Climate Change Vulnerability Assessment Lang Sen Wetland Reserve, Viet Nam

Tran Triet, Nguyen Thi Kim Dung, Le Xuan Thuyen, Tran Thi Anh Dao

Mekong WET: Building Resilience of Wetlands in the Lower Mekong Region

Federal Ministry
for the Environment, Nature Conservation,
Building and Nuclear Safety

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List of abbreviations

BMUB	German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety
CPC	Commune People's Committee
DPC	District People's Committee
ICF	International Crane Foundation
IKI	International Climate Initiative
IPCC	Inter-governmental Panel on Climate Change
IUCN	International Union for Conservation of Nature
LSWR	Lang Sen Wetland Reserve
MONRE	Ministry of Natural Resources and Environment
PPC	Provincial People's Committee
PRA	Participatory Rural Appraisal
RCP	Representative Concentration Pathway
US $	United States Dollar (1 US $= 22,000 VND, based on long-term average)
VND	Vietnam Dong

Executive summary

Lang Sen Wetland Reserve (LSWR) is one of the key sites for wetland biodiversity conservation in the Mekong Delta, Vietnam. LSWR covers 4,802 hectares and preserves a remnant of the Plain of Reeds, a vast wetland complex on the floodplain of the Mekong Delta – once covered 800,000 hectares in both Vietnam and Cambodia. LSWR was designated a Wetland of International Significance (Ramsar Site) in 2015. It was selected as one of the ten focal wetlands in the IUCN's "Mekong Wet: Building Resilience of Wetlands in the Lower Mekong Region" project. In this study, a climate vulnerability assessment was conducted as a first step in a participatory adaptation planning process for LSWR. The main objectives of the assessment were to assess the vulnerability of ecosystems and livelihoods to the impacts of climate change and to identify options to increase the resilience of the wetland.

Major climate threats to LSWR's wetlands are severe droughts, higher air temperatures and salinity intrusion because of sea level rise. In addition, occurrence of extreme events, such as heat waves, strong storms, and torrential rains, will be more frequent and mostly unpredictable. For habitat vulnerability assessment, we selected three main wetland habitats: melaleuca forest, seasonally inundated grassland and lotus swamp. Six wetland species were selected for species assessment, including three plant species (*Eleocharis*, lotus and *Melaleuca*), one bird (Oriental darter) and two fish (Siamese mud carp and giant snakehead fish). We interviewed people from three villages – Ca Sach, Ca No and Roc Nang – for information about climate impacts on wetland livelihoods.

Result of vulnerability analysis showed that lotus swamp and seasonally inundated grassland are highly vulnerable to climate change and melaleuca forest moderately vulnerable. Of the six species studied, only one, Siamese mud carp, was assessed highly vulnerable to climate change; the other five were moderately vulnerable. Higher air temperatures in combination with droughts will increase the risks of uncontrollable fires in grasslands and melaleuca woodlands. Severe and prolonged droughts but also potential saline intrusion due to sea level rise are key threats for all wetland habitats and species. Decreasing flood pulse of the Mekong River because of upstream hydropower development is also a major risk. Variation in annual rainfall would further exacerbate the extent of hydrological change and its impact on wetlands. Cumulative impacts of climate change and Mekong upstream development are expected to be significant but are poorly understood.

Local people's livelihoods are also highly vulnerable to climate adversities. Farming, the main source of income for most people near LSWR, is strongly dependent on weather and climate changes. In addition to droughts and high temperatures, local people reported significant impacts of floods and storms on farming activities, dwellings and health. The link between ecological vulnerability of wetlands and social-economic vulnerability of local people in the case of LSWR is strong. A significant proportion of local villagers relies on natural resources provided by LSWR for their income and/or subsistence. Man-made systems, especially rice fields, tend to be less resilient to the impact of extreme weather events and climate change than natural wetlands such as melaleuca forests. Wetland resources are, therefore, important to people's lives and livelihoods when natural disasters strike.

Results of our assessment suggest that climate adaptation planning for LSWR should prioritize on developing a water management plan and an environmental monitoring system that help LSWR's species and habitats adapt to both climate change and Mekong River development changes. For local people, alternative livelihood opportunities need to be developed so that people become less dependent on farming activities which are highly vulnerable to climate and development changes.

1. Introduction

This study was carried out under the "Mekong WET: Building Resilience of Wetlands in the Lower Mekong Region" Project, led by the International Union for Conservation of Nature (IUCN). The Mekong WET project aims to harness the resilience of wetlands in Cambodia, Lao PDR, Thailand and Vietnam. Mekong WET will help the four countries to address their commitments to the Ramsar Convention, an international treaty for the conservation and sustainable use of wetlands, and to achieve the Aichi Biodiversity Targets. Through its focus on wetland ecosystems, the project also supports governments in implementing their National Biodiversity Strategies and Action Plans (NBSAPs) under the Convention on Biological Diversity and pursuing their commitments on climate change adaptation and mitigation under the United Nations Framework Convention on Climate Change.

In Vietnam, the focal wetlands are Lang Sen Wetland Reserve (Long An Province), Phu My Species and Habitat Conservation Area and U Minh Thuong National Park (both in Kien Giang Province). As a first step of a participatory adaptation planning process in these sites, vulnerability assessments have been conducted. These assessments combine scientific assessments with participatory appraisals and dialogues with communities living at the sites and the authorities in charge of site management. This report presents results of the vulnerability assessment for Lang Sen Wetland Reserve, further referred to as LSWR.

The main objectives of the assessment were:

- To assess the vulnerability of ecosystems and livelihoods to the impacts of climate change.
- To identify options to address vulnerabilities and increase the resilience of wetlands and livelihoods to the impacts of climate change.

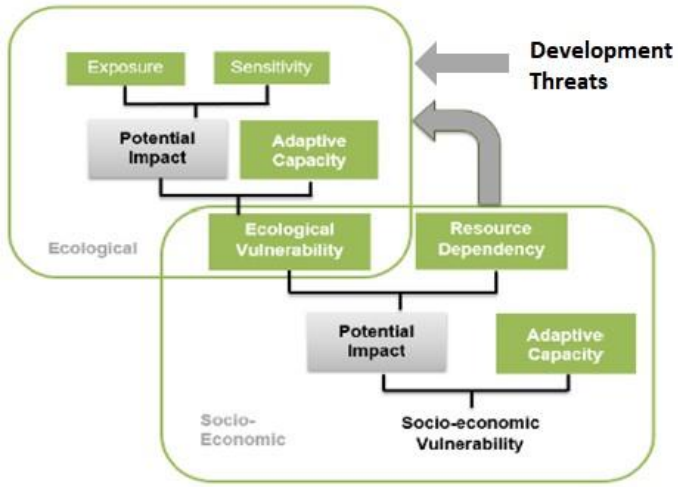
The climate change vulnerability assessment carried out in this study followed methodologies and utilized assessment tools provided by IUCN (IUCN, 2017). In the study, wetlands are considered complex socio-ecological systems; linkages between the wetland ecosystems and the communities who depend on resources provided by that wetland were evaluated in the context of climate change. A conceptual framework of the study is presented in Box 1.

The study was conducted by a team of experts from the University of Science at Ho Chi Minh City, Vietnam, and the International Crane Foundation, Wisconsin, USA. The research team also consulted with experts who are specialized on particular wetland species being assessed (Appendix 1 provides a list of the team members and experts).

Field data collection and interviews were carried out at LSWR in October 2017. A validation session was conducted in January 2018, when the research team revisited LSWR to present the initial results of assessment and received feedbacks and recommendations from LSWR's staff and representatives of local communities. A list of LSWR staff that participated in the study is provided in Appendix 2.

Box 1: Conceptual framework Vulnerability Assessment (after Marshall, 2009; GIZ/ISPONRE/ICEM, 2016)

According to the Intergovernmental Panel on Climate Change (IPCC, 2007), **vulnerability** is defined as the degree to which something (a species, an ecosystem or habitat, a group of people, etc.) is susceptible to, or unable to cope with, the adverse effects of climate change, including climate variability and extremes. Vulnerability is further explained as a function of the character, magnitude, and rate of climate variation to which a system/species is exposed, the system/species' sensitivity, and the system/species' adaptive capacity.



Exposure is defined as the extent to which a region, resource or community experiences changes in climate. It is characterised by the magnitude, frequency, duration and/or spatial extent of a weather event or pattern.

Sensitivity is defined as the degree to which a system is affected by climate changes.

Together, exposure and sensitivity describe the **potential impact** of a climate event or change.

This interaction of exposure and sensitivity is moderated by **adaptive capacity**, which refers to the ability of the system to change in a way that makes it better equipped to manage its exposure and/or sensitivity to a threat.

Within the context of Mekong WET which is focuses on wetlands, the **ecological system** consists of two elements: species and habitats. The **socio-economic system** refers to the socio-economic vulnerability (i.e., livelihoods) of the villages or communities that are dependent on resources derived from the wetlands. Socio-economic and ecological information collected during the assessments evaluates how the ecological and socio-economic system interact to determine the overall potential climate change impact.

2. Description of the wetland

2.1 Location and site description

LSWR is located in the upper part of the Plain of Reeds, one of the two floodplains of the Mekong Delta (Figure 1). Administratively, LSWR belongs to Tan Hung District, Long An Province, covering an area of 4,802 hectares (including core and buffer zone). Long An Province first declared Lang Sen a protected area in 1994. In January 2004, Long An Province established the "Lang Sen Wetland Reserve" with the objective of preserving a portion of the Plain of Reeds wetland ecosystem – a complex system that once covered 800,000 hectares in Cambodia and Vietnam (Tran 2016). Most of the original Plain of Reeds has been converted to farm lands, only a few small areas were protected; largest among them are LSWR and Dong Thap Muoi Medicinal Plants Protected Area (an area of 633 ha) in Long An Province and Tram Chim National Park (with 7,300 ha) in Dong Thap Province (Tran, 2016). LSWR became a Ramsar site in November 2015.

Even though LSWR is located close to the old alluvium terrace of the Mekong Delta, it is largely within the depressed area of the Plain of Reeds. Land elevations range from 0.4 to 1.2 meters above the mean sea level; 74% of land area is within an elevational range of 0.7 – 1.0 meter (Le et al. 2017). The vegetation of LSWR is a mosaic of melaleuca woodlands (named after *Melaleuca cajuputi* – the dominant tree species), aquatic vegetation on permanent swamps and seasonally inundated marshes. LSWR provides habitats for many resident and migrating fish and bird species (Nguyen et al. 2006).

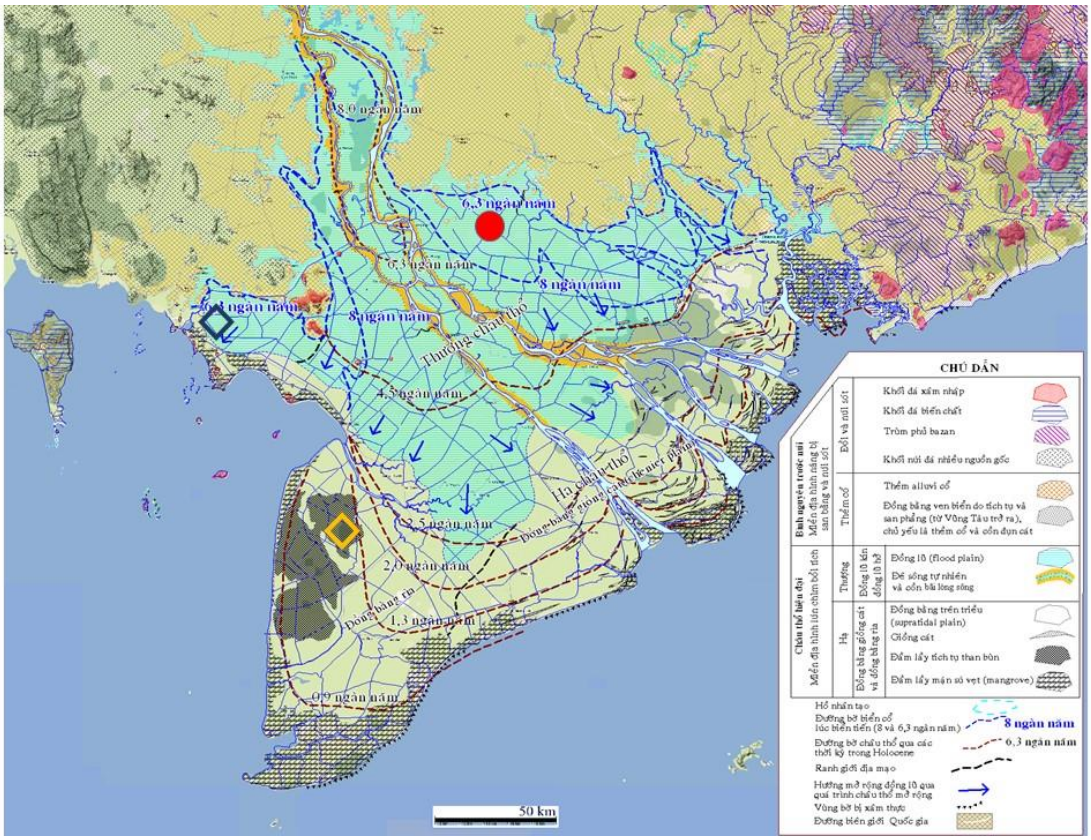


Figure 1: Location of LSWR (red circle) in the Mekong Delta. Locations of the other two wetlands included in the climate change vulnerability assessment for Vietnam – Phu My and U Minh Thuong - are shown in

diamonds. Base map shows main geomorphological formations of the Mekong Delta (source of base map: Truong 2017).

