Xi'an Shiyou Daxue Xuebao (Ziran Kexue Ban)/
Journal of Xi'an Shiyou University, Natural Sciences Edition
ISSN: 1673-064X
E-Publication: Online Open Access
Vol: 66 Issue 05 | 2023
DOI 10.17605/OSF.IO/KTDQU

FUNCTIONS AND VALUES OF WETLANDS

PHAN TRUONG KHANH
Faculty of Environment-Technology-Engineering, An Giang University –Vietnam National University-Ho Chi Minh City, Vietnam.

TRAN THI HONG NGOC
Faculty of Environment-Technology-Engineering, An Giang University –Vietnam National University-Ho Chi Minh City, Vietnam.

Abstract

Wetlands are areas of land where the soil is saturated with water for a significant period of time. They can be found in a variety of locations, including near rivers and lakes, along coastlines, and in low-lying areas. Wetlands have many important functions, including: Water storage and filtration, reducing flooding, biodiversity support, store large amounts of carbon, which helps to mitigate the effects of climate change. Wetlands provide opportunities for activities recreation and significant culture for many communities. Overall, wetlands are an important natural resource with many ecological, economic, and cultural benefits. Protecting and preserving these valuable ecosystems is essential for maintaining a healthy planet. This paper will focus on analyzing the value of wetlands in two countries, Vietnam and Sri-Lanka.

Keywords: Freshwater wetlands, Saltmarsh wetlands, Functions of wetland, Vietnam, Sri-Lanka

INTRODUCTION

A wetland is an area of land that is saturated with water either permanently or seasonally. These areas are characterized by unique soils and vegetation that are adapted to wet conditions. Wetlands play a vital role in maintaining the health of our planet by providing important ecosystem services such as water filtration, nutrient cycling, and habitat for a variety of plant and animal species. Wetlands can be found in a variety of landscapes, from coastal marshes to inland swamps, and can be classified into different types based on their physical and biological characteristics. Some common types of wetlands include marshes, swamps, bogs, and fens. Unfortunately, wetlands are one of the most threatened ecosystems on earth due to human activities such as land development, agriculture, and resource extraction. The loss of wetlands has serious consequences for the health of our planet and the species that depend on them. It is important to protect and restore wetlands to ensure their continued existence and the benefits they provide to our environment. This article will provide useful information on wetlands so that readers can gain a deeper understanding of the value of wetlands and see it as a unique resource for their conservation.

Common wetland types

Wetland is a land area that is saturated with water, either permanently or seasonally, so that it bears the characteristics of a distinct ecosystem (Department of Environmental Protection State of Florida Glossary, 2011)*. These* are the areas where water covers the soil, or water is present either at or near the surface of the soil during all year or for varying

Xi'an Shiyou Daxue Xuebao (Ziran Kexue Ban)/
Journal of Xi'an Shiyou University, Natural Sciences Edition
ISSN: 1673-064X
E-Publication: Online Open Access
Vol: 66 Issue 05 | 2023
DOI 10.17605/OSF.IO/KTDQU

periods of time during the year. It could be a place where the land is covered by water, either salt, fresh or somewhere in between. Water saturation (hydrology) largely determines how the soil would develop and the types of plant and animal communities living in and on the soil. Wetlands support both aquatic and terrestrial species. Further, the prolonged presence of water creates conditions that favor the growth of specially adapted plants (hydrophytes) and promote the development of characteristic wetland (hydric) soils (EPA, 2016a).

Wetlands create the link between land and water, and would be some of the most productive ecosystems in the world. Depending on the type of wetland, it may be filled mostly with trees, grasses, shrubs or moss. In order to call a wetland, an area must be filled or soaked with water at least part of the year. However, some wetlands are dry at certain times of the year (Defenders of Wildlife, 2016). Marshes and ponds, edge of a lake or ocean, delta at the mouth of a river, low-lying areas that frequently under flood are considered as wetlands **(World Wildlife Fund, 2016).** Swamp, marsh and bog are common names for different types of wetlands.

Wetland ecosystems typically show three characteristic ecological conditions, all of which are potential stressors for plant survival and growth: (i) periodic to continuous inundation or soil-saturation with fresh or saline water; (ii) soils that are periodically anoxic (hydric soils); and (iii) hydrosoils with rhizospheres experiencing periods of low or no oxygen availability (Craft, 2005). The primary factor that distinguishes wetlands from other land forms or water bodies is the characteristic vegetation of aquatic plants, adapted to the unique hydric soil *(Butler, 2010).*

Wetlands are very diverse ecosystems which provides many benefits the human being which include: coastal zone ecosystems such as coral reef flats, seagrass beds, intertidal mud and sand flats, mangrove forests, estuaries and river mouths; and freshwater habitats such as rapids, marshes, swamp forests, floodplain lakes as well as saline marshes and salt lakes.

There are many different types of wetlands. However, Matthews and Fung (1987) divided wetlands into 5 classes: (i) forested bogs, (ii) non-forested bogs (where bogs are formed by infilling of shallow lakes; usually with no inflow or outflow), (iii) forested swamps, (iv) non-forested swamps (swamps found in poorly drained areas near streams or lakes) and (v) alluvial formations. Bogs and fens are the most common wetlands across large areas of the northern hemisphere (Aselmann and Crutzen, 1989). It is estimated that about half of the world's wetlands are in the boreal region, mostly in the form of bogs (Matthews, 1990). However, according to Aselmann and Crutzen (1989), the most widespread wetland category is bogs, covering 1.9×10^6 km^2, followed by fens and swamps, contributing about 1.5×10^6 km^2 and 1.1×10^6 km^2, respectively. Floodplains add another 0.8×10^6 km^2, whereas marshes and lakes contribute only 7% to the total. Other major types of wetlands of the world fall into the categories of coastal river deltas, inland river deltas, great riverine forests, saltmarshes, northern peatland, inland freshwater marshes and swamps, and constructed wetlands (Mitsch, 1994).

ISSN: 1673-064X
E-Publication: Online Open Access
Vol: 66 Issue 05 | 2023
DOI 10.17605/OSF.IO/KTDQU

Wetlands vary widely because of regional and local differences in soils, topography, climate, hydrology, water chemistry, vegetation and other factors, including human disturbance. Wetlands are found from the tundra to the tropics and on every continent except Antarctica. Two general categories of wetlands are recognized: coastal or tidal wetlands and inland or non-tidal wetlands (EPA, 2016b).

