Economic Valuation Study of CNMI Inland Wetlands

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Wolfs Company, in collaboration with VU University Amsterdam and Brander Environmental Economics

Contents

Acronyms

BECQ	Bureau of Environmental and Coastal Quality
CDA	Commonwealth Development Authority
CNMI	Commonwealth of the Northern Mariana Islands
CUC	Commonwealth Utilities Corporation
DEQ	Division of Environmental Quality
DCRM	Division of Coastal Resources Management
DCCA	Department of Community and Cultural Affairs
DFW	Department of Fish & Wildlife
DPL	Department of Public Lands
DLNR	Department of Lands and Natural Resources
EPA	United States Environmental Protection Agency
ES	Ecosystem service
HPO	Historic Preservation Office
MVA	Marianas Visitors Authority
MINA	Micronesia Islands Nature Alliance
NOAA	National Oceanic & Atmospheric Administration
NMC	Northern Marianas College
OPD	Office of Planning and Development
USACE	United States Army Corps of Engineers

Executive summary

"We use nature because it is valuable. We lose it because it is free" - Pavan Sukhdev

Our natural environment provides significant benefits. Some of these, such as a water supply or crop growth, provide us with sustenance. Regulating services, including nutrient cycling and erosion prevention, ensure a healthy and safe living environment by protecting us against extreme weather events and algal blooms. Others, such as natural beauty and cultural heritage, and even simply its existence, provide us with so much joy and fulfilment.

In the past, we have not quantified many of these values because they have not been included in our economic analyses. However, they form the basis of our wellbeing, health and livelihoods. Without quality soil and water, there would be no agriculture. Without beautiful coral reefs and beaches, there would be little tourism. Without shoreline protection, we would be more exposed to storms and flooding. We typically receive these benefits without paying a price to conserve the ecosystems that provide them. Often, this leads to a collective underestimation of the value of these ecosystems to society,

The Bureau of Environment and Coastal Quality's (BECQ) Division of Coastal Resource Management (DCRM) commissioned an analysis of wetlands in the CNMI. This analysis set out to value, in economic terms, the benefits that our industries and communities receive from our wetland areas. These include the lakes and streams that connect our islands to the sea around us. Most of these wetlands in the CNMI, especially those more valuable to people, are found on Saipan, Tinian and Rota. The environment of these three islands has experienced much change and is increasingly under pressure from human activities and development. It is becoming increasingly relevant therefore to have solid support for the conservation and restoration of these natural areas, especially those Areas of Particular Concern (APCs), as established by the DCRM regulations. There are specific permitting and evaluation requirements for development projects that may have impacts in these designated areas. Besides wetlands, these include coastal hazards, Managaha island, lagoons and reefs, ports and industrial areas, and shorelines.

This study was challenged to identify important ecosystem services provided by relevant wetlands on the islands of Saipan, Tinian and Rota. Using available data, it was necessary to provide appropriate economic valuations of these services. The study takes into account the values that different stakeholders derive from wetlands on the CNMI and therefore provide an inclusive overview of the benefits that are affected when considering any potential adaptation of these areas. The values can be especially useful early in the development process to inform the mitigation hierarchy. This process explains how to '*Avoid'* as much damage as possible, '*Minimize'* what is not avoidable, and '*Offset'* what is eventually impacted.

A range of local stakeholders from the public and private sector were involved in a workshop in April 2019. This provided valuable insight into the priority wetlands and ecosystem services that are provided. Extensive secondary data were also collected and analyzed to provide the final valuations of each service and wetland. An overview of key threats to these systems is also provided.

The most valuable service by total, yearly value was '**pollutant and sediment removal**'. An aspect that not many people would immediately think about but is worth nearly **US$ 5 million per year**. If they degrade and CNMI's wetlands lose the capacity to filter these particles, sediments will damage local infrastructure or flow into the sea and Saipan's lagoon, thereby adding nutrients to the water. This has a direct effect on surrounding coral reefs, which provide many valuable services such as coastal protection and tourism. It is often these consequential effects, which are underestimated and undervalued.

'Water supply' from wetlands was another particularly high-valued service. At over **US$ 4.5 million per year**, this provides valuable insight into how expensive it is to artificially produce local drinking water. It is often much more cost-effective to conserve the natural source than to build infrastructure to replace the service once it has degraded. The individual wetlands with the highest values were, '**Lake Susupe**' on Saipan, '**Talakhaya**' on Rota, and '**Makpo**' on Tinian, representing **US$ 4.1 million**, **US$ 2.4 million**, and **US$ 2.3 million** per year, respectively.

Other key provisioning and regulating services were also valued economically in this project. Some services, including aesthetics and recreation, cultural heritage, and habitat support, were analyzed qualitatively. Early settlements in the Marianas, for example, where local wetlands provided food and raw materials are described in the report. Also, the habitat locations of key species, such as the Mariana moorhen and Rota blue damselfly are spatially indicated. There is also significant international value associated with CNMI's wetlands. The ability of these ecosystems to sequester carbon and store it in their soils, vegetation and water bodies is essential for global climate control. The value of the total carbon stored in these ecosystems is over **US$ 18 million** per year. This is equivalent to the expected costs of global damages associated with the release of all this carbon, if the wetlands become degraded.

These values can be particularly useful when informing conservation actions and evaluating potentially significant impacts of site-specific development proposals. Also, when adverse impacts to the APCs occur or are expected to occur, these values can help to inform appropriate enforcement and mitigation processes. This can also help inform future spatial planning efforts, making it clear which areas need particular attention and protection from adverse effects. Overall, these values provide a wealth of new information about CNMI's extensive wetland ecosystems. These natural areas, are under pressure from human activities, provide essential provisioning, regulating, and cultural services to the local community and global population. It is of great importance that their conservation, and restoration, when possible, is supported.

1. Introduction

Natural areas such as wetlands are often the source of many essential services that contribute to the wellbeing of the local, and often also regional and global, population. Wetlands in the Commonwealth of the Northern Mariana Islands (CNMI) control floods and safeguard water quality, store freshwater, provide nitrogen fixation and carbon sequestration, support habitats of federally-recognized threatened and endangered species, and contribute areas of recreation for locals and tourists (CNMI, 2011; DCRM, 2017). Their degradation could therefore lead to irreversible, critical and costly consequences, such as an increase of vulnerability to hazards in some areas, a decrease in groundwater recharge, and a higher risk of contamination of coastal water due to altered wetland filtration functions (CNMI, 2011).

Due to the open-access nature and public good characteristics of wetlands, they are often undervalued. This leads to situations where the full societal value of wetlands is not incorporated in development decisions, thereby leading to land-use planning that does not fully consider or account for the many services these systems provide. To remedy these challenges, there are many types of fiscal and market-based tools available to governments to assess and quantify these values in order to provide economically efficient natural resource management solutions. Understanding the value of natural areas and the services they provide is essential for well-informed decision making and policy development. These resource management planning dialogs should be underpinned by strong, data-driven methodologies that are useful for the intended purposes of the information.

Through the expression of the value of wetlands in monetary units, guidance is provided to stakeholders and those responsible for the management on how benefits and costs are affected when changes to the ecosystem are made. This analysis can help to provide insight when there are opportunity costs for land-use and for the development and implementation of rules and regulations.

For the CNMI this economic valuation of high-priority wetlands aims to support review and updates of existing laws, policies, and management measures. Wetland compensation claims and mitigation hierarchy guidance require more detailed economic information regarding the total economic valuations of sites. This will aid more accurate cost-benefit analyses and provide more precise comparability between sites and offer opportunities for improved mitigation and restoration outcomes. To obtain improved baseline information and support ongoing management planning efforts the CNMI Bureau of Environmental and Coastal Quality's Division of Coastal Resources Management (DCRM) has contracted the consortium of Wolfs Company, Brander Environmental Economics and the Institute for Environmental Studies, VU University, Amsterdam to carry out an economic valuation of the services provided by inland wetland ecosystems in the CNMI. This report describes the methodology used for the baseline valuation, the results and policy recommendations for the application the established wetland values.

2. Scope of ecosystem services assessment and valuation

2.1 Geographical scope

This wetland ecosystem service valuation study focuses on inland wetlands considered a priority present on the islands of Saipan, Tinian, and Rota, as seen in Figure 1. Saipan, Rota, and Tinian are the three developed islands of the 15 islands that make up the CNMI. Alongside the island of Pagan, these four islands support all primary inland wetlands of the CNMI. The islands became a Commonwealth of the United States in 1986 and are now subject to all U.S. environmental laws.

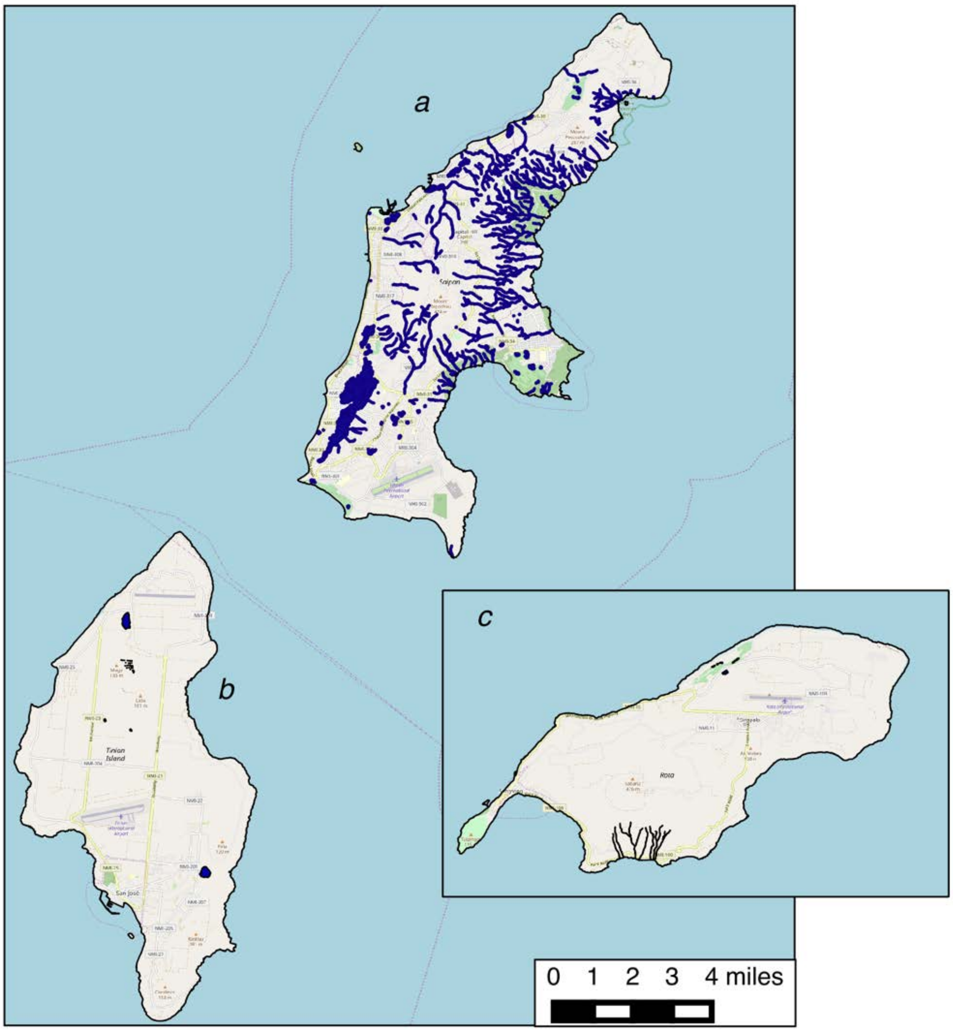

Figure 1 – Geographical scope of the ecosystem services valuation. The study area consists of three islands of the CNMI, Saipan (a), Tinian (b) and Rota (c). Marked blue areas represent wetlands, as defined by DCRM regulations as "Areas of Particular Concern" (NMIAC § 15-10-330). Note: the location of Rota was moved closer to Saipan and Tinian for easier representation in the figure.

2.2 Wetlands on the islands of the CNMI

Wetlands, as defined by the U.S. Federal Water Pollution Control Act (Clean Water Act) (33 U.S.C. §§ 1251–1387), are "areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil condition". In the CNMI, wetlands are ecosystems, which are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal conditions do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. The presence of the following indicators are used to assess these systems: presence of hydric soils, hydrophytic vegetation, or visible wetland hydrology (CNMI, 2016; NMIAC §15-10-020 zzz). This definition covers all swamps, marshes, mangroves, lakes, natural ponds, surface springs, streams and estuaries in the CNMI. Although not all of the wetlands on CNMI have been delineated, the most recent survey reports 717.8 acres of wetlands on the islands on Saipan, Tinian, and Pagan, with Rota having streams and associated riparian areas (BECQ, 2018). Most of the freshwater wetlands are palustrine emergent (non-tidal wetlands, or tidal with a salinity due to ocean derived salts of less than 0.5 percent, dominated by emergent) and provide habitat for obligate wetland reed species.

Saipan hosts the most wetlands on CNMI, the largest being the brackish-water lake Susupe. The 40-acre Lake Susupe and 350 acres of contiguous palustrine emergent and forested freshwater wetland surrounding the lake, located on the southwestern coastal plane of Saipan, comprise about 75 percent of Saipan's freshwater wetlands (60% total CNMI's freshwater wetlands). Streams on Saipan are intermittent, originating from mountain ridges, and provide wetlands with water during heavy rains. Many depressional wetlands are situated along the western coast of Saipan (AECOS, 2005).

There are smaller wetlands on Tinian, most of them ephemeral. The largest wetland is Lake Hagoi (38.2 acres), which is never completely dry under typical conditions. On Tinian there are also several seasonal wetlands, and two wetland complexes suspected to be artificial (Mahalang and Bateha, a result of past military/war activities). Makpo Swamp water levels have been considerably reduced due to municipal groundwater pumping (USDN, 2009). There are no permanent streams on Tinian.

Natural surface water on the island of Rota is limited to streams and associated riparian areas as well as a few smaller depressional wetlands that depend on the island's streams which can completely dry out during drought conditions (AECOS, 2005).

Water quality monitoring results by the Bureau of Environmental ad Coastal Quality's Department of Environmental Quality (BECQ-DEQ) indicate water quality issues in wetlands in the CNMI. Development activities, water diversion, nutrient loading, and invasive species are pressures that reduce wetland extent and water quality (CNMI, 2016; BECQ, 2018).

The majority of the potential study sites are inland wetlands, with some riparian or mangrove areas. The 1991 Comprehensive Wetlands Management Plan for Saipan and 2015 Rapid Assessment Method (RAM), performed by the DCRM, already identified and conducted initial valuation assessments of a list of potential priority wetlands. However, this list is limited to a small set of typical wetland types on Saipan. This study expands on that assessment with enhanced valuation data and extends the list in order to provide a comprehensive overview of priority wetlands on the islands of Rota, Tinian, and Saipan.

2.3 Data availability

A wide variety of spatial and socio-economic data were collected and used throughout the study. A full list of data sources can be found in Annex 1. While spatial data concerning the terrain, climate, land use and vegetation were of very high quality (in terms of spatial resolution and how recently they have been updated), data on more detailed wetland characteristics are largely absent. Such data are however crucial to differentiate between different wetlands. Regarding locations of wetlands, only those delineated by CNMI experts are available. Additional information on wetland specifics would contribute to more informed policy support. Such information could include, among others:

- Exact wetland type;
- Presence of surface water (in both the dry and wet seasons);
- Depth of wetland;
- Soil type;
- Vegetation types;
- Presence of fauna (i.e. other than only the endangered Marianas Moorhen);
- Quality of water (e.g. pollution levels); and
- Threats to wetlands.

Moreover, common names of the wetlands should be defined. Some wetlands (such as Susupe, Hagoi, and Makpo) are named, and their location is well known. Other wetlands are named only by their location, where often the exact location is not clear. Local authorities have spent considerable efforts in updating the data on wetlands in the past years. Improving these data would demand regular monitoring. Additionally, based on the stakeholder discussions, there are likely more wetlands on CNMI that have not yet been mapped, or identified (e.g. they may have been degraded some decades ago).

Additional data that would also have been desired are updated data on agricultural activities. The 2009 agricultural census was used for the purposes of this study. We therefore had to rely on stakeholder consultation to derive better estimates of livestock and cropland activities, amount of fertilizer used, and irrigation activities. Other data that were not available include information on damages due to sediment deposition after rainfall events or potential costs related to their removal. Finally, data on past wetland conversions, both permitted and unpermitted, as well as historic compensation values of wetlands exchanged or compensated for under wetlands exchange program authorized by Public Law 5-33 were not available to us. Such data would assist in identifying the extent of past compensations or land exchanges and could help inform additional discussions regarding mitigation and restoration opportunities moving forward.

2.4 Selection of ecosystem services

The Economics of Ecosystems and Biodiversity (TEEB) is a global initiative focused on 'making nature's values visible' that reflects growing international efforts to mainstream the values of biodiversity and ecosystem services into resource management decision-making. TEEB aims to achieve this goal by following a structured approach to valuation that helps decision-makers identify the wide range of benefits provided by ecosystems and biodiversity, demonstrate their values in economic terms and, where appropriate, capture those values in decision-making.

Table 1 Ecosystem services (ES) provide by wetlands and considered a priority for the CNMI based on wetland related assessments and strategies. The final list will be selected during a stakeholder workshop.

		ES classification for inland wetlands		
Service		**MEA**	**TEEB**	**CNMI***
Provisioning	Food (aquaculture)	✓		
	Fresh water (households, tourism, industry)	✓	✓	✓
	Agricultural production (crops and livestock)	✓		✓
Regulating	Climate regulation (carbon sequestration)	✓		✓
	Water regulation (hydrological flows, groundwater recharge and storage)	✓	✓	✓
	Pollution control (water purification, nutrient cycling and waste treatment)	✓	✓	✓
	Erosion regulation	✓		
	Natural hazard control (flood, storm, drought)	✓	✓	✓
Cultural	Spiritual and inspirational	✓		
	Recreational	✓	✓	✓
	Aesthetic	✓	✓	✓
	Existence value of biodiversity	✓	✓	✓

*Coastal and Estuarine Land Conservation Plan for CNMI; Coastal Resources Management Program Assessment and strategy 2016-2020 report; Guidance for Establishing Wetland Buffers in CNMI to protect "Environmentally Sensitive Areas" and ensure "No Net Loss", Climate Vulnerability assessments for Rota, Tinian and Saipan.

An overview of ecosystem services, as outlined by the Millennium Ecosystem Assessment (MEA, 2005), The Economics of Ecosystems and Biodiversity (Russi et al., 2013), and selected documents from the CNMI is presented in Table 1. The final list of ecosystem services that need to be evaluated was developed together with the stakeholders during a workshop on Saipan. Some of the ecosystem services identified as important by the MEA and TEEB may not be important for the CNMI. On the other hand, through the involvement of different stakeholders (experts from various CNMI departments) the context specific relevance can be investigated for various ecosystem services. For example, while the presence of introduced fish species (e.g. tilapia) is mentioned in some documentation as problematic because it is an invasive species, this could also be considered as the food (fish) provision service of specific wetlands.