2.2 Current and historic climate

LSWR has a typical monsoonal climate, characterized by the succession of a dry and a wet season each year. Long-term weather records from Moc Hoa weather station, one that is located closest to LSWR, showed an average annual rainfall of 1,430 mm/year, which is lower than the Mekong Delta's average of 1,600 mm to 1,800 mm per year. Mean annual temperature is 27.3 ^{o}C; highest monthly average is 28.7 ^{o}C in April and lowest monthly average is 25.5 ^{o}C in January. These temperature records are similar to those of other provinces in the Mekong Delta. Data and information about historic climate conditions at LSWR are very limited, therefore we refer to historic climate trends that were analysed for Vietnam and selected information most relevant to LSWR to provide a general account for past climate conditions of the area.

In 2016, the Ministry of Natural Resources and Environment (MONRE) of Vietnam released the document "Climate change and sea level rise scenarios for Vietnam". The study included an analysis of past climate changes as recorded by monitoring stations (Tran Thuc et al. 2016). The analysis used climate data from 150 climatological stations and sea level data from 17 oceanographic stations located throughout the country's land and sea. Historic changes in weather characteristics and sea levels for Vietnam during 1985 – 2014 are summarized as follows:

- Mean temperature increased 0.42 ^{o}C during 1985 – 2014; maximum high temperatures increased, recorded by most climatological stations throughout the country.
- Annual rainfall decreased in the north of the country and increased in the south; torrential rain incidents decreased in the northern lowland but increased in the central highlands and southern provinces.
- More droughts occurred during dry season.
- Stronger influence from El Nino and La Nina episodes; strong typhoons occurred more frequently.
- Sea levels in the near shore areas increased on average 3.3 to 3.5 (±0.7) mm/year between 1993 – 2014; sea level rise measured at Con Dao, Phu Quoc and Tho Chu oceanographic stations were 4.8 (±0.9) mm/year, 3.4 (±0.8) mm/year and 5.3 (±0.8) mm/year, respectively – all higher than the country average.

Many of these past climatic trends were also observed at Lang Sen. Local people, who were interviewed, reported recent changes in local weather conditions, including higher air temperatures, irregular rainy seasons, more droughts, and more hot days. Lang Sen area experienced a severe drought during 2015 – 2016 and two big floods in 2000 and 2011.

2.3 Hydrological characteristics

The hydrology of LSWR has typical characteristics of a deltaic flood-pulse system, with a distinctive annual wet-dry cycle. In a normal year, surface water level is often lowest in March and highest in October. Mekong river flood and local rainfall create flooding conditions at LSWR for 3 to 4 months a year, typically from August to November/December.

Flood water from the Mekong River reaches Lang Sen area mainly through primary canals such as Canal 79, Canal 28 and Hong Ngu – Long An Canal. Water depths during peak flood can reach 2.5 – 3.5 meters (Nguyen et al. 2017). The hydrology of LSWR is, however, strongly regulated by man-made structures. The entire core zone of LSWR is surrounded by high dykes, which were initially built to manage water levels in core zone to reduce the risk of forest fires. However, the system also prevents surface flows of flood water coming into the core zone; flood water only

enters the core zone through sluice gates. Furthermore, the core zone is divided into 12 sub-zones, each zone is also surrounded by dykes. Water, therefore, cannot freely move between sub-zones, nor between each sub-zone and the inner canal system.

LSWR is still impacted by tides from the East Sea, mainly in the dry season with a tidal amplitude of less than 0.5 meter (Le, 2017). Being located close to Vam Co Tay River, the hydrology of LSWR may also be influenced by Vam Co Tay River hydrology, especially in terms of the flooding regime. However, there has been very little research on this aspect.

2.4 Wetland habitats

Wetland habitats in LSWR can be categorized into natural types: melaleuca forest, seasonally inundated grassland, and lotus swamp (see Figure 2), and man-made waterbodies or canals, and paddy fields.

Figure 2: Aerial view of LSWR showing melaleuca forest, seasonally inundated grasslands and lotus (open) swamps (photo credit: Nguyen Truong Sinh, March 2018).

Melaleuca forests in LSWR are dominated by *Melaleuca cajuputi*. Perhaps all melaleuca stands in LSWR are planted, since the area was originally a melaleuca plantation. Melaleuca forest covers 2,300 hectares, making it the largest habitat type of LSWR (Le et al., 2017). Historically, there was an area of riverine forest on the bank of Vam Co Tay River that was part of the reserve, but it has been removed almost entirely after it was detached from the core zone and was no longer protected.

Seasonally inundated grassland habitat has an herbaceous vegetative cover and is flooded seasonally during the wet season. In the dry season, most areas of inundated grasslands become dry. Most common wetland plant species found on seasonally inundated grasslands at LSWR are *Eleocharis* spp., *Ischaemum* spp., *Panicum repens*, and *Cyperus* spp. Seasonally inundated grasslands cover an area of about 800 hectares in LSWR (estimated from data provided in Le et al. 2017).

Lotus swamps (or open swamps; “láng sen” or “đầm sen” in Vietnamese) hold water all year round, except during severe droughts (such as those in 2015 – 2016). The lotus is the most common and popular plant species of these open swamps and the Reserve has been named after it. Besides lotus (*Nelumbo nucifera*) there are many other aquatic plants such as water lilies (*Nymphaea* spp.), *Polygonum tomentosum*, *Commelina* spp., *Ludwigia adcendens*, *Utricularia aurea, and Nymphoides nouchali*. Floating mats of aquatic vegetation cover significant surface areas of open swamps and are expanding according to LSWR’s rangers. Common plant species that form floating mats are *Pseudoraphis brunoniana, Leersia hexandra, Polygonum tomentosum,* and *Cyperus digitatus*. Open swamps in LSWR are also heavily invaded by aquatic alien plants, including water hyacinth (*Eichhornia crassipes*) and water lettuce (*Pistia stratiotes*).

Canals support permanent waterbodies that hold water all year round and serve as important habitat for fish and many other aquatic plants and animals. The dykes associated with canals provide high grounds that may never be flooded even during peak floods, which can be inhabited by terrestrial organisms.

Rice paddies in the reserve cover approximately 1,600 ha and are mainly located in the buffer zone. Most rice fields are planted with two crops of rice per year. There are also areas protected by dykes where farmers can grow three rice crops per year.

2.5 Biodiversity

Results from several biodiversity surveys show that remnant wetlands in LSWR have high species diversity, those that are typical of the Plain of Reeds wetlands (Buckton et al. 1999; Nguyen et al. 2006; Nguyen et al. 2017). Le et al. (2017) compiled lists of plant and animal species recorded for LSWR, including 152 plant, 127 bird, 17 reptiles, 80 fish and 7 mammal species. Among these species, 15 are listed in the Red Data Book of Vietnam. Some species are of great biodiversity conservation concerns for the Mekong Delta region such as giant catfish (*Pangasianodon gigas*), fishing cat (*Felis viverrine*) and sarus crane (*Grus antigone sharpii*). The populations of these species are, however, very small in LSWR. LSWR is seriously affected by several invasive alien species, most importantly giant mimosa (*Mimosa pigra*), water hyacinth (*Eichhornia crassipes*), water lettuce (*Pistia stratiotes*) and golden apple snail (*Pomacea canaliculata*).

2.6 Land use

Lands that are located inside the core zone are strictly protected in their natural state. In the buffer zone, there are two major types of land use: a publicly-owned melaleuca plantation (1,137 ha) and privately-owned rice fields (1,694 ha). Many efforts have been made to add the melaleuca plantation to the overall management structure of LSWR, but so far it is still managed as a commercial plantation (Figure 3).

Figure 3: Satellite image of LSWR area (source: Google Maps, accessed 20/4/2018)

2.7 Drivers of change

Changes in the hydrology and sedimentation of the Mekong River due to upstream hydropower development are perhaps the most important drivers of change for wetlands of LSWR. Changes in timing, duration and magnitude of floods, as well as severe reduction in sediment loads of flood water will have profound negative impacts on wetland ecosystems of LSWR.

2.8 Conservation and zoning

LSWR consists of a core zone (1,971 ha) and a buffer zone (2,831 ha). The core zone is further divided into 12 units, separated from each other by a system of dykes and canals (Figure 4). This compartmentalization was created before LSWR was established, when the area was still a forestry enterprise. The purpose was to actively manage water levels inside each compartment for fire control to protect the melaleuca stands. The compartmentalization resulted in land units being completely isolated from each other and from the inner canal system. Recently, an experiment in Unit TK1 allowed for water exchange between the Unit and the inner canal system by opening a section of the dyke. An assessment, done 6 months after opening the dykes, showed that the wetland ecosystems had responded well; water quality improved and there were less invasive species such as the water hyacinth (Nguyen et al. 2017).

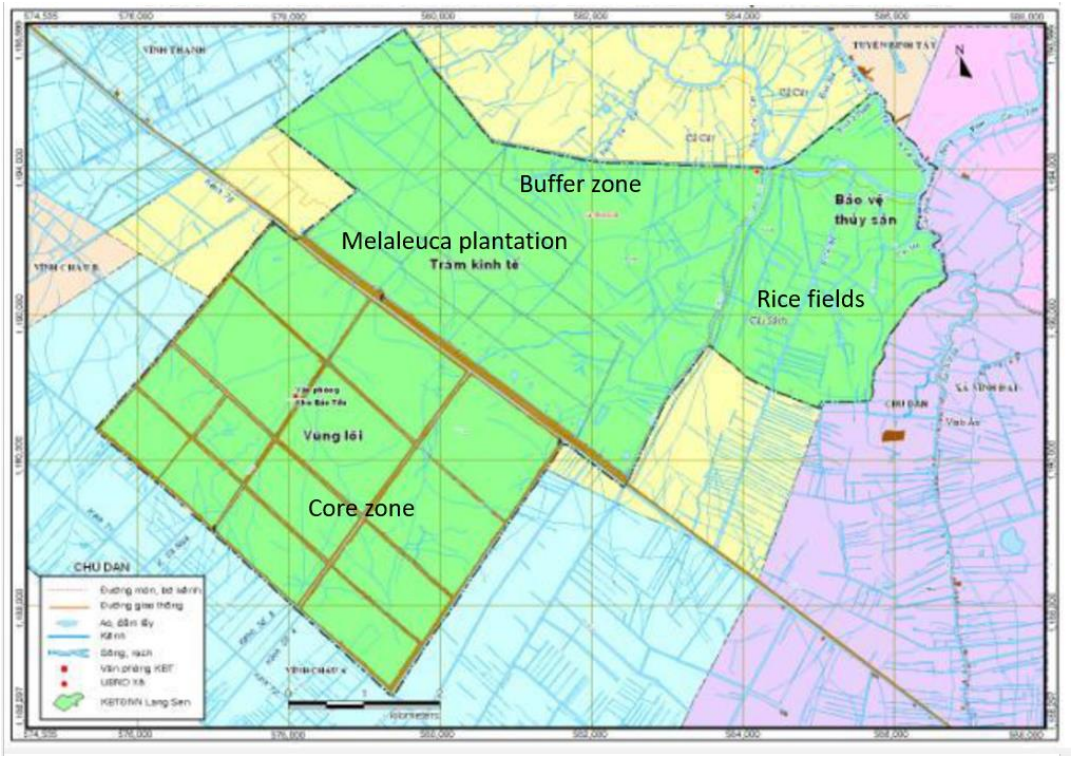


Figure 4: Map of LSWR with core zone (divided into 12 sub-zones) and buffer zone (including melaleuca plantation and rice fields) (source: Le et al. 2017).

3. Communities and wetland livelihoods

3.1 Communities and population

There are about 4,000 households with 12,700 people living in the buffer zone and around LSWR. The people belong to the communes of Vinh Dai (889 households), Vinh Loi (1,170 households) and Vinh Chau A (1,946 households), representing 7 villages; all are in Tan Hung District. The people belong to the Kinh ethnic majority. The average level of education in the area is 'primary school'. According to the LSWR Management Board, illiteracy rate is only 2 %, and most people who cannot read or write belong to the poorer segments of the communities. About 8 % of the people are considered poor by the State (earning less than US $ 1.5 per day). Regarding population distribution, the majority of inhabitants are located along the natural canals and Vam Co Tay River in order to take advantage of transportation, services and natural resources. Acidic soils in the area make it difficult to cultivate crops, which means that most people depend on natural resource exploitation.

3.2 Key livelihood activities

According to a survey in 2015, the main livelihood activities in LSWR included agricultural production, melaleuca planting, the provision of services and working as hired labourer. In terms of agriculture, rice cultivation with two crops per year is dominant, yielding about 10 tons/year, along with animal husbandry (pigs, cows, goats, chickens, and ducks) and aquaculture. Some households run small shops such as motorbike repair and agricultural services to diversify their income. Members of households with little or no productive land, try to find a job as company employee/worker or as hired labourer (harvesting rice, planting melaleuca, cutting melaleuca timber, etc.) (Le et al., 2017).

Households living along the boundary of and along the canals across the reserve, do not only exploit natural resources inside the reserve, but also exploit resources in other places outside the reserve to increase their income. They increasingly use fishing techniques and tools, such as scrubbing (made of iron and fish net, laid on the bed of river, dragged by boat to catch all fish on the way), shingles (20-40 m^2 of fish nets put on bed of river or canal, surrounded and covered by tree branches to attract fish and shrimp to shelter, and harvested all after 30-45 days), rakes (made of bamboo, placed in swamp to attract fishes in and blocked inside), gill nets and even electro-fishing to catch all types and sizes of fish, causing a dramatic decline in fishery resources in the area (Le et al., 2017).

3.3 Use of wetland resources

Most of the communities in LSWR rely on agriculture and natural aquatic resources. They use canal and river water for irrigating their rice cultivation systems and vegetable crops. Water is also used to raise livestock such as pigs and ducks. Therefore, water is an essential resource for communities' livelihoods. Once water sources are depleted, local production and living conditions will be severely affected. Aquatic resources, especially fishes, provide food and a main source of income for the people. Wild fish are exhaustively caught in the whole year for food and sale. Natural fish seedlings of the wetlands are provided for the development of local farmed fish (aquaculture). In addition to fish resources, local people also exploit abundant plants to increase income such as lotus and wild vegetables (Le et al. 2017). Wild grasses are also harvested for feeding cattle.