Non-tidal wetlands are the most prevalent type. They are mostly freshwater marshes, although some are brackish or alkaline. They frequently occur along streams in poorly drained depressions and in the shallow water along the boundaries of lakes, ponds and rivers. Water levels in these wetlands generally vary from a few centimeters to about 1 m, and some marshes, like prairie potholes, may periodically dry out completely (EPA, 2016b).

Tidal wetlands can be found along protected coastlines in middle and high latitudes worldwide. These wetlands can be freshwater marshes, brackish (somewhat salty), and saline (salty), but they are all influenced by the motion of ocean tides. Tidal marshes are normally categorized into two distinct zones, the lower or intertidal marsh and the upper or high marsh (EPA, 2016b).

The RAMSAR classification of wetland types is intended as a means for fast identification of the main types of wetlands for the purposes of the convention. According to that the wetlands are classified into three major classes: marine/coastal wetlands; inland wetlands and human-made wetlands (RAMSAR, 2016).

Classification of wetlands has been however, a problematic task, especially with the commonly accepted definition of which constitutes a wetland being among the major difficulties. In the 1970s, the RAMSAR Convention on Wetlands of International Importance introduced the first attempt to establish an internationally acceptable wetland classification scheme (Scott and Jones, 1995). The degradation risk of wetlands is becoming a serious problem in many parts of the world due to rapid increase of population and the resulting pressure on natural resources (Turner, 1991; Koch et al., 2001; Mitsch & Gosselink, 2007). Factors such as loss of wetland area, changes to the water regime, changes in water quality, over-exploitation of wetland products and introduction of alien species have increased and wetland degradation has been therefore amplified (Shine and Klemm, 1999). Destruction and degradation of wetlands can lead to serious consequences such as increase of flooding, extinction of species and declining water quality (Shine & Klemm, 1999; Kotagama & Bambaradeniya 2006).

The RAMSAR convention was established more than 40 years ago to protect wetlands around the world. Today, there are more than 2,000 wetlands, covering 192,712.55 ha, designated as Wetlands of International Importance. This means that the country where the wetland is located is committed itself to protect the pacticular site from development, pollution, and drainage. About 75% of the sites were added to the list since 1999 as a result of WWF’s work (**World Wildlife Fund, 2016). Several terms are used most freqently to describe natural wetland systems. These terms are based primarily on**

ISSN: 1673-064X
E-Publication: Online Open Access
Vol: 66 Issue 05 | 2023
DOI 10.17605/OSF.IO/KTDQU

the salinity of the water which influences the vegetation of the wetland and on the growth form of the resulting vegetation. These wetland classes are broken into two physical categories based on water salinity (Robert, 1996). Freshwater wetlands those that are inundated with fresh water (salinities less than about 1000mg/l); Saltwater wetlands those that are inundated with brackish or saline waters (sanilities greater than 1000mg/l) (Robert, 1996).

Freshwater wetlands

Freshwater wetland ecosystems are affected by permanent or temporary inundation. Such ecosystems play a crucial role in the regulation of water flow and water quality to whole catchments. Further, these are key habitats for certans fauna (including migratory species) and provide refuge for fauna during droughts. However, dominated by shrubs, sedges and herbs, this vegetation classification excludes wetlands that occur in the alpine zone (Alpine bogs and fens), which are dominated by trees (Forested Wetlands) or contain significant quantities of salt (Saline Wetlands) (NSW, 2016). Freshwater wetlands are highly productive environments that support an abundance of micro-invertebrates, crustaceans, fish, frogs and water birds. However, these have been altered dramatically by humans via draining and aeration of fertile soils into productive cropping lands or urban development. Diversion and regulation of water flows for irrigation of inland crops has also had a profound effect. As a result, freshwater wetlands continue to be degraded, reduced in area, while many communities have experienced a change in composition, structure and functioning (NSW, 2016).

Freshwater wetlands in the Mekong Delta, Vietnam cover a large floodplain in the center of the Mekong Delta. Permanent riverine wetlands are major tributaries of the Tien and Hau Rivers, and of other rivers and channels, covering 128,139 ha. Seasonal riverine wetlands have an area of 1,771,381 ha and are mainly rice fields, fruit gardens and other agricultural cultivation areas (Vietnam Environment Protection Agency, 2005).

Wetlands are distributed in lakes of *Melaleuca* forests in the Lower U Minh (Ca Mau Province), lakes of *Melaleuca* forests in the U Minh Thuong (Kien Giang Province) and in Tram Chim National Park (Dong Thap Province). In the past, *Melaleuca* forests covered almost all acid sulphate regions of the Mekong Delta (Vietnam Environment Protection Agency, 2005). However at present only 182,170 ha of *Melaleuca* forests remain, and are distributed mainly in the U Minh peatland area, in the acid sulphate soil area of the Plain of Reeds and in the Ha Tien grassland region (Southern Sub-FIPI, 2004). These are habitats for many freshwater aquatic species and also provide wood, fuel, fish and honey. An outstanding feature is that a peaty soil layer in the U Minh *Melaleuca* forests which plays a very important role in the ecosystem (Vietnam Environment Protection Agency, 2005).

Swamps and marshes in the Mekong Delta are mainly intermittent marshes used for agricultural cultivation. They are distributed in the Plain of Reeds and Long Xuyen Quadrangle. Some typical wetlands in the region are wetland national parks and nature

Xi'an Shiyou Daxue Xuebao (Ziran Kexue Ban)/
Journal of Xi'an Shiyou University, Natural Sciences Edition
ISSN: 1673-064X
E-Publication: Online Open Access
Vol: 66 Issue 05 | 2023
DOI 10.17605/OSF.IO/KTDQU

reserves that have been established by the Prime of Minister of Vietnam. The wetlands of the Mekong Delta were once extensive and varied. However, with the time, much of the Delta has lost its natural habitats, although remnants of the once extensive peat swamp forests, freshwater forests and flooded grasslands are represented in these wetlands. As the last representation of these significant habitats, important distinctive plant communities, threatened bird communities and other significant animals, conservation efforts are highly critical and are an urgent priority (Torell, 2003). There are 10 priority wetland sites are in need of conservation in the Mekong Delta. The seasonally inundated grasslands of Ha Tien Plain, Kien Giang Province, demand the highest priority as their unique biodiversity is being threatened by agricultural intensification. Next is Tram Chim National Park, U Minh Thuong, Dat Mui, Vo Doi, Bai Boi, Lang Sen, Tinh Doi, Lung Ngoc Hoang Nature Reserve (Torell, 2003).