In this report we therefore propose methods to quantify, analyze, and value, to the highest extent possible, the ecosystem services provided by wetlands on CNMI. Such quantification will enable the prioritization of the wetlands and their ecosystem services and support the future development of mitigation and compensation schemes in the CNMI.

3 Local policy and relevance of ecosystem service valuation

3.1 Wetland exchange and compensation schemes

The purpose of this study is to better understand the extent of ecosystem services provided by wetlands on CNMI. Through prioritization of wetlands on the island, assessment of their related ecosystem services and eventual valuation, local restoration and conservation efforts will be supported. Finally, it will be used to inform the process of mitigation that needs to be followed in order to protect key wetlands and to better formulate the requirements for mitigation. This section describes how wetlands are currently managed in the CNMI and how the results of this study are expected to be incorporated.

3.2 Current state of wetland compensation on the islands of the CNMI

Saipan, Tinian and Rota experience significant development pressure due to the growth of the population, expansion of commercial activities (mostly tourism) and military activities, and demand for products and services. The island of Tinian hosts considerable military activities and is slated for increasing military build-up in the Marianas as part of the 2010 Guam and CNMI Military Relocation Record of Decision (75 FR 60438). New airport and infrastructure projects are planned for construction. As appropriate land for development has become scarce, some wetlands were filled (legally through 404 CWA permitting or illegally and discovered as after the fact violations) or their ecologically important vegetated buffer zones (transitional vegetated areas surrounding wetlands) were cleared, leading to increases in invasive species and at times decreasing water quality and condition of the wetland itself. These pressures have led to demand for environmental regulation surrounding the destruction of wetlands. Wetlands on CNMI are protected by three main policy tools:

Clean Water Act Programme: Section 401 Water Quality Certification Program and its permitting provisions;

Clean Water Act Programme: CNMI Water Quality Standards / National Park Service: anti-degradation policy; and

Division of Coastal Resource Management: Areas of Particular Concern, Mitigation Hierarchy, and “No net loss of wetlands” policy, as well as federal consistency provisions.

The water quality standards (WQS) “anti-degradation” policy states, that “all wetlands are to remain in as near their natural state as possible and shall be protected to support the propagation of aquatic and terrestrial life”. The “no net loss” policy does not only address wetlands (in terms of acreage), but also no net loss of their ecosystem services (functions and productivity) (BECQ, 2014).

Although compensatory mitigation was established under the Clean Water Act federally throughout the U.S., this has been observed to lead to small, isolated wetlands being restored without long-term value (USDI, 2003). Therefore, wetland banking was considered, to provide compensation for numerous impacts to wetlands in advance of the impact (USDI, 2003). Consistent with federal U.S. policy it was proposed to introduce a wetland banking system for the CNMI (DCRM, 2017, 2017; Gilman, 1997).

Table 2 Examples of wetland mitigation on Saipan. Sources: (DEQ, 2004; Gilman, 1999)

Project name	Year	Aim	Impact activity	Type of impacted wetland	Type of mitigation wetland	Area of impacted wetland (ha)	Area of mitigation wetland (ha)
Fina Sisu, Susupe	1992	N.A.	road construction and filling the wetland	palustrine emergent	N.A.	0.06	0.06 (un-successful)
Falig, Achugao	1993	moorhen habitat	construct private home, filling wetland	palustrine forested	palustrine emergent with open water	0.9	0.43
JG Sablan / PSS	N.A.	moorhen habitat	construct commercial and government buildings, fill wetlands	palustrine emergent	palustrine emergent	N.A.	N.A.
Kagman	1994	moorhen habitat	agricultural flood control project, filling a wetland	palustrine emergent	2 wetlands, 0.04 enhanced, 0.68 created palustrine and lacustrine	0.18 (4 wetlands)	0.72
Chalan Pale Arnold, Tanapag	1994	reed warbler and moorhen habitat	road widening, filling wetland	palustrine emergent	palustrine emergent with open water	0.57	0.57
Power Center, Susupe	1995	moorhen habitat	construct commercial buildings, filling wetlands	palustrine emergent and forested wetland	created 0.88 and enhanced 1.49 palustrine with open water	0.88	2.37
Chalan Monsignor Guerrero, Oleai	1995	reed warbler and moorhen habitat	road widening, filling wetland	palustrine emergent and forested wetland	palustrine emergent with open water	0.65	0.65
Guerrero, Oleai	1996	moorhen habitat	construct commercial buildings, filling wetlands	palustrine forested	lacustrine	0.31	0.31

For the development of private lands, for example, which may affect an area of wetland, consultation with DCRM must also take place. If permission is rejected and the wetland is classified as “high value”, land exchange or financial compensation may be pursued by the applicant with DPL pursuant to CNMI Public Law 5-33. DPL uses a dedicated appraisal process to determine these values.

Following the U.S. Endangered Species Act, 33 USC § 1531 et seq., the U.S. Fish and Wildlife Service now determine whether degradation of wildlife habitat from development projects are unavoidable and have been minimized to the maximum extent possible. In some jurisdictions if these criteria have been met, credits from a mitigation bank may be bought or sold to offset impacts. Currently, however, there are no active wetland mitigation banks in the CNMI.

CNMI has submitted a Coastal and Estuarine Conservation plan, which calls for acquisition priority for the following wetlands: Lake Susupe and its surrounding wetlands, Laolao Bay, Obyan Beach, the Talakhaya area (Rota), the area on Rota surrounding the Mochong Latte site, and several sensitive areas on Tinian, especially the area surrounding that island's water supply (CNMI, 2011). Additionally, the U.S. Navy has a wetland management plan for the wetlands in the Tinian Military Lease Area (Hagoi, Mahalang, Bateha), where conservation and restoration of wetland functions is planned (USDN, 2014). However, as can be seen in several examples in wetland mitigation projects, these efforts have generally resulted in replacing wetlands with simple water bodies and not with functionally comparable wetlands (Table 2). This demonstrates that it is important to understand which services are lost and which must be compensated when carrying out these types of projects.

3.3 Options for wetland compensation on the islands of the CNMI

To cope with the growing development pressure and limitations in terms of available land, establishing and managing a wetland mitigation bank to compensate for activities resulting in wetland degradation and loss has been suggested (DCRM, 2017; Gilman, 1997).

Gilman (1997) also provides alternative methods to streamline the CNMI wetland regulatory framework and maximize wetland quantity and quality from compensatory wetland mitigation (Table 3).

Before compensatory wetland mitigation banking can take place, the mitigation sequence must be followed, which was agreed through a Memorandum of Agreement (MOA) between the Environmental Protection Agency (EPA) and the Department of the Army in 1990. This sequence follows the steps outlined below:

- Avoid impacts - Adverse impact to aquatic resources are to be avoided and no discharge shall be permitted if there is a practicable alternative with less adverse impact.

- Minimize impacts - If impacts cannot be avoided, appropriate and practicable steps to minimize adverse impacts or restore impacted systems and values must be taken.
- Offsets for unavoidable residual impacts - Appropriate and practicable *compensatory mitigation* is required for unavoidable adverse impacts which remain (2 CMC § 15-311). The amount and quality of compensatory mitigation may not substitute for avoiding and minimizing impacts.

Also, once permission for development has been granted, the mitigation hierarchy, described above, must be followed (see 2 CMC 15-10-311 and Mitigation Hierarchy Policy Guidance). The Mitigation Hierarchy Policy Guidance document also provides suggestions of project types that can be implemented to address particular ecosystem-related issues. Specific guidance is provided for wetland ecosystems. An indication of its potential enhancement value and cost estimate is also provided.

Table 3. Alternative methods to improve the wetland regulatory framework, based on Gilman (1996).

Method	Description
Acquire privately owned wetlands	Acquisition of privately-owned wetlands by land exchange or purchase.
Voluntary protection	Encouraging private wetland owners to protect wetlands by using tax breaks, permitting the sale of transferrable development rights, bargain sales and educational outreach.
In-lieu fee-based compensatory wetland mitigation	Investors in authorized projects that impact wetlands are required to pay a public or private entity who uses the money for wetland preservation and conservation
ADID and categorization	Clean Water Act Advanced Identification process allows identifying wetlands of low value, that are permitted to be degraded. Ranking of CNMI wetlands is necessary to do so.
Comprehensive Wetlands Plan	A plan, that would coordinate activities of all wetland regulators, provide assessment of all wetlands, and identify wetlands that are permitted to be impacted. The plan allows to account for cumulative impacts to wetlands, locate compensatory mitigation wetlands, and ensure that site-specific ecosystem services are not lost. The plan could also account for recovery of endangered species that depend on wetland habitats.
Apply section 401 water quality certification program to wetlands regulation	A Section 401 Water quality certification, required for projects that involve a discharge of pollutants, could be used to prevent impacts to wetland's water quality (sediment retention, pollutant and nutrient uptake)

Implementing programs that address non-point source pollution and other causes of indirect impacts on wetlands	Developing a non-point source program protecting wetlands from some of the indirect impacts (non-point pollution, storm water discharge, groundwater lowering, alterations to hydrology) that are not regulated by Section 404 or 401 programs.
State or Commonwealth assumption of Section 404 program	The state's or Commonwealth's regulatory program would have to provide the same level of protection as the section 404 program.
USACE General Permit	The USACE can issue permits for discharges of dredged and fill material in water of the US (including wetlands). General permits can apply to a particular category or activity that will not cause significant impact to wetlands.
Streamlined permit application requirements	Streamlining application processes by submitting only one application and putting a reasonable maximum time limit on regulatory agencies.

There are three distinct mechanisms for compensatory mitigation as outlined by the EPA Wetlands Compensatory Mitigation factsheet.

- **Permittee-Responsible Mitigation**: At-site or off-site mitigation where the permittee is responsible for the implementation and success of the mitigation.
- **Mitigation Banking**: A wetland area that has been restored, established or enhanced (or sometimes preserved), which is then set aside to compensate for future conversions of wetlands for development activities.
- **In-lieu Fee Mitigation**: Usually a public agency or non-profit organization collects fees from multiple permittees in order to pool finances. These are then used to build and maintain the mitigation site. The sponsor is ultimately responsible for its success and the site is typically built after the permitted impacts.

To deduce levels of mitigation or offset, many conservation and mitigation banks have used acreage as currency although this approach has been criticized as an imprecise measure of losses of ecosystem values and benefits (Fox & Nino-Murcia, 2005). Mitigation requirements (restoration, offset, or compensation) should be proportionate to the extent of the impact – acreage of wetland loss however cannot be considered proportionate to loss of water supply, destruction of habitats for endangered species, or regulation of hazards. A valuation of ecosystem services will create insight into the scale of compensation or mitigation required for different services. For example, hydrological functioning of wetlands, watershed wide implications of nutrient cycling, and acreage necessary to support certain species or habitat to a minimum standard based on species behavior.

Often, mitigation ratios are used to identify the number of specified units necessary to mitigate wetland impacts. Ratios can be based on general knowledge, for example the relationship between the amount of remaining habitat and a particular species' conservation needs. Ideally, different impacts are evaluated individually. Mitigation ratios can be based on qualitative factors (such as scale of impact), however any ratio needs to be based on sound rational that is easily explained and consistent (USDI, 2003). Valuation of wetlands is therefore of highest importance in order to identify the amount of currency for mitigating impacts on wetlands in CNMI.

An example of a mitigation bank established on CNMI is the Saipan Upland Mitigation Bank Area (SUMBA). The mitigation bank was established to protect, manage and maintain the habitat of the Nightingale Reed-warbler (Acrocephalus hiwae) (DLNR, 2002). The size of the mitigation bank was 1035 acres, and 97 credits in ratio 2:1 have been awarded (U.S. Species Banking, 2019). This program is still being managed by DFW today.

4 Wetland prioritization

4.1 Participatory wetland and ecosystem services identification

We identified, mapped, and prioritized wetlands and their ecosystem services (ES) on CNMI using a participatory approach. We included local experts on wetlands and nature in general during a visit to the CNMI to prioritize the wetlands and collect any information and data, that was necessary for an economic valuation of wetland ecosystem services as described later. This workshop was particularly important for wetlands, that have not been assessed in the RAM. The workshop took place on April 12, 2019 on Saipan. In total, 23 experts from different institutions involved in managing wetlands on CNMI participated in the workshop:

- Department of Public Lands
- Department of Lands and Natural Resources, Division of Fish and Wildlife
- Bureau of Environmental and Coastal Quality:
    - Division of Coastal Resources Management
    - Division of Environmental Quality
- Micronesian Islands Nature Association (MINA), a local non-profit
- National Oceanic and Atmospheric Administration (NOAA)
- Local environmental consultants
- Northern Marianas College
- United States Army Corps of Engineers

The workshop was divided in separate parts:

1 Identification of ecosystem services provided by wetlands on CNMI

2 Prioritization of wetlands that provide these services

3 Identification of threats to wetlands

4 Providing data and setting up meetings in the days following the workshop.

Results of the workshop were directly used in the valuation study and were digitized (mapped using a Geographic Information System) by Wolfs Company after the workshop.

Identification of ES provided by wetlands on CNMI

In the first step of the workshop we introduced the CNMI wetland valuation project, and the objective of the workshop. We then presented the stakeholders with the preliminary list of ecosystem services provided by wetlands on CNMI, based on the MEA and TEEB frameworks, and information from CNMI documents. Stakeholders were then invited to include additional benefits received by the residents from wetlands or remove those ecosystem services deemed as not important. This list served as a final selection of ecosystem services and as a basis for assessment and valuation in this study.

Prioritization of wetlands that provide these services

The second step of the workshop was spatially explicit wetland prioritization. The stakeholders identified wetlands of high priority for each group of ecosystem services. Stakeholders were asked to associate the wetlands on the map with each of the identified ecosystem services. For example, when asked about recreation, the stakeholders were asked to point out the wetlands that are in areas used for recreation by the local population and tourists. Ecosystem services were assessed at watershed-scale – stakeholders were encouraged to consider the vicinity of wetlands and potential uses that do not directly occur on wetlands themselves (e.g. recreation could occur in a wider wetland area). We asked the stakeholders to identify four (4) "most important" wetlands for each ecosystem service for each island (Rota, Saipan, and Tinian).

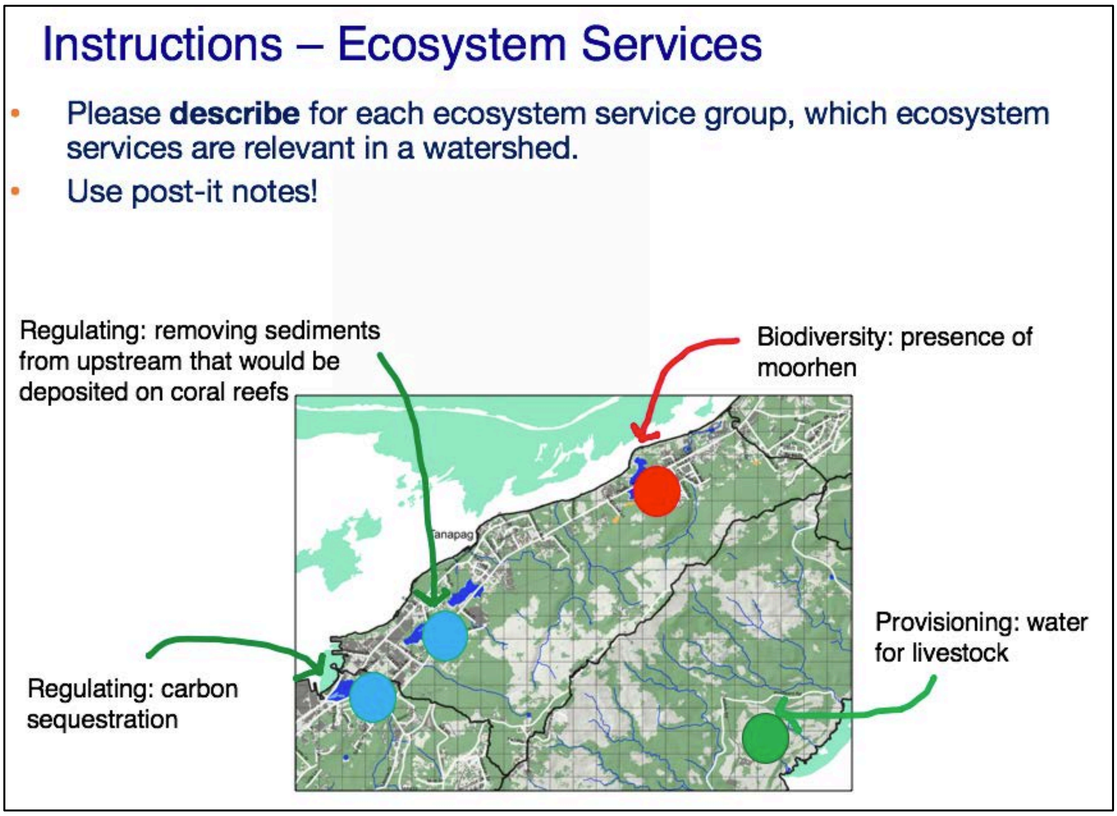

Figure 2. Example instruction on identifying priority wetlands and the threats to CNMI wetlands

The stakeholders were provided instructions on how to define the wetlands on the map using a set of different colors and a variety of means (sharpies, post-it notes, additional paper, see example instructions in Figure 2. Participatory mapping (Figure 3) was performed by delineating spatial features or points of interest (such as wells, past hazard events, invasive species, endangered species) on a map prepared before the workshop.

The map included all wetlands mapped in the "Areas of Particular Concern" data provided by DCRM, with delineated watersheds and a land cover and terrain map serving as background to facilitate the identification of correct locations. Supplementary maps on soil, erosion, hydrology, land use, geology, vegetation, and coastal habitats were also provided to the participants so they could consult them during the mapping.

Besides identifying priority wetlands for the valuation, this step also served as a mapping exercise for wetland ecosystem services that cannot be quantified due to a lack of data (e.g. recreation), services for which a value cannot be derived (e.g. importance for cultural heritage), or any other reason (such as no possibility to collect primary data).

Figure 3. A group of involved stakeholders identifying priority wetlands.

Identification of threats to wetlands

The stakeholders were asked to identify the main threats to wetlands on CNMI, and to map the locations and wetlands that are subject to these threats on the same maps as were used to map priority wetlands (Figure 4). The threats could be long-term and past threats (such as settlement expansion), or expected future threats (such as infrastructure expansion, pollution, and climate change).