3.4 Land tenure and land use rights

According to Decision No.199/QD-UB issued by Long An Provincial People's Committee in 2004, the total area of LSWR ought to be 5,030 hectares (see Table 1). However, the current land area

of LSWR counts 4,802 hectares because some of the land was taken by Tan Hung district. Since the establishment of LSWR, there have been several efforts to come to an integrated management of areas within the reserve, but this has been difficult. Most of the lands in the buffer zone are agricultural private lands. Moreover, while the site of the Vinh Loi Forest Enterprise is managed by the State, it is still separate from the overall management of the reserve.

Table 1: Land tenure in LSWR based on Decision No.199/QD-UB issued by Long An Provincial People's Committee in 2004.

Land area	Ownership	Status	Area (ha)
Conservation area (core zone)	State	Melaleuca forest, lotus swamp and grassland	2,150
Vinh Loi Forest Enterprise	State	Planted melaleuca forests	1,200
Tan Hung district	State	Forest land along Vam Co Tay River and Cai He Canal	400
Households	Private	Rice, melaleuca, grassland	1,280
Total			**5,030**

Note: Total area of LSWR is now 4,802 ha, because some land was taken back by Tan Hung District.

Local households use their private land for rice, melaleuca, and grass cultivation. According to Le et al. (2017), most poor households have about 0.25 ha of land, average-income households 0.8 – 3 ha, and those who are rich more than 5 ha. As indicated before, people are officially not allowed to make use of wetland resources in the core zone, but in practice they do – especially those who are poor.

3.5 Governance

In the process of formation and development, LSWR has undergone three changes of management authority. Firstly, the reserve was managed by Long An Provincial People's Committee (PPC) (2004-2007), then by the Department of Natural Resources and Environment (DONRE) (2007-2010), and since 2010 by the Department of Agriculture and Rural Development (DARD). Directly administrated and directed by DARD, LSWR's objectives are: to protect wetland biodiversity; to sustainably use wetland biodiversity resources; to support community development in the buffer zone by engaging the community in protecting natural resources and wetland biodiversity; and to become a centre for eco-tourism and education (not only for Long An province but also for the whole Mekong Delta region).

To carry out the assigned functions and tasks, LSWR has set up several divisions to ensure task completion. Current staff counts 41 members, but it is lacking some skills in important sectors such as biology, forestry, nature conservation, and hydrological management. Community development, participatory conservation, and tourism skills are also underdeveloped. Under its governance structure, the reserve also receives financial support from DONRE and the Department of Science and Technology (DOST) through scientific research activities. District People's Committee (DPC) of Tan Hung and Commune People's Committees (CPC) of Vinh Dai, Vinh Loi, Vinh Chau A collaborate with the reserve in land-use and water surface management, livelihood development, and wildlife law enforcement.

The management structure of the reserve is presented in Figure 5.

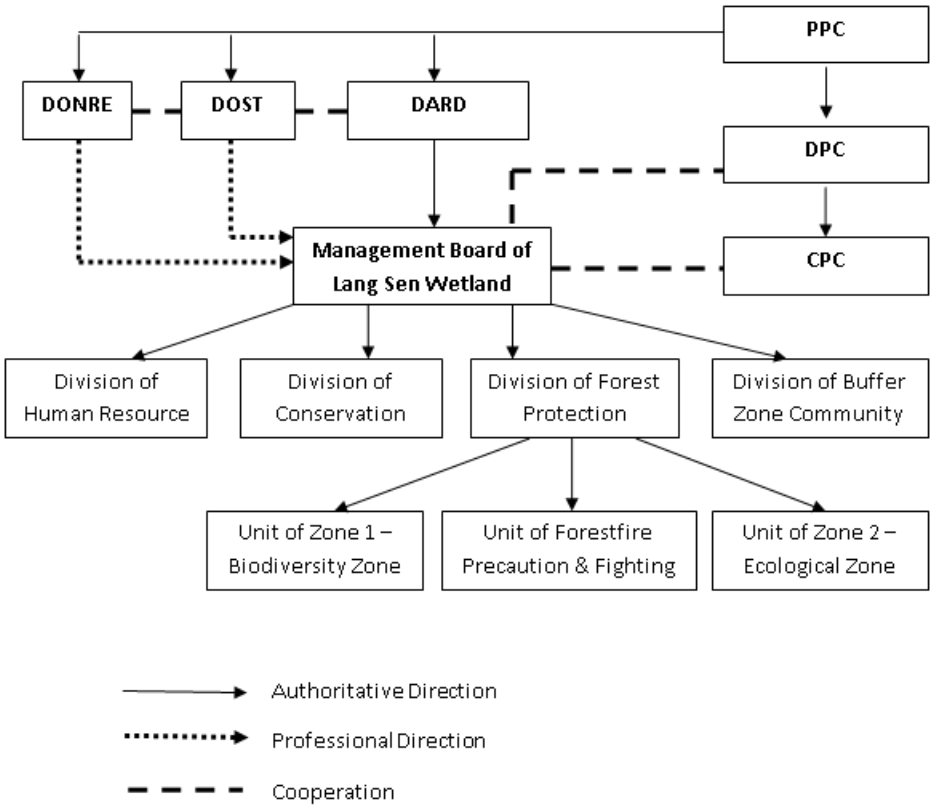


Figure 5: Management structure of LSWR

3.6 Stakeholder analysis

LSWR cooperates with provincial authorities, national agencies, and international organizations in scientific research and sustainable management of the wetlands, buffer zone community development, and ecotourism development. Besides working closely with agencies and authorities at the provincial and district level, the reserve has worked with the Vietnam National Administration of Tourism to develop an ecotourism development strategy in coordination with the provincial tourism sites. Since the establishment of the reserve, it has also cooperated closely with the authorities of Vinh Loi and Vinh Dai communes, which has been highly appreciated by other stakeholders (Le et al. 2017).

LSWR has also coordinated efforts with international NGOs, universities and research institutes to undertake a biodiversity assessment. WWF and IUCN have implemented a program on biodiversity conservation and sustainable use of wetland resources with community participation in the Lang Sen area between 2007 and 2010. The Swiss Agency for Conservation and Sustainable Use of Biodiversity has also collaborated with WWF to conserve biodiversity and sustainable use of natural aquatic resources in the area (Le et al. 2017). These conservation and research efforts have been and are often supported by national universities and institutes, and sometimes through private sector involvement.

The lives of local people are closely linked to the wetlands. Population pressure, insufficient income and low awareness of sustainable resource exploitation have placed LSWR in a vulnerable state due to human activities. To reduce pressure on the protected areas, community livelihood development has been become a key priority (Le et al. 2017). In addition to the support of IUCN, CARE International and WWF for community livelihood development activities in the Lang Sen buffer zone, LSWR – along with commune authorities and social organizations – has

organized community groups of sustainable livelihood and resource users to promote their income through the wise use of wetland resources (Le et al. 2017).

An overview of relevant stakeholders of LSWR is provided in Table 2.

Table 2: Main stakeholders of LSWR.

Actor	Name	Role
Government	Vietnam National Administration of Tourism	Has been cooperating in and is involved in developing an ecotourism strategy for LSWR
	PPC of Long An Province	Has authorized establishment of LSWR and is overall responsible at the provincial level
	DARD (province)	Directs LSWR's management
	DONRE (province)	Provides financial support for scientific research
	DOST (province)	Provides financial support for scientific research
	DPC of Tan Hung	Cooperates in land-use and water surface management
	CPC of Vinh Loi, Vinh Dai, and Vinh Chau A	Cooperate in livelihood development in buffer zone and land-use and water surface management; participate in trainings on biodiversity, ecosystem, and community livelihood development, and in wildlife law enforcement
	Management board of LSWR	Directly manages the reserve
Universities/ Institutes	Centre for Environmental Science and Ecology (CESE)	Works with others in implementing scientific research
	University of Science, HCMC; Can Tho University (and others)	Conduct student research relating to LSWR ecosystem and biodiversity
NGOs	IUCN	Implements biodiversity conservation and sustainable use of wetland resources
	WWF	Works with local people to build a conservation network for long-term sustainable wetland use and improving recognition of community rights
	CARE International	Supports sustainable livelihood development
International organizations	Swiss Agency for Conservation and Sustainable Use of Biodiversity	Collaborates with WWF on biodiversity conservation and sustainable use of natural aquatic resources in LSWR
	French Agency for Nature Conservation	Supports a project of biodiversity conservation and sustainable use of natural resource
Private enterprise	The Intel Vietnam – Malaysia	Planted 7,000 trees at LSWR to restore degraded forests and help community adapt to climate change (with WWF)
Communities	120 households in communes of Vinh Dai and Vinh Loi	Community groups for sustainable use of biodiversity resources and livelihood development

3.7 Gender and vulnerable groups

Households with no or limited farmland and low education are most vulnerable to the impact of climate change. Early 2018, the overall poverty rate in Tan Hung district was 4.4 %, but in the communes in LSWR's buffer zone this number reaches 8 %; these households have less than 0.25 ha of farmland. They may depend more on natural resources when there is not enough support. Men's family tasks are related to rice cultivation, fishing, and hired labour, while women do the housework, harvest water hyacinth, take care of children, and work as hired labourers as well. Since women are expected to take care of domestic work and are often less educated than men, they are particularly vulnerable; this also counts for elderly. To support socio-economic development, local governments have introduced health insurance schemes and trainings in non-

agricultural careers for local labourers. Gender equality, rural development, and sustainable poverty reduction are also officially supported and enforced through government programs (Tan Hung Government, 2018). These measures are also expected to mitigate climate change impacts for poor households in LSWR's buffer zone.

3.8 Perceived threats to wetland habitats and livelihoods

Some of the main threats are directly or indirectly related to forest fires:

- First, forest fires are a main risk during the dry season in the absence of water; between 2005 and 2015, there were three cases of melaleuca forest fires that affected ecosystems and biodiversity.
- Secondly, the system of canals and dykes, initially built to manage water levels inside the core zone to control forest fires, has adversely affected ecosystems. Before, Lang Sen area was used to high floods from September to November every year; but dyke sluices in LSWR have limited the flow of water into the reserve (Le et al. 2017), resulting in severe water shortages and drought over the past two years. Moreover, oxidation of acid sulphate soils has contaminated water in the canals. Since drainage of (acidic) water to outside the reserve is constrained, this has caused severe damages to the fishery resources.

Other perceived threats are:

- The overhunting of waterfowl and other wildlife in the melaleuca plantation forest, managed by the Vinh Loi Forest Enterprise, has caused a decline in water bird species; in addition, turning riverine land into agricultural land and poorly managed fisheries have also contributed to biodiversity loss and ecosystem threats (Le et al. 2017).
- Pesticides and other chemicals used in production processes of agriculture, forestry and aquaculture – but especially in rice cultivation – contaminate water sources and spread throughout the reserve, affecting aquatic resources and animals, especially water birds.

4. Climate projections for the site

As mentioned before, MONRE published a report in 2016 on climate change and sea level rise scenarios for Vietnam (Tran Thuc et al. 2016). It is the most up-to-date and comprehensive analysis of trends and predictions of climate change and sea level rise in Vietnam. Some projections were downscaled to district levels. The climate change scenarios used in the MONRE's analysis followed those introduced in the IPCC Fifth Assessment Report (IPCC 2013). These scenarios are based on the concentration of greenhouse gasses. In this study, we have focused on two scenarios: RCP8.5, an extreme scenario without policy action, leading to global temperature increase of 4.9 ^{o}C by the end of the century; and RCP4, a moderate scenario with policy action, whereby temperature increase is contained to 2.4 ^{o}C by the end of the century.

The study provides detailed projections for all geographical regions and provinces of Vietnam. We present here a summary of climate change and sea level rise projections for Vietnam, with selected information that are most relevant to LSWR.

4.1 General trends

Temperatures are expected to increase throughout Vietnam in the 21st century, with increases in the north of the country slightly higher than in the south. For Long An Province, mean air temperature is projected to increase by 1.9 ^{o}C under RCP4.5 and 3.4 ^{o}C under RCP8.5 by the end of the century. Meanwhile, the monsoon season is projected to arrive sooner and end later, resulting in longer monsoon seasons. Total **rainfall** during summer months and the occurrence of intense rain events are all projected to increase. Rainfall in Long An Province is projected to increase by almost 17 % under RCP4.5 and 20 % under RCP8.5 by the end of century. Table 3 summarizes temperature and rainfall projections under RCP4.5 and RCP8.5 for Long An Province; since LSWR is located near the border with Dong Thap Province, projections for Dong Thap Province are also provided.

Table 3: Temperature and rainfall projections under RCP4.5 and RCP8.5 scenarios for Long An Province and Dong Thap Province (adapted from Tran Thuc et al. 2016).

Scenario/time period		**RCP4.5**			**RCP8.5**		
		2016-35	**2046-65**	**2080-99**	**2016-35**	**2046-65**	**2080-99**
Temperature change (^{o}C)	**Long An**	0.7	1.4	1.9	0.8	1.9	3.4
	Dong Thap	0.7	1.4	1.8	0.9	1.8	3.3
Rainfall change (%)	**Long An**	11.7	20.6	16.7	12.8	16.1	19.9
	Dong Thap	10.0	17.9	17.2	11.0	16.2	23.7

Under RCP4.5, frequencies of **typhoons and tropical depressions** in the East Sea are projected to change little throughout the 21st century, whereas storm intensity would increase by 2 – 11 % and precipitations within a 100 km radius from storm eyes by 20 %. Under RCP8.5, storm frequencies would even decrease. Under both scenarios, the numbers of typhoons and tropical depressions would decrease during early storm season (June – August) but increase towards the end of the season (October – December). While the occurrence of weak to medium typhoons may decrease, the numbers of strong to very strong typhoons show a clear upward trend.

