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Mangrove Ecosystem and Its Adaptive Capacity to Climate Change in Myanmar







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Table of Contents

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Abstract

Mangroves are unique forests that consist of halophytic woody plants species adaptable to brackish and saline water and grow well in tropical and subtropical tidal rivers and coastal zones but are widely exposed to climate change. This paper was a part of the Ph. D research carried out in the Ayeyarwaddy Delta Coastal Zone (ADCZ), one of three coastal zones in Myanmar coast, as it was assumed to be the most vulnerable area to climate change impacts. The objectives of this study are: 1) to assess the vulnerability of local community and the mangrove ecosystem in Ayeyarwaddy delta coastal zone (ADCZ) based on three dimensions: Exposure, Sensitivity, and Adaptive capacity and 2) to identify policy recommendations strengthening community and mangrove ecosystem sustainability. Field survey comprised identification and documentation of flora and fauna species and their composition, quantifying the vegetative cover and biomass measurement, sedimentation rate and water quality test while desk work included climate data analysis for 38 years (1981-2018) and satellite imagery were being carried. A modified cluster transects (MCT) survey was developed and applied. Climate data analysis on NOAA and CHIRPS time series satellite data for 38 years from 1981 to 2018 were included. Mangrove cover and land use change analysis, digital elevation data, and sea level data analysis were conducted alongside household surveys and vulnerability score rankings. The average precipitation was 3395.73 ± 371.21 mm, with an increasing of 17.26 mm/yr. The average surface air temperature was rising at the rate of 0.031 ºC/yr. The average water salinity ranged from 0.53 ± 0.25 to 28.82 ± 0.55 PSU. The mean sea level increases at the rate of 3.917 mm/yr. *Aegiceras corniculatum*, *Ceriops decandra* (CD), *Exceocaria agallocha*, *Heritiera fomes*, and *Phoenix paludosa* were not only species that thrive in high salinity environments but also demonstrated the highest adaptive capacity to the widest salinity change range. The wider salinity tolerance of CD proved its least vulnerability to climate change impacts. The vulnerability assessment results demonstrated a high vulnerability of the integrated mangrove ecosystem and coastal community due to medium adaptive capacity. The “3P strategy” formulation in terms of coastal resource law development, amendment of existing laws, budget allocation and technology improvement, enhancing community participation, and promoting flora and fauna species richness is recommended.

Key words: Climate Change, Sea Level Rise, Mangrove Ecosystem, Coastal Community, Vulnerability

မြန်မာနိုင်ငံတွင် ဒီရေတောဂေဟစနစ်နှင့် ၎င်း၏ရာသီဥတုပြောင်းလဲမှုအပေါ် လိုက်လျောညီထွေဖြစ်နိုင်စွမ်း