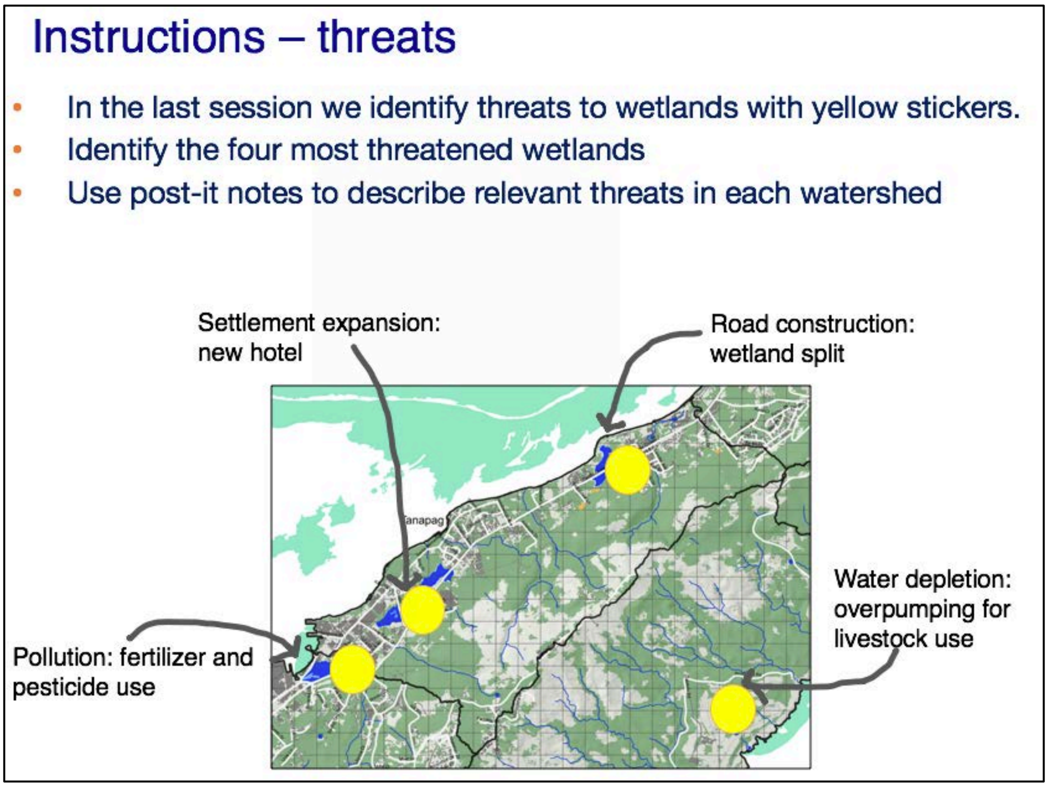

Figure 4. Example instruction on the threats to CNMI wetlands

Providing data and setting up meetings in the days following the workshop

At the end of the workshop the stakeholders were asked to provide data behind their choices of priority wetlands and their threats. We aimed to collect any additional data on specific wetlands, including but not limited to amounts of freshwater being extracted, hazard events and damages, presence of invasive species, and recreation and aesthetic value of a wetland. Using the maps of priority wetlands and threats the stakeholders identified which data they can provide or provided contacts of other experts in CNMI that had such data. Meetings with all experts mentioned as data providers were arranged in the next days on Saipan, and we were provided with additional data as well as unpublished reports.

4.2 Ecosystem services addressed in the study

From the shortlist of key ecosystem services and based on the preliminary research and workshop, a final selection was chosen. These can be found in Table 3.

Table 3 Ecosystem services identified by the stakeholders that are addressed in this study

ES group	Description
Provisioning	
Water supply	Provision of drinking water
Water for agriculture	Water use for irrigation and livestock
Regulating	
Shore erosion prevention	Preventing or mitigating shoreline erosion
Drought mitigation	Supplying emergency feed and pasture for livestock
Climate regulation	Carbon sequestration
Habitat support	Moorhen habitat Nursery for mangroves Habitat/nursery for important marine species
Pollution and sediment control	Treatment of pollutants in water (e.g. fertilizers) and capturing sediments
Cultural	
Aesthetics and recreation	Recreation in or near wetlands and appreciation of their aesthetics
Cultural heritage	Sites of early Chamorro settlements Traditional local food harvesting
Research and outreach	Wetlands important for research, outreach and education

4.3 Priority wetlands

Below we provide a list and maps of priority wetlands based on the workshop and stakeholder consultation. For each wetland we provide the ecosystem service for which it was identified as having high significance. Some wetlands are not named, so they are identified either by their location, the name assigned by stakeholders, or the name used by documents provided by DCRM and other stakeholders (for example, “A guide to the CNMI’s wetlands and permit processes” and the “Saipan Comprehensive Wetlands Management Plan”). A spatial shapefile is also provided with this study using identical nomenclature.

Some wetlands are grouped due to several reasons. They are either a group of smaller wetlands that were potentially a larger wetland in the past, a group of larger wetlands where it made sense to treat them as one wetland complex due to its complexity and importance (for example, all Susupe wetlands), or were treated as a group by stakeholders and the data/documents they provided.

The individual wetlands and their contribution in terms of different ecosystem services, are described in more detail in the chapter “Ecosystem services valuation”. The location of wetlands are shown on Figure 5, Figure 6, and Figure 7.

4.4 Identified threats to CNMI wetlands

The stakeholders identified a wide variety of threats to particular wetlands on CNMI:

Invasive species

The stakeholders identified both the encroachment of invasive vegetation (introduced plants), as well as animals (mostly fish). Wetlands, that are under threat due to invasive species are all on Saipan, specifically:

- Susupe wetland complex;
- Chalan Lao Lao / Chalan Kiya wetlands; and
- Tanapag / As Mahettok wetlands.

Pollution and illegal waste

The stakeholders identified wetlands that are under threat by sediment deposition due to human activities surrounding them (after extreme rainfall events), wastewater discharge, pollution due to excessive nutrients (fertilizers), and illegal dumping of solid waste. Wetlands identified to be under threat by pollution and waste are all on Saipan, specifically:

- Garapan / American memorial park wetlands;
- Sadog Tasi mangroves and inland wetland complex;
- San Roque / Puntan Achugao wetlands;
- Kagman watershed wetlands; and
- Susupe wetland complex.

Stakeholders also identified constructed wetlands on golf courses on Saipan as being under threat due to pollution (fertilizers and pesticides used on golf courses). Moreover, the Makpo wetland on Tinian experienced severe pollution in the past decades due to intensive agriculture surrounding it. The issue is however resolved, as it was impacting the only water source on the island, and agricultural activities in the Makpo area are now limited.

*Table 4 Priority wetlands with the ecosystem services they provide for each of the three islands under investigation. Wetlands marked with * are artificial wetland that do not necessarily fall under the Clean Water Act definition. The order of wetlands does not imply any prioritization.*

		Prov.		Regulating					Cultural			Threats				
ID	**Wetland(s) name**	water supply	agricultural production	shore erosion	drought	climate	habitat support	sediment and pollutant	aesthetics and recreation	cultural heritage	research and outreach	invasive species	pollution and illegal waste	development	water withdrawal	other threats
Saipan																
1	As Lito wetland							x	x							
2	Bakery wetlands						x				x					
3	Chalan Lao Lao, Chalan Kiya wetlands						x	x	x		x	x		x		
4	Flores wetland						x				x					
5	Garapan wetlands / *American Memorial Park**						x	x	x		x		x	x		
6*	*Kagman drainage wetland**							x			x		x			
7*	*Kagman North / Mitigation wetland**						x				x		x			
8*	*Kagman South**							x					x			
9	Lake Susupe, Susupe and Chalan Kanoa wetlands					x	x	x	x	x	x	x	x	x		
10	Sadog Tasi (mangroves and inland wetland)			x			x	x		x	x		x			
11	San Roque / Puntan Achugao wetlands						x	x		x	x		x	x		
12	Tanapag / As Mahettok wetland						x	x			x	x		x		
13	Tanapag lower base wetland						x	x			x			x		
14	North of Kagman (ID117)							x		x			x			
*15**	*Marianas Country Club Golf Course**						x		x		x					
*16**	*North East (ID144)*						x				x					
*17**	*Lao Lao Bay Golf Course**						x		x		x					
*18**	*Kingfisher Golf course**						x		x		x					
20	Tanapag stream mangroves			x			x	x			x			x		
21	DanDan driving range / southwest San Vincente wetland						x				x					

ID	Wetland(s) name	Prov.		Regulating					Cultural			Threats				
		water supply	agricultural production	shore erosion	drought	climate	habitat support	sediment and pollutant	aesthetics and recreation	cultural heritage	research and outreach	invasive species	pollution and illegal waste	development	water withdrawal	other threats
Tinian																
1	Bateha wetlands						x				x					x
2	Hagoi				x		x			x	x					x
3	Mahalang wetlands						x				x					x
4	Makpo	x	x								x				x	
Rota																
1	Talakhaya watershed streams		x				x		x		x					
2*	*Rota resort**						x		x		x					

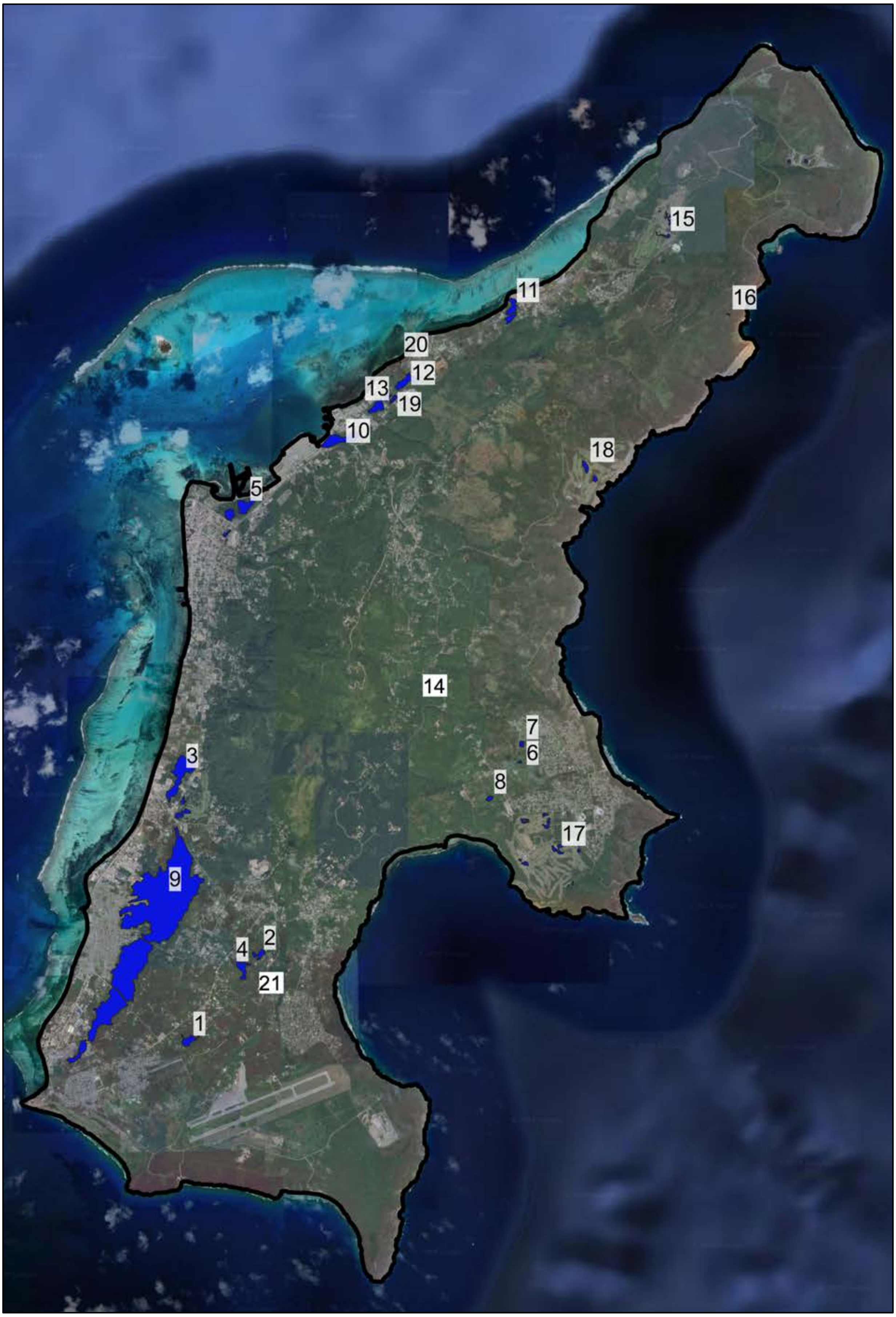

Figure 5. Priority wetlands on Saipan. Numbers refer to the wetlands in Table 4.

Figure 6. Priority wetlands on Tinian. Numbers refer to the wetlands in Table 4.

Figure 6. Priority wetlands on Tinian. Numbers refer to the wetlands in Table 4.

Figure 7. Priority wetlands on Rota. Numbers refer to the wetlands in Table 4.

Development

Wetlands on CNMI are being impacted by encroachment of infrastructure (e.g. roads and other infrastructure dissecting natural areas), but also expansion of settlements. This does not need to have a direct effect (e.g. building over a wetland), as in the past some wetlands near settlements have been drained and/filled. Wetlands that were identified to be under threat by development are all on Saipan:

- Tanapag, Lower Base wetland;
- Tanapag / As Mahettok wetlands;
- Susupe wetland complex;
- Garapan / American Memorial Park wetlands;
- Chalan Lao Lao / Chalan Kiya wetlands; and
- San Roque / Puntan Achugao wetlands.

Water withdrawal

The Makpo wetland serves as the main source of drinking water for Tinian, which is a sole source aquifer system. The primary source of water on Rota is in the Talakhaya watershed, where the water is also heavily pumped for drinking water and agricultural activities. The stakeholders identified that both wetlands could be under threat in case of increased water withdrawal, particularly in dry periods. Makpo could as well be under threat of possible nutrients or other contaminants that may enter the groundwater associated with development or military build-up activities. This would affect the quality of the water in the wetland and could lead to irreversible consequences (loss of water resources).

Other threats

Other threats to wetlands were identified as well. Hagoi, Mahalang, and Bateha wetlands on Tinian were identified to be under threat due to current and proposed military activities in the surrounding areas that could lead to pollution or degradation of the wetland vegetation and wildlife. Local stakeholders mentioned that numerous wetlands on Saipan were under threat by free roaming animals (goats and cattle), which can result in pollution of wetlands and eutrophication. Exact wetlands subject to this threat were however not identified.

5 Economic value of wetland ecosystem services

Wetlands on CNMI support the local population in numerous ways, including by supplying people with freshwater, supporting habitats for important species, offering opportunities for recreation, and contributing to important economic sectors such as tourism. The economic value of the main wetland ecosystem services estimated in this chapter demonstrates the importance of the benefits that the population of CNMI receives from wetland ecosystems.

The following subsections describe the approach of the economic valuation and provide descriptions of methods and results of the valuation of each ecosystem service included in the analysis. For some ecosystem services it was not possible or appropriate to calculate economic values. For such ecosystem services we provide qualitative descriptions of their importance to the population and economy of CNMI.

5.1 Ecosystem services valuation methods and data collection

Market based valuation

Many provisioning services are either directly or indirectly traded in markets (e.g. water consumption, fish catch). Assessing the economic value of these services is done by estimating the market value of the products (market pricing) or estimating their value as an input in production (production approach).

Valuation based on avoided damage and replacement costs

Most regulating services (e.g. water flow, waste treatment, flood control) are not traded in markets. However, economic costs will increase if these regulating services disappear. Also, provisional services (e.g. water) can be lost due to degradation, and their replacement results in financial burden.

Qualitative methods

Cultural, aesthetic and recreational ecosystem services rarely traded in markets. Surveys assessing the Willingness to Pay (WTP), Willingness to Accept, or Willingness to Work for these services are often used. However, primary data collection such as this is not part of this study. Additionally, analyses can be carried out using social media platforms such as Flickr or Panoramio, which allow the classification of photos to rank the perceived importance of certain areas. This is particularly important in case of no primary data collection. Services can also be described using stakeholder input and literature.

Data collection

This study is predominantly based on secondary data sources. Between January and July 2019, numerous experts on ecology, water management, land use planning, wetlands, and environmental resources in general were contacted in order to collect data in support of the study. Published and unpublished reports were received, and analysis included expert opinion, scientific papers, audit reports, and spatial data that can be analyzed using a Geographic Information System (GIS) where appropriate. The data used are presented in each respective chapter.

There was no primary data collection performed during this study. However, a wide range of experts and stakeholders have been invited to participate in a workshop, where a considerable portion of data collection was performed, including as a participatory mapping exercise.

Table 5 Valuation techniques used in this study (Brander et al., 2006; Liu et al., 2010).

Ecosystem service	Value	Valuation technique
Provisioning		
Water supply	Direct use	Replacement cost
Water for agriculture	Direct use	Market based: production approach
Regulating		
Shore erosion prevention	Indirect use	Replacement cost
Drought mitigation	Indirect use	Avoided damage
Climate regulation	Indirect use	Avoided damage
Habitat support	Existence and indirect use	Qualitative and replacement costs
Pollution and sediment control	Indirect use	Avoided damage
Sediment and flood control	Indirect use	Avoided damage
Cultural		
Aesthetics and recreation	Existence and indirect use	Qualitative
Cultural heritage	Existence and indirect use	Qualitative
Research and outreach	Existence and indirect use	Qualitative

5.2 Water supply

5.2.1 Methods

Wetlands on CNMI provide freshwater for the local population (drinking water) and for agricultural activities (livestock and irrigation). Depressional wetlands on Saipan are not directly providing freshwater due to the geological characteristics of the island (freshwater occurs as ground water, and the main wells are situated in areas where the aquifers are unaffected by wetlands) and the location of wetlands, most of them being situated on the western coast downstream (Carruth, 2003; DNA, 2015a). However, freshwater stream sources on the east side of the island are used to supplement supply lines on Saipan. It is possible that depressional wetlands and wetland fringe areas serve groundwater recharge functions that contribute water volume and can help improve water quality of Saipan's groundwater sources. Although there is currently no evidence to demonstrate this, there is a USGS groundwater study in progress at the time of writing, which may provide additional insight. Wetlands on Tinian and Rota have been identified as priority wetlands in terms of fresh drinking water supply (Figure 8). The Makpo (or Marpo) wetland on Tinian provides water for the whole population of Tinian (DNA, 2015b) by supplying water for the Maui II well. The Hagoi wetland was identified as a potential water source for cattle during dry months, however, more research is necessary to quantify this, which is why it is not considered in the valuation.

The primary water source for the population of Rota are the springs of Onan and Main (Water) caves from the largest aquifer on the island in the Talakhaya watershed below Mt. Sabana (DNA, 2015c; Keel et al., 2005). Although USEPA and DEQ consider the source itself to be “groundwater”, this seep/spring system as a whole tends to demonstrate wetland characteristics (personal communication with local experts). Because it is not possible to treat the source and streams separately, we considered the whole Talakhaya watershed in our study.

Unfortunately, data on different types of commercial users was not available, however all commercial users get billed the same way. Businesses are considered as metered, which means that we had to use the total current commercial water withdrawal as water used commercially.