Freshwater wetlands of Sri Lanka that fit into the definition given by the RAMSAR Convention could be divided into two broad categories; inland natural fresh water wetlands (eg. rivers, stream, water falls, marshes, swamp forests, freshwater springs, montane bogs/swamps, and “Villus”) and man-made freshwater wetlands (eg. tanks, reservoirs, rice fields, irrigation canals, aquaculture ponds). As a whole, about 15% of the land area in Sri Lanka consists of both natural and man-made wetlands. About two-thirds of all wetlands in Sri Lanka include man-made wetlands (MOENR, 2002).

Sri Lanka has an extensive network of rivers and streams that drains a total of 103 distinct natural river basins. These flowing water bodies, more than 4,500 km in length, cover an area of 59,245 km^2. Mahaweli, Walawe, Kalu and Kelani rivers originate from the central highlands and flow through all three peneplains. The river basins originating in the wet highlands are perennial while many of those in the dry zone are seasonal. The Mahaweli River (355 km) accounts for the largest basin, covering 16% of the Island and has a high socio-economic and ecological value. The streams and rivers that flow through the high and mid altitude areas of the Island have several water fall habitats (Samarakoon and Renken, 1999).

Although natural lakes are not present in Sri Lanka, there are several flood-plain lakes, commonly referred to as “Villus”, which cover a total area of 40,000 ha which are often cut-off former river bends. Many of the larger villus are located in the Mahaweli flood-plain in the East, and the Kala oya and Modargam Aru flood-plains. A typical example is the inter-connected Handapan and Pendiya villus (796 ha), which together is the largest of the entire Mahaweli villu system (Jayasinghe, 2000; de Silva 1998).

These villus are shallow inland depressions located mainly in rural areas either connected to a river or receiving water through surface run-off river floodwater and ground water seepage. Partially decomposed organic material in such marshes form peat, characterised by water logged sticky soil. A typical example is the Muthurajawela Marsh, which is the largest peat bog in Sri Lanka. The Wilpattu National Park also contains several villu and freshwater marsh ecosystems (Samarakoon and Renken, 1999).

ISSN: 1673-064X
E-Publication: Online Open Access
Vol: 66 Issue 05 | 2023
DOI 10.17605/OSF.IO/KTDQU

The late successional stage of a freshwater marsh ecosystems comprise of trees that are adapted to grow in shallow stagnant water. Swamp forests are seasonally inundated with river water. It is the most rare wetland type in Sri Lanka and a good example is the Walauwa Watta Wathurana Swamp Forest (12 ha) located in the Kalu river basin (Silva 1998; MOENR, 2002).

Although there are no natural lakes in Sri Lanka, an array of ancient irrigation tanks have substituted for the former wetland type. Numbering nearly 12,000, these man-made wetlands depict the rich cultural heritage of Sri Lanka. The major irrigation reservoirs (each more than 200 ha) cover an area of 7,820 ha, while the seasonal/minor irrigation tanks (each less than 200 ha) account for 52,250 ha. These man-made tanks and reservoirs account for approximately 4.6% of the surface land area in the country. Typical ancient irrigation tanks include the Parakrama Samudraya and the Minneriya tank. Apart from the ancient irrigation tanks, several reservoirs have been built over the last four decades mainly for hydropower generation (IUCN, 2004). These include reservoirs in the upper catchment areas including Castlereigh, Norton, Lakshapana, Norton and Mousakelle, while the river Mahaweli has been dammed to create a series of multi-purpose reservoirs, including Kotmale, Victoria, Randenigala and Rantambe (Samarakoon and Renken, 1999; Jayasinghe, 2000).

Rice fields are characterised by the presence of a standing water body, which is temporary and seasonal. Hence, flooded rice fields can be considered as agronomically managed marshes. They are temporary and seasonal aquatic habitats, subject to varying levels of agronomic management. The total area under rice cultivation at present is about 780,000 ha (approximately 12% of the total land area), which is distributed over all the agro-ecological regions except for areas located at very high elevation. Approximately 75% of rice lands in Sri Lanka are located in the inland valley systems of varying form and size while the rest are found in alluvial plains and also on terraced uplands in the interior (MOENR, 2002).

Saltmarsh wetlands

Salt marsh or saltmarsh, also known as a coastal salt marsh or a tidal marsh, is a coastal ecosystem in the upper coastal intertidal zone between land and open salt water or brackish water that is regularly flooded by the tides (Adam, 1990). It is dominated by dense stands of salt-tolerant plants such as herbs, grasses, or low shrubs (Adam, 1990; Woodroffe, 2002). These plants are terrestrial in origin and are essential to the stability of the salt marsh in trapping and binding sediments. Salt marshes play a large role in the aquatic food web and the delivery of nutrients to coastal waters. They also support terrestrial animals and provide coastal protection (Woodroffe, 2002). Mangroves are unique ecosystems occurring along the sheltered inter-tidal coastlines, mudflats, riverbanks in association with the brackish water margin between land and sea (IUCN, 2006). The bio-geographic distribution of mangroves is generally confined to the tropical and sub-tropical regions and the largest percentage of mangroves is found between 5° N and 5° S latitude (Giri et al., 2011).

ISSN: 1673-064X
E-Publication: Online Open Access
Vol: 66 Issue 05 | 2023
DOI 10.17605/OSF.IO/KTDQU

Saline coastal wetlands in Vietnam are distributed along the coastline of the East Sea, southwest of the Ca Mau Peninsula and the Gulf of Thailand. Out of 1,636,069 ha in total, 879,644 ha are permanently flooded wetlands distributed in the sea region at depths less than six meters at low tide, and 756,425 ha are seasonally flooded. The most common wetland types in this area include permanently flooded and non-vegetated saltwater wetlands, seasonal saltwater wetlands for agricultural cultivation, and seasonal saltwater wetlands for aquaculture. Mangrove forests along the coastline play a very important role in the coastal wetland ecosystem. In the past, mangrove cover was extensive along the coast, but mangroves have since been degraded and reduced substantially in terms of both quantity and quality.

Estuarine wetlands are distributed mainly in the mouth of the Mekong River in the provinces Long An, Tien Giang, Ben Tre, Tra Vinh and Soc Trang. They are either seasonal saltwater wetlands for agricultural cultivation or seasonal saltwater wetlands for aquaculture. Saltwater lagoons are distributed in Dong Ho Lagoon (Ha Tien) and Thi Tuong Lagoon (Ca Mau) within the coastal area of the Gulf of Thailand.