ဒေါက်တာဆန်းဝင်း၊ ဒုတိယညွှန်ကြားရေးမှူး
ပတ်ဝန်းကျင်ထိန်းသိမ်းရေးဦးစီးဌာန

စာတမ်းအကျဉ်း

ဒီရေရောက်သစ်တောများသည် ဆားငန်ဓါတ်ပါဝင်မှုများသည့်ရေနှင့် ရေချိုရေငန်စပ်ရေများ နှင့် လိုက်လျောညီစွာ ခံနိုင်ရည်ရှိသောသစ်မျိုးများပါဝင်သည့် ထူးခြားသစ်တောများ ဖြစ်ပြီး အပူပိုင်းနှင့် အပူပိုင်းသမဒေသရှိ ဒီရေ အတက်အကျရှိသည့်မြစ်/ချောင်းများ၊ ကမ်းရိုးတန်း ဒေသများတွင် ကောင်းစွာပေါက်ရောက်ထူးခြားသစ်တောမျိုးများ ဖြစ်ပါသည်။ သို့ရာတွင် ရာသီဥတုပြောင်းလဲမှု ဒဏ်ကိုကျယ်ပြန့်စွာ ထိတွေ့ခံစားနေရပါသည်။ ယခုစာတမ်းမှာ မြန်မာ့ကမ်းရိုးတန်းတစ်လျောက်ရှိ ကမ်းရိုးတန်းဇုန်(၃)ခုအနက် ရာသီ ဥတုပြောင်းလဲမှုဒဏ် အများဆုံး ခံစားရသည့် ဧရာဝတီ မြစ်ဝကျွန်းပေါ်ကမ်းရိုးတန်း ဒေသတွင် သုတေသနပြုခဲ့သည့် ပါရဂူဘွဲ့သုတေသနကျမ်း၏ အစိတ် အပိုင်း တစ်ရပ်ဖြစ်ပါသည်။ ရည်ရွယ်ချက်များမှာ ၁) ဧရာဝတီမြစ်ဝ ကျွန်းပေါ်ကမ်းရိုးတန်းရှိ ဒီရေရောက် သစ်တောများ နှင့် ဒေသနေဒေသခံ ပြည်သူ များ၏ ရာသီဥတု ပြောင်းလဲမှုဒဏ် ခံရနိုင်မှု အခြေအနေအား ရှုထောင့် ၃ မျိုး (ထိခိုက်ခံရမှု၊ ထိခိုက်ခံနိုင်မှု၊ လိုက်လျောညီထွေဖြစ်နိုင်စွမ်း) အခြေခံ၍ ဆန်းစစ်ရန် ၂) ဒီရေတောဂေဟစနစ် ရေရှည် တည့်တံ့ရေးနှင့်ဒေသခံပြည်သူများ၏ လူမှုဘဝ မြင့်မားစေ ရေးအတွက် မူဝါဒဆိုင်ရာ သုံးသပ်ချက်များအား ဖေါ်ထုတ်တင်ပြနိုင်ရန် တို့ ဖြစ်ပါသည်။ ကွင်းဆင်းတိုင်းတာမှုများတွင် အပင်နှင့်သတ္တဝါ မျိုးစိတ်များအမျိုးအစား ခွဲခြားခြင်းနှင့် မှတ်တမ်းတင်ခြင်း၊ ၎င်းတို့ ဖွဲ့စည်း တည်ရှိမှု၊ သစ်ပင်ဖုံးလွှမ်းမှုနှင့် ဇီဝဒြပ်ထုများ၊ နုံးပို့ချမှုနှုန်း၊ ရေအရည်အသွေးစမ်းသပ် တိုင်းတာ တွက်ချက်ခြင်း လုပ်ငန်းများပါဝင်သကဲ့သို့ သုတေသန ခန်း အတွင်း ဂြိုဟ်တုဓါတ်ပုံများ ဆန်းစစ် လေ့လာခြင်းနှင့် ၁၉၈၁ မှ ၂၀၁၈ ခုနှစ်အထိ ၃၈ နှစ်ကာလ ရာသီဥတုအချက်အလက်များအား ဆန်းစစ်ခြင်းများ ပါဝင်ပါသည်။ ပြန်လည်မွမ်းမံ ထားသည့် အလွှာခွဲခြားလိုင်း (modified cluster transect (MCT)) စနစ်