Using the amounts of water extracted by the Commonwealth Utilities Corporation from the Makpo wetland we were able to quantify the provision of water for residential and commercial users of Tinian. After discussing with local experts it became clear that the current water resources from the Makpo wetland are sufficient to provide the local population with water, and that the resources are not under threat, provided the current water withdrawal quantity does not increase and CNMI does not experience serious drought conditions. Such a situation would change, however, if there were drastic alterations to the wetland such as its conversion or use of the wetland or the surrounding areas for intensive agriculture (both cropland and livestock grazing). In this case, the water source would most likely need to be replaced with a reverse osmosis (RO) desalination plant. We therefore estimated the costs for replacing the water source of Makpo by looking at the water treatment and maintenance costs of a reverse osmosis plant:

$$V_{water} = eW_s * C_e + C_{RO}$$

Where the value of water supply (V_{water}) is a sum of total water treatment costs defined by multiplying the estimated current water supply (eW_s) in gallons, with current energy costs (C_e) of treating a gallon of water (US$ per gallon) and the costs of building and maintaining a reverse osmosis plant for this size (C_{RO}) in US$ per year. To calculate the current energy costs, we considered electricity rates per kWh charged by the local utilities corporation, together with the current fuel adjustment charges (CUC, 2019). The cost of treating a gallon of water on CNMI depend mostly on the cost of producing electricity used to treat the water, as CNMI currently uses fossil fuels (diesel) to produce electricity. To estimate the costs of a reverse osmosis plant, as well as operating costs, we compared different RO plant manufacturers and current costs of RO plants present on CNMI. Existing RO plants on CNMI are however much smaller, with much higher costs per gallon of water, compared to new RO desalination plants.

5.2.2 Results

The Maui II well at the Makpo wetland provides water for 2,984 inhabitants in 926 households, with 900,000 gallons of water being extracted from the well daily (CNMI CSD, 2019; DNA, 2015b). The Talakhaya watershed provides water for 2527 inhabitants in 923 households on Rota, where also 900,000 gallons of water are being extracted daily. A direct valuation of water supply was difficult, as the local utilities corporation that manages the water resources reports over 70% of the total water extraction being unbilled. This is due to leaks, unauthorized water connections, and overuse of agricultural and business water billed at a flat rate. Most of the households are at this point still unmetered, however fully equipping households with meters is in progress, and the Commonwealth Utilities Corporation (CUC) estimates that the average household water consumption will be 125 gallons per day per capita (compared to the current production of 301 gpd/per capita for Tinian and 356 gpd/per capita for Rota). The improved future total household water production was calculated to be 373,000 gallons per day (or 136,145,000 gallons per year) for Tinian, and 315,875 gallons per day (or 115,294,375 gallons per year) for Rota. This present 42% and 35% of the actual current water production for Tinian and Rota respectively. Together with the value for the existing water production, we also estimated the value of water supply for such a situation. We therefore used two different values to identify the size of the proposed RO plant, based on its production (gallons/hour).

The total annual value of replacing the water source to satisfy the water produced by Makpo and Talakhaya is US$ 4,621,990 annually ($2,310,995 each). If metering or other efficiency measures reduced per capita demand from the current 301 gpd (Tinian) and 356 gpd (Rota) to 125 gpd, the replacement value would be reduced to US$ 985,600 and 824,120 for Makpo and Talakhaya respectively.

Table 6 Total annual value of water supply by the Makpo wetland and the Talakhaya watershed.

		Makpo, Tinian		Talakhaya, Rota	
Total annual value		Current water production	Improved water production	Current water production	Improved water production
Daily water consumption per capita	Gallons/ day	301	125	356	125
Total annual water production	Gallons	328,500,000	136,145,000	328,500,000	115,294,375
Production of RO desalination plant	Gallons/ hour	37,500	15,600	37,500	13,200
Reverse Osmosis plant annual costs (investment + operational costs,)	US$	281,067	126,500	281,067	109,120
Electricity costs, annual	US$	2,029,928	859,100	2,029,928	715,000
Total costs	US$	**2,310,995**	**985,600**	**2,310,995**	**824,120**

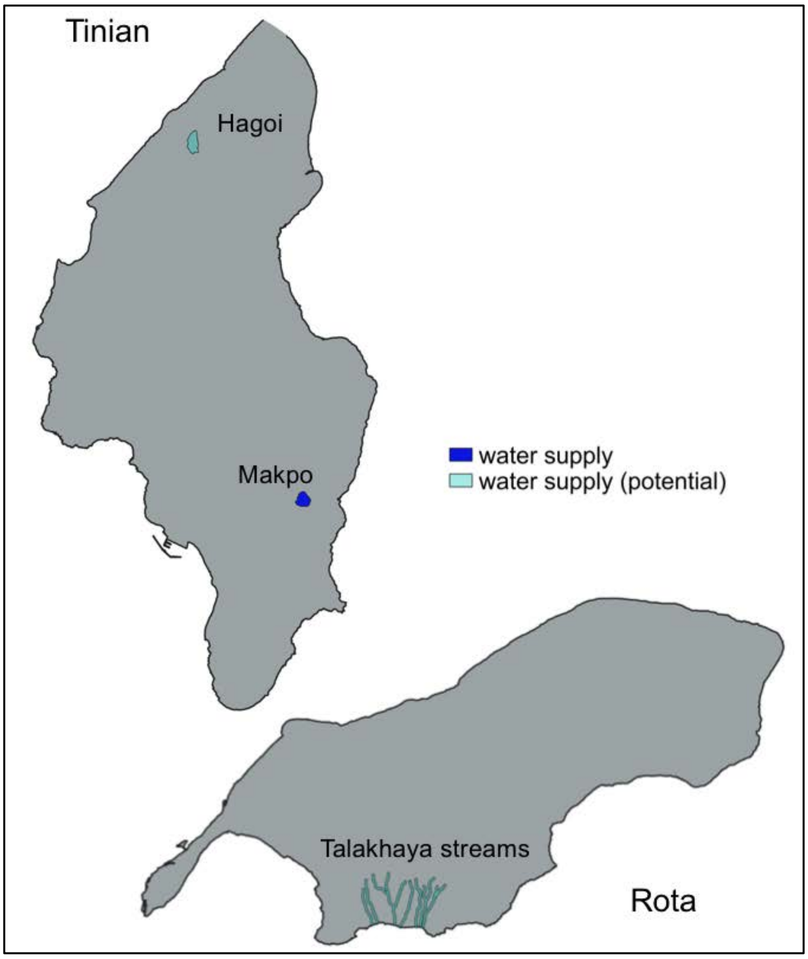

Figure 8. Priority wetlands for provisioning services on Tinian and Rota. Hagoi is displayed as a potential source for cattle, as mentioned during the stakeholder workshop, but there is no data to confirm this.

5.3 Agricultural production

5.3.1 Methods

Commercial and subsistence agricultural activities take place on Rota, Saipan, and Tinian. The farmers that mostly depend on wetlands for their water are on Tinian and Rota, as they rely on the water extracted from the Makpo (Tinian) and Talakhaya (Rota) wetlands. Most recent and detailed data on farmers and their water use are only available for Tinian. Over recent decades however, agricultural outputs on Tinian have decreased due to dwindling local and tourist populations. Tinian also experiences extended periods of drought, roughly every 5-10 years. A bit more than a third (37.5%) of producers on Tinian obtain water from the municipal water distribution system, which depends on the Makpo wetland water source (Duponcheel, 2017). According to 62.4% of producers on Tinian, water-related costs make up 40-60% of farm expenditures.

Out of 97 farms on Rota, 63 irrigate their land. A small proportion of farmers (8) directly use water from freshwater streams in the Talakhaya watershed (DCRM, 2015), and 52 receive their water from the public utility (USDA, 2009). In total, 60 farms are dependent on wetlands on Rota for irrigation according to the available data.

On Saipan, farmers do benefit from the Kagman watershed project, that was planned to support agricultural activities and protect the Kagman watershed from floods and sediments. The wetlands built in the course of the project are however man-made and fall outside the scope of this study (although they do contribute to irrigation activities, the data on such activities is however unavailable).

In this study, we therefore considered the wetlands on Tinian and Rota providing water for agricultural activities (Figure 8). To estimate the value of the wetlands on those two islands for agricultural production, we calculated the added value of agriculture. We used data from the Agricultural census of CNMI (USDA, 2009) and the most recent producers survey for Tinian (Duponcheel, 2017). In the survey, 24 producers of a total of 43 were interviewed on their agricultural activities and water use.

To calculate the added value of agriculture supported by wetlands, we used the following equation:

$$V_{agri} = eF_W * (A_s - A_e)$$

Where agricultural added value (V_{agri}) is defined by the estimated share of farms directly depending on water from wetlands (eF_w), total sales of agricultural products (A_s) and total expenses (A_e). This added value can only be achieved by utilizing the water provided by the wetlands. Farmers would either need to cease their operations or find a more expensive water source in case a wetland would be depleted. Based on our stakeholder consultation, terminating with agricultural activities is however more likely, due to high costs associated with alternative water sources (e.g. reverse osmosis which would result in unreasonably higher water costs). Data is accessible only for the year 2007, which was adjusted using the consumer price index for CNMI since 2007 (CNMI CSD, 2019).

5.3.2 Results

Using the sources mentioned above, we estimated that in total 76 farms (16 on Tinian and 60 on Rota) and their activities directly depend on water from wetlands. This represents 46% of all farms on CNMI. Wetlands on both islands result in 343,665 US$ agricultural added value. Despite the small number of farmers depending on wetlands on Rota, farmers on this island have a high added value (considering sales and expenses), also due to the fact that higher value crops (such as taro) are grown on the island.

Table 7 Total annual value of agricultural production supported by water from wetlands. Values corrected according for current prices using the 2018 consumer price index.

Total annual value		Makpo wetland, Tinian	Talakhaya streams, Rota
Total annual sales (2007 US$)	US$	126,047	713,423
Total annual expenditures (2007 US$)	US$	121,674	374,132
Agricultural added value (2007 US$)	US$	**4,374**	**339,291**

5.4 Shore erosion prevention

5.4.1 Methods

Coastal wetlands such as mangroves are crucial in preventing shore erosion (Brander et al., 2012; Brown et al., 2006; Spaninks and van Beukering, 1997). Their roots slow water flows, control sediments, and build and bind soils, all necessary functions that prevent erosion (Spalding et al., 2014). At present, only a small portion of mangroves are still present on Saipan. The reduction in mangrove cover on the western coast of Saipan increased exposure to erosion. This threatens crucial road infrastructure (Beach Road) and private properties, as this is the most densely populated part of the CNMI. Considerable efforts have been proposed by the local government to reverse the erosion trends and prevent future erosion by restoring wetlands which will collect the incoming sediment (U.S. Army Corps of Engineers, 2017). These efforts consist both of hard measures (engineered structures), as well as of soft measures, such as vegetation restoration (both seagrass and mangrove and replanting of shoreline vegetation). A study had been performed to estimate the cost of such measures (U.S. Army Corps of Engineers, 2017), which we use as estimates for replacement costs. The study was performed for preventing shore erosion in the area between the American Memorial Park and Sugar Dock.

We first looked at the costs associated with different types of shore protection measures provided by the study. The costs vary and are provided both for the initial investment of the implementation of the measure, as well as total costs per 1000 feet construction or restoration in the next 50 years, which also include maintenance of such infrastructure, or periodical replacements of the vegetation (for example replanting mangroves every few years in ecologically appropriate areas). The values were recalculated per one foot of mangrove per year using the 50-year total cost of the project.

Secondly, we measured the current shoreline protected by mangroves on Saipan using field visits, photographs, and spatial data on mangroves. This presented challenges for several reasons. First, the spatial data on the coastline of Saipan is coarse, not capturing the length of the shores of mangroves at sufficient detail. Secondly, it is possible that the shores have changed since the last time they were mapped. Additionally, as the shore covered by mangroves are parts of estuarine wetlands, a larger section of the shore could be affected in case the mangroves would be degraded. We used high-resolution satellite images to map the shore, potentially affected by mangrove removal (Figure 9). We confirmed the location of these wetlands by field visits, wetland reports and stakeholder consultation (Figure 10). Subsequently, we calculated the value of shore erosion prevention for these wetlands using the following method:

$$V_{erosion} = E_v * S_l,$$

where the total annual value of erosion (Verosion) is calculated by taking the replacement costs of building erosion protection measures (Ev), expressed as US$ per foot per year, and multiplying it with the length of the shore covered by wetlands expressed in feet (Sl).

Figure 9. Delineation of the shore covered by mangroves (example of the Sadog Tasi mangrove in Puerto Rico)

5.4.2 Results

Based on the Garapan shoreline erosion study, the U.S. Army Corps of Engineers concluded that it is likely that the most suitable erosion prevention measure is the combination of beach nourishment and T-head groins. Such measure might be necessary in case of severe shore erosion and was used to estimate the replacement costs for the remaining mangroves on Saipan. It would cost US$ 23.5 million per 1000 feet over 50 years: US$ 5.2 million construction costs and including maintenance costs for 50 years (U.S. Army Corps of Engineers, 2017). This amounts to US$ 470,000 per 1000 feet annually.

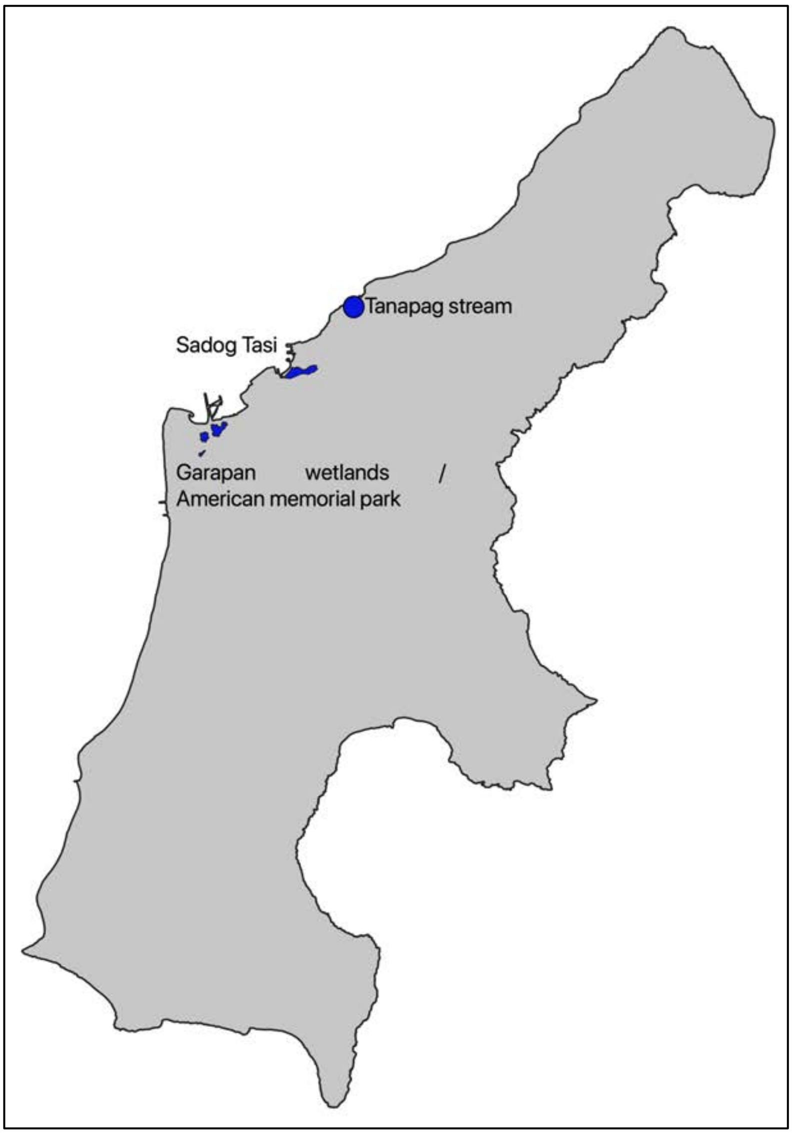

Figure 10. Wetlands with mangroves on Saipan

The Sadog Tasi and San Roque / Puntan Achuago wetlands (Figure 10) prevent shore erosion, as they host the last remaining mangrove areas on Saipan, consisting mostly of the native large-leafed orange mangrove or Mangle macho in Chamorro (*Bruguiera gymnorhiza)* (Jarzen and Dilcher, 2009; Mosher and Fancy, 2002). In total, both wetlands protect 895 feet of shoreline, amounting to a total US$ 420,650 erosion prevention value annually. The Garapan / American Memorial Park wetlands also host mangroves, both in relatively natural drainage systems in the central area of the park as well as in a constructed wetland drainage system in the western corner of the property. The constructed wetlands project was supported by US EPA and implemented by DEQ to address water quality concerns in the area but have been used recently as a mitigation project to re-establish mangroves that were impacted due to the Puerto Rico Dump closure and Peace Park development.

Table 8 Total value of shore erosion prevention

Total annual value		Sadog Tasi, Puerto Rico	Tanapag stream
Estimated mangrove length	Feet	755	140
Annual replacement costs	US$	**354,850**	**65,800**

5.5 Drought regulation

5.5.1 Methods

Wetlands, which store inland water and support vegetation growth, can provide valuable drought impact reduction functions during extremely dry periods. Droughts in CNMI occur frequently on all islands and have considerable effects on the vegetation, agricultural activities, and the quality and quantity of water resources (DCRM, 2015; Greene and Skeele, 2014).

Although agricultural activities on the island are adapted to dry periods every year, the islands also experience drought events with higher magnitudes that seriously impact local agriculture. One such event was the drought in 1998, where only 52% of the average annual precipitation occurred (DCRM, 2015). The drought had a very large impact, resulting in agricultural damage, with particularly high mortality rates of cattle on the island of Tinian. Only a portion of the cattle on Tinian survived, as the animals were able to graze around the Hagoi wetland. We therefore used the number of surviving cattle as the carrying capacity of this wetland in times of drought. Moreover, we used the number of cows that survived to identify potential costs that the farmers will have, as they would replace the dead animals with new cattle. We used cattle sales and purchase values from the agricultural census (USDA, 2009), and accounted for inflation to derive current estimates on values as such data were not available (CNMI CSD, 2019).

The value of drought regulation (V_{dry}) was calculated as follows:

$$V_{dry} = W_h * V_c$$

Where W_h is the holding capacity of a wetland, identified as the number of cattle that survived the extreme 1998 drought event, and V_c is the value of the cow when sold on the market.

5.5.2 Results

The 1998 drought severely impacted vegetation growth, resulting in unavailable feed for the livestock. Estimates suggest that only 25% of cattle survived, thanks to the emergency feed and pasture from the vegetation surrounding the Lake Hagoi (DCRM, 2015). The surviving number of cows was used to estimate the value of the drought mitigation capability of this particular wetland. While there were 4,077 cows on Tinian in 1990, already prior to the drought in 1998, the number decreased to 1,469. From the 1998 cattle population, 367 are estimated to have survived the drought and the remaining animals died as the supplementary feed in the wetland could not maintain more animals. It is possible that wetlands on Saipan and Rota have a similar function to support cattle in periods of drought, but there is no evidence to support this.

According to the CNMI Census of Agriculture, farmers sell their cattle on average for US$ 965 per head (US$ 757 in 2007 US$). This resulted in total US$ 354,082 total annual value for drought mitigation for the Hagoi wetland.

Table 9 Total value of drought mitigation for Hagoi.