Under RCP4.5, number of **high temperature days** (days with max temperatures ≥ 35 ^{o}C) would increase by 25 – 35 days mid-century and more than 50 days by the end of the century. Under RCP8.5, the projected increases are 35 – 45 days mid-century to more than 100 days by the end of the century. **Droughts** are projected to be more severe in southern provinces from March to May.

4.2 Sea level rise

Sea level rises as result of climate change are projected to be higher in the southern provinces than in the northern provinces. By 2100, sea level rise projections for the coastal area between Ke Ga Cape and Ca Mau Cape are expected to be 53 cm (with 90 % confidence interval of 32-77 cm) under RCP4.5 and 73 cm (48-105 cm) under RCP8.5. This near-shore sea area covers the estuaries of the Mekong River and would most strongly affect LSWR (see Table 4).

Table 4: Sea level rise projections in cm (with 90% confidence intervals) for the near shore sea area between Ke Ga Cape and Ca Mau Cape under RCP4.5 and RCP8.5 climate change scenarios (adapted from Tran Thuc et al. 2016).

	2030	**2040**	**2050**	**2060**	**2070**	**2080**	**2090**	**2100**
RCP4.5	12 (7 ÷ 18)	17 (10 ÷ 25)	22 (13 ÷ 32)	28 (17 ÷ 40)	33 (20 ÷ 49)	40 (24 ÷ 58)	46 (28 ÷ 67)	53 (32 ÷ 77)
RCP8.5	12 (8 ÷ 17)	18 (12 ÷ 26)	25 (16 ÷ 35)	32 (21 ÷ 46)	41 (27 ÷ 59)	51 (33 ÷ 73)	61 (41 ÷ 88)	73 (48 ÷ 105)

If the sea level would rise with 100 cm (which would be extreme, but possible by the end of the century under RCP8.5), 39 % of the Mekong Delta would be inundated (see Table 5; Figure 6). In the Mekong Delta, Hau Giang, Kien Giang and Ca Mau are the three provinces most at risk. Long An Province, on the other hand, would not be as severely affected (Table 5; Figure 7), with 27 % of the land covered by water. Tan Hung District, where LSWE is located, has a very low inundation risk; only 8.5 % would be covered.

Table 5: Land inundated (%) at different levels of sea level rise for Long An Province and Tan Hung District (adapted from Tran Thuc et al. 2016).

		Sea level rise					
	Area (ha)	**50cm**	**60cm**	**70cm**	**80cm**	**90cm**	**100cm**
Mekong Delta	3,969,550	5 %	9 %	15 %	21 %	28 %	39 %
Long An Province	449,100	1 %	1.5 %	3 %	7 %	13 %	27 %
Tan Hung District	49,892	0 %	0 %	0.2 %	0.5 %	3 %	8.5 %

Even when inundation risks are limited for Tan Hung District in the short-term (2030-2050), brackish or even saline water may reach LSWR as sea levels rise, especially at high tides during the dry season. During the drought of 2016, the salinity level of Vam Co Tay River was 1.9 – 4.3 g/l higher than in 2015; salinity levels of 4 g/l (a general threshold for rice cultivation) were measured 95 – 105 km upstream from the east coast (To et al. 2016). This is possibly related to stronger salinity intrusion from the East Sea, but this has not been analysed and discussed in MONRE's climate change scenarios study.

4.3. Implications for Lang Sen Wetland Reserve

Climate projections applicable to LSWR are: higher temperature, more hot days/heat waves and frequent droughts; irregular monsoon season, higher rainfall, and frequent torrential rains; typhoons and tropical depressions may be less frequent, but strong to very strong typhoons may occur more frequently. Even though inundation risk due to sea level rise may not be high, salinity intrusion is a serious concern. And since LSWR is strongly influenced by the Mekong River's hydrology, the potential cumulative impacts of climate change and Mekong upstream hydropower development are expected to be significant.

LSWR is most seriously threatened by severe droughts, which combined with high temperatures increase risks of uncontrollable fires in grasslands and melaleuca woodlands. Salinity intrusion due to sea level rise imposes a significant threat on the freshwater wetlands – and will be more

pronounced during severe long droughts. A decrease in annual flood pulse from the Mekong River due to upstream development would further compromise Lang Sen's wetlands, which depend on the Mekong River's flooding regime.

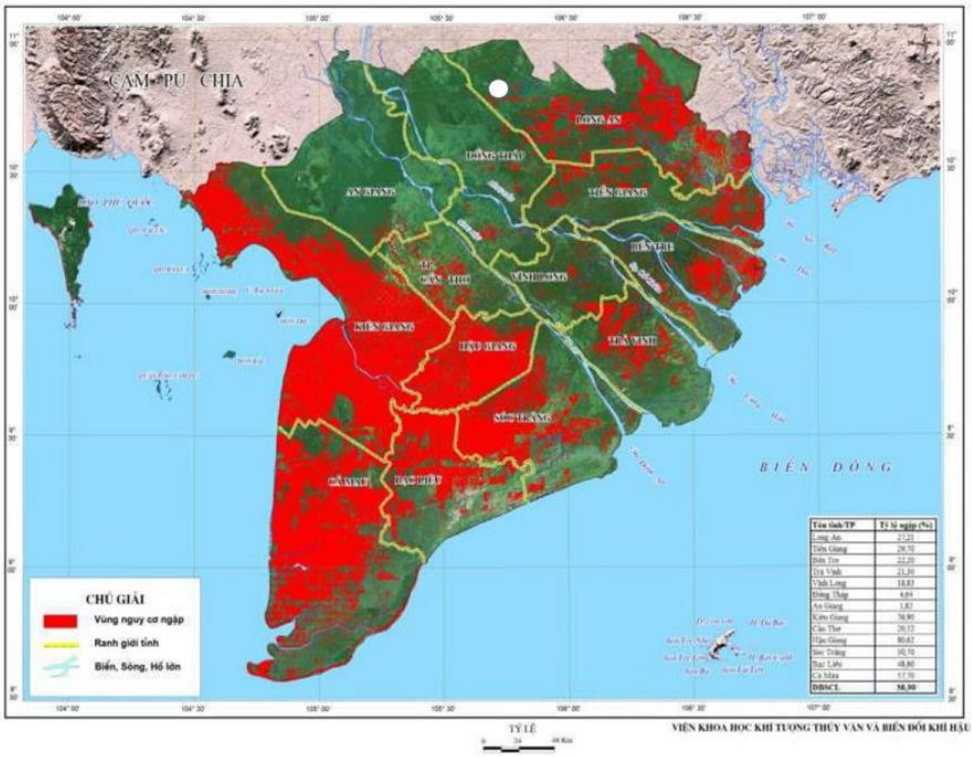


Figure 6: Map of inundation risk for the Mekong Delta when sea level rises with 100 cm; the white circle shows the location of LSWR (source: Tran Thuc et al. 2016).

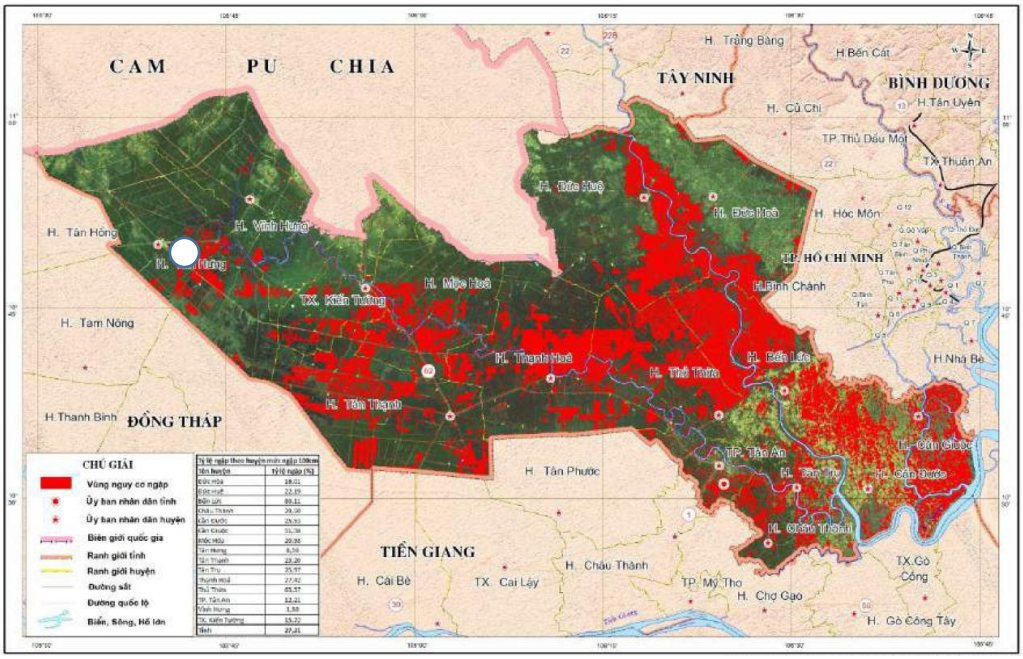


Figure 7: Map of inundation risk for Long An Province when sea level rises with 100 cm; the white circle shows the location of LSWR (source: Tran Thuc et al. 2016).

5. Results of vulnerability assessment

5.1. Habitat vulnerability

After consulting with Lang Sen managers, the assessment team selected the following wetland habitat types for climate change vulnerability analysis: melaleuca forest, seasonally inundated grassland, and lotus swamp. These are the most representative of Lang Sen's wetlands, as well as having the largest areas (see Section 2.4). The team did not focus on man-made habitats such as rice paddies and canals.

5.1.1. Baseline conservation status

Baseline conservation status of habitats was assessed based on their regional and local representation and trends (increasing or decreasing), biodiversity conservation values (presence of flagship, keystone species), protection status, national or international recognitions, and their ability to recover from extreme weather events in the past. Baseline conservation status reflects the importance of protection and was assessed using expert opinion, including those of the assessment team and LSWR's managers; scores range from 1 to 3, with score of 3 being high and 1 being low.

Melaleuca forest covers the largest area among all habitat types of LSWR. It is also a common habitat type in the Mekong Delta. Most melaleuca stands in the Mekong Delta, including those inside LSWR's core zone, are planted ones. Melaleuca trees can withstand prolonged inundation but still need a dry period for optimal growth. Permanent inundation leads to poor growth and suppresses natural regeneration of melaleuca forests. Melaleuca is a fire tolerant tree species, but fire suppression practices lead to increased fuel loads on forest floors, which can result in catastrophic fires that destroy large melaleuca stands. Melaleuca forests generally recover well of extreme weather events, such as two big floods in 2000 and 2011 and a severe drought in 2015-2016. *Melaleuca cajuputi* is the dominant tree species of this forest type and can be considered a keystone species in LSWR. Our analysis yielded a baseline conservation score of 1.7 for melaleuca forest habitat in LSWR. The relatively low score reflects the fact that melaleuca forest is a common habitat type of the Mekong Delta and it can tolerate a wide range of extreme weather events.

Seasonally inundated grassland is one of the typical wetland habitats of the original Plain of Reeds. They now exist only in protected areas such as LSWR and Tram Chim National Park. Grasslands in LSWR provide dry season habitats for the eastern sarus crane, which can be considered a flagship species for wetland conservation in the Mekong Delta, even though the number of cranes coming to LSWR has declined in recent years. Grasslands in LSWR require a wet-dry hydrological regime to maintain their ecological integrity. They are susceptible to fires during the dry season but can tolerate low to moderate fire intensities and frequencies. One of the most common plant communities of seasonally inundated grasslands in LSWR – and an important food source for sarus cranes – is the *Eleocharis* community. *Eleocharis* species tolerate highly acidic soils, as well as deep water inundation, and can be considered keystone species of this type of habitat. Grasslands in LSWR are threatened by *Mimosa pigra*, one of the most notorious invasive alien plant species in wetlands of the Mekong Delta. Seasonally inundated grasslands are strictly protected in the core zone of LSWR. The current management of this habitat, however, is problematic; the compartmentation of the core zone and the practice of

keeping high water all year round to suppress fires, negatively affects seasonal grassland communities. Our analysis yielded a score of 2.0 for seasonally inundated grassland habitat.

Lotus swamp represent open swamp ecosystems of LSWR. Lotus (*Nelumbo nucifera*) can be considered a flagship species for this type of habitat given its cultural value in Vietnamese society. It is also an economically important species for local communities since many parts of the plant are harvested for their commercial value. The area of lotus swamps inside LSWR seems to have been reduced recently, especially after the drought years of 2015-2016. It has been heavily invaded by water hyacinth (*Eichhornia crassipes*) and water lettuce (*Pistia stratiotes*). The expansion of floating aquatic vegetation mats, made up of mostly water hyacinth, water lettuce and other floating plants such as *Polygonum tomentosum* and *Ludwigia adscendens*, also reduce open water areas of lotus swamps. Natural lotus swamps are very rare outside of LSWR. Areas of planted lotus ponds, however, have been increasing in provinces of the Plain of Reeds in recent years. Lotus swamp habitat is not tolerant to fire and very sensitive to drought. Lotus swamps are important for wetland diversity conservation because they provide year-round habitats for many aquatic species. Lotus swamps are strictly protected in the core zone of LSWR. Our analysis yielded a score of 2.2 for Lotus swamp, the highest baseline conservation status score among the three habitat types assessed for LSWR.

5.1.2. Climate change vulnerability

Table 6 presents a summary of major climate issues, exposure, sensitivity and adaptive capacity of the three habitat types being assessed for LSWR.

Table 6: Summary of climate vulnerability characteristics of wetland habitat types at LSWR.