တိုင်းတာခြင်း စနစ်အားဖန်တီး၍ အသုံးပြုဆောင်ရွက်ခဲ့ပါသည်။ ဒီရေတော ဖုံးလွှမ်းမှုနှင့် မြေအသုံးချမှု၊ ဒီဂျစ်တယ်နည်းဖြင့် တိုင်းတာထားသည့် မြေအနိမ့် အမြင့် အချက်အလက်များနှင့် ပင်လယ်ရေမျက်နှာပြင်အမြင့် အချက် အလက်များ ဆန်းစစ်ခြင်းများ ဆောင်ရွက်သည့်နည်းတူ အိမ်ထောင်စုအလိုက်လေ့လာ ဆန်းစစ် ခြင်းနှင့်ထိခိုက်ခံရနိုင်မှုအမှတ် ပေးအဆင့်တွက် ချက်ခြင်းများကို လည်းဆောင်ရွက်ခဲ့ပါသည်။ နှစ်စဉ် မိုးရွာသွန်းမှုမှာ တစ်နှစ်လျှင် ၁၇.၂၆ မီလီမီတာနှုန်း တိုးနေပြီး ပျမ်းမျှမိုးရေချိန်မှ ၃၃၉၅.၇၃ ± ၃၇၁.၂၁ မီလီမီတာဖြစ်ကြောင်း၊ အပူချိန်မြင့်မားလာမှု မှာ တစ်နှစ်လျှင် ၀.၃၁ စင်တီဂရိတ်နှုန်း ရှိကြောင်း၊ ပျမ်းမျှ ဆားငန်ရေပါဝင်မှုပမာဏမှာ ၀.၅၃ ± ၀.၂၅ မှ ၂၈.၈၂ ± ၀.၅၅PSU ရှိကြောင်း၊ ပျမ်းမျှ ပင်လယ်ရေ မျက်နှာပြင်မြင့်တက်မှုနှုန်းမှာ တစ်နှစ် လျှင် ၃.၉၁၇ မီလီမီတာရှိကြောင်း၊ *Aegiceras corniculatum*၊ *Ceriops decandra*၊ *Exceocaria agallocha*၊ *Heritiera fomes*၊ *Phoenix paludosa* သစ်မျိုးများမှာ ဆားငန်ရည်ပါဝင်မှုမြင့်မားသည့် ပတ်ဝန်းကျင်တွင် သာမက ဆားငန်ရည်အနိမ့်အမြင့်မြင့်မားမှုပမာဏအများဆုံး ခံနိုင်ရည် အရှိဆုံး သစ်မျိုးများ ဖြစ်ကြောင်း၊ *Ceriops decandra* သည် ရာသီဥတုပြောင်းလဲမှုဒဏ်ကို ခံရနိုင်အနည်းဆုံးသစ်မျိုးဖြစ်ကြောင်း လေ့လာတွေ့ရှိခဲ့ပါသည်။ ဆန်းစစ်ချက်ရလဒ်အရ ဒီရေတော ဂေဟစနစ်နှင့် ကမ်းရိုးတန်းဒေသခံ ပြည်သူများ၏ လိုက်လျောညီထွေဖြစ်နိုင်စွမ်း မှာအသင့်အတင့်သာရှိသဖြင့် ရာသီဥတုပြောင်း လဲမှု ဒဏ်ခံရနိုင်မှုမှာ မြင့်မားကြောင်း သက်သေပြနိုင်ခဲ့ပါသည်။ အပင်နှင့်သတ္တဝါမျိုးစိတ်များ ကွဲယ်ဝမှုတိုးတက်စေရန်၊ ဒေသခံ ပြည်သူများ၏ ပူးပေါင်းဆောင်ရွက်မှုမြှင့်တင်နိုင်ရန်၊ နည်းပညာ တိုးမြင့်ခြင်းနှင့် ရံပုံငွေခွဲဝေချ ထားခြင်း၊ တည်ဆဲဥပဒေများပြင်ဆင်မွမ်းမံခြင်း၊ ကမ်းရိုးတန်း သယံဇာတဥပဒေ ထုတ်ရေးတို့ ပါဝင်သည့် မဟာဗျူဟာ“3P strategy” အား အဆိုပြုတင်ပြအပ်ပါ သည်။

Mangrove Ecosystem and its adaptive capacity to Climate Change in Myanmar

1. Introduction

Mangroves are unique habitats of flora: halophytic woody plants species adaptable to saline and brackish water in salt marsh and fauna: aquatic animal, wild animal, and birds, etc. along tropical and subtropical riverine and coastal zones (Gilman, et al., 2008) which provide a range of ecosystem services, including coastal protection from waves, wind and extreme events such as cyclones and tsunamis. The degree of protection they offer to the coast partly depends on their wood density. Myanmar has been ranked 2nd with CRI score of 14 (S. Kreft, 2014). Geographically, Myanmar is the largest country of mainland in Southeast Asia with varied topographic regions including high hills and rugged mountains, elevated plateaus, highlands, floodplains, coastal plains and deltas.