Total annual value		**Hagoi wetland**
Estimated cattle holding capacity during drought	Number	367
Annual total value of animals supported by the wetland during drought (2007 US$)	US$	354,082

5.6 Climate regulation

5.6.1 Methods

In this study the economic value of carbon sequestration is estimated using the avoided damage method. The economic value of this service therefore represents the damage costs of climate change that are avoided due to the additional storage of carbon from the atmosphere in wetlands.

The economic value of carbon storage in wetlands (EVt) is estimated as the product of the carbon storage potential (Cstore) and the social cost of carbon (SCC) per ton of carbon dioxide. The conversion factor included in the formula (i.e. 3.67) corresponds to the ratio of the molecular weights of carbon and carbon dioxide. This ratio is used for estimating the equivalent carbon dioxide that can be produced if the carbon stored in the system is released to the atmosphere (Howard et al., 2014). This is summarized in the following formula:

$$EVt = 3.67 \cdot Cstore \cdot SCC$$

To estimate the quantity of stored carbon in estuarine wetlands on the CNMI, carbon storage values for similar land cover types in comparable environments were used. Donato et al. (2012) investigated above- and belowground carbon pools in soil and vegetation on two island groups, Yap and Palau, in Micronesia approximately 500km distance from Saipan. The test sites were distributed among three main vegetation structural types: mangroves, upland forests, and open savanna. The mean (total ecosystem) carbon storage per vegetation structure type was used as a proxy for wetlands on Saipan and Tinian. Open water and grassland were deemed to be most closely related to open savanna. Shrubland and forest were assigned values for upland forest and mangroves values were used for the short coastal mangrove sections on Saipan. Each wetland was assessed for its distribution of various vegetation types and assigned relevant mean values to calculate a total amount of carbon stored in the wetland.

Although wetlands form a complex system that results in the uptake and release of greenhouse gases, Mitsch et al. (2013) have indicated that methane release from wetlands becomes insignificant compared to carbon sequestration rates after a period of around 300 years. In this study, most wetlands on Saipan and Tinian were valued, Rota was excluded in these calculations, largely because all wetlands on the island are artificial and values for riparian systems in the Pacific are not well established.

To estimate the economic value of stored or avoided release of carbon, the relevant economic value per metric ton of CO_2 is the social cost of carbon (SCC), which is the monetary value of damages caused by emitting one more metric ton of CO_2 in a given year (Pearce, 2003). The SCC therefore also represents the value of damages avoided for a small reduction in emissions, in other words, the benefit of a CO_2 reduction (EPA, 2016; IWGSCGG, 2016). The SCC is intended to be a comprehensive estimate of climate change damages but due to current limitations in the integrated assessment models and data used to estimate SCC, it does not include all important damages and is likely to under-estimate the full damages from CO_2 emissions. The estimated SCC used by the US EPA and other US agencies for appraisal of emissions reductions in 2020 is US$ 64/metric ton CO_2, in 2007 US$ using an annual discount rate of 2.5% (IWGSCGG, 2016).

5.6.2 Results

Results of the assessment of total ecosystem carbon pool and valuation for the majority of wetlands found on Saipan and Tinian can be found below in Table 10. Although these values provide information from a comparable research site, a total of 24 observations were used. Additional research would be useful to assess the true value of carbon pools and sequestration rates of the CNMI wetlands and associated marine systems. As described in the literature review, the valuation of climate regulation is often calculated using annual, carbon sequestration, and rates of biotic and abiotic matter. Unfortunately, no relevant, local data were found on sequestration rates of similar vegetated wetland types. Therefore, we calculated the value of the total carbon pools present in the estuarine wetlands because relevant data were available for this. It must be noted that unlike the other values in this report, these are not annual values. These are values for the total carbon stored in the mentioned ecosystem types. This provides insight into the avoided cost of damage associated with degradation and ultimate release of greenhouse gases into the atmosphere. The total value corresponds to complete degradation and release of all stored carbon pools.

Table 10 Carbon pool of relevant wetlands on Saipan and Tinian, including economic valuation using the social cost of carbon.

Wetland(s) name	Area (ha)	Total carbon pool (tons carbon)	Total economic value (U.S. $ per wetland)	Value per ha (U.S. $)
Saipan				
As Lito wetland	2.91	563	132,248	45,446
Bakery wetlands	1.83	469	110,270	60,257
Chalan Lao Lao, Chalan Kiya wetlands	18.02	4,052	951,715	52,814
Flores wetland	3.46	746	175,154	50,623
Lake Susupe, Susupe and Chalan Kanoa wetlands	202.36	53,339	12,528,253	61,911
Sadog Tasi (mangroves and inland wetland)	8.69	3,327	781,369	89,916
San Roque / Puntan Achugao wetlands	4.85	1,115	261,780	53,975
Tanapag / As Mahettok wetland	4.42	1,169	274,461	62,095
Tanapag lower base wetland	5.1	1,306	306,822	60,161
North of Kagman (ID117)	0.22	59	13,773	62,602
North East (ID144)	0.06	16	3,761	62,686
DanDan driving range / southwest San Vincente wetland	0.34	68	16,033	47,157
Tinian				
Bateha wetlands	0.86	212	49,806	57,914
Hagoi	15.22	3,087	725,035	47,637
Mahalang wetlands	10.29	3,291	772,914	75,113
Makpo	12.94	5,094	1,196,471	92,463
Total		**77,912**	**18,299,864**	

5.7 Habitat support

5.7.1 Methods

Wetlands on Saipan, Rota, and Tinian are supporting crucial habitats for important wildlife species such as the endangered and endemic Mariana common moorhen (*Gallinula chloropus guami*). We obtained information on wetlands hosting the Mariana moorhen and any other species during the prioritization workshop, but also from mostly unpublished reports provided to us by the involved experts (local environmental consultants and the Division of Fish and Wildlife). The experts regularly monitor wetlands on CNMI by field visits, where they either perform visual identification, or auditory surveys by recording their sounds.

Additionally, there has been anecdotal evidence of other freshwater biodiversity present, such as eels and shrimp. These have been mentioned in flood control reports and articles on living conditions during World War II. Also, Leberer and Cai (2003) have reviewed shrimp species on the nearby island of Guam. Six species have been found, with five described, in habitats including inland freshwater and brackish waters.

The Sadog Tasi and San Roque / Puntan Achuago wetlands host the last remaining mangrove areas on Saipan, which were also identified by the experts as important habitat for marine species. Another important regulating function is, that the mangroves in these two wetlands can serve as important propagation sources for mangrove restoration on Saipan. We did not consider the Garapan / American memorial park mangroves as sources for habitats of marine species, as they are situated inland within the park (and are situated in a constructed wetland).

It is difficult to estimate the monetary values of wetlands that support important habitats, which is why habitat support has principally been evaluated qualitatively. The literature review provides in ‘Box 3’ an example of how an economic valuation of key species may be carried out. A value function has been developed by Amuakwa-Mensah et al. (2018), which takes into account a number of variables such as level of charisma and classification. The valuation is based on 56 primary value estimates of survey respondents’ ’willingness to pay’, which is a contingent valuation method form of analysis.

5.7.2 Results

Wetlands on Saipan that are high priority habitats for Mariana moorhen (Figure 11) are displayed in Figure 14. While the moorhen seems to occupy wetlands of all sizes, larger wetlands with surface water such as the lake in the Susupe wetland complex and Hagoi on Tinian are particularly important and classified as crucial habitats, hosting large portions of the total global Mariana moorhen population (DEQ, 2002; ERCE, 1991; Liske-Clark, 2015). Smaller, man-made wetlands were however also identified as important for the moorhen, which is why they were also included in the prioritization (U.S. FWS, 1992). The replacement costs of a wetland that can host moorhen are considered negligible by local experts, and mostly consist of building a pond or other similar, small body of water.

Wetlands on Saipan (Figure 14), that have been identified as important habitats for the Mariana Common moorhen include (wetlands marked with* are confirmed nesting sites, in other wetlands nesting cannot be excluded nor confirmed):

- Susupe wetland complex*
- Chalan Lao Lao / Chalan Kiya wetlands,
- Garapan / American memorial park wetlands,
- As Lito south wetland
- As Lito

- Flores pond*
- DanDan driving range / southwest San Vincente wetland
- Bakery wetlands
- Tanapag lower base
- Tanapag / As Mahettok wetland
- Constructed wetlands: Marianas country club golf course, North East, Lao Lao bay golf course, Kingfisher golf course, old Japanese water tank.

Lake Susupe, Tanapag lower base, and As Lito south are also a confirmed Nightingale reed-warbler (*Acrocephalus hiwae*) habitats (ERCE, 1991). The Nightingale reed-warbler is also an endangered species, however, does not directly depend on wetlands for its habitat and occupies the surrounding vegetation.

Figure 11. The Mariana common moorhen Gallinula chloropus guami, source: (Liske-Clark, 2015)

On Tinian, the following wetlands are important for moorhen (wetlands marked with* are confirmed nesting sites, in other wetlands nesting cannot be excluded nor confirmed):

- Hagoi lake*
- Bateha wetlands
- Mahalang wetlands

On the island of Rota, the moorhen can only be found in constructed wetlands of the Rota Resort, and it is assumed that they do not nest on the island itself but possibly on Guam, personal communication with experts on the island.

The Talakhaya streams on Rota support habitats for the Rota blue damselfly (*Ischnura luta*, Figure 12), which is an endemic species known only to Rota (Polhemus and Asquith, 2000). The Rota blue damselfly is endangered, with a remarkably limited spatial distribution. It is restricted to the streams in the Talakhaya watershed and has not been observed in any other wetland on Rota, let alone another island in the Mariana archipelago (Polhemus and Asquith, 2000).

Figure 12. The Rota blue damselfly Ischnura luta, (earth.com, 2019)

The Sadog Tasi and San Roque / Puntan Achuago wetlands host the last remaining mangrove areas on Saipan (Figure 13). The mangroves in the Sadog Tasi and San Roque / Puntan Achuago wetlands were identified as nursery grounds for important marine species, both fish and crustaceans. According to the involved stakeholders, pups of the endangered scalloped hammerhead shark (*Sphyrna lewini*) have been observed recently, with further monitoring necessary to confirm the area as an established nursing area.

Figure 13. Mangroves on Saipan, source: Wolfs Company.

We did not estimate the value of wetlands to support habitats in CNMI. However, other studies show, that restoring these habitats might be costly to prevent irreversible damage to habitats (or local extinction of species). For example, based on the mangrove restoration study, it would costs US$ 10 million per 1,000 feet in 50 years to restore mangrove habitats on CNMI: US$ 1 million construction costs and including maintenance costs over 50 years (U.S. Army Corps of Engineers, 2017). This amounts to US$ 200,000 per 1,000 feet annually. It may be possible to reduce these costs in practice, through the use of local capacity and efficient seed procurement, however these figures provide a recent guideline.

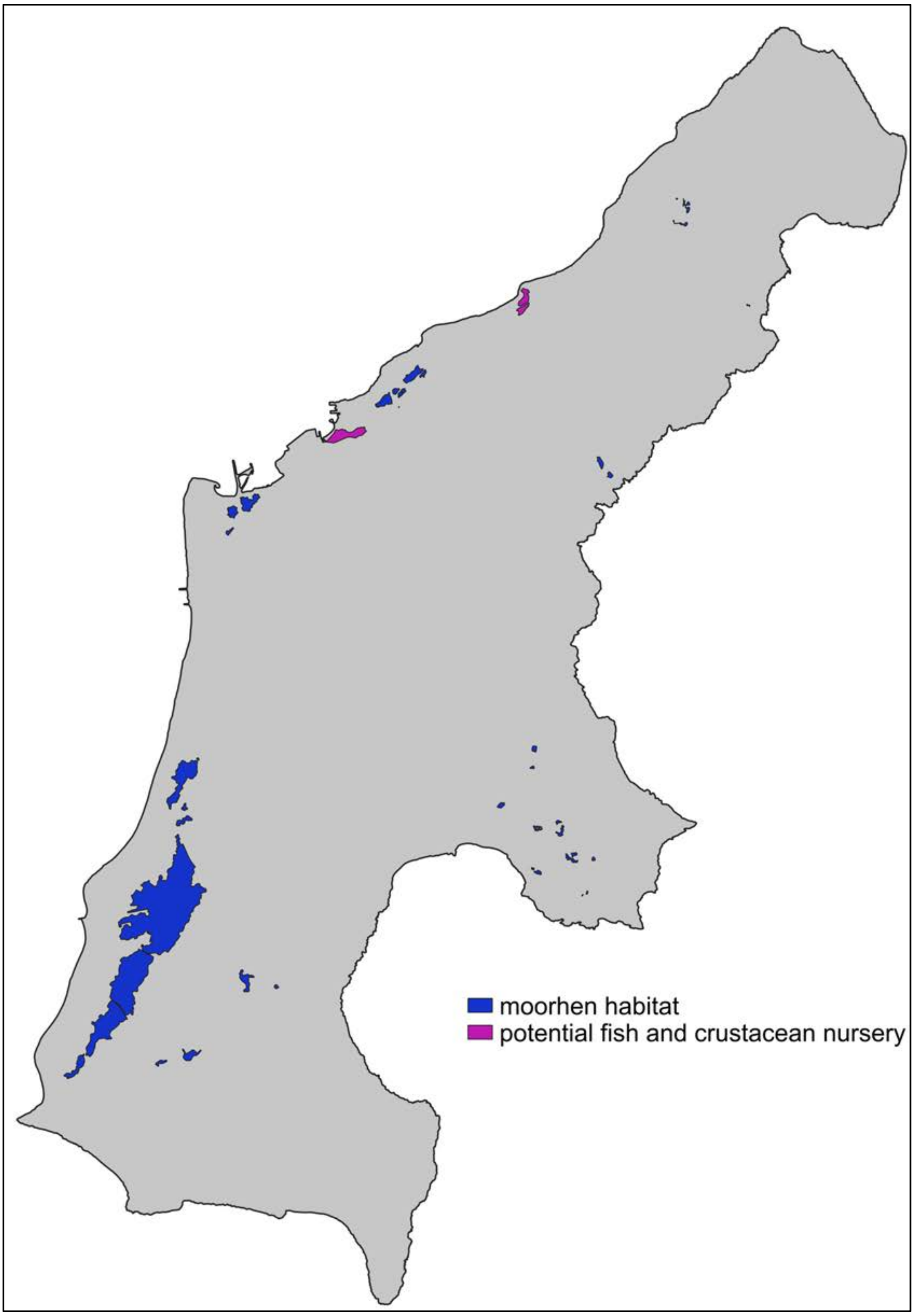

Figure 14. Priority wetlands for habitat support on Saipan

5.8 Pollutant and sediment control

5.8.1 Methods

Wetlands in CNMI control and mitigate sediment runoff and safeguard water quality by capturing and chemically converting or "fixing" nitrogen and phosphorus (CNMI, 2011). These services are particularly important with regard to the water quality of coastal receiving waters and the health of coral reefs. The degradation of wetlands might therefore lead to irreversible consequences in terms of a higher risk of contamination of coastal waters and degradation of the coral reefs, making the regulation of pollutants and sediments a benefit that is currently not explicitly recognized.

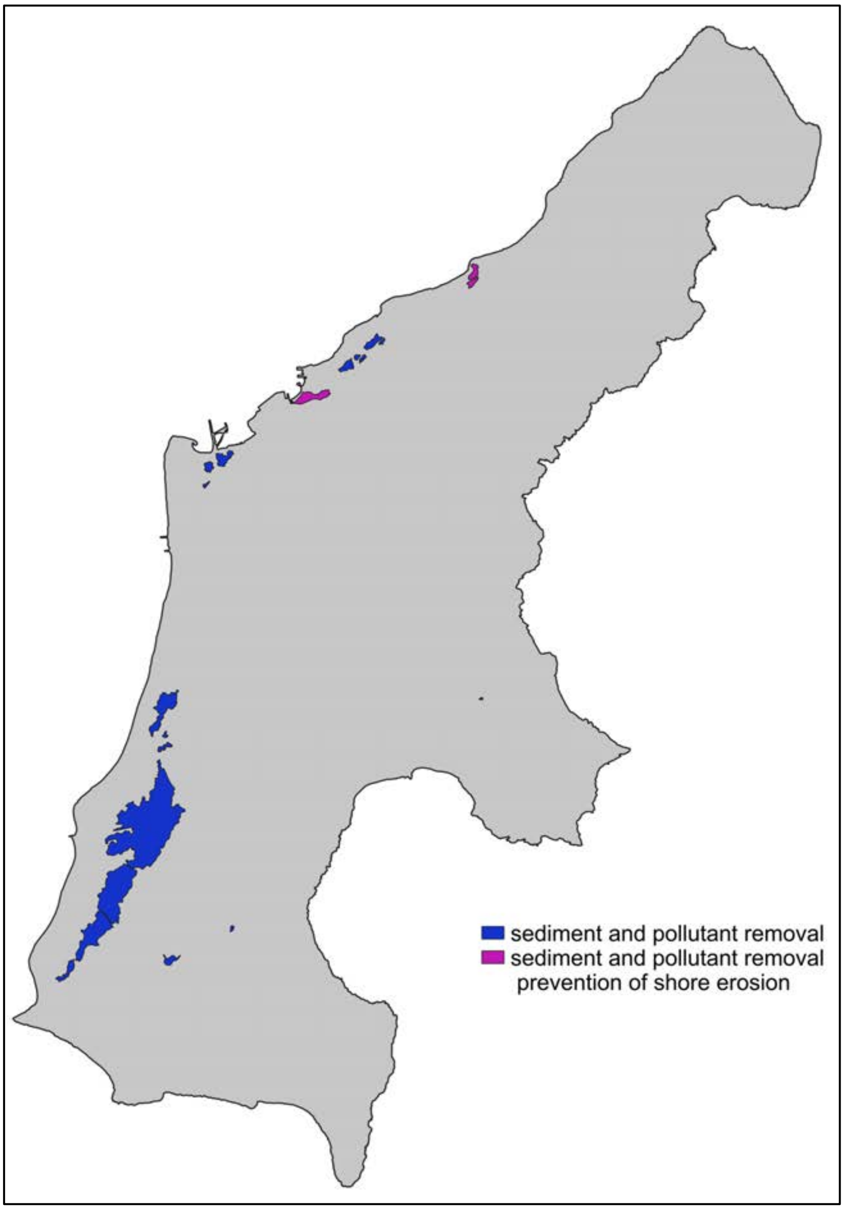

Figure 15. Priority wetlands for regulating sediments and pollutants, and shore erosion prevention on Saipan

Relationships between activities on land (development, agriculture, etc.) and their environmental consequences in coastal ecosystems are complex and not well understood. We therefore applied a sequence of different models to study and explain the role of inland wetlands on CNMI to protect coral reefs. In this section, we focus only on Saipan, as the stakeholders identified only wetlands on this island playing a significant role in capturing pollutants and sediments that would otherwise flow directly to the Saipan Lagoon (Figure 15). Moreover, wetlands on Saipan are the only wetlands on the three islands that are situated on the western shore, downstream of intensive human activities, therefore having a potential to capture sediments and pollutants. This is not the case for wetlands on Tinian or Rota as identified by our preliminary analysis.

