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Mangrove status, its ecosystem, and climate change in Myanmar: A study in Ayeyarwaddy Delta Coastal Zone

San WIN¹, Sirintornthep TOWPRAYOON^{2,3}, Amnat CHIDTHISONG^{2,3}

¹Environmental Conservation Department, Ministry of Natural Resources and Environmental Conservation, Nay Pyi Taw, Myanmar ² Joint Graduate School of Energy and Environment, King Mongkut's University of Technology Thonburi, 126, Pracha Uthit road, Bang Mod, Bangkok, Thailand ³Center for Energy Technology and Environment, Ministry of Education, Bangkok, Thailand

E-mail: sanwin.ecd@gmail.com

Abstract. Myanmar is a country belonging mangrove and its ecosystem, a unique vegetative species with a high ecosystem services: much higher carbon sequestration than terrestrial forests and climate change induced disaster defence power to community and biodiversity. The degree of its ecosystem services depends on their biological and physical system status. Alternatively, it is one of the most fragile ecosystems and vulnerable to disturbances including climate change. 80 % of the Ayeyarwaddy mangroves was seriously damage by the cyclone Nargis (2008). The study was conducted in Ayeyarwaddy Delta Coastal Zone by adopting transect survey, climate data analysis and reviewing scientific papers and policy documents with two main objectives: understanding climate change, awareness raising on ecosystem and local livelihood status, and enhancing mangrove ecosystem conservation and protection in terms of technology and policy. To recover the mangrove back it took for eight years minimum. Mangrove tree species number is decreasing from 45 to 30 in 37 years. Salinity variation is driving habitat of aquatic fauna species and local livelihoods. Myanmar climate change policy, National Environmental Policy, and Forest Policy become powerful tools to achieve the Nation's sustainable development goal in the context of addressing climate change and the ecosystem protection through institution and technology enhancement. Ecosystem conservation is suggested to minimize not only to minimize climate change impacts but also to improve sustainability of the local community and the ecosystem.

1. Introduction

Myanmar is the biggest countries among South East Asia countries in the context of land mass area. It is well-known for its richness in diverse natural resources and ecosystems through a completeness in topography composing with a long coastline of 2400 - 2832 km, a dry, hot, and flat land, and a surrounded mountainous land. The Myanmar coast provide a habitat for mangrove and its ecosystem, a unique vegetative species with a high ecosystem services: much higher carbon sequestration than terrestrial forests and climate change induced disaster defence power to community and biodiversity. Winarso et al. (2015) reported that mangrove ecosystems are globally playing a key role in supporting and providing a unique adaptive capacity to climate change as well [1]. The ecosystem plays a key role in important economic sectors such as fishery sector, national GDP growth, and community livelihoods,



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finally food security and healthy society. The fishery sector is one that relies on mangroves ecosystems as mangroves are breeding grounds, habitats, and nurseries of various marine species [2,3]. The degree of its ecosystem services depends on their biological and physical system status. Alternatively, it is one of the most fragile ecosystems and vulnerable to disturbances including climate change. The Ayeyarwaddy Region is composed of the biggest and most complex river network of the Ayeyarwaddy River which flows down from Mount Hkakaborazi (at 5881 m the highest peak in Southeast Asia) in northern Myanmar into the Andaman Sea [4]. Forest Department, in Nov 2008, under the Ministry of Natural Resources and Environmental Conservation which was Ministry of Forestry before reported its survey result of 80 % of the Ayeyarwaddy mangroves was seriously damage by the cyclone Nargis in the first week of May 2008. The cyclone killed over 0.138 million people. The research has been conducted with two main objectives: understanding climate change, awareness raising on ecosystem and local livelihood status, and enhancing mangrove ecosystem conservation and protection in terms of technology and policy.

2. Methodology

2.1. Study area

Among three main coastal zones, habitat of mangrove and breeding ground of aquatic animal, in Myanmar: 1) the Ayeyarwaddy Delta Coastal Zone (ADCZ) at the Southern edge of the Ayeyarwaddy, Yangon, and Bago regions facing and bordering the northern Andaman Sea, 2) the Tanintharyi Coastal Zone (TCZ) bordering the eastern edge of the Andaman Sea, and 3) the Rakhine Coastal Zone (RCZ) bordering the eastern edge of the Bay of Bengal at Rakhine State and the Ayeyarwaddy Region, the ADCZ is more well-known for its mangrove area, species diversity of flora and fauna, low elevated topography, fishery and forest products, and high dependency on the mangrove ecosystem. The Myanmar coast is exposed to frequent natural disasters: tropical storms and cyclones during premonsoon (April to May), monsoon (June to September), and post monsoon periods (October to December). The ADCZ was acknowledged as the most vulnerable area to climate change among three coastal zones in terms of natural disasters with references of its losses and damages during Cyclone Nargis in May 2008.