Coastal ecosystems including mangrove ecosystem and coastal community are more vulnerable than others to climate change and sea level rise due to nature of mangrov's dynamic ecosystems (Field, 1998) and location community area closet to coast. As a result of its enormous services, not only coastal biodiversity but also coastal people in developing countries including Myanmar are dependent on mangrove ecosystems. 25.01 million people or about half of total population is living in 2 states, Rakhine and Mon States and 3 Regions, Ayeyarwaddy, Yangon, and Bago situated along Myanmar coast.

On the other hand, it is one of the most fragile ecosystems and continues to disappear (Gupta & Shaw, 2013) even though still abundant in South and Southeast Asia. FAO (2007) reported world mangrove forest cover, in 124 countries including 25 in Asia, has decreased from 18.8 million hectares in 1980 to 15.2 million hectares in 2005 while Asia mangrove has decreased from 7.8 in 1980 to 5.9 million hectares in 2005 (FAO, 2007). It was reportedly 5029 km^2, 7th largest mangrove area of sharing 3.3 % of global mangrove in 2010, after Malaysia and followed by Bangladesh in the reported World atlas of mangrove prepared by International Society for Mangrove Ecosystem (ISME) (Spalding, et al., 2010).

Mangrove deforestation and its ecosystem deterioration are mainly caused by both anthropogenic and natural actions (Liu, et al., 2014) accounting for 90% of the reported loss (Gupta & Shaw, 2013). Anthropogenic actions include population pressure, livelihoods, overexploitation and development of shrimp ponds, urban area expansion, clear cutting for tourism and agriculture, lack or limited awareness on climate change impacts, mangrove ecosystem conservation, livelihoods system, and improper land use system (Alongi, 2007) (NIVA, 2014).

In the context of natural actions, its ecosystem is vulnerable to sea level rise (Gilman, et al., 2008), storm surge, precipitation changes, atmospheric temperature changes (Liu, et al., 2014), alter sediment budget, higher level of atmospheric CO_2 level (Ellison, 1994), flood (FAO, 2007), coastal water temperature changes, ocean acidification (EPA, 2014), salinity or salt water intrusion (Joye, 2013), etc.

2. Objectives

The objectives of this study are: 1) to assess the vulnerability of local community and the mangrove ecosystem in Ayeyarwaddy delta coastal zone (ADCZ) based on three dimensions: Exposure, Sensitivity, and Adaptive capacity and 2) to identify policy recommendations strengthening community and mangrove ecosystem sustainability.

3. Materials and Methods

3.1. Study area

This paper was a part of research conducted in Myanmar coast line composed with three main coastal zones: 1) the Ayeyarwaddy Delta Coastal Zone (ADCZ) at the Southern edge of land boundary of three Regions, Ayeyarwaddy, Yangon, and Bago facing and bordering the Andaman Sea, 2) the Tanintharyi Coastal Zone (TCZ) at the western edge of land boundary facing and bordering the Andaman Sea, and 3) Rakhine Coastal Zone (RCZ) at the western edge of land boundary of Rakhine State and Ayeyarwaddy facing and bordering the Bay of Bengal in Myanmar. The Myanmar coastal region is exposed to frequent tropical storms and cyclones during pre-monsoon (April to May), monsoon (June to September) and post monsoon (October to December).