We followed the upgraded conceptual model of nutrient enhancement of algal dominance on coral abundance, which states that the degradation of coral reefs often involves a phase shift from abundant coral to abundant macroalgae (McCook, 1999; Smith et al., 2006). This has also been observed on Saipan, where macroalgae have been identified to limit coral recruitment (Anderson, 2004; Houk and Camacho, 2010; Houk and van Woesik, 2008). We performed a preliminary investigation using ground data on coral health and macroalgae cover from NOAA (Anderson, 2004), and identified a negative correlation between live corals and macroalgae (R=-0.34). Macroalgae can also affect seagrass cover and health (McGlathery, 2001), however we found no correlation between macroalgae distribution and seagrass for Saipan. This is why did not consider other lagoon habitat types (e.g. seagrasses). Moreover, due to uncertainties related to bathymetry, we only performed our analysis on the coral cover in the Saipan lagoon, using the benthic habitat map (Anderson, 2004) – we assumed that corals outside the Saipan lagoon are not directly affected by the sediments and pollutants from Saipan’s land area.

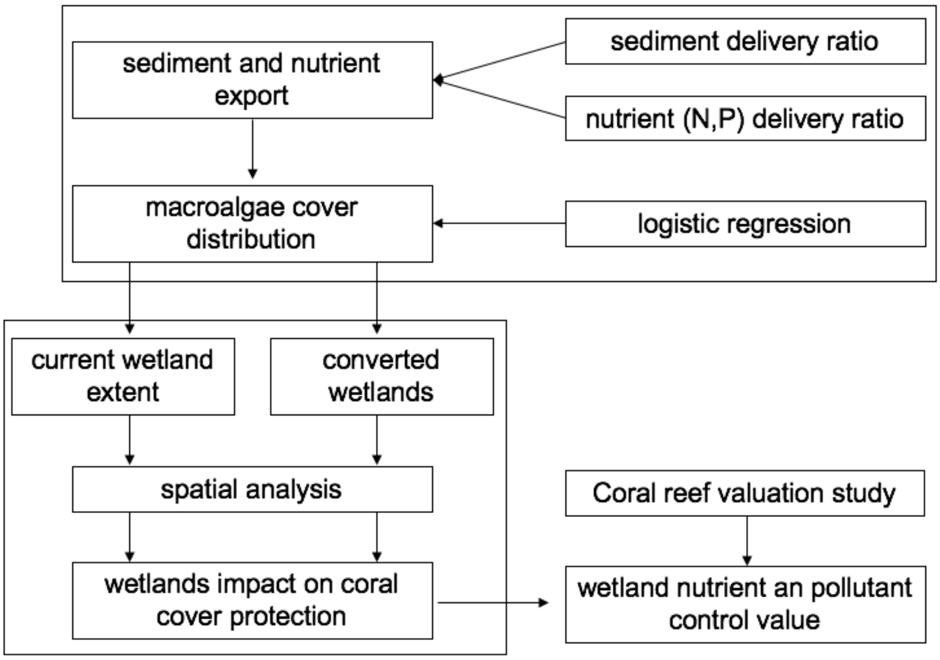

Figure 16. Conceptual model of pollutant and sediment control by wetlands on Saipan

Due to the criticism of the conceptual model of macroalgae abundance on its inability to fully explain coral-macroalgal phase shifts, we did not assume that increases in nutrients and sediments from the terrestrial surface directly lead to decreases in coral abundance. This is why, we developed our own conceptual model (Figure 16), where we studied the relationships between sediment and nutrient export, distance from the coastline, and lagoon floor type on the spatial distribution of macroalgae. We studied how the change in wetland area might result in changes in nutrients that reach the lagoon, which can in turn affect macroalgae cover and coral abundance. We did so by simply analysis how many areas with coral cover can be affected by macroalgae cover, if wetlands are converted or degraded. The model steps are described in more detail below.

Sediment and nutrient export

We first modelled the current sediment and nutrient export from human activities into the Saipan lagoon. We applied the sediment delivery ratio (SDR) and nutrient delivery ratio (NDR) models available in the InVEST modelling platform (Natural Capital Project, 2019). Both models are spatially explicit and account for the location of wetlands (potential removal of sediments and pollutants) and the receiving area, where sediments and pollutants are deposed.

The SDR model first calculates the annual soil loss for each unit on the elevation map provided, accounting for human use of the area. The soil loss is computed using the revised universal soil loss equation:

$$RUSLE = Ri * Ki * LSi * Ci * Pi$$

Where:

- Ri is the rainfall erosivity, defined by the amount and distribution of rainfall for each location;
- Ki is the soil erodibility defined by the type of soil at the location;
- LSi is a slope length-gradient factor defined by the elevation and computed by the model based on the slope of each location;
- Ci is the cover management factor, defined by the type and intensity of human use of the surface; and
- Pi is a support practice factor, which is defined by potential different cropland management practices (such as terracing). This was not considered in our analysis.

The SDR model then estimates the amount of these sediments that actually reaches the streams, and in our case, the lagoon, by looking at the area upslope of each location, and the flow path (based on the hydrology of the location) between the location and the nearest stream (Sharp et al., 2019). This is important, as the amount of sediments captured by wetlands depends on their location (e.g. wetlands upstream human activities cannot capture sediments resulting from these activities).

To simulate nutrient export, we used the NDR model, which calculates the mass of nutrients that move through space and reach the lagoon. It accounts for sources of nutrient loads across the landscape (e.g. cropland), which are defined by the land cover and associated loading rates. Moreover, the model also calculates the amount of nutrients captured by different land cover types, with wetlands being particularly effective in capturing such nutrients. We considered both nitrogen and phosphorus nutrient export, as they are together important for macroalgal growth (Smith et al., 2006). The model itself is similar to the SDR model (in accounting for the location in terms of distance to the nearest stream and the flow towards the lagoon).

For both models, we used spatial data on land cover, elevation, soil and hydrology of Saipan, provided by DCRM and NOAA (NOAA, 2018). We used the R-factor map for Saipan that is modified from the one for Guam by applying a rainfall coefficient for Saipan (Lander, 2004). We used the same modified OpenNSPECT coefficients for soil erodibility and cover management factors as used in a preliminary study for the Garapan area (Greene, 2017; NOAA, 2012). For nutrient loading rates, we used data on total fertilizer use on Tinian (DEQ, 2002), and ratios for nitrogen and phosphorus in fertilizers used by farmers for Guam (Schlub, 2011), as there was no data available for the CNMI. For nutrient retention efficiency, we used values from an extensive literature review (Sharp et al., 2019) combined with consultation with local stakeholder on the effectiveness of nutrient capture by wetlands on CNMI. It has to be noted, that due to the lack of local data, often proxy data and estimates had to be used. Where this was the case, we consulted with local experts.

The final result of the SDR and NDR models are the amount of exported sediments and nutrients (nitrogen and phosphorus) respectively for every watershed (the point where the sediments reach the lagoon).

Macroalgae cover distribution

To identify how simulated sediment and nutrient export influences the spatial distribution of macroalgae in the Saipan Lagoon, we developed a spatially explicit logistic regression model. We used the data on the most recent spatial distribution of macroalgae in the Saipan lagoon (Anderson, 2004). We first performed a spatially balanced sample of 125 presence of macroalgae points, and a sample of the same size to sample areas without macroalgae. Each point was assigned to the closest watershed based on Euclidean distance to the shoreline (in absence of more detailed flow data). We then associated all 250 points with variables describing the relationship between sediments, nutrients and the type of ocean floor (Table 11), as commonly identified as significant for macroalgae distribution by different sources (Fong et al., 1994; Houk and van Woesik, 2008; McCook, 1999; Smith et al., 2006). We performed a binary logistic regression and calculated the Receiver Operating Characteristics (ROC) to calculate how well the model represents the spatial distribution of algae.

The regression showed which are the most significant factors contributing to the spatial distribution of macroalgae in the Saipan lagoon, and lead to a development of a spatially explicit regression model:

$$Lm = C + Bv1 * V1 + Bv2 * V2 + .. + Bvn * Vn$$

- *Lm* is the likelihood for macroalgae at a location;
- *C* is the regression model constant;
- *BVx* is the regression coefficient for the significant variable;
- *Vx* is the value of the significant variable.

The variables, their significance and regression coefficients are summarized in Table 11 and were used to map the spatial distribution of macroalgae in the Saipan lagoon.

Table 11 Variables used in the logistic regression

Variable	Description	Data source
Soft ocean floor	Presence of areas with a soft ocean floor	(Anderson, 2004)
Distance to shore	Distance to the shore of Saipan	GIS calculations by Wolfs Company
Shore length of watersheds	Shore length of the closest watershed	GIS calculations by Wolfs Company
P	Exported phosphorus for each watershed	NDR model
P per shore	Amount of exported P per shoreline unit of closest watershed	NDR and GIS by Wolfs
P per distance	Amount of exported P normalized per reverse distance from shore	NDR and GIS by Wolfs
N	Exported nitrogen for each watershed	NDR model
N per shore	Amount of exported N per shoreline unit of closest watershed	NDR and GIS by Wolfs
N per distance	Amount of exported N normalized per reverse distance from shore	NDR and GIS by Wolfs
Sediments	Exported amount of sediments per watershed	SDR model
Sediments per shore	Amount of exported sediments per shoreline unit of closest watershed	SDR and GIS by Wolfs
Sediments per distance	Amount of exported sediments normalized per reverse distance from shore	SDR and GIS by Wolfs

To identify the role that the wetlands have on coral cover protection, we performed the above-mentioned analysis for the current situation, using the most recent land cover data, and a situation, where the wetlands are converted to another use. This way, we were able to compare the amount of nutrients and sediments, and the resulting macroalgae distribution, for both situations, and identify the extent of the wetlands' role to protect the coral cover in the Saipan lagoon.

Value of nutrient and sediment capture

To identify the value of wetlands and their role in safeguarding the coral cover on Saipan we used the most recent study on the value of ecosystem services from coral reefs and seagrass habitats in CNMI (ERG, 2018). We first used the change in the spatial distribution of macroalgae to identify areas where coral cover can be drastically affected by expansion of macroalgae. Due to the complex and uncertain process of the shift from coral to macroalgae, we assumed that all areas that experienced an increase in the local regression value of more than 0.5, will be converted to macroalgae, or that the functions of corals will be affected in a way that limits their ecosystem service provisioning. The regression values of the current macroalgae distribution model were distributed roughly between 0 and 1, meaning that we considered areas with considerably high increases only when looking at changes to coral cover. We did this to reduce uncertainties, that can be found when comparing two different maps results in smaller differences.

We then used the same values as calculated by ERG (2018) for different ecosystem services. While for some services, ERG calculated average value per unit for all corals no matter their location (e.g. commercial and non-commercial fishing and biodiversity), for other ES they calculated different values based on the location of the coral (e.g. coral reefs closer to mooring buoys and beach access points had a higher value). We used the same rules to calculate the value of the coral reef that is projected to be lost in case wetlands are converted. The value of nutrient and sediment capture therefore equals the value of coral reef ES lost if wetland ES would be lost as well.

5.8.2 Results

Nutrient and sediment capture and macroalgae distribution

We have demonstrated that nutrient and sediment export play an important role in the distribution of macroalgae in the Saipan Lagoon (Figure 17). The Receiver Operating Characteristic (ROC), which describes how well the model represents the spatial distribution of algae, is 0.8, showing a good fit.

*Table 12 Regression model describing the spatial distribution of macroalgae. *P<0.1, **P<0.05, ***P<0.001.*

Variable	Regression coefficient
Constant	-2.4186
Presence of areas with a soft ocean floor	-1.4079***
Distance to the shore of Saipan	-0.0010***
Shore length of the closest watershed	0.0004*
Exported phosphorus for each watershed	Not significant
Amount of exported P per shoreline unit of closest watershed	-4188.7510***
Amount of exported P normalized per reverse distance from shore	0.3716**
Exported nitrogen for each watershed	Not significant
Amount of exported N per shoreline unit of closest watershed	1757.1287***
Amount of exported N normalized per reverse distance from shore	-0.1530**
Exported amount of sediments per watershed	Not significant
Amount of exported sediments per shoreline unit of closest watershed	Not significant
Amount of exported sediments normalized per reverse distance from shore	-0.0006*

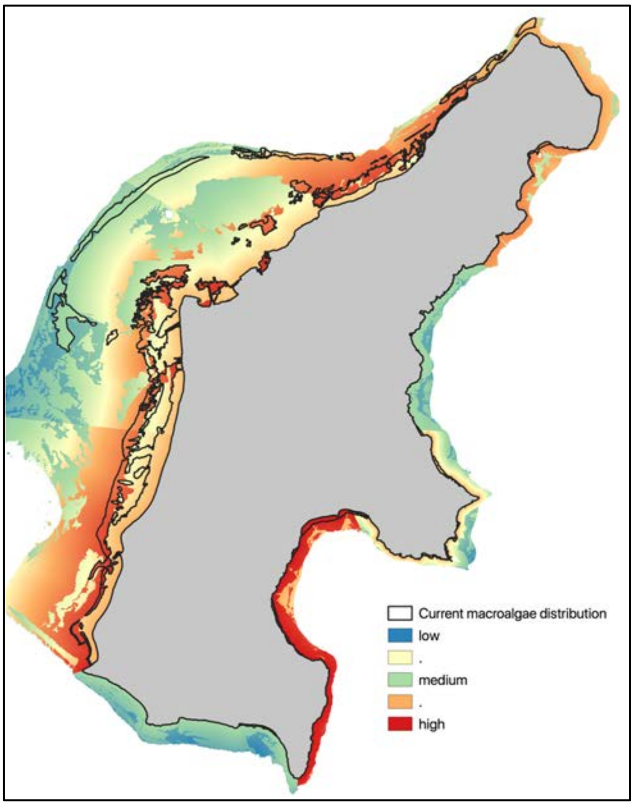

Figure 17. Spatial probability for macroalgae occurrence based on the logistic regression model.

A considerable portion of coral cover in the Saipan Lagoon is affected by a projected increase in macroalgae probability, if the wetlands would be converted or degraded (Figure 18). This projected change is based on the logistic regression model (above), and describes which locations currently covered by corals might experience competition from macroalgae (the spatial probability or likelihood), and not the amount of macroalgae cover that will take over the corals. Nevertheless, we considered all areas with a high increase of macroalgae cover likelihood as degraded with a lost economic value.

In total, we identified that 1,016 ha of coral reefs in the Saipan Lagoon are susceptible to macroalgae cover encroachment, mostly in the southwestern part of the lagoon (Figure 18). This is due to the vicinity of the Susupe wetland, which is the largest wetland complex on the island. We estimate that the wetlands on Saipan therefore contribute US$ 4,881,156 annually to protection of the coral reefs, based on their ability to capture and store sediments and nutrients before they reach the lagoon. The average value of coral reefs affected by potential wetland conversion is US$ 4,803 /ha, higher than the average value of all coral reefs on CNMI which is US$ 667 /ha (ERG, 2018). This is because the coral reefs directly protected by wetlands are closer to the Saipan shoreline, playing a more important role in coastal protection, recreation and tourism. Wetlands on Saipan that contribute to pollutant and sediment removal amount to 243 ha. The average value of protecting coral reefs in the Saipan lagoon is therefore US$ 20,106 annually per ha.

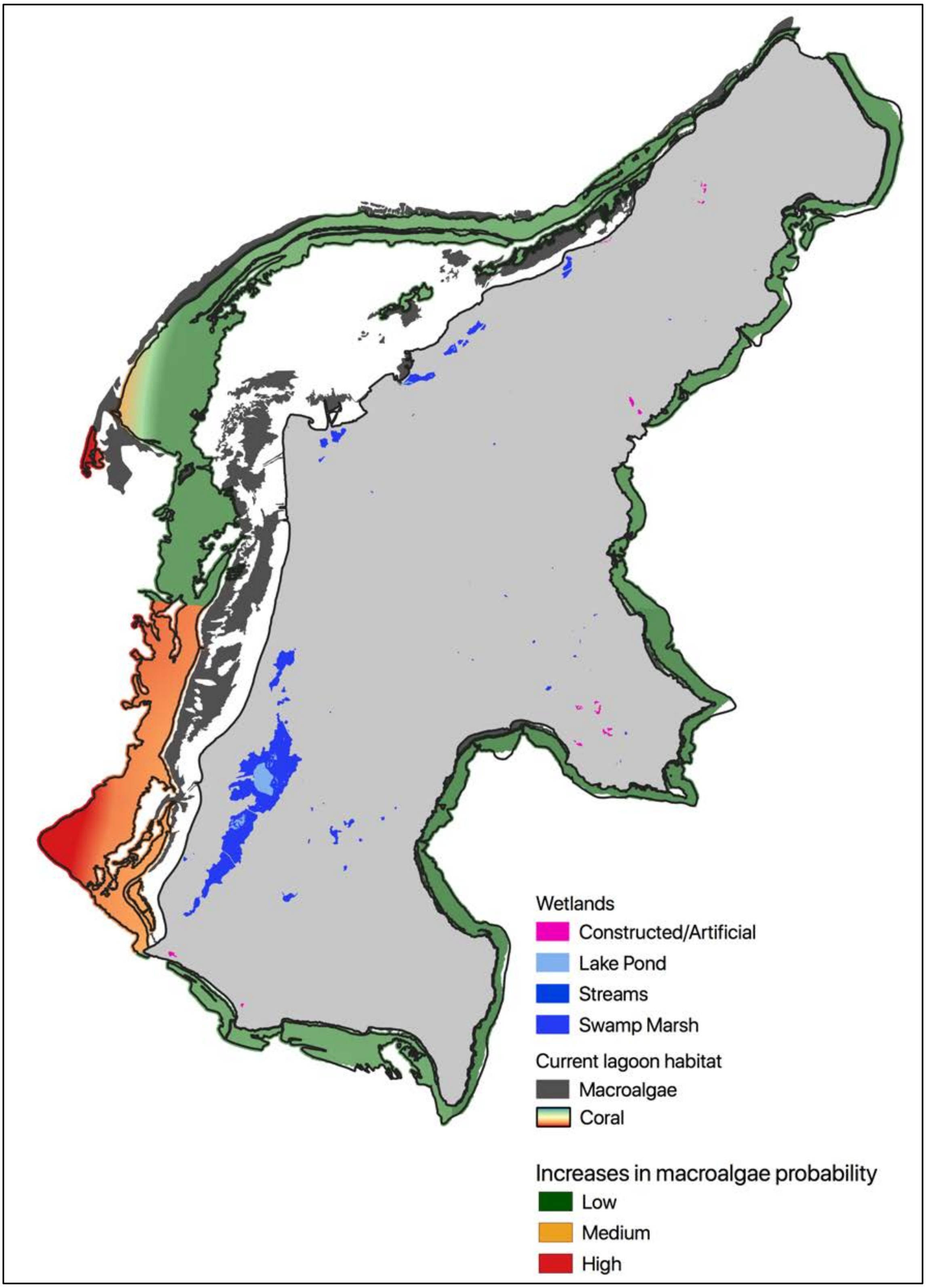

Figure 18. Increases to macroalgae probability due to converted wetlands and consequent increase in sediment and nutrient (phosphorus and nutrient) deposition in the lagoon. The colour gradient of the current coral cover shows the changes to probability of macroalgae on current corals.