	Major climate issues	**Exposure**	**Sensitivity**	**Adaptive capacity**
Melaleuca forest	Drought; extreme events	All areas being exposed	No major sensitivity issues	High
Seasonally inundated grassland	Drought; hydrological change	All areas being exposed	Sea level rise; soil erosion; sedimentation	Low
Lotus swamp	Drought; hydrological change	All areas being exposed	Drought; sea level rise sedimentation	Low

Melaleuca forest is most vulnerable to drought and, to a lesser extent, to salinity intrusion. It is relatively tolerant to flooding (if not permanent inundation), high temperatures, intensive rainfall, and changes in sedimentation and water quality. Strong winds may knock down melaleuca trees during a storm but are not expected to cause permanent damages as melaleuca can regenerate quickly. Seasonally inundated grasslands are also vulnerable to drought, hydrological change and salinity intrusion. It can tolerate moderate fires but would be badly affected by frequent fires. It tolerates natural flooding events (e.g., caused by typhoons or tropical depressions) but would be severely impacted by permanent inundation from poor water management. There is little space available for this type of habitat outside LSWR and dykes function as major spatial barrier to escape climate change impacts within the reserve. Lotus swamps are most vulnerable to droughts and hydrological variations due to changes in flooding regime, sedimentation and water quality. Extreme events such as typhoons would cause temporary disturbances but are not expected to cause permanent damages to the habitat. Given its relatively small area, LSWR's lotus swamps would be entirely exposed to most climate change phenomena. The habitat is not tolerant to drought and has only limited capacity to cope with changing hydrology and saline intrusion. The dyke and canal systems are also major barriers for lotus swamps that prevent 'movement' under the influence of climate change.

Overall, the capacity of melaleuca forest to adapt to climatic changes is much higher than that of seasonally inundated grasslands and lotus swamps. Melaleuca forest of LSWR has a climate vulnerability score of 2.1, belonging to the “Moderately Vulnerable” category. Our analysis yielded a climate vulnerability score of 2.4 for seasonally inundated grassland habitat, placing it in the “Highly Vulnerable” category. Louts swamp has a climate vulnerability score of 2.6, which is in the “Highly Vulnerable” category.

5.1.3. A comparison between habitats

The scores for baseline conservation status and climate change vulnerability for the three main habitats in LSWR are summarized in Table 7. As indicated in the previous section, lotus swamp and seasonally inundated grassland are “highly vulnerable” to climate change while melaleuca forest is “moderately vulnerable”. Melaleuca forest also has a below-average baseline conservation status, reflecting that this type of habitat is common throughout the Mekong Delta. The confidence in the assessments (based on a scale from 1 – 4) is high, given the available information about these habitat types in the Mekong Delta.

Table 7: Summary of habitat assessment results for LSWR.

	Baseline conservation status		**Climate change vulnerability**	
	Score	**Confidence**	**Score**	**Confidence**
Melaleuca forest	1.7	3.9	2.1	3.3
Seasonally inundated grassland	2.0	4.0	2.4	3.4
Lotus swamp	2.2	3.9	2.6	3.3

Figure 8 presents the results for the three habitats in LSWR compared to other wetland habitat types assessed in the Mekong Delta. Lotus swamps of LSWR are comparable to peat swamps of U Minh Thuong National Park, with high baseline conservation values and high vulnerability to climate change. Seasonally inundated grasslands of LSWR and Phu My Species and Habitat Conservation Area have similar conservation status values, but grasslands of LSWR are less vulnerable to climate change, most likely because habitats in Phu My are facing stronger impacts from sea level rise. Melaleuca forests of both LSWR and U Minh Thuong National Park have lower conservation status values and are less vulnerable to climate change compared to other habitat types assessed; they are more resilient and are commonly found in the Mekong Delta (as opposed to the type of melaleuca found in Phu My).

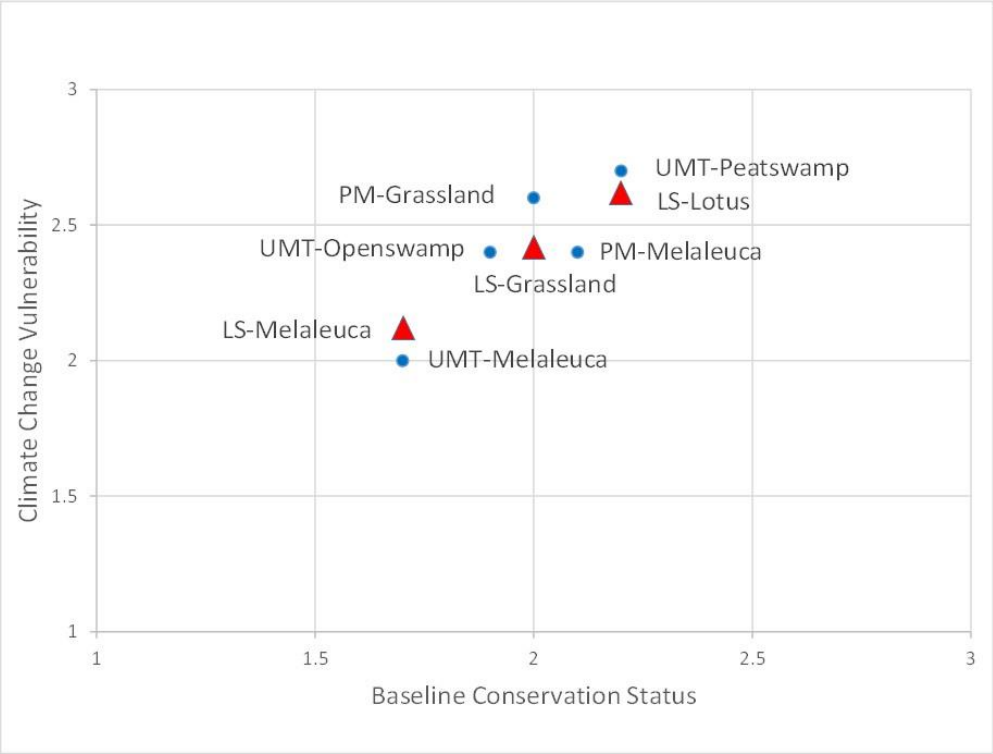


Figure 8: Conservation status/Climate vulnerability diagram for all habitats assessed for Vietnam wetland sites. LS: Lang Sen Wetland Reserve; PM: Phu My Species and Habitat Conservation Area; UMT: U Minh Thuong National Park. LSWR's habitats are represented by red triangles.

5.2 Livelihood vulnerability

Three villages were selected for the vulnerability assessment, namely Ca No, Ca Sach (both Vinh Loi commune) and Roc Nang (Vinh Chau A commune). Ca No and Ca Sach were selected for their dependence on wetland resources, and their involvement in livelihood projects, while Roc Nang is regarded as being closest to the breeding habitats of fishes of the reserve. The locations of the villages are indicated in Figure 9.

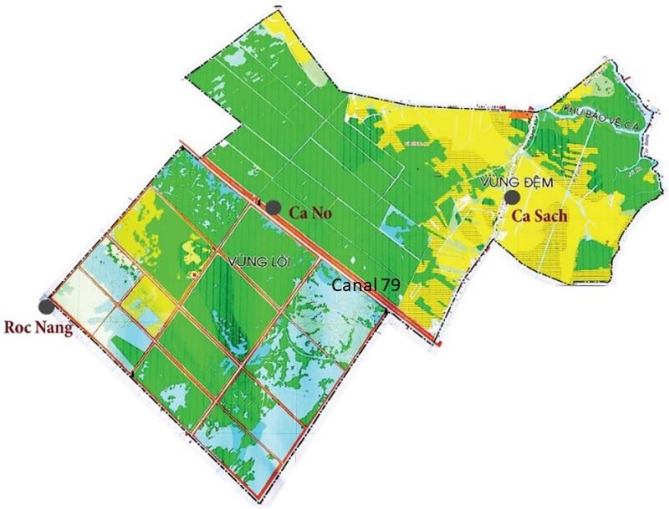


Figure 9: Locations of three villages assessed in this study.

At every village, the team engaged with village members and applied PRA (Participatory Rural Appraisal) to mobilize villagers and learn from their knowledge. PRA is an appraisal process conducted in a short time and helps villagers to share, consolidate and analyse their knowledge and living conditions. PRA tools included seasonal calendars, timelines, village resource maps, and rankings. In this study, PRA tools were used to collect data on resource

priorities, resource distribution over space and time, and recollection of extreme weather events and their impacts. In addition, group discussions were organized on coping behaviour and wetland management. Needs and perspectives of women and men were included through separate focus groups.

5.2.1. Dependency on wetland resources

The selected villages represent different levels of dependency on wetland resources of the reserve. People of Ca No Village are mainly (melaleuca) plantation workers, while inhabitants of Ca Sach and Roc Nang are predominantly rice farmers; and since Roc Nang is located next to the core zone, its people tend to access LSWR more frequently. Key livelihood resources for all surveyed villages, however, include rice, wild fish, farmed fish, water hyacinth, frog and rodent (field rat); the relative importance of other resources such as melaleuca, grass, python and other snakes, wild vegetables, snails and crabs varied strongly between villages (Table 8).

It may seem surprising that Ca No Village did not refer to water (canal, river or rain) as an important resource, but people in Ca No use water from a clean water supply system already installed in the village, while the other villages do not have this yet. Further, rain water in Ca Sach and Roc Nang was appreciated much more by men than by women; this might come from the fact that main family tasks of men in these villages are related to rice cultivation. Some areas in Ca Sach and Roc Nang – where canal water and river water cannot reach –strongly depend on rain water for their rice fields.

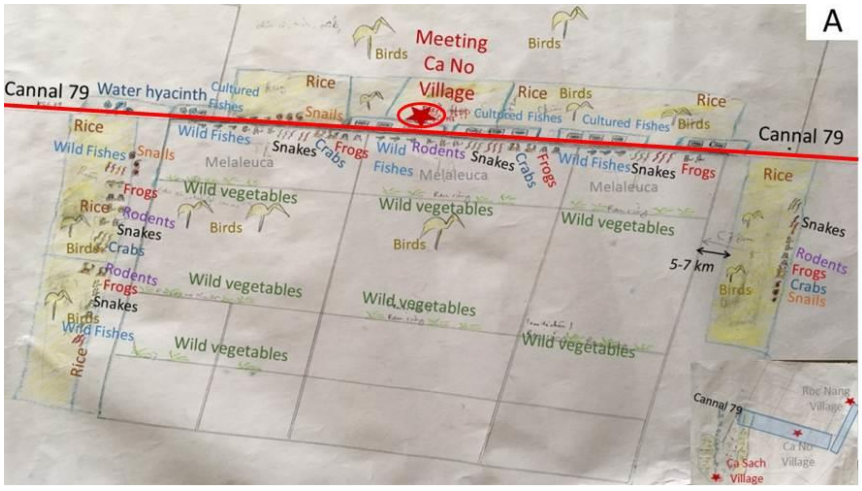
Table 8: Ranking of key wetland resources by men (M) and women (F) from Ca No, Ca Sach and Roc Nang Village.

	Wetland resources	**Ca No**		**Ca Sach**		**Roc Nang**		**Resource-use**
		M	F	M	F	M	F	
1	Melaleuca	1	1	-	-	-	-	Cutting melaleuca and replant after harvest as hired laborer (sold for firewood/construction)
2	Rice	4	3	1	1	1	1	For food and sale
3	Canal water	-	-	-	-	2	2	For household consumption and irrigation
4	River water	-	-	2	2	-	-	For transportation, consumption, irrigation
5	Wild fishes	2	4	4	5	4	3	For food and sale
6	Farmed python	5	2	-	-	-	-	For sale
7	Cattle, pig, poultry	6	2	-	-	6	4	For sale
8	Farmed fishes	3	5	5	6	5	6	For food and sale
9	Golden apple snail	-	-	7	4	-	-	For food and rice pest control
10	Water hyacinth	7	7	6	3	7	5	Harvested, sun-dried, and used for handicrafts
11	Rain water	-	-	3	10	3	-	For household consumption and irrigation
12	Frogs	10	9	10	8	9	8	For food and sale
13	Field rats	-	6	8	7	8	7	For food and sale
14	Snakes	8	8	-	-	-	-	For food and sale
15	Grasses	-	-	9	9	-	-	For husbandry

16	Crabs	9	10	-	-	-	9	For food and sale
17	Wild vegetables	-	-	-	-	10	10	For food and sale

To get better understanding of the distribution of resources over space and time, resource maps and seasonal calendars were made with members of the three villages (see Figure 10 and 11). Generally, these were consistent with the resource table, although there were also some inconsistencies, e.g. collection of wild vegetables seems important in Ca No (in calendar and map) but was not mentioned in the resource table; grass cutting was mentioned as activity for both Ca Sach and Roc Nang, but not mentioned as key resource in Roc Nang; cattle, pig and poultry were mentioned as a resource in Ca No, but not in the calendar; golden apple snail was mentioned as resource in Ca Sach but appeared in the calendar only for Ca No. Most differences seem, however, related to “less” important resources, whereby the limit of a top 10 for each village may have restricted them in filling out the resource table.

When we turn to the resource maps and calendars, we see that Ca No villagers practice a 2-crop rice system, while Ca Sach and Roc Nang practice a 2 or 3 crop system depending on each individual household. Some activities can be done throughout the year, such as: water hyacinth harvesting (all); raising pigs and goats (Roc Nang); collection of wild vegetables (Ca No, Roc Nang); cultivating vegetables (Roc Nang), catching rodents, frogs, crabs or snakes (all); and working as employees (all). Since most people in Ca No village do not have sufficient land for cultivation, many are working as hired labourer throughout the year on melaleuca plantations. Other activities depend on the wet season, such as farming fish (all) between June and January, and wild fishing (all), mostly in the wet season from July – January but the whole year in case of Roc Nang. Python husbandry is also seasonal (July – December) and is practiced only at Ca No village with support from a livelihood development project. Overall, Roc Nang village seems most reliant on the wetlands in terms of water for rice cultivation, vegetable cultivation and husbandry, as well as wild fish, grasses, frogs and crabs. Ca Sach people also strongly depend on river water for their rice crops and natural resources such as water hyacinth and wild fish for income. People in Ca No rely strongly on melaleuca plantation forests for their income.