Ayeyarwaddy Region is composed of the biggest and complex river network. The Ayeyarwaddy River (Figure 3. 2 and Appendix8. 1) flows down from the Mount Hkakaborazi (at 5881 m the highest peak (Worldatlas, 2017) in Southeast Asia) in northern Myanmar into the Andaman Sea. ADCZ receives fertile sediment deposited from the Ayeyarwaddy River every year. ADCZ especially AYWD is a primary habitat for mangrove species. However, the mangroves suffer from degradation and deforestation due to natural and anthropogenic drivers. The ADCZ was acknowledged as the most vulnerable area to climate change among the three coastal zones in terms of natural disaster with references of its losses and damages during the Cyclone Nargis in May 2008.

The study area covers mangroves in the ADCZ. Plots were selected in the dominant areas: Laputta Township (LPT), home for 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 Ayeyarwaddy Region, Ayeyarwaddy Delta Coastal Zone (Figure 1).

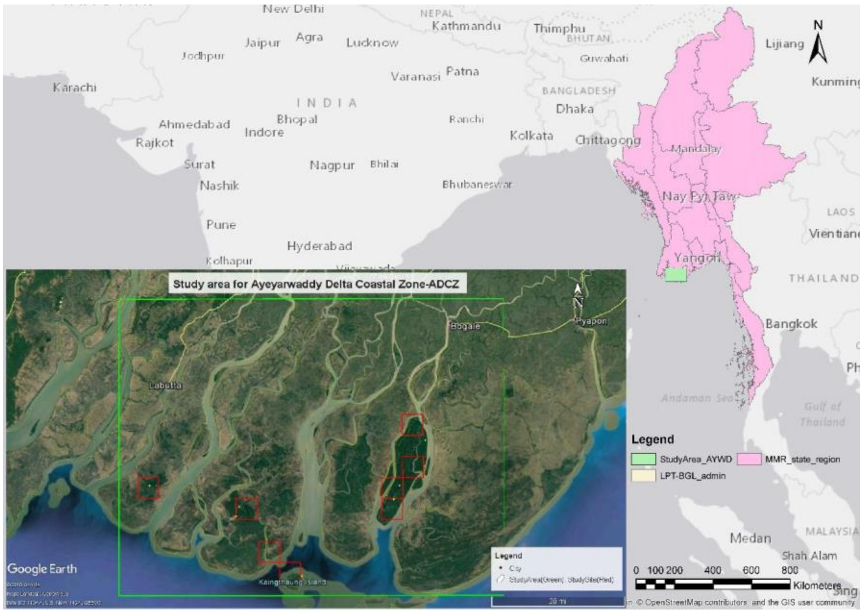

Figure 1: Study area

This paper is mainly intended to assess the adaptative capacity of mangrove ecosystems. The vulnerability assessment is an important step towards preventing ecosystem deterioration and coastal community vulnerability, strengthening conservation and legislation measures, and preparing policy makers to adapt to climate change. The research methods are comprised of two main categories—desk-based research and field-based research. Research works are accompanied by three main dimensions: exposure (E), sensitivity (S), and adaptive capacity or resilience (AC). Ground research work includes household level socioeconomic surveys, semi-structured interviews, modified cluster transect (MCT) surveys on mangrove fauna and flora species, biomass measurements, soil and water quality analysis, ground validation for enhancing accuracy of satellite imagery analysis (Figure 2). A modified cluster transect (MCT) survey was developed and applied. Climate data analysis on NOAA and CHIRPS time series satellite data for 38 years from 1981 to 2018 were included. Mangrove cover and land use change analysis, digital elevation data, and sea level data analysis were conducted alongside household surveys and vulnerability score rankings.