According to statistical data provided by the Vietnam Forest Science Institute in 2001, Vietnam had approximately about 155,290 ha of mangrove forest, of which natural mangrove forests cover was 32,402 ha (21 %) and planted mangrove forest cover was 122,892 ha (79%). Mangrove forests play a vital role in coastline protection, mitigation of wave and storm impacts and local climate stabilisation. Mangroves also provide tourism and recreation areas as well as medicine and animal food sources. Mangrove forests have many important functions and values, including: provision of wood, fuel, fish and other resources; provision of breeding, feeding and nursing areas for many species which have economic values; stabilisation of newly formed tidal mudflats; protection of the coastline from impacts of waves, storms and tsunamis; and provision of habitats for many local and migratory wildlife species (bird, mammal, amphibian, reptile). According to Hong (1999), the Red River Estuary has 111 mangrove species which can be used as food and medicinal sources, 13 species provide food source for cattle, and 33 species can play a role in dike protection and mitigation of impacts from waves, wind and soil erosion.

Coral reefs: Coral reefs are among the most unique marine habitats in the country with a great diversity of species, huge volume of primary production and marvelous landscapes. Coral reefs are distributed widely throughout Vietnam, from the north to the south with an area of about 1,112km^2, concentrated mainly in the sea of Southcentral and Southeastern Vietnam.

Seagrass beds: Seagrass beds are ecosystems with high values, providing habitats, breeding and nursery grounds for many species of algae, zoobenthos, and marine fish and mammals. Seagrass as provide food sources for organisms like fish, sea turtles, and dugongs and are also sources of raw materials for the production of paper, chemical fertiliser, food for livestock, and are good sites for tourism. They play important roles in trapping sediments and in protecting against wave and coastal erosion. Out of 16 seagrass species present in entire Southeast Asia, 15 species have been recorded in

ISSN: 1673-064X
E-Publication: Online Open Access
Vol: 66 Issue 05 | 2023
DOI 10.17605/OSF.IO/KTDQU

Vietnam. Seagrass beds are distributed in coastal tidal areas, around islands, estuaries, mangroves, bays, and in brackish swamps with a depth of 0-20 m, within a salinity concentration of 5-32%. In the Tam Giang-Cau Hai lagoon, seagrass beds cover approximately 1,000 ha with 5 species of seagrass present and a total stock of approximately 95,500 tons of fresh seagrass (Nguyen, 2004).

Rivers and Streams: Vietnam has an extensive river and stream system due to a high rainfall regime and unique topographical characteristics, where 75% of the total natural areas are hills and mountains. A typical characteristic of rivers and streams in Vietnam is the diversity of phytoplankton populations although the abundance is low. Rivers and streams are important habitats for fish, for example move between freshwater and saltwater. Fish are important consumers and prey species), 243, 134 and 255 fish species are present in the rivers of northern, central and southern Vietnam respectively (Vietnam Environment Protection Agency, 2005). Algae are the most dominant vegetation in streams, providing an important food source for fish and invertebrates. According to scientists, there are high numbers of endemic species of aquatic fauna and flora of stream ecosystems and many species have yet to be discovered (Vietnam Environment Protection Agency, 2005). However, dam and embankment construction, mineral (sand and gravel) exploitation, waterway development, waste disposal, and other activities have and continue to destroy much of the environment and natural resources of this ecosystem (Vietnam Environment Protection Agency, 2005).

Saltmarsh wetlands in Sri Lanka: These are inter-connected coastal wetland types in Sri Lanka. Estuaries are formed in places where rivers enter the sea. The daily tidal fluctuation and the intermediate salinity between salt and freshwater (commonly termed “brackish water”) are main characteristics of this ecosystem (IUCN, 2004). There are about 45 estuaries in Sri Lanka (Kotagama, 2006) and mangroves comprise very diverse plant communities that are adapted to grow in unstable conditions of estuarine habitats. The mangroves are a rapidly diminishing wetland type in Sri Lanka, consisting of less than 10,000 ha of discontinuously distributed patches along the coastline (Kotagama, 2006). Typical examples of estuaries with mangrove wetlands in Sri Lanka include the Maduganga estuary and the Bentota estuary. Saltmarsh wetlands are salt or brackish water coastal wetlands separated from the sea by a low sand bank with one or more relatively narrow permanent or seasonal outlets to the sea (Kotagama, 2006). These can also harbour other coastal wetland types such as mangroves, mud flats and seagrass beds. Around 42 lagoons are found around the coast in Sri Lanka (Kotagama, 2006). Examples include the Bundala lagoon, Mundel Lake, and Kalametiya lagoon. These are two important sub-tidal marine wetlands (below 6 m in depth) in Sri Lanka.

Coral reefs: Coral reefs consist of calcareous structures secreted by a group of marine invertebrates which are famous for their spectacular beauty and are rich in biological diversity that could be compared to a tropical rainforest. Extensive coral reef habitats occur in the Gulf of Mannar, in the east coast from Trincomalee to Kalmunai, and in

ISSN: 1673-064X
E-Publication: Online Open Access
Vol: 66 Issue 05 | 2023
DOI 10.17605/OSF.IO/KTDQU

several areas of the South and South-western coast (eg. Rumassala and Hikkaduwa) (IUCN, 2003).

Seagrass beds: Seagrass beds are composed of rooted, seed bearing marine plants. These occur in shallow, sheltered marine waters, as well as in lagoons and estuaries. The most extensive sea grass beds occur in the northwest coastal waters of Sri Lanka (eg. Kalpitiya to Mannar) (IUCN, 2003).

FUNCTIONS AND IMPORTANCE OF WETLANDS

Carbon storage

Wetlands play an important role in regulating exchanges of greenhouse gases to and from the atmosphere, including water vapour, carbon dioxide, methane, nitrous oxide and sulfur dioxide. They tend to be sinks for carbon (Figure 1) and nitrogen and sources for methane and sulfur compounds, but situations vary from place to place, time to time and between wetland types (Pritchard, 2012).

All wetlands are capable of sequestering and storing carbon through photosynthesis and accumulation of organic matter in soils, sediments and plant biomass. While recognising the complex processes that occur in wetlands, in general wetland plants grow at a faster rate than they decompose, contributing to a net annual carbon sink (John, 2012). Waterlogging of wetland soils limits oxygen diffusion into sediment profiles creating anaerobic conditions. These conditions also slow decomposition rates, leading to the buildup and storage of large amounts of organic carbon in wetland sediments (John, 2012).