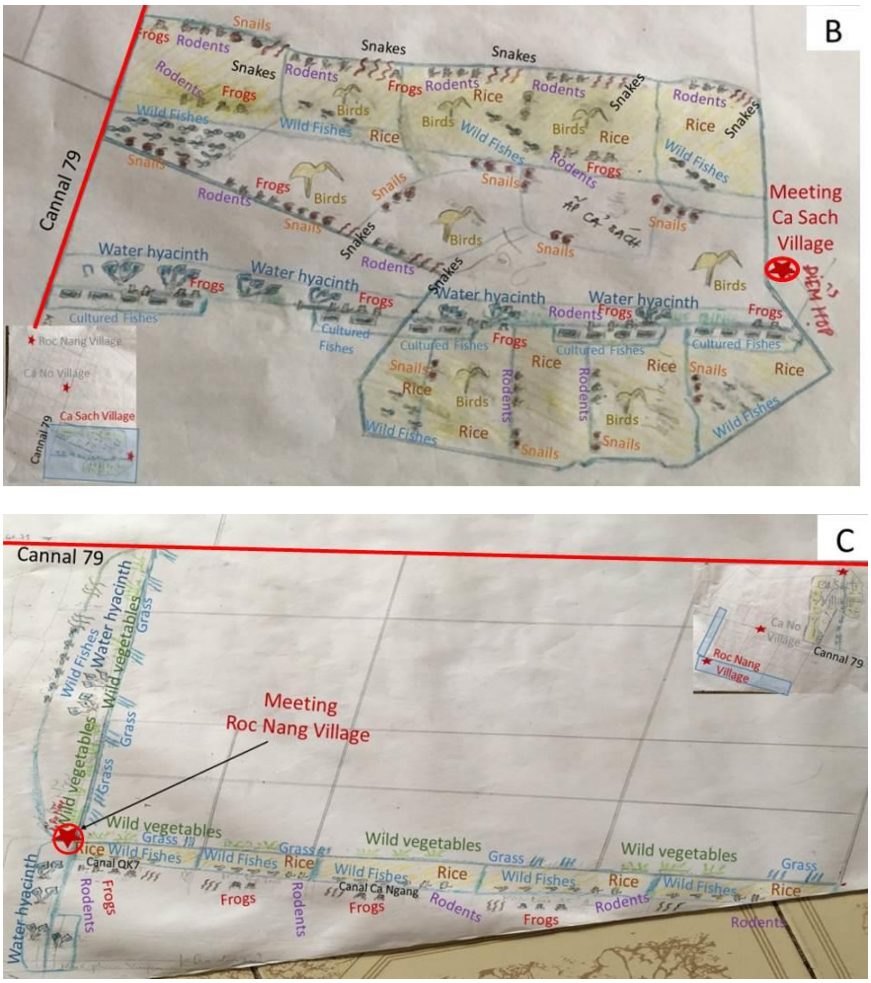
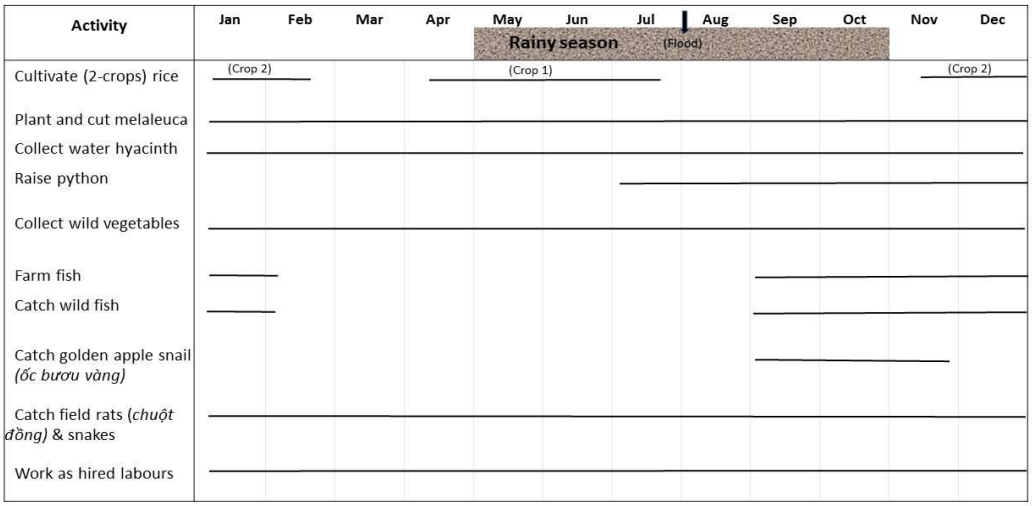
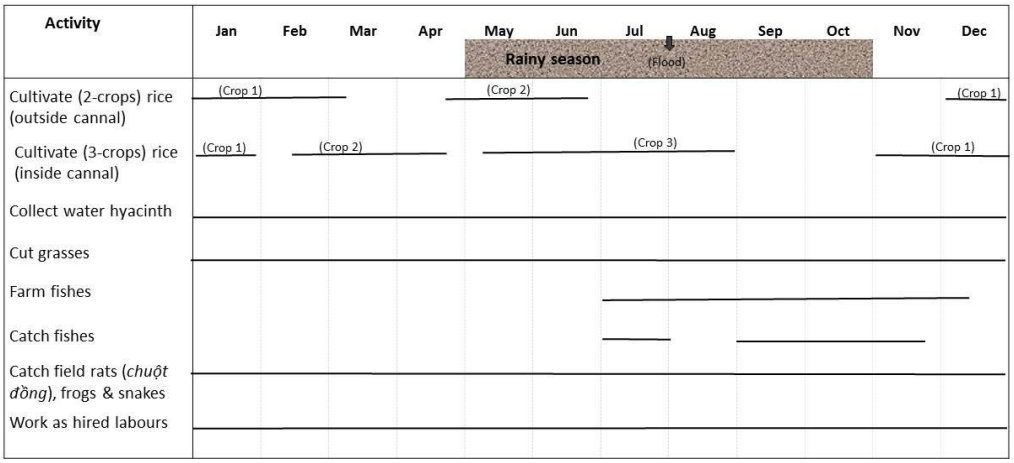


Figure 10. Resource map of Ca No (A), Ca Sach (B) and Roc Nang (C) Village (note: orientation of map A and C is similar to that of Figure 9, except map B which is turned a quarter clockwise (see inserts and position Canal 79)

Ca No



Ca Sach



Roc Nang

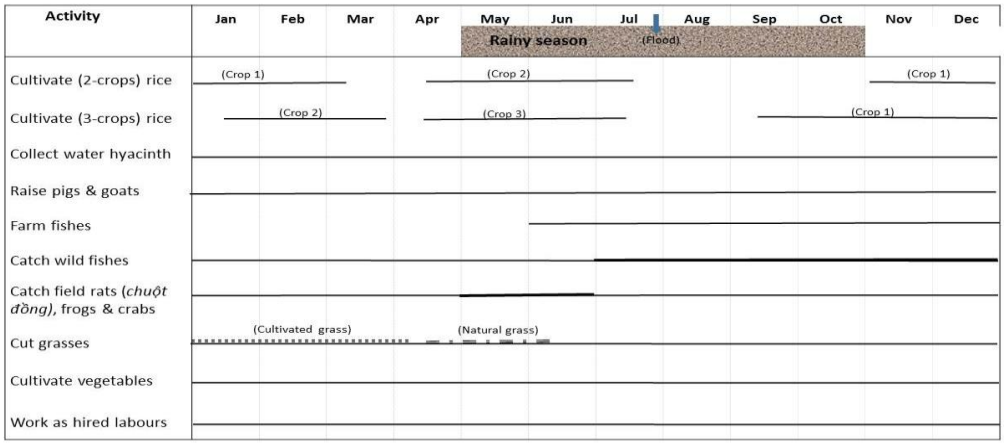


Figure 11. Seasonal calendars of Ca No, Ca Sach and Roc Nang Village

5.2.2. Extreme weather events and impacts

All three villages reported severe impacts due to extreme weather events that occurred in the area over the last 10 years, including droughts, hot weather with smog, floods, heavy rainfalls and storms; they also reported changes in river water flow, water colour, odour and sediments (see Table 9).

Table 9: Extreme weather event in the past and current as reported by local people.

Extreme events	Year	Village	Description and impacts
Drought	2015	Ca No, Roc Nang	Fishery resources and rice productivity seriously affected; water resources polluted by pesticides used in rice fields.
Haze (hot and humid)	2017	Ca Sach	Rice crops and poultry affected by diseases; water polluted because of contaminating pesticides.
Flood	2011	Ca No, Ca Sach, Roc Nang	The flood made rice fields inundated and damaged; farmed fish, cattle and poultry were lost; houses were damaged.
	2017	Ca Sach	River hydrology changed with stronger water flows and less sediments; harvested water hyacinth could not be sun-dried.
Heavy rain / strong wind	2014	Ca No	Rice collapsed, and fish farming was affected.

In 2011, Ca No village was struck by a flood. Lotus and cultivated fruit trees were heavily affected but melaleuca survived. Fish became abundant, but harvesting was difficult due to high water levels. Farmed fish escaped, causing loss of income. Rice fields were also flooded and damaged, but houses were safe. Three years later, in 2014, Ca No was hit by heavy rain and strong winds, causing rice to collapse. Then, in 2015, the village experienced a drought, affecting fish and rice fields. Moreover, during the drought, villagers were not hired for cutting melaleuca, leading to a serious decrease in income.

Ca Sach village was hit by two floods, in 2011 and 2017. Rice was heavily affected because of not being harvested in time. Many houses were inundated and collapsed; roads were damaged. Fish became more abundant, but water hyacinth could not be sun-dried after harvesting as usual and decreased in quality. The villagers also experienced hazy (hot and humid) weather in 2017, leading to disease outbreaks in crops and animals; rice productivity decreased dramatically – yielding only 2 tons (normally 8-9 tons) per hectare – and fish, ducks, and chickens died. When the rains appeared after the hot/humid weather, many fishes re-appeared, mostly climbing perch which can survive well in hash conditions such as hot/drought weather and polluted water. Canal and river water were polluted because of discharged water from the rice fields, containing pesticides used for killing golden apple snails.

Members from Roc Nang village reported a flood in 2011. Houses broke down and walls burst because of swirling winds. Pigs and cows had to be moved to other locations for safety. When the flood came, the rice crops had been harvested already, thus there was no crop damage. Fish became more abundant, but villagers could not catch them because of high water. Farmed fish escaped because embankments broke. People could not find jobs during the flood. After the flood, rice productivity increased thanks to fertile sediments left behind. People also witnessed a drought in 2015, leading to water shortage. White fish (which includes various migratory fish which thrive in good quality water such as catfish) in the wetland reserve were most strongly affected and died in large numbers. Rice yield reduced by 30 – 40%, leading to a serious decrease in income. Water was also polluted due to discharges of polluted rice field water.

Although there have been some differences in type and year of extreme weather events between the three villages, droughts and floods have had the biggest impacts. Ca No and Roc Nang may seem more vulnerable to drought, while Ca Sach seems more exposed to flood and haze; the type and level of impact are, however, more closely related to the specific resources used by each village and the timing of impact.

5.2.3. Coping strategies and wetland management

In each village, men and women were asked how they cope with the impact of extreme weather events and how they would deal with them in the future when they are expected to become more frequent and intense due to climate change. Table 10 – 12 summarize current and future coping strategies.

Over the past 10 years, droughts, floods and strong winds have led to crop and income loss, damages to houses and roads, reduction in fish stock, and pollution of water sources. Activities reported by men and women to cope with these impacts have not been very effective. In case of droughts most people tried to minimize the impact by pumping more water in the rice fields; and in case of floods people harvested their rice early and prevented farmed fish to escape by consolidating embankments or by pulling nets above the water level. People also compensated for the loss in income by taking on temporary jobs and by relying more strongly on natural resources, such as wild vegetables, wild fish and water hyacinth. People also used pesticides and chemicals to protect crops from pest and disease outbreaks due to extreme weather, but this may have had negative impacts for natural resources and ecosystems. Moreover, the increased demand for agricultural chemicals, but also the need to pay for other expenses during tough times, has led people to borrow money from family and neighbours and at the black market (against high interest rates), especially when access to formal government loans was not available.

When asked how they can cope better with climate change impacts in the future, people's responses remained rather passive, reflecting a strong dependency on the State. Besides the suggestion to shift from a 3-crop rice system towards 2-crops – for improved production and reliability per crop, while reducing costs and labour – most strategies were more of the same with careful suggestions for diversification. They proposed improved livestock production (including poultry), good aquaculture practice with consideration of breeding stock, improved cultivation techniques, effective and profitable policies on agricultural product consumption and trading, and stable prices (with less influence of traders). Often, they expect the government to help them financially and otherwise. While stronger reliance on natural resources such as fish and wild vegetables could help people to cope better with adverse impacts, it also puts more pressure on the wetland; which are further compromised by increased fertilizer and pesticide use to improve agricultural production. Most of these measures are only effective to some extent; they do not take away the risk that people may lose their assets, income and food when hit by a flood, drought or other extreme event.