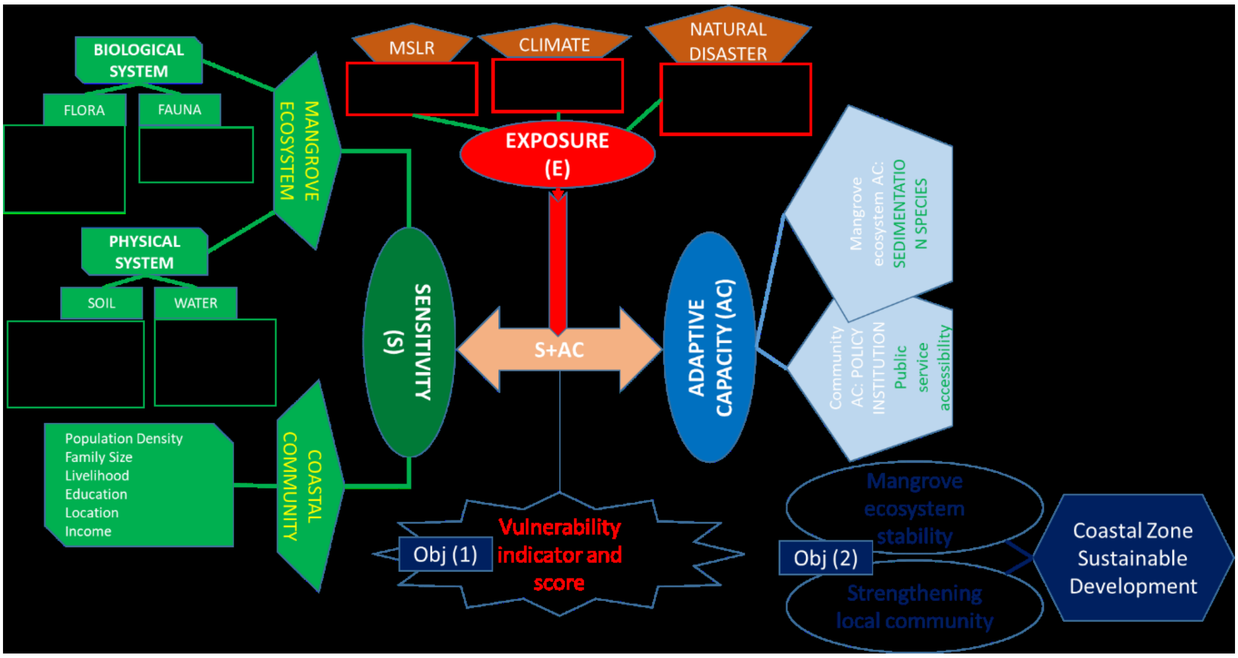

Figure 2: Conceptual framework of methodology applied

3.2. Method

A modified cluster transects (MCT) survey was developed by amending the structure and length of transect applied in different studies and applied. Canopy height (m) and diameter at breast height (DBH) measurement in each sample plot (15 m X 15 m), flora and fauna species identification and enumeration, soil sample collection in sub-sample plot (1 m X 1 m) were conducted (Win, et al., 2019) and (Win, et al., 2019) (Figure 3). MCT survey methods included fauna species identified and enumerated in square subsample plots of 1 m^2 (1 m ×1 m).

Precipitation plays a key role for mangrove ecosystems in terms of water quality changes, especially dilution of salinity in brackish water and relieving saline intrusion in deltas and coastal regions. Modified GEE script, adopting scripts were used in different studies with GEE (Ceccato et al., 2016; Funk, et al., 2015; GEE, 2018), were applied to generate precipitation data (mm/pentad) in the Google Earth Engine (GEE).

Similar to temperature and tide gauge data, the Forest Department (FD) weather station was set up by the Forest Department (FD) and Japan International Cooperation Agency (JICA) in the KDKN. Bogalay provided the precipitation data, but only for 36 months: December 2013 – November 2016. Phyapon station, the nearest weather station to the study area, also did not provide long term data, but was used to calculate annual mean, maximum, and minimum temperature. Additionally, soil surfaces and atmospheric temperature analysis results were conducted by analyzing the radiance value of Landsat8 bend 10 (L8B10) acquired in Feb 2017 (Figure 6). Finally, a satellite dataset called "Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS), 30+ year Quasi-global rainfall dataset", provided us with long term time series precipitation data, from 1981 to 2018, for 38 years.