Table 13 Values of wetlands' pollutant and sediment capture.

Ecosystem service provided by coral reefs	Distribution factor / type	Value per ha of coral reef	Area of coral reefs affected by wetland conversion	Total value per area
Commercial fishing		65	1,016.13	66,049
Non-commercial fishing		69	1,016.13	70,113
Foreign tourism	*0-500m from beach access*	12,083	18.66	225,499
	500 – 1,000m from beach access	6,712	129.32	867,996
	1,000 – 1,500m from beach access	4,028	106.62	429,475
	More than 1,500m away	1,343	761.53	1,022,731
	Total tourism			2,545,702
Recreation	0-100m of mooring buoys	1,675	0	0
	100-200m of mooring buoys	931	1.1	1,019
	200-300m of mooring buoys	558	7.5	4,181
	Beyond 300m of mooring buoys	186	1,007.6	187,403
	Total recreation			192,604
Amenity-based value	0 – 500m from shore	618	63.5	39,221
	500 – 1000m from shore	177	169.4	29,910
	Beyond 1,000 m from shore	88	783.3	69,157
	Total amenity			138,288
Biodiversity – research, non research	Value of living coral	351	1,016.13	356,276
Coastal protection	0 – 500m from shore	11,714	117.1	1372,112
	500 – 1000m from shore	3,347	33.5	112,009
	Beyond 1,000 m from shore	1,673	16.7	28,002
	Total coastal protection			1,868,400
Total value of sediment and nutrient capture		**4,803.7**	1,016.13	**4,881,156**

5.9 Aesthetics and recreation

5.9.1 Methods

Wetlands also provide nonmaterial benefits to people through aesthetics and recreational experience (Brown et al., 2006; MEA, 2005). The valuation of aesthetics and recreation is difficult, as it is often addressed through the collection of primary data (for example with surveys), which was outside the scope of this study. We therefore used the results of the participatory mapping workshop to identify priority wetlands in terms of aesthetics and recreation. The workshop participants identified wetlands or their surroundings which are used by people for recreation and aesthetic appreciation. We also looked at social networks to confirm and upgrade the workshop results. We looked for data on social networks that focus on sports and recreation (Runkeeper, 2019; Strava, 2019), and picture exchanging platforms.

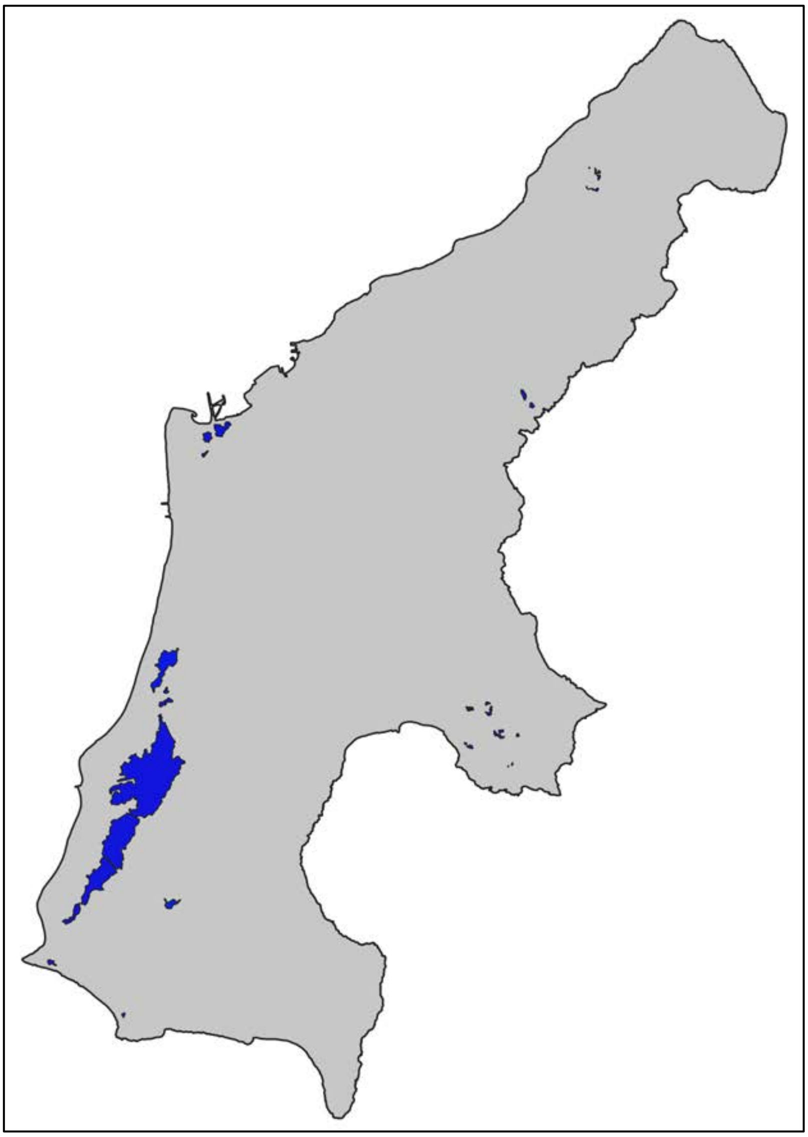

Figure 19. Locations of wetlands important for recreation and aesthetics on Saipan.

5.9.2 Results

Wetlands on CNMI are currently not directly used for recreation. In the past, Lake Susupe had been used by the locals for fishing and boating, however access to the lake is today limited due to existence of private property and vegetation as well as perceptions regarding degraded water quality. Nevertheless, wetlands on CNMI are appreciated for their aesthetic qualities, with Lake Susupe being the most appreciated wetland, mostly due to its size, lush vegetation, and presence of surface water. Wetland users emphasized that access to the lake was easier in the past and that they regularly visited the area when they were younger. Wetlands in the American Memorial Park were also identified as wetlands with high priority in terms of aesthetics and recreation, also due to its presence in the tourism center of Saipan (Garapan). Other wetlands with high value for recreation and aesthetics are constructed wetlands on golf courses, and the As Lito wetland and Chalan Lao Lao, Chalan Kiya wetlands.

The streams in the Talakhaya watershed on Rota were identified as high priority wetlands for aesthetic appreciation, as the perennial streams also host numerous waterfalls. These are among the rare perennial streams with waterfalls on the islands of Saipan, Tinian, and Rota.

5.10 Cultural heritage

5.10.1 Methods

Wetlands can have a high value in terms of cultural heritage due to their potential to provide spiritual enrichment and reflection to the local population (MEA, 2005). While such nonmaterial benefits can be difficult to estimate, often such provisions have extremely high value due to their significance for the cultural heritage and everyday lives of the locals. To identify wetlands of high importance in terms of cultural heritage we therefore used a qualitative approach.

First, we asked the stakeholders at the workshop to identify wetlands with high priority for cultural heritage. The stakeholders emphasized, that the wetlands on CNMI play an important role as they have hosted ancient settlements, well before the arrival of European settlers. We therefore contacted local experts on archaeology, who provided us with additional data on areas, where the ancient Chamorro and Refaluwasch (Carolinians) have settled in the past. We identified wetlands where archaeological remains have been found or where other evidence suggests that these areas might have been significant throughout history for the local population.

5.10.2 Results

Wetlands on CNMI have played an important role since the first inhabitants settled on the islands, as demonstrated by archaeological evidence found throughout the islands. Several wetlands have been identified to host human activities more than 3000 years ago. Most importantly, despite widespread transformations of the terrestrial surface on the islands of Saipan, Tinian, and Rota, wetlands, due to the presence of water and hydric soils, preserve valuable archaeological remains, and therefore potentially host even more evidence of early human remains. For these reasons they are also highly valued by local and international archaeologists and are still regularly studied by researchers. This makes them highly important not only locally, but in a wider context of the Micronesian and Asia-Pacific region.

Early settlements in the Marianas were floating villages, often situated near or on wetland areas (Carson, 2016, 2014). The swamps provided the local population with food (taro, fish, shrimp, eel), raw materials (fiber) and shelter, protecting them from potentially devastating high-tides and storm if the settlements were situated directly on the coast. The food sources have also been mentioned in accounts of ancient Chamorro practices. Freshwater eels, shrimps and coconut crabs are mentioned in anecdotal information as having been part of the local diet, not only in ancient times but also during World War II. One of such settlements is close to Unai Chulu on Tinian, with archaeological observations found to be in the area of the Hagoi wetland (Carson, 2016; Craib, 1993). Evidence shows that the earliest settlements in the Hagoi area appeared as early as in 1800 BC (Craib, 1993). The Hagoi area has been heavily transformed numerous times in history, most recently during the presence of the German and Japanese (mostly for agricultural reasons), but also due to military activities of the U.S. during and after World War II.

Evidence of human presence has also been found in the Kagman watershed, where most of the wetlands have been transformed and do not exist anymore. Nevertheless, findings of charcoal and evidence of large scale change to vegetation suggests that the Kagman watershed has been used by the early Chamorro population for agriculture already 2800 BC (Athens and Ward, 2005). More research is necessary to identify individual wetlands with high importance for cultural heritage in the Kagman watershed. Consultations with local experts and literature however suggests that natural wetlands in Kagman have high potential to host additional archaeological evidence.

Early settlements on Saipan are also assumed in the Achugao wetlands. Existing knowledge is not conclusive in terms of identifying the exact location, however evidence of human activities was found in the areas near the wetlands and along these coastal areas (Carson and Kurashina, 2012). San Roque wetlands area also mentioned as sites were archaeological evidence was found, meaning that they potentially hosted human activities as early as in 1500 BC (Carson, 2016). In Sadog Tasi there is evidence that the ancient indigenous people harvested *Strombus gibberilus* shells in the wetland area (CRM, 2008), making it a potentially important area for cultural and spiritual significance.

Lake Susupe and the surrounding wetland complex is the area where most evidence on early human settlements have been found. Earliest evidence on human presence (charcoal) in the Susupe area suggests, that humans have occupied this area already in 2800 BC. Evidence was found both in the lake itself, as well as in its surroundings – particularly in its western part, which was likely directly connected to the Saipan lagoon in the past (Athens and Ward, 2005). The site at Chalan Piao (southwestern part of the Susupe wetland complex) is particularly important, as valuable artefacts have been found there (pottery, shell beads and other ornaments, stone tools) (Amesbury et al., 1996).

Besides high historic value and value in terms of potential new sites hosting archaeological evidence, wetlands have a high spiritual value. Based on the consultations with stakeholders on CNMI and local experts, the evidence suggests that wetlands did not only host human settlements and areas for crop cultivation, but that these areas were where the early Chamorro and Refaluwasch communities had their burial grounds. This suggests that wetlands where human remains have been found also have a considerably high value in terms of spirituality and being considered as sacred areas.

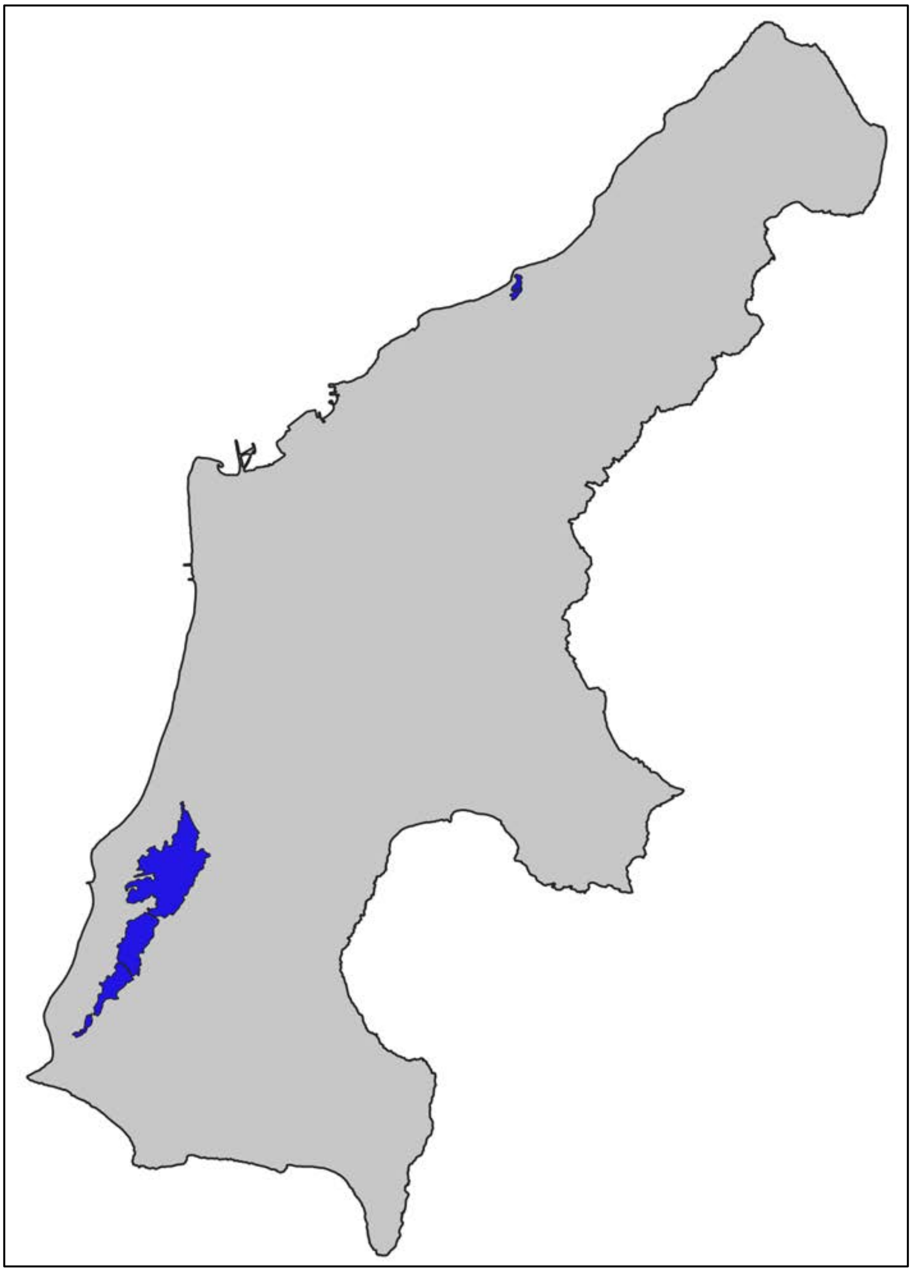

Figure 20. Wetlands with found archaeological evidence on Saipan. Exact locations of findings are not possible to identify and also the whole wetland extents have not been surveyed.

5.11 Research and outreach

5.11.1 Methods

We provide values of money spent annually on research related to wetlands and endangered species that depend on wetlands such as the above-mentioned moorhen to quantify research values of wetlands in CNMI. We received such data from local experts, and government agencies responsible for Mariana moorhen monitoring. We received information on research projects for the last 3 years, however, were informed that most of such projects are ongoing and therefore regular funding is provided. Data on amounts spent on research on other wetland related topics, such as archaeological studies, are not accessible.

Moreover, we looked at research priorities related to wetlands on CNMI, by different funding agencies (both CNMI, and US federal), mostly performed or lead by the Water and Environmental Research Institute of the Western Pacific (WERI) of the University of Guam. Additionally, we looked at awarded grants from US federal agencies dealing with wetlands (grants.gov, 2019; NOAA, 2019). Finally, we use the results from the participatory mapping workshop, where the experts identified wetland with highest priority for research and outreach.

5.11.2 Results

Annually, US$ 80,397 are spent on Mariana moorhen monitoring and research on Saipan. This includes regular monitoring and research projects. In addition, the National Oceanic and Atmospheric Authority regularly award grants on different Coastal Zone Management projects, some of them potentially applicable to wetlands, as they support new initiatives such as wetlands valuation and a no net loss policy for wetlands. Exact amounts spent on wetland research and projects is unknown, whole funding awards were as follows:

- Award period: 2009-2012. Funding amount: 1,027,200 US$
- Award period: 2010-2013. Funding amount: 945,000 US$
- Award period: 2015-2018. Funding amount: 934,000 US$
- Award period: 2016-2019. Funding amount: 1,028,000 US$

The United States Geological Service Sponsored research program identifies several research priorities related to CNMI's wetlands (WERI Guam, 2019):

- Research that leads to a better understanding of human activities and natural processes of CNMI's water quality;
- Modelling the transport of pollutants in CNMI's freshwater systems;
- Research to investigate new and existing regulations dealing with CNMI's freshwater quality issues;
- Research aimed at improving the sustainability of CNMI's water resources (including mitigating floods);
- Research on identifying wetlands; and
- Projects that lead to improved public awareness on water resources.

Experts identified several wetlands with high importance for research and outreach. First, all wetland that serve as the Mariana common moorhen habitat are of high priority. The wetlands in the Kagman and Takpochao watershed, American memorial park / Garapan and the Susupe wetland complex on Saipan, and Makpo on Tinian also contribute to local educational activities, as they are used as examples to demonstrate the value of wetlands and nature in general to local school children.

Additionally, wetlands with a high scientific value were identified either by researchers involved in the workshop or are mentioned as such in local wetland related documents (AECOS, 2005; ERCE, 1991). Makpo is important due to regular research in its role in safeguarding freshwater resources. Streams in the Talakhaya watershed were also identified as having high scientific and research value, both due to the fact that these area only perennial streams on CNMI, as well as the presence of endemic species. Finally, the Susupe wetlands complex was identified as important for research due its size, diversity (different wetland types in one wetland complex), presence of endemic and endangered species and historic importance (archaeology).

6 Conclusions and recommendations

6.1 Overview of the economic value of wetlands on CNMI

In total, wetlands on CNMI provide **US$ 10.7 million** tangible benefits to the local population annually. Through long term storage of carbon, there is additional value of **US$ 18.3 million** attributable to the wetland ecosystems, although this is not an annual value. On top of that, there are numerous benefits that are not possible to quantify, however have high significance for activities, everyday lives and spiritual, as well as cultural and aesthetic appreciation. Not all wetlands however provide the same extent of ecosystem services.

Provisioning services

Only wetlands on Tinian (Makpo) and Rota (Talakhaya) provide water for the local population and agricultural activities. Nevertheless, these wetland areas are crucial for maintaining the two islands as habitable and enable agricultural activities that would otherwise be restricted by high costs for water.

Regulating services

The two wetlands hosting mangroves on Saipan prevent shore erosion (Figure 10), and act as nurseries for important marine species. Mangroves are dynamic ecosystems, and their extent should be regularly monitored which can reflect in a different value in the coming years. Lake Hagoi was identified as the only wetland mitigating the effects of drought for the local livestock farmers. This is also due to the fact that other wetlands that do enable lush vegetation during the time of drought are not possible to be used for livestock activities due to their protection status (Susupe) or being a water source (Makpo). It was not possible to quantify the habitat support values for wetlands that host important species (Mariana common moorhen, Nightingale reed-warbler and the Rota blue damselfly). The habitat support of mangroves could therefore be much higher or lower, depending on the health of the mangroves. Wetlands on Saipan are important for capturing and storing nutrients and sediments originating from human activities (agriculture) and the changes to the environment (road infrastructure, clearing the forest). While we assign one value to all wetlands on Saipan, the size of the wetland and its location play an important role. Lake Susupe and its surrounding wetland complex is therefore the most important wetland in terms of protecting the lagoon and its coral reefs.