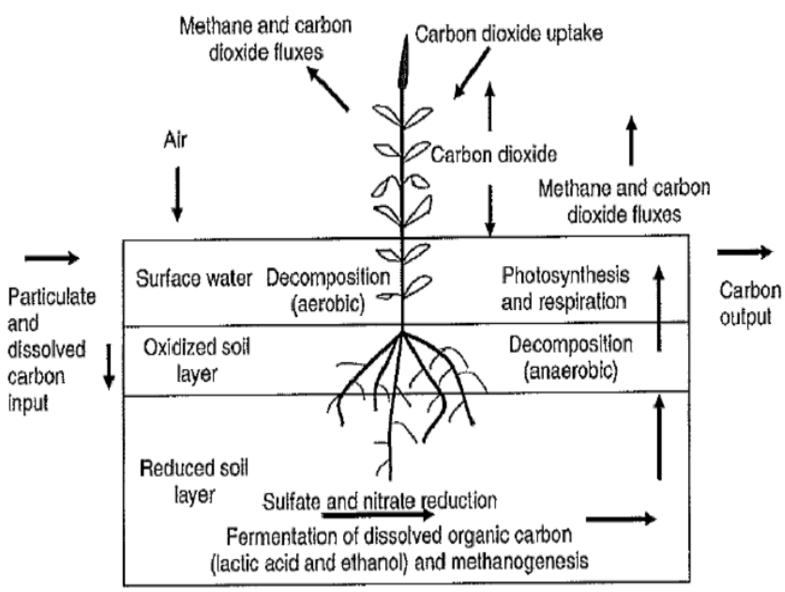

Figure 1: Carbon cycle in wetlands (Source: Kayranli et al., 2012)

ISSN: 1673-064X
E-Publication: Online Open Access
Vol: 66 Issue 05 | 2023
DOI 10.17605/OSF.IO/KTDQU

Wetlands are also involved in horizontal transport of carbon between ecosystems. These vegetations can trap carbon-rich sediments from catchments, but may also disperse carbon through water flow into floodplains. The hydrological connections between watercourses and their associated floodplains are important for the exchange of carbon and nutrients (Thoms, 2003). Wetlands may therefore be either sources or sinks of carbon, depending on their type, and can switch between being sinks of carbon to becoming net sources. This switching can be a natural process due to seasonal or other factors or can be affected by human management. Negative feedback mechanisms due to climate change may undermines the sequestration potential of wetlands, for example, by increasing the incidence and severity of fires and droughts (Dudley et al., 2010).

However, the role of wetlands in the global carbon cycle requires more research, particularly on different wetland types and their function as both sources and sinks of greenhouse gases (CBD, 2007). In 2007 the RAMSAR calculated that there were 1,280 million ha of wetlands (9% of the planet's land surface). According to Nahlik and Fennessy (2016), there is more carbon held in the soils of the earth than that is in the atmosphere, and wetlands hold a hugely disproportionate amount of that carbon (Nahlik, 2016). Despite only occupying 9 % of the earth's land surface, wetlands hold between 20 and 30 % of its estimated global soil carbon. The data collected by Nahlik (2016) show that levels of carbon retention are significantly lower in wetlands with the greatest human activity compared to the sites with lesser amounts of human activity (Nahlik, 2016). Although their study does not determine causality, it illustrates the need to protect wetlands from disturbances in order to avoid releasing carbon into the atmosphere, accelerating climate change (Kenyon, 2017). Coastal blue carbon ecosystems is known as the carbon stored in tidal wetland ecosystems, which includes tidally influenced forests, mangroves, tidal marshes and seagrass meadows are the planet's greatest carbon storehouses. They are capable of capturing and storing excessive atmospheric carbon with burial rates 20 times greater than any other terrestrial ecosystem, including boreal and tropical forests. However, when cleared or degraded, blue carbon ecosystems can transform into worrisome emission sources (Leona, 2017). Currently, global greenhouse gas emissions from unsustainable coastal development amount to one billion per year (Leona, 2017). Given its large carbon stocks, mangroves hold high potential economic value under climate adaptation and mitigation schemes like the Reducing Emissions from Deforestation and Forest Degradation (REDD+) mechanism of the United Nations (Leona, 2017).

Biodiversity and habitat protection

Wetlands can be thought of as biological supermarkets (EPA, 2017), because they provide great volumes of food that attract many animal species. These animals use wetlands for part of or all of their life-cycle. Dead plant leaves and stems break down in the water to form small particles of organic material called detritus. This enriched material

ISSN: 1673-064X
E-Publication: Online Open Access
Vol: 66 Issue 05 | 2023
DOI 10.17605/OSF.IO/KTDQU

feeds many small aquatic insects, shellfish and small fish that are food for larger predatory fish, reptiles, amphibians, birds and mammals (EPA, 2017).

Wetlands are also productive areas for plant life, animals and wetland agriculture. Compared to many other ecosystems, those are one of the most productive habitats in the world, with greater species diversity, nutrient recycling and niche specialisation than most other ecosystems. Therefore wetlands represent a rich and high diverse natural resource. These vegetations are home to many uniquely adapted biodiversity. Of which, the mangrove ecosystem is among wetlands which plays a key role by providing the link between marine and terrestrial ecosystems. This link provides and maintains the stability, not only to the mangrove habitats itself, but also to the other related coastal ecosystems, such as sea grass beds, coral reefs (Cannicci et al., 2008; Nagelkerken et al., 2008; Badola & Hussain, 2005; Kaplan et al., 2009). This ecosystem further plays a significant role in replenishing various fish populations for the coastal and lagoon fish industry. The nutrients given to the lagoon as a detritus from the mangrove ecosystem is carried in to the coastal waters by the tidal currents. They become food for marine micro-organisms, which is the first step of the marine food chain.

The shallow inter-tidal reaches that characterise the mangrove wetlands offer refuge and nursery grounds for juvenile fish, crabs, shrimps, and mollusc. Additionally, manatees, monkeys, fishing cats, monitor lizards, sea turtles, and mud-skipper fish use the mangrove wetlands as their habitat (IUCN, 2006). Plants species growing in mangrove vegetations are also quite abundant. Other than woody species, mangrove trees provide a firm substrate on which other plants can grow (Hogarth, 2007). Climbers include such plants as the vines *Caesalpina* and *Derris* (Leguminosae), lianes, the mangrove rattan palm (*Calamus erinaceus*) of Malaysia, the orchid *Vanda*, and climbing ferns. These are rooted in the soil, usually on the landward fringe, but use mangrove trees as support and may extend their shoots into the more seaward mangrove trees. Some plants are truly epiphytic, and grow entirely on mangrove trees with no direct connection with the soil. These include lichens growing on the bark of trunks and branches, and vascular plants. Among them, there are several species of ferns and orchids (Hogarth, 2007).