Hastuti et al., (2012) studied water quality parameter: temperature, salinity, DO, pH by handheld devices on the site study sites and soil quality parameter: organic matter, nutrient, and sedimentation at a laboratory at Semarang and Demak coast. The study emphasized *Avicennia marina* species and observed that growth rate mainly depends on salinity and DO in positive correlation.

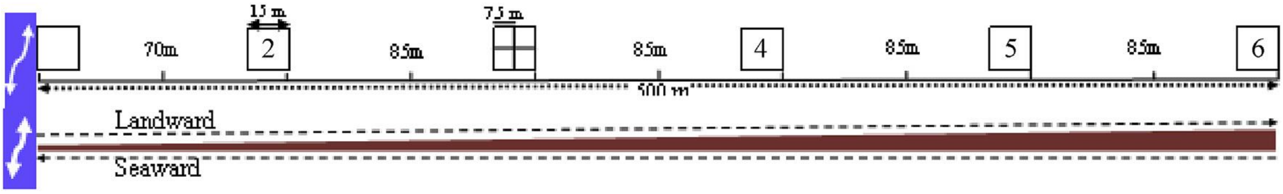

Figure 3: Lay out transect line (500 m) and sampling plots.

4. Results and discussion

The average precipitation was 3395.73 ± 371.21 mm, with an increasing of 17.26 mm/yr (Figure 4). Time series analysis demonstrated the annual temperature is changing in both positively and negatively (Win, et al., 2019). The average surface air temperature was rising at the rate of 0.031 ºC/yr (Figure 5 & 6). This temperature increase is likely to influence mangrove species composition, phenology, productivity, and ultimately the latitudinal range of their distribution. NOAA (2015) and IPCC (2013) reported about rising temperature than falling 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). Krauss et al. (2008) reported that rising temperature influences the ability of mangroves biochemical reactions limit (Ball, 1988) and very low temperature enhance cellular rupture. If temperature exceeds 38 – 40 °C, productivity of mangrove decline (Clough et al., 1982).

