to support good populations of species. This study was presented in Myanmar's Sixth National Report on Biodiversity to Convention on Biological Diversity as a case to demonstrate the country's formal commitment to "integrate the value of biodiversity and ecosystem services into its national accounting" (Nay Pyi Taw, 2018). This assessment was also reported in the country's 2018 National Report to the 13th Conference of the Parties (COP13) of the Ramsar Convention as an evidence of ecosystem service approach being a key component in the preparation of the current management plan for Moeyungyi WWS.

By demonstrating the important benefits that Moeyungyi WWS provides to people across all sectors, better decisions were subsequently made at other wetland sites across the country. For example, five other wetlands were consequently designated as Wetlands of International Importance (Ramsar Sites): Indawgyi Wildlife Sanctuary (47,884 ha; designated in 2016), Meinmahla Kyun Wildlife Sanctuary (50,000 ha; 2017), the Gulf of Mottama (42,500 ha; 2017), Inlay Lake (5,797 ha; 2018), and Nanthar Island and Mayyu Estuary (3,608 ha; 2020). Ecosystem services provided by the Gulf of Mottama mudflats and ecosystem are being incorporated in its management plan so that more equitable and sustainable outcomes can be achieved. Similarly, activities related to livelihood development and sustainable use of wetland resources are consequently included in the management plans for Indawgyi and Meinmahla Kyun Ramsar Sites.

In this period of change for Myanmar and with expanding development opportunities on the horizon, wetland conservation values are now being incorporated into Moeyungyi WWS management plan to retain the important biodiversity and ecosystem functions of wetlands so that they can continue to provide benefits to people into the future. For example, the economic importance of fishing activities at Moeyungyi WWS for many livelihoods – a knowledge generated by using TESSA – has led the Norway-Myanmar bilateral project "Conservation of Biodiversity and Improved-Management of Protected Areas in Myanmar" to demarcate Core Zone, Transition Zones and Wise Use Zones within the wetland in 2019 to enhance conservation activities and to introduce sustainable fishing practices to local fishermen. Following the success story from Moeyungyi WWS, the project will extend the wise-use practices to other Ramsar sites in Myanmar.

Using the experience gained from this study, we recommend the managers of Moeyungyi WWS to use the latest version of TESSA (version 2.0) for monitoring ecosystem services at their site. Since the assessment methods remain unchanged, the data of the future monitoring cycles obtained by using TESSA version 2.0 could be compared with this study for detecting expected change. This version of the toolkit would also enable them to assessing additional benefits such as pollination services, if there are insect-pollinating crops around the wetland, and non-recreational cultural services. The TESSA assessment of the non-recreational cultural benefits does not involve monetary valuation techniques. Therefore, future assessments of Moeyungyi WWS, as well as other wetlands, would require to adopt an integrated valuation approach that combines different disciplines and methods (see Jacobs et al. 2016).

5. Conclusion

Our rapid ecosystem service assessment at Moeyungyi WWS has raised awareness among local and national stakeholders about the importance of wetlands for supporting the livelihoods of the large population living around them and perhaps, rice production downstream. Our case study demonstrates how a site-based ecosystem service assessment has contributed to the ecosystem service approach being institutionalised in wetland policy development and participatory governance of wetland conservation in Myanmar; and how a simple ecosystem service tool like TESSA could aid in the development of current wetland management practices. However, more work has yet to be done. This study can be viewed as a pilot assessment which could be applicable across all of Myanmar’s wetland sites. BirdLife International has identified 29 further wetlands in the country that would qualify as Ramsar Sites according to the criteria (BirdLife International 2005). These are sites which are likely to provide substantial benefits to people, but have little or no protected status.

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Table 1. 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**

Table 2. Economic valuation of carbon storage and greenhouse gas 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 Goverent (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 Goverent (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

Table 3. Carbon storage and greenhouse gas 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

Table 4. Net values of all affected 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 5. 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

Figure legend

Figure 1. Location map of Moeyungyi Wetland Wildlife Sanctuary. Green line denotes the boundary of the wetland; features of the wetland such as permanent water body and its tributaries are in blue; and land occupied by the villages are represented by red patches outside the wetland.

Supplementary material

Appendix S1. 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 S2. 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 S3. 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)		
	Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec		

<table>
<tr><td>2.3) How does the provision of 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</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

<table>
<tr><td rowspan="7">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</td><td>Main uses (tick all that apply)</td><td>Alternative sources (In wet season)</td><td>Alternative sources (In dry season)</td></tr>
<tr><td>Irrigation of crops</td><td></td><td></td></tr>
<tr><td>Water for livestock</td><td></td><td></td></tr>
<tr><td>Drinking (domestic use)</td><td></td><td></td></tr>
<tr><td>Cooking & washing (domestic use)</td><td></td><td></td></tr>
<tr><td>Sanitation (domestic use)</td><td></td><td></td></tr>
<tr><td>Other uses (please specify)
............................</td><td></td><td></td></tr>
<tr><td colspan="4">3. Freshwater quantity and seasonal use</td></tr>
<tr><td>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)</td><td colspan="3">Drinking:

Cooking & washing:

Sanitation:</td></tr>
<tr><td>3.2) How much time do you spend collecting water each time?</td><td colspan="3"></td></tr>
<tr><td>3.3) Does your household use less water in dry seasons? If yes, how much less?</td><td colspan="3">o Yes, we use.... [enter an actual proportion or percentage]
o No</td></tr>
</table>

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	*[Increased, no change or decreased]* *[describe when – year, month, duration – cause and effect]*

of sediment in the water during 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 S4. 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 S5. 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 S6. 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*?		
* 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)			