Wetlands are the major habitats for most of the world’s waterbirds and a key habitat for migratory species. Most of the world’s waterbirds use wetlands as feeding and breeding grounds. Migratory waterbirds use wetlands throughout their range which can sometimes literally be from pole to pole. The feeding, breeding and stop-over areas across and between continents that migratory birds depend on requires coordinated wetlands conservation efforts among many nations (CBD, 2015).

Populations and species suffer when their habitat becomes degraded or is lost completely. Nonetheless, many issues concerning the response of biodiversity to habitat loss and fragmentation are less clear-cut or they are not widely appreciated. Habitat loss leaves large numbers of species to gradually decline and then to extinct. If there is no proper awaress of this, there is a tendency to underestimate the level of threat to biodiversity (Hanski and Ovaskainen, 2002).

ISSN: 1673-064X
E-Publication: Online Open Access
Vol: 66 Issue 05 | 2023
DOI 10.17605/OSF.IO/KTDQU

More than one-third of the United States' threatened and endangered species live only in wetlands, and nearly half use wetlands at some point in their lives. Many other animals and plants also depend on wetlands for survival. Estuarine and marine fish and shellfish, various birds and certain mammals must have coastal wetlands to survive. Most commercial and game fish breed and raise their young in coastal marshes and estuaries. Menhaden (*Brevoortia tyrannus*), flounder (*Pseudopleuronectes americanus)*, sea trout (*Salmo trutta)*, spot, croaker and striped bass are among the more familiar fish that depend on coastal wetlands. Shrimp, oysters, clams, and blue and Dungeness crabs likewise need these wetlands for food, shelter and breeding grounds (EPA, 2017).

For many animals and plants such as wood ducks, muskrat, cattails and swamp rose, inland wetlands are the only places they can live. Beaver may actually create their own wetlands and for others such as striped bass, peregrine falcon, otter, black bear, raccoon and deer, wetlands provide food, water or shelter. Many of the breeding bird populations in the United States, including ducks, geese, woodpeckers, hawks, wading birds and many song-birds feed, nest and raise their young in wetlands. Migratory waterfowl use coastal and inland wetlands as resting, feeding, breeding or nesting grounds for at least part of the year. Indeed, an international agreement to protect wetlands of international importance was developed because some species of migratory birds are completely dependent on certain wetlands and would become extinct if those wetlands were destroyed (EPA, 2017).

Wood supply

Fuel wood and wooden poles are derived from mangrove forests by some communities only for their subsistence use (IUCN, 2006). However, mangrove wood is used for many purposes. The wood of *Rhizophora mucronata* and *Avicennia marina* are good for firewood. The charcoal of *Rhizophora mucronata* is considered to be of high quality (Pinto, 1996). Mangrove wood contains high percentage of tannins and therefore naturally protects from insects. The wood is used for beams and poles in housing construction. *R. mucronata*, *Bruguiera cylindrica*, *A. marina* are used for building construction (Pinto, 1996).

Non-wood forest products supply

Wetlands yield fuelwood for cooking, thatch for roofing, fibers for textiles and paper making, and timber for building. Medicines are extracted from their bark, leaves, and fruits. They also provide tannins and dyes, used extensively in the treatment of leather (WWF, 2017). Species are commonly exploited and used by local people to treat common diseases such as Spatholobus suberectus, Hydnophytum formicarum, Hyptis capitata, Volkameria inermis, Euphorbia hirta, Lygodium japonicum, Eupatorium odoratum, Calophyllum inophyllum. Particularly, Dischidia major is now being exploited and used as medicine (Dang et al., 2015). Species commonly used by local people as edible plants such as spices, vegetables, edible fruit including: Dioscorea hispida, Peperomia pellucida, Piper lolot, Willughbeia edulis, Aganonerion polymorphum, Stenochlaena

Xi'an Shiyou Daxue Xuebao (Ziran Kexue Ban)/
Journal of Xi'an Shiyou University, Natural Sciences Edition
ISSN: 1673-064X
E-Publication: Online Open Access
Vol: 66 Issue 05 | 2023
DOI 10.17605/OSF.IO/KTDQU

palustris. Especially, Rhodomyrtus tomentosa is the most commonly exploited and used species, the fruits of which are used to produce specialty branded wine of Phu Quoc Island, Kien Giang province, Vietnam (Dang et al., 2015).

Flood control, shoreline and storm protection

The most significant social and economic benefit that wetlands provide is flood control. Peatland and wet grasslands alongside river basins can act like sponges, absorbing rainfall and controlling its flow into streams and rivers (WWF, 2017). When peat becomes completely saturated and unable to absorb any more water, surface pools and peatland vegetation, including sedge meadows and some types of forests help to slow and reduce runoff. Similarly, floodplains alongside the lower reaches of major rivers, such as the Nile, Yangtze and Danube allow heavy rainfall or spring snowmelt to spread out slowly. When the peat bogs are drained or the floodplains reduced, the risk of flash floods is increased (WWF, 2017).

Natural phenomena such as hurricanes, cyclones and Tsunamis cause damages sewer to the human being and intra structure. Worldwide, an estimated 200 million people who live in low-lying coastal regions are at potential risk from catastrophic flooding. Coastal wetlands such as reefs, mangroves and saltmarshes act as frontline defenses against such potential devastation. The roots of wetland plants bind the shoreline together, resisting erosion by wind and waves and providing a physical barrier that slows down storm surges and tidal waves, thereby reducing their height and destructive power (WWF, 2017).

Social benefits

Throughout the history, humans have gathered around wetlands and these areas have played an important part in human development and are of significant religious, historical or archeological value to many cultures around the world. For example, on the Coburg Peninsula (the world's first RAMSAR site), traditional Aboriginal owners still conduct an active ceremonial life and undertake semi-traditional hunting and gathering in this coastal wetland (WWF, 2017). Beyond water availability and quality, wetlands are very much valuable in supporting climate change mitigation and adaption, disaster risk and impact reduction health as well as livelihoods, local development and poverty eradication (CBD, 2015).