Nineteen transect lines, individual length of 125 - 25 m and 1500 m minimum interval, composed with six square simple plots (individual size of 15 m x 15 m) were allocated in nine study sites (SS) in the mangrove dominant areas: Laputta Township (LPT), home to 0.33 million people; Mawlamyinekyun Township (MLMK), Bogalay Township (BGL16°17'11.16"N, 95°24'6.51"E), home for 0.21 million people; and Phyapon Township in the Ayeyarwaddy Region, Ayeyarwaddy Delta Coastal Zone (Figure 1 (left)). The Ayeyarwaddy Region is composed of the biggest and most complex river network (Figure 1 (right).

2.2. Methods

The study was conducted by applying integrated method of transect survey, climate data analysis and reviewing scientific papers and policy documents. Modified cluster transect survey (MCT) method developed by Win. S et al. (2018) was adopted to identify and measure size of trees species in two main parameters: diameter at breast height (DBH) in centimetre and height in meter [5]. Shrub species and fern species growing in open or among scattered and/or smaller tree species in each sample plot were noted in sketch map but not measured as the study mainly focused on tree species. Each transect line (125 - 250 m) composed with six square sample plots (15 m x 15 m) was developed perpendicularly to the mangrove seaward or riverbank line. 19 transects (125 - 500 m) were developed at minimum intervals of 1500 m in 9 study sites (SS). To understand the mangrove recovery satellite imagery analysis developed by Win et al. (2016) was adopted and reviewed [6]. Win et al., (2016) conducted a satellite imagery analysis by using Landsat 8 images acquired in Feb & Nov, 2008 and Feb, 2016 by generating supervised classification methods to understand the Cyclone Nargis's impacts and recovery of mangrove

within five "Reserved Forest" boundaries: Kadon Kani, Mainmahla in Bogalay and Kyarkankwinpaut, Pyindrel in Laputta.

Time series climate data analysis on a satellite dataset called "Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS), 30+ year Quasi-global rainfall dataset (1981 – 2017)" was conducted by using the Google earth engine (Win et al., 2020) [7]. Surface temperature Data accuracy analysis in Excel sheets and validation of ground truth were conducted. Review and analysis of departmental documents, forest policy, forest law, national environmental policy (NEP), environmental conservation law, Myanmar climate change policy (MCCP), Myanmar climate change strategy (MCCS), and Myanmar climate change master plan (MCCMP) were organized to understand the policy concern and management. A questionnaire survey was also conducted to 299 community households. One informant from each household was interviewed. The questionnaire contains 84 questions, grouped into four groups, and allowed us to examine the local communities' livelihoods, experience and awareness on mangrove ecosystem and climate change impacts, and comments on policy law and regulations.



Figure 1. Study area (left) for Ayeyarwaddy Delta Coastal Zone – ADCZ and AYWD river network (right) in ADCZ.

3. Result and discussion

3.1. Mangrove and its ecosystem

All together 30 tree species including two palm tree species "*Nypa fruitican* and *Phoenix paludosa*" and excluding shrub species were recorded in the study area for ADCZ. Different species composition demonstrated two sub-study areas (SSAs), low salinity area (LSA) such as Bogaly Township (BGL) and high salinity area (HSA) such as Laputta Township (LPT). According to different salinity values, 24 species or 53% of total tree species in LSA and 21 species or 32% in HSA were recorded. Species *Ceriop decandara* demonstrated the highest tree species density of 245 trees/ha followed by *Heritiera fomes* 169 trees/ha and *Exceocaria agalocha* 149 trees/ha in ADCZ (Figure 2). Forest Department (1990) reported 45 mangrove tree species in ADCZ. Declination rate of tree species number -15 in 27 years was observed. It is like to be consequence effects mangroves degradation and deforestation due to climate change impacts and anthropogenic impacts such as various development pressures, including conversion to aquaculture and harvesting daily fuelwood, poles, and posts not only for household use but also for income generation.

Fern species especially *Acorstichum aureum* were observed more abundantly in Bogalay than Laputta but *Acrostichum speciosum* was observed only in Laputta. *Acorstichum aureum* are useful to Estuarine Crocodiles "*Crocodylus porosus*" mainly observed in Mainmahla Island Reserved Forest and Wildlife Sanctuary as their nests for laying eggs during the late rainy season. 15 species belonging to nine families, growing in both low and high saline water quality, could be able to resist and acclimatize to the range of brackish water salinity variation (0.05–28.82) [8].



Figure 2. Tree species density ranking in ADCZ.