As a follow-up, villagers discussed strategies to more effectively manage key wetland resources (see Table 13). Rice pricing and trade were proposed to support local livelihoods, but people also suggested converting rice into other crops to increase diversity and resilience. Villagers from Ca No specifically proposed the State to plant more melaleuca forests for job creation, while water hyacinth was mentioned more generally as having great potential to improve local livelihoods through the development of handicraft businesses based on sun-dried and processed material. Also, fish is an important and widely used resource. Wild fish is however decreasing, and villages struggle to develop effective management systems. In Roc Nang, the right to catch wild fish in the area has been put up for auction, approved by the CPC; it is unclear, however, how this will work, how benefits will be shared, and whether it will be sustainable. People realize that water is central to the use of wetland resources and the overuse of chemicals in rice cultivation needs to

be addressed to improve water quality. Golden apple snails are an important problem in rice and directly linked to pesticide overuse; Asian open-billed storks could possibly be promoted and contribute to biological snail control while reducing the need for pesticides.

Generally, issues of water management for irrigation and drainage, but also clean water supply, call for government attention and investment. Villages in the buffer zone of LSWR will need technical and financial support to shift towards more climate resilient and sustainable crop and livelihoods systems.

Table 10. Summary of current and future coping strategies as identified by people from Ca No Village.

Extreme weather events	Impacts	Current coping strategies		Future coping strategies	
		Men	Women	Men	Women
Drought	Crop damage	Pumping canal water into their rice fields despite of being alum due to drought	Waiting for drought over and pumping water into rice fields	Pumping water from canals into rice fields	Replanting other crops
	Income loss	Looking for jobs and being employed	No coping strategies.	Looking for jobs in other villages/places	Looking for jobs and being employed
	Reduced natural fish stock	No coping strategies	Switching to using farmed fish and waiting for natural fish regeneration	No coping strategies	No coping strategies
Flood	Income loss	Asking for money from neighbours	Looking for jobs and being employed; asking for money from neighbours; collecting wild vegetables; catching natural fishes	No coping strategies	Looking for jobs and being employed
	Crop damage	Early harvesting rice crops and waiting for drainage to cultivate next crops	Early harvesting rice crops and waiting for drainage to cultivate next crops	Shifting to cultivating two rice crops per year, instead of three	No coping strategies
	Reduced fish stock	Preventing fish from escaping out of farms by raising preventing nets	Let it be natural; no coping strategies	Developing snakehead fish farming	No coping strategies
Strong wind and thunders	Income loss	Looking for jobs and being employed	Looking for jobs and being employed; asking for money from neighbours; collecting wild vegetables; catching natural fishes	No coping strategies	Looking for jobs and being employed
	Crop damage	No coping strategies	No coping strategies	No coping strategies	No coping strategies

Table 11. Summary of current and future coping strategies as identified by people from Ca Sach Village.

Extreme weather events	Impacts	Current coping strategies		Future coping strategies	
		Men	Women	Men	Women
Flood	Crop damage	No coping strategies	No coping strategies	No coping strategies	No coping strategies
	Damage to dwelling	Making house floor higher; picking vegetables and catching fish around the house	Making the house floors higher; fixing and stabilizing the house; receiving state support of about US$ 20 per household	Making house floors higher to stay during the floods	Rebuilding and strengthening houses and expecting state financial supports
	Disrupted transport	Going by boat. Waiting for the state to fix the road	Collecting money from community and fixing roads and bridge together	Going by boat; no other coping strategies	Expecting state financial supports
Haze (heat and smoggy)	Reduced fish stock	Still having enough fish. No need to improve	Having no available coping strategies	Let it regenerate naturally	No ideas to cope with the impact
	Polluted water	Pumping water from canal to use	Pumping water from river for use; treating alum water for household use such as bathing and cooking	Need for controlling chemical use	Expecting the state to help with clean water supply system
	Income loss	Looking for jobs and being employed; asking for money from neighbors; selling land	Harvesting water hyacinth; looking for jobs and being employed in other places; using nets to catch fishes; catching field rats and frogs for food and sale; borrowing money from neighbours	Expecting to have other farming models such as mushroom cultivation; expecting state to support seedlings, cultivating techniques, and product consumption	Expecting state help stabilize prices of rice and water hyacinth, instead of being determined by middlemen and traders
	Crop damage	Dealing with rice diseases by using chemicals and applying fertilizer	Being in debt when bought chemicals from retailers; selling lands to pay for loans and interests	Expecting state technical assistance to treat rice disease; needing help to monitor and predict disease occurrence	No ideas to cope with the impact

Table 12. Summary of current and future coping strategies as identified by people from Roc Nang village.

Extreme weather events	Impacts	Current coping strategies		Future coping strategies	
		Men	Women	Men	Women
Drought	Crop damage	Pumping canal and river water into rice fields	Buying pesticides with debt to treat rice disease.	Weeding and preparing land for the next crop; using chemicals to kill golden apple snails	Buying pesticide to treat rice disease
	Income loss	Looking for jobs and being employed. Harvesting water hyacinth. Weaving water hyacinth	Borrowing money from neighbours. Buying rice with debt. Looking being employed.	No coping strategies	Taking state or private loans; buying food and groceries with debt; looking for being employed
	Reduced natural fish stock	Farming more fish	Keeping fishing for food	No coping strategies	Using nets to fish
	Polluted water	Waiting for rain water to wash rice field naturally	Switching to using bottled water. Taking water in the wetland reserve for household use	Waiting for rain water to wash the rice fields naturally	Buying purified and bottled water for use; taking water from the reserve for household use
Flood	Income loss	Catching wild fish daily for food; receiving financial supports from state	Taking state loans or heavy interest loans from black market; fishing by nets; harvesting water lily, lotus, water spinach, and wild vegetables for food and/or for sale	Fishing daily for food	Collecting water lily and lotus for sale; fishing wild fish for food and sale; taking state loans or private loans with heavy interests
	Damage to dwelling	Making house floor higher; waiting for drainage to rebuild houses; moving to temporary location for safe shelter; keeping valuable items to places that are not flooded	Building temporary shelters to stay. Cutting trees for rebuilding houses. Buying leaves for fixing house roofs. Borrowing money from neighbours to fix houses; receiving state financial supports	Making house floor higher. Rebuilding the house. Moving to safer temporary location; keeping valuable items in safe places	Staying in temporary shelters and waiting for drainage; fixing houses after the flood; receiving state financial supports Borrowing money from neighbours.
	Reduced fish stock	No coping strategies for this impact	Raising fish nets higher; drying dead fish for food	Growing husbandry and poultry	Pulling fish nets higher; drying dead fish for food

Table 13: Current and future wetland management strategies of key resources in Ca No (CN), Ca Sach (CS), and Roc Nang (RN) Villages

Resource	Current management	Future management
Melaleuca	Managed by state-owned forestry enterprise; harvested after 7 years (CN).	Replanting melaleuca forests for exploitation and for jobs related to cutting and planting melaleuca (CN).
Rice crops	System of 2-3 rice crops per year. The dykes facilitate irrigation and prevent alluvium getting into the field. Productivity has decreased recently from 8-9 tons per ha to 2-4 tons due to disease outbreaks. Villagers are responsible for rice disease treatment (types of pesticides/ways of spraying) and product trading (CS, RN). Overall, though, rice cultivation is becoming less profitable; middlemen/traders determine price and harvesting time.	Need for stabilizing rice prices. The state should provide villagers with technical assistance and research to create higher income from rice cultivation (CS, RN). It is also possible to convert rice to other crops such as lotus cultivation, but this requires capital investment (RN).
Canal water	Not yet managed; canal water is contaminated with pesticides and chemicals used to kill snails. Switching to purified water for drinking and cooking (RN).	Need for state support to build a system of clean water supply (RN).
River water	Water from rice fields carrying pesticides and polluting the river water (CS).	Needing for help to manage water quality (CS).
Wild fishes	Wild fishes are decreasing. No effective management. In RN, wild fish in canals are managed by the Commune PC. People catch wild fish for food in small quantities by using rudimentary fishing equipment. The rights to exploit water surface and wild fish in large area are put up for auction and legitimized by Commune PC (RN).	Need for fish exploitation management. Using electricity for catching fish should be strictly controlled (CN). Having no ideas on how to gain exploitation rights over wild fish resource (RN).
Farmed python	Not yet managed (CN)	Need for financial supports to develop python farms (CN)
Husbandry and poultry	No state management.	Shifting to raising ducks in flood season (RN).
Farmed fishes	No state management. At present, there is a decrease in number of fish farmers due to low profits (CS).	Need of stabilized fish price and improved farming techniques (CS, RN).
Golden apple snail	Use of pesticides to control golden apple snail; due to overuse, water has become polluted (CN, CS).	Keep using pesticides to kill golden apple snail, but need for control (CN, CS).
Water hyacinth	Not yet managed. Naturally growing in large rivers (RN). When abundant, blocking traffic on rivers and canals (CN). In CS village, households divide/zone the water surface in front of their houses, so that they can keep water hyacinths for their own exploitation.	Needs to be managed for convenient transportation (CN). Hopefully developing business relating to water hyacinth products (CN, RN). Expecting help, especially for women, with technical training on making handicraft from dried water hyacinth and trading their products (CS).
Rain water	Let it be natural (CS)	Let it be natural (CS)
Frogs	Let it be natural	Let it be natural
Field rats/rodents	Let it be natural	No intervention ideas but need to control rat population (CS).
Snakes	No management; according to people in CN, the number of snakes as decreased by 20%.	Let it develop naturally.
Grasses	Let it be natural	Let it be natural
Crabs	Let it be natural	Let it be natural
Wild vegetables	Let it be natural.	Suggest planting short-term vegetables in accordance with flooding regimes (RN).

5.3 Species vulnerability

The assessment team selected 6 species for the climate change vulnerability analysis, including 3 species of plant (*Eleocharis*, Lotus and *Melaleuca*), one bird (Oriental darter) and two fish (Siamese mud carp and Giant snakehead fish). These were identified in consultation with the Land Sen managers. Reasons for selection are presented in Table 14.

Table 14: Species selected for climate vulnerability assessment for LSWR.

Species	Reasons for selection
Eleocharis dulcis	Keystone species
Melaleuca cajuputi	Keystone, economically important
Lotus (*Nelumbo nucifera*)	Flagship, keystone, economically important
Siamese mud carp (*Henicorhynchus siamensis*)	Economically important; migrating fish from the Mekong River
Giant snakehead fish (*Chana micropeltes*)	Economically important; abundant in LSWR but rare elsewhere in the Mekong Delta
Oriental darter (*Anhinga melanogaster*)	Representing water birds that breed in LSWR

5.3.1. Baseline conservation status

Species conservation status was assessed based on population size and trend, habitat preference, ability to disperse, current threats, protection status, national or international priorities, and their ability to survive recent extreme weather events. Species conservation status scores ranged from 1 to 3, with 3 being high and 1 being low.

Eleocharis dulcis and ***Melaleuca cajuputi*** are both common plant species. They can be found in many locations and are protected in many areas in the Mekong Delta. *M. cajupati* is a popular tree species being planted in the Mekong Delta for use as fuel woods or construction materials. Areas of natural *E. dulcis*, on the other hand, have been reduced outside of protected areas because their habitats were converted to farm lands. Both *Eleocharis* and *Melaleuca* can withstand natural flooding well and can tolerate low to moderate water salinity for a short period of time. Both species are capable of long distance wind and water disperse thanks to their numerous small seeds. *Eleocharis* and *Melaleuca* are sensitive to water management inside LSWR's core zone. A high-water regime will negatively impact the growth of both species. *Eleocharis* is sensitive to hydrological changes that result in changing water quality and sedimentation. A low pH and less turbid water conditions favour *Eleocharis* growth. *Melaleuca*, on the other hand, is less sensitive to changing water pH and sediment loads. Baseline conservation status of *E. dulcis* and *M. cajupati* were average with 1.8 and 1.9, respectively.

Lotus is a common freshwater wetland plant, not only in Vietnam but in many tropical countries. In the Mekong Delta, natural lotus communities are now only found in protected wetlands, but its planted area seems to be increasing. Lotus grows in permanent water bodies but can withstand short dry periods. Its seeds can stay viable for a long time in moist to waterlogged soils. Prolonged soil dryness, however, can kill lotus rhizomes and reduce its area. The baseline conservation status of lotus was 2.2.

Siamese mud carp is a migrating fish from the Mekong River, coming to LSWR area in large quantities during flood season. Mud carp is an important fish resource for local communities living around LSWR. The movement of mud carp depends on Mekong River's flooding pattern; changes in the River's hydrology will strongly affect this species. **Giant snakehead** instead is a resident fish and depends on permanent waterbodies for its habitat. The reserve is one of a few places in the Mekong Delta where a healthy population of giant snakehead fish can be found. It can grow to 1 meter in length and 20 kg in weight and it is common to find giant snakeheads in LSWR that weigh 10 kg. The fish is strictly protected inside LSWR. It is, however, favourably caught outside

the reserve by local people for food. Illegal fishing inside LSWR also occurs. Baseline conservation status of Siamese mud carp was 2.4 and that of giant snake head 2.3, which were the highest baseline conservation scores among the species assessed in LSWR.

Even though the **Oriental darter** is listed in Vietnam's Red Data Book of Threatened Species, its population is expanding in Vietnam and in other Mekong countries (Nguyen Hoai Bao, pers. comm.). The bird is currently listed Near Threatened in 2017 IUCN's Red List. Oriental Darter is a fish-eating bird, which depends upon a healthy fish stock to support its population. This species, as well as other fish-eating water birds, may actually benefit from the water stocking policy that is currently applied at LSWR because permanent water increases fish populations on which these water birds feed. Even though Oriental darter is protected inside LSWR, it is among the many water birds that are being hunted for food in the Mekong Delta. Despite being hunted, the baseline conservation status score for Oriental darter is relatively low with 1.8, and a result of its expanding population and habitat availability outside of LSWR.

5.3.2. Climate change vulnerability

Major climate issues, exposure, sensitivity and adaptive capacity of selected species are presented in Table 15.

Table 15: Summaries of climate change vulnerability characteristics of 6 species assessed for LSWR.