Tourism

Wetlands provide important leisure facilities such as canoeing and fishing, shell collecting and bird watching, swimming and snorkeling, hunting and sailing (EPA, 2016). In Trinidad, tourists are attracted by the scarlet ibises (*Eudocinus ruber*) of Caroni Swamp, and in Florida and Honduras by the chance to kayak among the mangroves. The nature reserve of Kuala Selangor, in Malaysia is a good example of well-organised ecotourism. It lies on the estuary of the river Selangor, within easy reach of the capital, Kuala Lumpur (Hogarth, 2007). Sri Lanka has a vast potential resources for the development of tourism which has diverse attraction to appeal the interest of tourists. The country boasts of seven UNESCO

ISSN: 1673-064X
E-Publication: Online Open Access
Vol: 66 Issue 05 | 2023
DOI 10.17605/OSF.IO/KTDQU

World Heritage sites, 13 National Parks, a biodiversity parkand 93 other protected natural areas, addingvalue to an eco-tourism resource based on immense abundance. The coast-based eco-asset tourism of Sri Lanka includes the 24 protected areas bordering the coastal zone (Coastal Zone Management Plan, 2003), associated with coastal habitats such as lagoons/estuaries, mangroves, salt marshes, etc. In addition, its hard coral reefs are rich in biodiversity; nearly 1,000 species of fish and many other invertebrate species offer unique opportunities for the undersea nature lovers. Oceanic waters around Sri Lanka support populations of whales and dolphins, including the blue whale and the sperm whale offering opportunities for establishing whale watching as a commercial tourist (Coastal Zone Management Plan, 2003). Among the natural wetlands in Sri Lanka, Bundala, Anaiwilundawa and Maduganga wetlands have been recognised as having international significance. Similarly man-made wetlands, which are popularly known as tanks, play a vital role in the ecotourism development of the country (Trip2Lanka, 2017). However, the government faces certain challenges to maintain the sustainability in ecotourism with proper management and conservation strategies. Some ecotourism projects have already failed to overcome its efficiency targets due to poor skilful management. For example, The Kirala Kele wetland has failed due to poor implementation and management (Jayathunga, 2009). Poor leadership and lack of vision are also contributing factors. Good leadership is the driving force behind the success of ecotourism project (Sudusingha, 2013).

CONCLUSIONS

Wetlands are important ecosystems that provide numerous ecological, economic, and societal benefits. They serve as habitats for a wide variety of plant and animal species, act as natural water filters, mitigate floods and erosion, and provide opportunities for recreation and tourism. However, wetlands are also threatened by human activities such as urbanization, agriculture, and resource extraction. This has led to significant losses and degradation of wetland habitats in Vietnam and Sli-Lanka, which in turn has had negative impacts on biodiversity and human well-being. Efforts are being made to conserve and restore wetlands through various means, including the implementation of international agreements and policies, such as the Ramsar Convention, and the development of wetland-specific conservation strategies and restoration programs. It is crucial to continue to prioritize the protection and restoration of wetlands to ensure their long-term sustainability and the benefits they provide to both the environment and society.

ISSN: 1673-064X
E-Publication: Online Open Access
Vol: 66 Issue 05 | 2023
DOI 10.17605/OSF.IO/KTDQU

References

1) Aselmann, I. and Crutzen, P.J. (1989). Global Distribution of Natural Freshwater Wetlands Rice Paddies, their Net Primary Productivity, Seasonality and Possible Methane Emissions. Journal of Atmospheric Chemistry, 8: 307-358.

2) *Butler, S. (2010). Macquarie Concise Dictionary (5th ed.). Sydney, Australia: Macquarie Dictionary Publishers Ltd.* ISBN 978-1-876429-85-0*.* Available at: https://en.wikipedia.org/wiki/Wetland.

3) Badola, R. and Hussain, S.A. (2005). Valuing ecosystem functions: an empirical study on the *storm protection function of Bhitarkanika mangrove ecosystem, India. Journal of* Environmental Conservation, 32 (1): 85-92.

4) Craft, 2005. Craft, C.B. (2005). Natural and Constructed Wetlands. In Encyclopedia of Hyrological Sciences, pp.1639-1655 [A Malcom and M Jeffrey, editors]: John Wiley.

5) CBD/Ramsar/STRP. (2007). Water, wetlands, biodiversity and climate change, p. 42.

6) Cannicci, S., D. Burrows, S. Fratini, S.Y. Lee, T.J. Smith III, J. Offenberg & F. Dahdouh-Guebas, 2008. Faunistic impact on vegetation structure and ecosystem function in mangrove forests: a review. *Journal of Aquatic Botany*, 89(2): 186-200.

7) CBD, 2015. The Secretariat of the Convention on Biological Diversity and Ramsa Convention on Wetlands, (2015). Wetlands and Ecosystem Services. Available at: https://www.cbd.int/waters/doc/wwd2015/wwd-2015-press-briefs-en.pdf

8) Coastal Zone Management Plan, (2003). Coast Conservation Department, Sri Lanka, Trans, pp. 24-28. Colombo, Sri Lanka.

9) Department of Environmental Protection State of Florida Glossary. (2011)*. State of Florida*. Retrieved 25 September 2011*.* Available at: https://en.wikipedia.org/wiki/Wetland

10) Dudley, N., Stolton, S., Belokurov, A., Krueger, L., Lopoukhine, N., McaKinnon, K., Sandwith, T. and Kekhran, N. (2010). Natural Solutions: Protected areas helping people cope with climate change, A report funded and commissioned by IUCN-WCPA, TNC, UNDP, WCS, The World Bank and WWF, Gland, Sitzerland, Washington DC, and New York, USA, p.36.

11) Defenders of Wildlife. (2016). Basic Facts about Wetlands. Available at: http://www.defenders.org/wetlands/basic-facts.

12) Dang, V.S., Tran, H., Le Huu Phu, Nguyen Chi Thanh, Nguyen Hong Quan. (2015). Diversity of Non-timber plants in Phu Quoc National Park, Kien Giang, Vietnam. The 6th National Conference on Ecology and Biological Resources. ISBN: 978-604-913-408-1.

13) EPA, (2016). The Importance of Wetland Areas. Available at: http:// www.epa.gov/wetlands/what-wetland.

14) EPA, (2016a)*.* What is a Wetland? Available at: http:// www.epa.gov/wetlands/what-wetland

15) EPA, (2016b). Wetlands Classification and Types. Available at: http://www.epa.gov/wetlands/wetlands-classification-and-types#marshes

16) EPA, 2017. Why are wetlands important? Available at: https://www.epa.gov/wetlands/why-are-wetlands-important.

17) Hogarth, P. (2007). The Biology of Mangroves and Seagrasses*,* Oxford University Press Published in the United States by Oxford University Press Inc., New York.

18) Hanski, I. and Ovaskainen, O. (2002). Extinction debt at extinction threshold. Conservation Biology, 16: 666-673.

ISSN: 1673-064X
E-Publication: Online Open Access
Vol: 66 Issue 05 | 2023
DOI 10.17605/OSF.IO/KTDQU

19) IUCN, (2003). Assessment of the economic value of Muthurajawela wetland. Available at:http://portal.nceas.ucsb.edu/working_group/valuation-of-coastal-habitats/review-of-social-literature-as-of-1-26-07/Emerton%202003.pdf.