Figure 3. Tree species share in high salinity area (Laputta Township – LPT) of $14.4 \pm 3.5-28.9 \pm 3.0$ PSU and low salinity area (Bogalay Township – BGL) of $0.5 \pm 0.5-14.4 \pm 3.5$ PSU.

Climate change and mean sea level rise are driving mangrove species composition, habitat area, and structure [9]. IPCC (2013) reported its predictions of MSLR of 0.8 - 2.0 meter in a century and are likely to threaten the mangrove flora species in low-lying areas and coral reefs in terms of habitat loss and vulnerability to associated storm surge [10]. Mangrove tree species distribution in accordance with topography, water quality, and soil formation is dependent on their adaptive capacities [8].

Amoora cucullata (Meliaceae) is a powerful medicinal plan enabling to cure marrow deficiency, diarrhoea, inflammation, skin diseases and in cardiac disease referring different studies in different

habitats: Myanmar, India, Indonesia, Malaysia, Nepal, Pakistan, Papua New Guinea, Solomon Islands, Thailand, Vietnam, and Bangladesh in South East Asia [11].

3.2. Mangrove change and recovery

Satellite imagery analysis results confirmed with a decrease of the mangrove cover from 98,921.61 ha in Feb 2008 (Figure 4(a)) to 81,065.40 ha in November 2008 or 18.05 % loss (Figure 4(b)) due to the Cyclone Nargis attack. 80 % of the Ayeyarwaddy mangroves was seriously damaged by the cyclone. The decrease and damage demonstrated that low defensive power of the degrading mangrove to against the Cyclone Nargis accompanied by strong wind of 111 - 130 mile/hr, storm surges of 4.2 m height in 2008. Local community confirmed that lives of the people staying in the mangrove forest, especially in the Mainmahla Island in Bogalay during the cyclone were safe. Our analysis confirms mangrove species recovery rate of 2265.6 ha/yr by having 97,491.24 ha in Feb 2016 (7 years and three after Nov 2008) (Figure 4(c)). This increase or gain was likely to happen mainly due to natural recovery process of mangroves and afforestation or plantation establishment by FD and NGOs [6]. Competition between losses and gains of mangroves in the Reserved Forest (RFs) were observed. An increase of deforested area after the cyclone is likely to be happened by conversion to agriculture and aquaculture farm by removing damaged mangrove. Area gain increases of the mangrove are likely to be driven by natural regeneration. Plantation establishments in encroached agriculture farms where farmer landowners died in the cyclone or migrated to other places. During this period, the establishment of 4,393.74 ha of mangrove plantation by Forest Department (FD), which represents a 26.75% mangrove area increase (1,642.84 ha) was observed. In this case, natural mangrove regeneration and recovery area could be more than the FD plantation area. According to a FD's 2016 annual report, 15,732.79 ha out of 21,522.27 ha of mangrove plantations established by FD, NGOs, and community or CF user groups from 1980 to 2015 were lost in the Cyclone in 2008 (Forest Department, 2016).

3.3. Community dependency on mangrove for their livelihoods

Household survey results prove that 20% working in agriculture, 57.6% working fisheries including 21.8% working both agriculture and fisheries, and the rest working other. All respondents confirm with firewood use in daily cooking. In this regard, the community livelihood is likely to highly dependent on mangrove and its ecosystem service and enhancing anthropogenic pressure on mangroves. Many studies such as (Roussy, 2008) (DWIR, 2014) (Directorate of Water Resources and Improvement of River Systems – DWIR) reported coastal community livelihoods are much more dependent on mangrove and terrestrial forest porducts, fishery resource in and around mangroves, mangrove ecosystem services, and mangrove related agriculture for their living [12, 13]. Roussy (2008) reported 40% percent of total population was jobless in general most of them work on forest product extraction, fishing, casual worker in agriculture and aquaculture farms [12].



Figure 4. Mangrove cover analysis in Reserved Forests; (a) LT5TM acquired in Feb 2008 (b) Nov 2008 (c) LC8 in Feb 2016 (d) Mangrove RFs and their compartments boundaries (red).

3.4. Addressing Climate change and ecosystem

3.4.1. Climate change. Time series climate data, 1981 - 2017, analysis result confirmed with rising temperature and rainfall The Myanmar Climate Change Alliance's (MCCA) project created the most extensive coordination structure in developing the climate change policy, strategy and master plan, including a Technical Working Group (TWG). disseminate new climate change projections and address other issues. NOAA (2015) and IPCC (2013) reported about rising temperature according to historical Global temperatures predicted to increase by up to 4.8° C by 2081-2100 relative to 1986-2005 (IPCC, 2013, RCP8.5) [10]. This temperature increase is likely to influence mangrove species composition, phenology, productivity, and ultimately the latitudinal range of their distribution. There are some mangrove species growing under extreme climate with a minimum air temperature of 16° C during the winter season (Saenger, 2002) and low sea surface temperature in North America (SST) and maximum temperature of $28-32^{\circ}$ C (Sobrado & Greaves, 2000)(Ball and Sobrado 2002) [14, 15, 16].