	Major climate issues	**Exposure**	**Sensitivity**	**Adaptive capacity**
Eleocharis dulcis	Drought, hydrological change	Hydrological change; refugia available	Hydrology	High
Melaleuca cajuputi	Drought, hydrological change	Drought; hydrological change; refugia available	No major issue	High
Lotus	Drought, hydrological change	Temperature change; hydrological change; drought; refugia available	Drought	Low
Siamese mud carp	Drought; hydrological change; temperature and extreme events (to juveniles and eggs).	Drought; Hydrological change	Heat; hydrology (flood regime)	Low
Giant snakehead fish	Drought, hydrological change	Drought; hydrological change; extreme events; refugia available	Heat (juveniles and eggs); hydrology	Intermediate
Oriental darter	Drought, hydrological change	No major issue	Juveniles and eggs may be impacted from diseases	Intermediate

All six species are vulnerable to drought and hydrological changes, although the level of vulnerability is less for *Melaleuca cajuputi* compared to the other five species. Even though the inundation risk due to sea level rise is projected to be low for LSWR, the risk of salinity intrusion that is associated with sea level rise is substantial and real, as exemplified by the high-water salinity and far inland intrusion of saline water on the Vam Co Tay River during the 2016 drought.

Among the species assessed, *Melaleuca* and *Eleocharis* are two plants that have the ability to produce large number of seeds that can be dispersed either by wind or water. This reproductive trait helps these plant species to cope better with climate change. Both plants (*Melaleuca*, *Eleocharis*) and the bird the Oriental darter also have better connectivity with habitats that are available outside of LSWR, contributing to their climate change resiliency.

Species' climate change vulnerability is however also complicated by changes in Mekong River hydrology and sedimentation due to upstream economic development and by water management practices at LSWR (see Beilfuss & Tran 2014 for an overview of adverse effects). The cascade of mainstream dams upstream of the Mekong River would lead to a new hydrological regime in the Delta area with less seasonal variability in flows and water levels (Rasanen et al. 2012). Being a migrating fish species, which depends on the Mekong River flood flows to reach the floodplain of the Delta, Siamese mud carp will face strong compound impacts of climate change and Mekong River development.

The climate change vulnerability analysis placed Siamese mud carp in the "Highly Vulnerable" category and the other five species in "Moderately Vulnerable". Climate change vulnerability of the plant species, *Eleocharis*, *Melaleuca* and lotus, was assessed as 1.9, 1.9, and 2.2, respectively. The scores for the two fish species, Siamese mud carp and giant snakehead fish, were 2.4 and 2.2. The Oriental darter scored average with 2.0 on climate change vulnerability.

5.3.3. A comparison between species

Results of the vulnerability analysis are summarized in Table 16. The 6 species assessed for LSWR are separated in two groups: *Melaleuca*, *Eleocharis* and Oriental Darter are of lesser conservation value and less vulnerable to climate change. Generally, these species have large populations and suitable habitats are available to them outside LSWR. Lotus, snakehead fish and Siamese mud carp have a higher baseline conservation score and are more vulnerable to climate change. And as a Mekong migratory species, Siamese mud carp is strongly affected by the combined effects of climate change and Mekong upstream development.

Table 16: Baseline conservation status and Climate change vulnerability scores of 6 species assessed for LSWR.

Species	**Baseline conservation status**		**Climate change vulnerability**	
	Score	**Confidence**	**Score**	**Confidence**
Eleocharis	1.8	3.7	1.9	2.7
Melaleuca	1.9	3.7	1.9	2.8
Lotus	2.2	3.7	2.2	3.0
Siamese mud carp	2.4	3.3	2.4	3.1
Giant snakehead fish	2.3	3.5	2.2	2.8
Oriental darter	1.8	3.7	2.0	2.5

Figure 12 provides a "conservation status – climate change vulnerability" diagram for species assessed in LSWR, as well as other species assessed for Vietnam wetland sites. Overall there seems to be a trend that species with higher baseline conservation status also have higher vulnerability to climate change. LSWR's species such as *Eleocharis*, *Melaleuca* and Oriental darter have a relatively low vulnerability compared to other species, while lotus, giant snakehead and Siamese mud carp score average. LSWR's *Melaleuca cajuputi*, which was also assessed at the other two wetlands, seems less vulnerable to climate change than *Melaleuca* in U Minh Thuong, mainly because it grows there on peat swamps which are more vulnerable to droughts and salinity intrusion caused by sea level rise. *Melaleuca* at Phu My, even though classified as the same species taxonomically, belongs to a rare plant community in the Mekong Delta, and is projected to be strongly affected by droughts and salinity intrusion. Among the grass and sedge

species assessed for seasonally inundated grassland habitats, *Eleocharis* at LSWR and *Phragmites* at U Minh Thuong have a lower conservation value and are expected to be less affected by climate change than *Lepironia* at Phu My. Both *Eleocharis dulcis* and *Phragmites vallatoria* are common species with habitats available outside these protected wetlands. *Lepironia articulata* on the other hand is a rarer plant species and does not have much habitat available outside Phu My. *Lepironia* also faces stronger impacts of sea level rise as compared to *Eleocharis* and *Phragmites*.

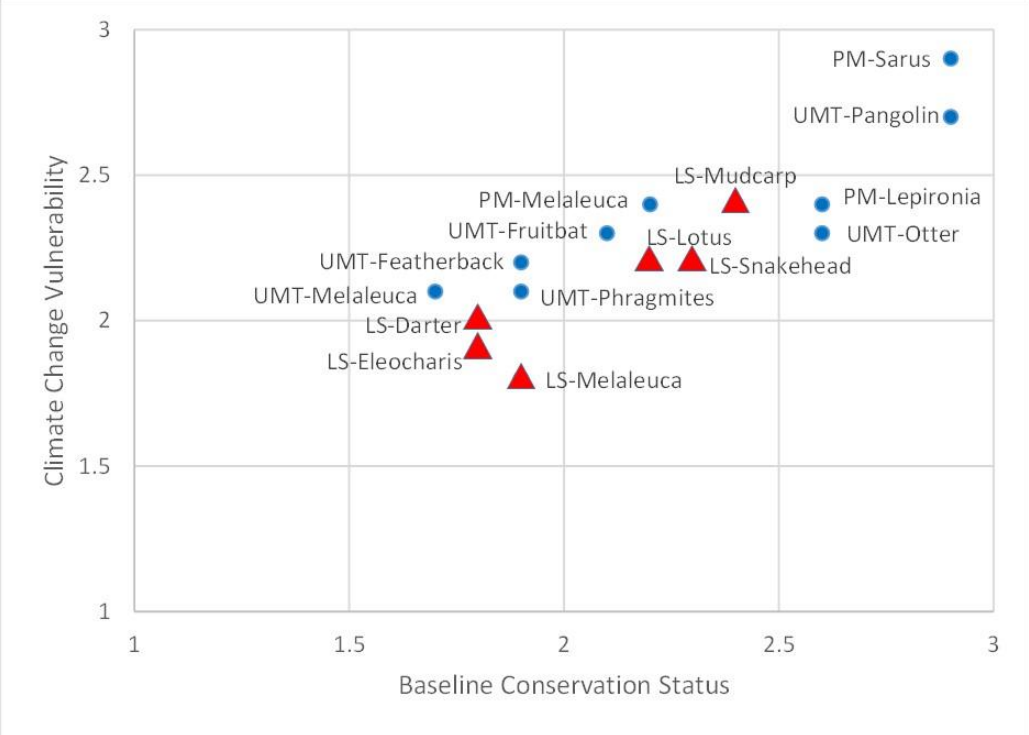


Figure 12: Conservation status/Climate vulnerability diagram for all species assessed for Vietnam wetland sites. LS: Lang Sen Wetland Reserve; PM: Phu My Species and Habitat Conservation Area; UMT: U Minh Thuong National Park. Species assessed for LSWR are shown in red triangles.

6. Conclusions

6.1 Summary of vulnerabilities

LSWR is one of the key sites for wetland biodiversity conservation in the Mekong Delta. Covering 4,802 hectare, the area is dominated by melaleuca woodland, permanent swamps and seasonally inundated grasslands, complemented with rice fields in the buffer zone. The area is influenced by a deltaic flood-pulse system, with distinctive annual wet-dry cycles. The hydrology of LSWR is, however, strongly regulated by man-made structures. Build to manage water levels inside the core zone to control forest fires, dykes and sluices have also limited the flow of flood water into the reserve, leading to severe water shortages in recent years.

The risk of water shortage in the core zone make habitats and key species of LSWR extra vulnerable to climate change, especially prolonged droughts. The severe drought in 2015-2016 offers good insights in the potential devastating impact of such events on wetland ecosystems. Except for the main canals, all areas of the core zone of LSWR were dried up, including lotus swamps. Large number of fish and aquatic animals died. Water was pumped in from outside the core zone to increase soil moisture and prevent forest fires, but this practice also increased the risk of bringing in environmental contaminants and invasive species.

Despite being located relatively far from the coastal area, wetlands of LSWR are also vulnerable to salinity intrusion as result of sea level rise, mainly via the Vam Co Tay River. High water salinity would be detrimental to many freshwater wetland species living in LSWR. Changes in Mekong River's hydrology and sedimentation due to hydropower development will further complicate the impacts of climate change on wetlands of LSWR. The cumulative impacts of climate change and Mekong upstream development are expected to be significant, but still poorly studied.

Not all habitats and species, however, are as vulnerable to the impact of climate change. Overall, the capacity of melaleuca forest to adapt to climatic changes is much higher than that of seasonally inundated grasslands and lotus swamps. And many plant species, such as *Melaleuca*, *Eleocharis*, lotus, but also a bird as the Oriental darter and the giant snakehead fish, can find refuge elsewhere in the Mekong Delta as their liveable habitats may still be available. Being a Mekong migratory species, however, Siamese mud carp is strongly affected by the compound effect of climate change and Mekong upstream development.

Climate adversities also affect the properties, income, and health of the people that live in LSWR. Most people living in LSWR's buffer zone are poor, with limited capacity. Many of them depend on support from the government and charity organizations to overcome times of difficulties. However, a significant proportion of local villagers also relies on natural resources provided by the wetland for their income and subsistence. Natural wetlands, such as melaleuca forests, tend to be more resilient to climate impacts than man-made systems, such as rice fields. Wetland resources are, therefore, an important source and buffer for people's livelihoods when natural disasters strike. There is a risk, however, when people rely too much on the wetland, stretching its resources, or when they resort to unsustainable livelihood practices to cope with adversities, such as the use of fertilizers and pesticides to stimulate agricultural production.

6.2 Adaptation planning

The following adaptation measures are deemed necessary to sustain the ecological integrity of wetlands in LSWR:

- Develop a water management plan that helps LSWR's species and habitats to adapt to both climate change and Mekong River development; the management plan needs to balance the ecological needs of species and habitats and the requirements of forest fire control (taking into consideration water flows and movement of aquatic organisms in and out of the reserve, as well as the exchange of water and species among management units of the core zone).
- Develop an environmental monitoring system (including air, water, soil and vegetation) that will provide data for the implementation of the water management plan and other ecosystem management activities at LSWR.
- Enhance the capacity of LSWR staff in climate change adaptation management and in wetland protected area management in general.

For livelihood adaptation for communities in the buffer zone, the following issues should be considered:

- There is a need to regulate water sources, monitor quality and treat polluted water; it is necessary to review the dam and dyke system that is affecting the quality of people's lives and livelihoods in the area.
- There is a need to develop small, community-based businesses and other occupations to create more jobs for local people, especially for those who are lacking farm lands; it is necessary to invest and cooperate with enterprises to develop sustainable business with community involvement related to hyacinth exploitation.
- The development of diversified, environmental-friendly farming systems and fair-trade policies of local agricultural products to help improve people's income; this includes resource sharing mechanisms for sustainable resource exploitation in the buffer zone.

Overall, there should be a coordinated unified management of natural resources in the area between the people, the management board of LSWR, and Vinh Loi Melaleuca Forest Enterprise.

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Appendix 1: List of members of the assessment team and experts

Name	Organization	Expertise
Tran Triet (VA team leader)	International Crane Foundation and University of Science – Ho Chi Minh City	Wetland ecology; aquatic plants
Nguyen Thi Kim Dung (VA team)	University of Science – Ho Chi Minh City	Social science
Le Xuan Thuyen (VA team	University of Science – Ho Chi Minh City	Delta morphology, geology
Tran Thi Anh Dao (VA team)	University of Science – Ho Chi Minh City	Zoology (amphibian, reptile)
Truong Anh Tho (VA team)	University of Science – Ho Chi Minh City	Project assistant
Le Bach Mai (VA team)	University of Science – Ho Chi Minh City	Project assistant
Nguyen Hoang Vu (VA team)	University of Science – Ho Chi Minh City	Project assistant
Hoang Duc Huy (expert)	University of Science – Ho Chi Minh City	Zoology (fish)
Nguyen Hoai Bao (expert)	University of Science – Ho Chi Minh City	Zoology (bird)
Vu Long (expert)	University of Science – Ho Chi Minh City	Zoology (mammal)

Appendix 2: List of Lang Sen staff who participated in the assessment study

Name	Organization/administrative unit	Role in project
Trương Thanh Sơn (Director)	Lang Sen Wetland Reserve	Advisor general park management
Võ Tấn Tuấn	Lang Sen Wetland Reserve	Advisor general park management
Nguyễn Công Trai	Lang Sen Wetland Reserve	Advisor general park management
Nguyễn Thị Thê	Lang Sen Wetland Reserve	Field guide
Phạm Văn Cỏ	Lang Sen Wetland Reserve	Field guide
Nguyễn Thị Lệ	Lang Sen Wetland Reserve	Field guide
Phan Thị Thảo	Lang Sen Wetland Reserve	Field guide
Nguyễn Thanh Nhu	Lang Sen Wetland Reserve	Field guide
Nguyễn Văn Đông	Cả Sách Village, Vĩnh Lợi, Tân Hưng	Community liaison