20) IUCN Sri Lanka, (2004). Wetland Conservation in Sri Lanka. Proceedings of the National Symposium on Wetland Conservation and Management: Sri Lanka, p.75.

21) IUCN Sri Lanka, Central Environmental Authority, (2006). National Wetland Directory of Sri Lanka. Colombo, Sri Lanka.

22) Jayasinghe, 2000; Jayasinghe, J.M.P.K. (2000). Inland Aquatic Resources. In. Arudpragasam, K. (Ed.). Natural Resources of Sri Lanka. National Science Foundation, Colombo, pp.195-211.

23) John Foster. (2012). the Role of Wetlands in the Carbon Cycle. The Department of Sustainability, Environment, Water, Population and Communities in consultation with the Wetlands and Waterbirds Taskforce.

24) Jayathunga, 2009. Jayathunga, R.D (2009). Investigation of relations between ecotourism and nature conservation in Sri Lanka. University Salzburg, Austria.

25) Koch M., Schmid, T. and Gumuzzio, J. (2001). The study of anthropogenic affected wetlands in semi-arid environments applying airborne Hyper-spectral Data. Teledeteccion, Medio Ambientey Cambio Global, pp.297-301.

26) Kaplan, M., Renaud, F.G. and G. LÃ¼chters. (2009). Vulnerability assessment and protective effects of coastal vegetation during the 2004 Tsunami in Sri Lanka. Natural Hazards and Earth System Sciences, 9: 1479-1494.

27) Kayranli, B., Scholz, M., Mustafa, A. and Hedmark, A. (2012). Carbon storage and fluxes within freshwater wetlands: A critical review Wetlands 30, pp.111-124.

28) Kotagama, S.W. and Bambaradeniya, C.N.B. (2006). An overview of wetlands of Sri Lanka and their conservation significance, National Wetland Directory of Sri Lanka, Colombo, Sri Lanka.

29) Kenyon College, (2017). Wetlands play vital role in carbon storage, study finds. Available at: https://phys.org/news/2017-02-wetlands-vital-role-carbon-storage.html.

30) Leona Liu, (2017). Blue carbon science for sustainable development. Available at: https://forestsnews.cifor.org/48271/blue-carbon-science-for-sustainable development?.

31) Mitsch, W.J. and Gosselink, J.G. (2007). Wetlands. 4th edition. *Journal of Wiley and Sons*, Hoboken, New Jersey, pp.582.

32) Matthews, E. (1990). Global data bases for evaluating trace gas sources and sinks. In Soils and the Greenhouse Effect, pp.311-325.

33) Mitsch, M.J. (1994). Global Wetlands Old World and New. Amsterdam, the Netherlands: Elsevier Science B. V.

34) MOENR, (2002). State of the Environment in Sri Lanka: A National Report prepared for the South Asian Association for Regional Cooperation. Ministry of Environment and Natural Resources, Battaramulla.

35) NSW, (2016). Freshwater wetlands. Available at: www.environment.nsw.gov.au/threatenedSpeciesApp/VegFormation.aspx?

36) Nagelkerken, I.S., Blaber, S., Bouillon, P., Green, M., Haywood, L.G., Kirton, J.O., Meynecke, J., Pawlik, H.M., Penrose, A., Sasekumar, P.J. and Somerfield. (2008). The habitat function of mangroves for terrestrial and marina fauna: a review. *Journal of Aquatic Botany*, 89(2): 155-185.

ISSN: 1673-064X
E-Publication: Online Open Access
Vol: 66 Issue 05 | 2023
DOI 10.17605/OSF.IO/KTDQU

37) Nahlik, A.M and Fennessy, M.S. (2016). Carbon storage in US wetlands, Nature Communications 7. Available at: http://dx.doi.org/10.1038/ncomms13835

38) Pritchard, D. (2012). Reducing Emissions from Deforestation and Forest Degradation in Developing countries, p.7.

39) Pinto, L. (1996). Mangroves of Sri Lanka. Natural resources, Energy and Science authority of Sri Lanka, Colombo.

40) Ramsar, (2016). Ramsar classification system for wetland type. Available at: https://en.wikipedia.org/wiki/Wetland_classification

41) Robert, (1996). Threatment Wetlands. Available at: https://books.google.hu/books?

42) Scott, D.A and Jones, T.A. (1995). Classification and inventory of wetlands: A global overview. Journal of Plant Ecology, 118(1-2): 3-16.

43) Shine, C. and de Klemm, C. (1999). Wetlands, Water and the Law. Using law to advance wetland conservation and wise use. IUCN, Gland, Switzerland, Cambridge, UK and Bonn, Germany, pp.8-20.

44) Southern Sub-FIPI, (2004). Southern Sub-Institute of Forest Inventory and Planning.

45) Samarakoon, J. and Renken, H. (1999). Wetland Atlas of Sri Lanka. Central Environmental Authority/Arcadis Euroconsult.

46) Silva, D.M. and Silva, P.K. (1998). Status, diversity and conservation of the mangrove forests of Sri Lanka. *Journal of South Asian Nation*, 3(1): 79-102.

47) Subasinghe, S.M.C.U.P. (2013). Variation of above ground biomass and total carbon with age for Eucalyptus grandis Hill ex Maiden in Sri Lanka. Research Report, University of Sri Jayewardenepura, Sri Lanka.

48) Turner, K. (1991). Economics and Wetland Management. *Journal of the Human Environment*, 20(2): 59-63.

49) Torell, M. and Salamanca, A.M. (2003). Wetlands management in Vietnam’s Mekong Delta: An overview of the pressures and responses, in: Torell, M., Salamanca, A.M., Ratner, B.D. (Eds.), Wetland management in Vietnam: Issues and Perspectives. The WorldFish Center, pp.1-19.

50) Thoms, M. (2003). Floodplain-river ecosystems: lateral connections and the implications of human interference. *Journal of Geomorphology*, 56: 335-349.

51) Trip2Lanka, 2017. Wetlands and Marshlands in Sri Lanka. Available at: http://trip2lanka.com/2017/05/wetlands-and-marshlands-in-sri-lanka/

52) Vietnam Environment Protection Agency (2005). Overview of Wetlands Status in Vietnam Following 15 Years of Ramsar Convention Implementation, p.72.

53) **World Wildlife Fund, (2016).** Overview of wetlands. Available at: http://www.worldwildlife.org/habitats/wetlands

54) WWF, 2017. The value of wetlands. Available at: http://wwf.panda.org/about_our_earth/about_freshwater/intro/value/.