3.4.2. Institution. Ministry of Environmental Conservation and Forestry – MONREC is mainly mandated to play a focal role in mainstreaming environmental conservation and climate change measures into all sectoral short, mid and long-term development plans and policies not only at the national level but also State and Regional level by following the guidance of Myanmar Sustainable Development Plan (2018-2030) (MSDP) (ECD, 2018)[17]. To address environment and climate change issues in Myanmar, Environmental Conservation Department – ECD has been established under the

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MOECAF (now, Ministry of Natural Resources and Environmental Conservation – MONREC) in Oct 2012. ECD becomes the focal department to environment and climate change issues at the international level, including UNFCCC negotiations and reporting.

3.4.3. Abiding international commitment. ECD, focal point to UNFCCC and GEF, and Designated National Authority – DNA, translates global-level decisions for national implementation. This includes endorsing projects for support under different climate change funds — the Least Developed Countries Fund – LDCF, Green Climate Fund – GCF, Global Environment Facility – GEF Trust Fund, Special Climate Change Fund, Adaptation Fund under the Kyoto Protocol and technical support from Climate Technology Centre and Network - CTCN. By following its commitment to UNFCCC, Myanmar submitted its first or Initial National Communication (INC) and National Adaptation Plans of Action -NAPA in 2012, and the second national communication (SNC) is under preparation. ECD is also responsible for engaging other ministries and departments to address climate change, but there are no formal institutional arrangements for such technical coordination. Most of the coordination is through project based institutional structures created to deliver the project outputs. To enhance national institutional capacity, the National Environmental Conservation and Climate Change Central Committee - NECCCCC composed with six technical working committees has been established under the patronage of the Vice President 1. Myanmar ratified the Paris Agreement in 2016 but its Intended Nationally Determined Contributions – INDC in 2015. The INDC includes 1) Mitigation contributions: Forestry and Energy and 2) Adaptation contributions in priority sectors in accordance with its NAPA (ECD & UNEP, 2015)[18]. Myanmar Reforestation and Restoration Programme - MRRP being formulated to meet the forestry contribution target of extension of permanent forest estate to be 40% of national land area (ECD & UNEP, 2015) is likely to strengthen mangrove ecosystem conservation as well. A 10-year plan, allocation of national budget USD 500 million, in the MRRP is to restore nearly 600,000 hectares of degraded forest through natural regeneration and enrichment planting, and to reforest nearly 600,000 hectares of bare land.

3.4.4. Policy. Forestry policy, National Environmental Policy – NEP (2019), Myanmar Climate Change Policy – MCCP (2019) are guiding tools in terms of addressing climate change impacts on both natural and human. MCCP highlights six guiding principles: Sustainable development, Precaution, Prevention, Environment integrity, Shared responsibility and cooperation, and Inclusiveness while MCCMP considers *Sustainable management of natural resources for healthy eco-systems* in six key sectors (MCCA, 2018)[19]. Even though, Myanmar is still facing with the technical, financial, institutional and human resource gaps and barriers. Forest Law recently being amended has expanded the categories of recognised conservation areas to include areas of land under traditional management practices. Meanwhile protecting local people's rights and encouraging local communities to practice registration of large areas of community forests by following the FD's Community Forestry Instructions.

4. Conclusion

To recover the mangrove back it took for eight years minimum. Mangrove tree species number is decreasing from 45 to 30 in 37 years. Salinity variation is driving habitat of aquatic fauna species and local livelihoods. Mangrove recovery rate of 2265.6 ha/yr is calling promotion of intensive conservation and management for putting a healthy mangrove ecosystem back not only in ADCZ but also in Myanmar coast. Mangrove ecosystem conservation and protection through systematic technology and management, staff with high capacity and equipped with smarter facilities, law enforcement, enhancing researches and innovation, broader awareness raising from the community to policy makers are recommended. Species enrichment plans should be in place to put missing and endangered species in the least tree density areas and mangrove degraded areas. Myanmar climate change policy, National Environmental Policy, and Forest Policy become powerful tools to achieve the Nation's sustainable development goal in the context of addressing climate change and the ecosystem protection leading to healthy and low carbon society. Community livelihood is highly depending on mangrove ecosystem

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services. Ecosystem conservation is suggested not only to enhance its resilience to climate change impacts but also to improve sustainability of local community and ecosystem simultaneously to support Paris Agreement's ambitious goal of maintaining global temperature rise to 1.5 $^{\circ}$ C above the pre-industrial levels by 2050.

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