Cultural services

Lake Susupe, the American Memorial Park, and the two mangrove wetlands on Saipan, and the Talakhaya streams on Rota have been identified as most important for aesthetics and recreation. In terms of cultural heritage and spiritual significance, wetlands where archaeological remains have been found are most important. Wetlands on all three islands are also regularly studied, however most research is performed on the Mariana common moorhen. Wetlands hosting this endangered species are therefore of highest priority.

Table 14 Total economic value of individual priority wetlands. Wetlands without values are wetlands where their ecosystem services were not quantified (e.g. cultural services). We do not provide values per unit for streams.

Wetland(s) name	Area (ha)	Total value per year (US$)	Value per ha per year (US$)	Total value of carbon pool (US$)	Value of carbon pool per ha (US$)
Saipan					
As Lito wetland	2.91	58,509	20,106	132,248	45,446
Bakery wetlands	1.83	40,290	22,016	110,270	60,257
Chalan Lao Lao, Chalan Kiya wetlands	18.02	13,348	27,240	951,715	52,814
Flores wetland	3.46	73,063	21,116	175,154	50,623
Garapan wetlands / American Memorial Park*	8.1	166,355	20,538		
*Kagman drainage wetland**	0.22				
*Kagman North / Mitigation wetland**	0.66	3,496	5,296		
*Kagman South**	0.73	3,496	4,788		
Lake Susupe, Susupe and Chalan Kanoa wetlands	202.36	4,072,166	20,123	12,528,253	61,911
Sadog Tasi (mangroves and inland wetland)	8.69	533,068	61,343	781,369	89,916
San Roque / Puntan Achugao wetlands	4.85	101,010	20,827	261,780	53,975
Tanapag / As Mahettok wetland	4.42	92,365	20,897	274,461	62,095
Tanapag lower base wetland	5.1	106,037	20,792	306,822	60,161
North of Kagman (ID117)	0.22	4,423	20,106	13,773	62,602
*Marianas country club golf course**	1.28	3,496	2,731		
North East (ID144)	0.06	3,496	58,259	3,761	62,686
*Lao Lao bay golf course**	4.24	3,496	824		
*Kingfisher golf course**	1.75	3,496	1,997		
Tanapag stream mangroves	streams	69,296			
DanDan driving range / southwest San Vincente wetland	0.34	10,332	30,387	16,033	47,157
Tinian					
Bateha wetlands	0.86	3,496	4,065	49,806	57,914
Hagoi	15.22	357,578	23,494	725,035	47,637
Mahalang wetlands	10.29	3,496	340	772,914	75,113
Makpo	12.94	2,318,864	179,201	1,196,471	92,463
Rota					
Talakhaya watershed streams	streams	2,359,609			
*Rota resort**	4.19	3,496	834		
Total	312.92 (291.57 for carbon)	**10,701,940**	29,086 (mean)	**18,299,864**	62,763 (mean)

Table 15 Total economic value of wetland ecosystem services on CNMI

Ecosystem service or value	Total annual value of current supply (US$)	Remark
Provisioning		
Water supply	4,621,990	Makpo (Tinian) and Talakhaya (Rota) only
Agricultural production	343,665	Makpo (Tinian) and Talakhaya (Rota)
Regulating		
Shore erosion prevention	420,650	Puerto Rico and Tanapag stream (Saipan)
Drought regulation	354,082	Hagoi only (Tinian)
Habitat support	n.a.	Wetlands on all three islands, Talakhaya streams the only Damselfly habitat (Rota)
Pollutant and sediment removal	4,881,156	Wetlands on Saipan
Cultural		
Aesthetics and recreation	n.a.	Wetlands on Saipan and Rota
Cultural heritage	n.a.	Wetlands on Saipan and Tinian
Research and outreach	80,397	
Total annual economic value of wetland ecosystem services	**10,701,940**	
Total (not annual) value of climate regulation services	**18,299,865**	This value corresponds to the total carbon stored in applicable wetlands

6.2 Policy recommendations

6.2.1 Supporting the mitigation of wetland loss

The Division of Coastal Resources and Management (DCRM) of the CNMI has designated wetland systems as Areas of Particular Concern (APCs, as defined in regulation § 15-10-330 Specific Criteria; Area of Particular Concern: Wetlands and Mangroves). These systems provide a range of benefits to the local communities, visitors to the island, and the global population in general, called ecosystem services. These include freshwater provision, sediment and nutrient retention, and carbon sequestration, among many others. Development projects, usually designed to support society through additional housing, amenities, and infrastructure, often have direct and indirect detrimental effects on the immediate and surrounding natural environment. When building in these areas, care must be taken to avoid damage to areas considered as APCs. This includes the establishment of ecologically protective buffers of 50-foot minimum distance. When development does occur outside these buffer areas that still is likely to result in significant impacts, or when unpermitted development or degradation occurs, a mitigation hierarchy process, also practised by the rest of the U.S., is followed by development and building projects on the CNMI (see 2CMC 15-10-311 and CNMI Mitigation Hierarchy, accepted in CNMI Register, March 28, 2019, Volume 41 Number 03). These adhere to the following three-step process:

1) Avoid - Adverse impact to aquatic resources are to be avoided and no discharge shall be permitted if there is a practicable alternative with less adverse impact.

2) Minimize - If impacts cannot be avoided, appropriate and practicable steps to minimize adverse impacts must be taken.

3) Offset / Compensate - Appropriate and practicable *compensatory mitigation* is required for unavoidable adverse impacts which remain. The amount and quality of compensatory mitigation may not substitute for avoiding and minimizing impacts.

Figure 21 below provides a simplified overview of where the mitigation hierarchy fits into the decision-making process on the CNMI and how the study results can inform this process. Consultation with public bodies is encouraged early in the development planning process to ensure adherence to rules and minimal disruption to APCs. Permission to develop public lands must first be granted by the Department of Public Lands of the CNMI through the issuance of a lease or permit. If wetland areas may be affected, an APC or a major siting permit for large projects must also be issued by DCRM. Once permission has been granted, the mitigation hierarchy, described above, must be followed (see 2 CMC 15-10-311 and Mitigation Hierarchy Policy Guidance). The Mitigation Hierarchy Policy Guidance document also provides suggestions of project types that can be implemented to address particular ecosystem-related issues. Specific guidance is provided for wetland ecosystems. An indication of its potential enhancement value and cost estimate is also provided.

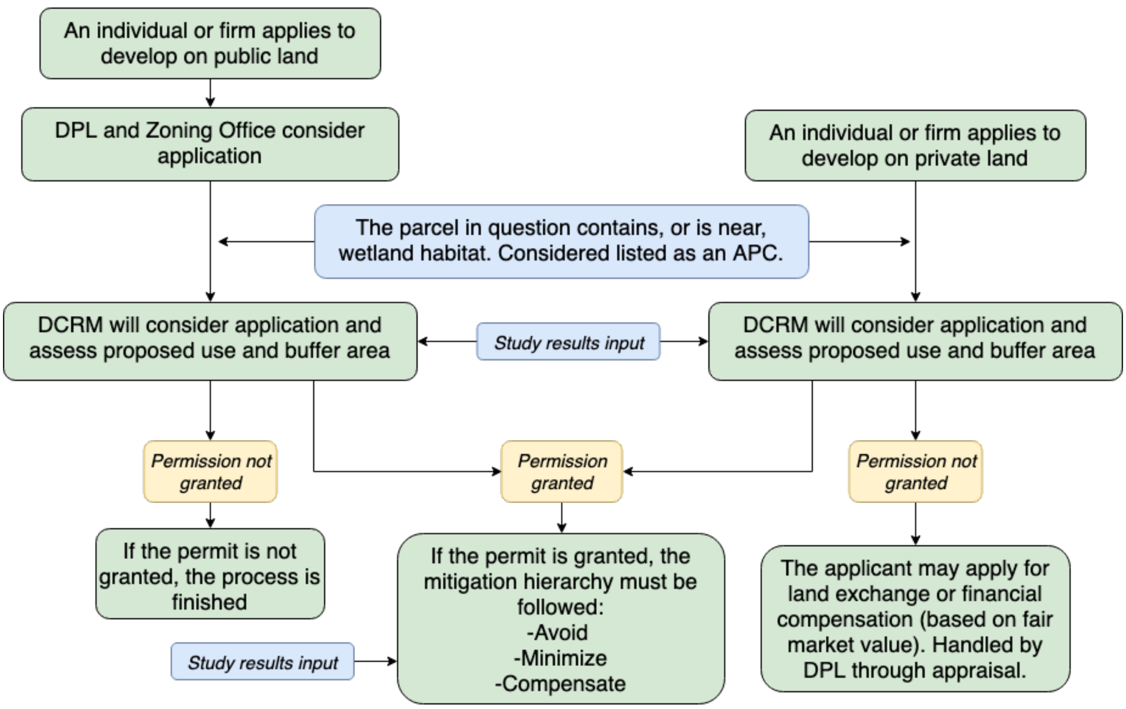

Figure 21 Overview of land development application process

For the development of private lands, which may affect an area of wetland, consultation with DCRM must also take place. If permission is rejected and the wetland is classified as "high value", land exchange or financial compensation may be pursued by the applicant with DPL pursuant to CNMI Public Law 5-33. DPL uses a dedicated appraisal process to determine these values.

These study results can also be used to inform spatial planning, which is relevant during the decision-making phase of granting permission to develop and when structuring the future development of the CNMI. They can also be used during the development phase, when following the mitigation hierarchy process. These are described in more detail in 7.1 and 7.2.

In order to properly inform policy, mitigation measures and spatial planning procedures, a comprehensive overview of biophysical information, relevant ecosystem services and corresponding economic valuations would contribute precious knowledge to the decision-making process. The results of this study significantly contribute to the above goal and can be used primarily for the purposes of mitigation policy, wetland conservation, and informed spatial planning.

6.2.2 Conservation of wetlands and quality enhancement

A total of 26 wetlands, or wetland areas, on the islands of Saipan, Tinian, and Rota have been assessed in this study. Many wetlands are under pressure from threats such as invasive species, pollution, and development. The assessment of ecosystem services and their values can be used to enhance effectiveness of conservation efforts, in addition to informing buffer zoning. When illegal wetland conversion occurs, ecosystem service values can also inform the mitigation process, after the event.

During this process, the application of the results of this study are the following:

1) With the aid of Table 4 found on pages 22-23), the study results can be used to inform how certain areas of land are valuable to the local community. Specifically, the key ecosystem services can be identified per wetland and areas where conservation is of highest value;

2) Wetland values can be used to inform the process of assigning buffer zones for particular APCs. They can provide insight into which factors need to be taken into account when developing near land that provides valuable ecosystem services;

3) If illegal conversion or degradation of wetlands occurs, this study can be used to inform the types of services that need to be mitigated and the value potentially lost to the local community. This can also inform precautionary processes and help support enforcement of policies; and

4) DCRM also practices a 'no net loss' policy when concerning wetland conversion. In addition to the above uses of the study results, the ecosystem service values can also be incorporated into this particular policy to assess whether the 'no net loss'

requirements have been fulfilled. This provides the opportunity to move on from a simple species habitat replacement method, to an ecosystem service replacement methodology.

6.2.3 Informed spatial planning

Results of the study have the potential to contribute to more informed spatial planning on the CNMI. The Office for Planning and Development of the CNMI is responsible for centralizing geospatial data and creating a comprehensive sustainable development plan to support long-term planning efforts.

High priority wetlands have been identified in this study through the assessment of ecosystem services and their values. Some services could not be quantified and have been described using available data and information. However, the information provided, and values assigned, to these wetlands can be used to inform future spatial planning policy, for example where ecosystem service provision may be more sensitive to development. The values we provide do not (always) present direct benefits to the society of CNMI, but present additional costs that would emerge in case wetlands are converted or degraded.

For example, the water supply service valued at over US$ 4.5 million is relevant only for Makpo on Tinian and Talakhaya on Rota. Although many of the wetlands provide important services for the local and regional population, Makpo and the Talakhaya area are assigned a relatively high value in this case. This warrants special attention for the protection of this service at this particular location as it would be very expensive to replace. Concrete recommendations for policy support include the following:

1. Future development must consider the diversity of different functions provided by the wetlands, not only due to potential amenities they provide (e.g. aesthetics, recreation, biodiversity), but also the negative consequences associated with the degradation of wetlands (e.g. increased sedimentation, pollution of the lagoon). The RAM methodology can be a useful tool in this process;
2. Not all wetlands provide the same services. Spatial planning related to recreation and nature protection can benefit from considering wetlands with particularly high values for those two services, as this can ensure more successful recreation and nature protection planning;
3. Some wetlands, and their surroundings, need to be conserved in a way that protects their integrity and characteristics fully. Such examples are Susupe and Makpo. Degrading them also only partially, by impacting their surroundings, could lead to irreversible loss to natural resource provision (e.g. freshwater) or increased sediment and pollution in the lagoon, which can affect coral cover. We recommend that all development in the vicinity of wetlands with highest values and diversity of services they provide is carefully planned. Ideally, the no net wetland loss policy, that CNMI strives towards, would be followed in such cases not only on a total basis (no net loss due to building mitigation wetlands after converting others), but no actual loss of key wetlands (so, all efforts are towards actual protection of

specific wetlands and maintaining their extent, characteristics and quality in terms of ES they provide);

4. The study can be used as a communication and/or negotiation tool, when pressures to convert them, or suggestions to adapt development and spatial plans, are raised. Having information on the actual benefits that the society of CNMI receives from a plot of land that is occupied by a wetland can help to steer development towards areas without valuable wetlands; and
5. The study can be used to guide restoration of wetlands degraded/converted in the past, as these were often replaced by wetlands, which do not share the same level of ecosystem service provision (mostly ponds).

6.3 Overall conclusion

This study provides insight into relevant services provided by priority wetlands on three islands of the CNMI. This information provides vital support to the sustainable development of the islands and key decision-making processes.

The islands of the CNMI are home to a range of wetlands, both natural and constructed. They provide a variety of key services to the local community and global population alike. For the purposes of this study, considering available data and information, a priority of wetlands and ecosystem services was selected.

The majority of wetlands were found to be palustrine emergent and often dry during extended periods of the year. Wetlands on Rota were all identified as man-made, whilst others have been subject to development pressures or degradation. Freshwater use, for example, for agriculture, livestock, and for drinking was identified as a key provisioning service of local wetlands. Shore erosion prevention, drought mitigation, climate regulation, habitat support and pollution and sediment control, which are often overlooked regulating services, were also analyzed in this study. The ability of wetlands to regulate sediments and pollutants was identified as a key regulating service underpinning many economic activities on Saipan. Without such wetlands, the islands on CNMI and their coastal ecosystems (most notably corals) could experience irreversible damages, which would result in negative consequences to the activities of the local population, and the economy of the CNMI in general.

Although some of the ecosystem services provided by wetlands on CNMI can be replaced, for example by constructing new wetlands, the majority of such services cannot be so easily re-established in case of loss. Other measures, usually in the form of infrastructure, could be much more costly.

Incorporating information on ecosystem services in decision making during the wetland mitigation process and spatial planning is crucial. In the wetland mitigation process, this type of information can contribute to:

- Inform total, societal land value;

- Inform buffer zones for APCs;
- More informed mitigation policy for illegal conversion; and
- Supporting the ‘no net loss’ policy.

For spatial planning, the insight into wetland ecosystem service can furthermore support:

- Consideration of diverse values when structuring development plans;
- Targeting key areas for their specific high-value services;
- Informing conservation extent with regards to high-value wetlands;
- As a communication and negotiation tool; and
- To inform the restoration of previously degraded and compensated wetland areas.

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4. Annex 1

Table of relevant data sources used.

Name	Description	Unit	Source
Water			
Water extraction and supply	Amount of water extracted from wells and supplied to the population, together with losses	Gallons/year	Commonwealth Utility Corporation
Water price	Price of water per gallon, defined as cost for water and surcharges for petrol (used for electricity production)	USD/gallon	Commonwealth Utility Corporation
Reverse Osmosis costs	Costs of producing reverse osmosis based on local estimates (small RO plants) and the state of the art RO costs available on the market	USD/gallon of water	Tinian Ice and Water Comparison of costs for reverse osmosis based on different producers of RO plants
Agriculture			
Water use cost	Expenses for agricultural water use (irrigation)	USD per year	Tinian Producer Survey 2017 USDA Agricultural Census 2007
Erosion			
Extent of mangroves	Length of shores covered with mangroves	**m**	Field work High-resolution satellite imagery Spatial data provided by DCRM
Costs for erosion prevention measures	USD per m of shore that needs to be protected by building technical measures	**USD/m**	U.S. Army Corps of Engineers 2017 Beach Erosion study
Drought			
Drought event	Information (date, magnitude…) of the drough event	**N.A.**	Climate Vulnerability Assessment Study for Tinian and Rota
Cattle value	Cattle sales and purchase values	**USD per cattle head**	USDA Agricultural Census 2007
Climate regulation			
Carbon storage economic value	Social costs of carbon	**USD per ton of CO2**	Howard et al. 2014
Wetland carbon storage potential	Potential of different wetland types to store carbon (values from Yap and Palau as proxy)	**Ton of Co2 / ha**	Donato et al. 2o12
Habitat			
Presence of important (endangered)	Wetlands where moorhen are regularly observed, or where they nest. Presence of the Rota blue damselfly	**Presence of moorhen**	Reports from CNMI Division Fish and Wildlife Workshop with experts
Mangrove habitat	Costs for restoring mangroves	**USD/m of shoreline**	U.S. Army Corps of Engineers 2017 Beach Erosion study
Pollutant and sediment control			
Macroalgae presence	Spatial distribution of macroalgae in the Saipan lagoon	**Location**	NOAA macroalgae cover map, Anderson 2004
Spatial data	Land cover map, elevation, soil, hydrology, R-factor	**Map**	NOAA 2018 DCRM

Erodibility coefficients	Soil erodibility and cover management factors	**Factor**	OpenNSPECT data, NOAA 2012 Greene 2017
Nutrient use	Nutrient use on cropland and pasture for Tinian, ratio for nitrogen and phosphorus for Guam	**Kg/ha**	Tinian Producer Survey 2017 DEQ 2002 Schlub 2011
Nutrient retention efficiency	Ability of different land cover types (also wetlands) to capture nutrients	**Factor**	Sharp et al. 2019
Economic value of coral reefs	Value of coral reef based on the recent coral reef valuation study	**USD/ha**	ERG 2018
Cultural			
Archeological remains	Remains of first settlers of the islands (settlements, burial grounds, agricultural activities…), based on reports, scientific journals and other evidence provided by stakeholders during the workshop and meeting with the local archaeologist	**Presence of remains**	Carson 2014, 2016 Craib 2013 Athens and Ward 2005 Carson and Kurashina 2012 Amesbury et al. 1996
Research values	Amounts spent on research related to wetlands on CNMI	**USD**	Values provided by the Division of Fish and Wildlife