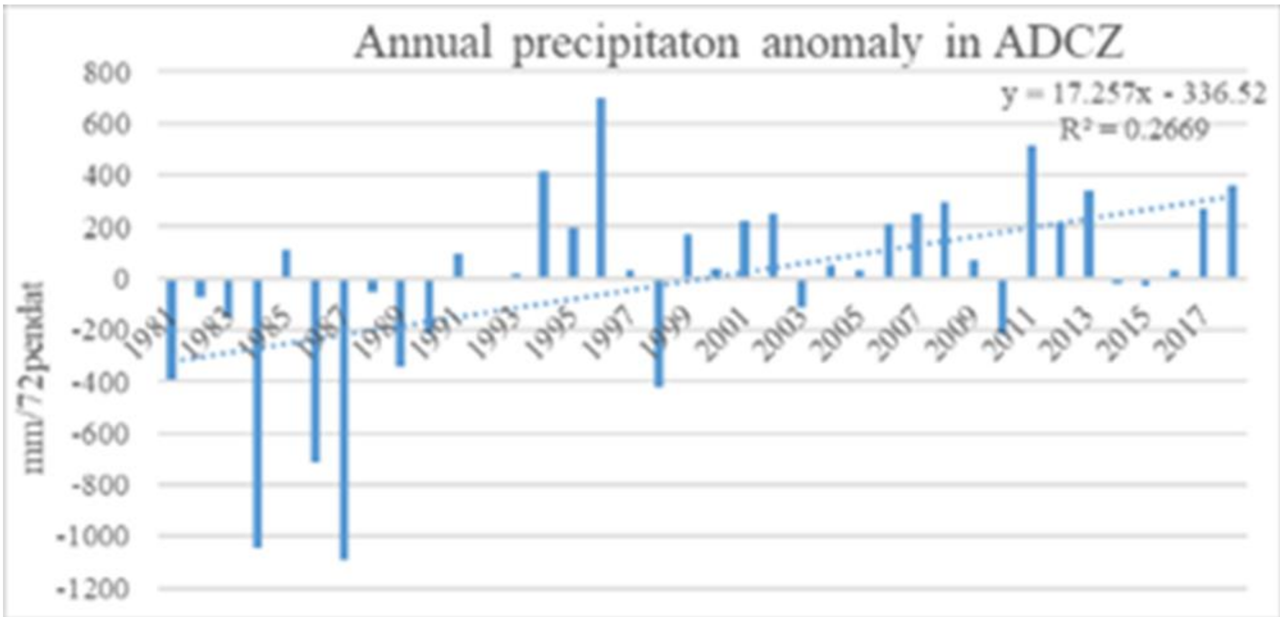

Figure 4: Annual accumulated precipitation

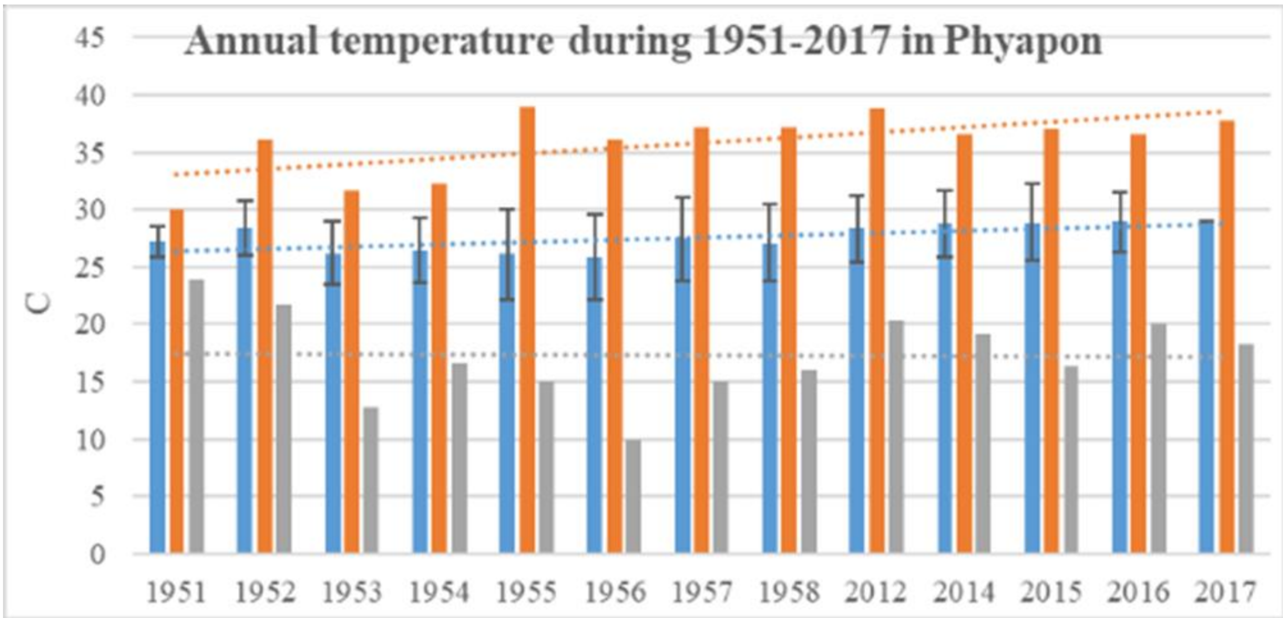

Figure 5: Annual average temperature trend during 1951 - 2017

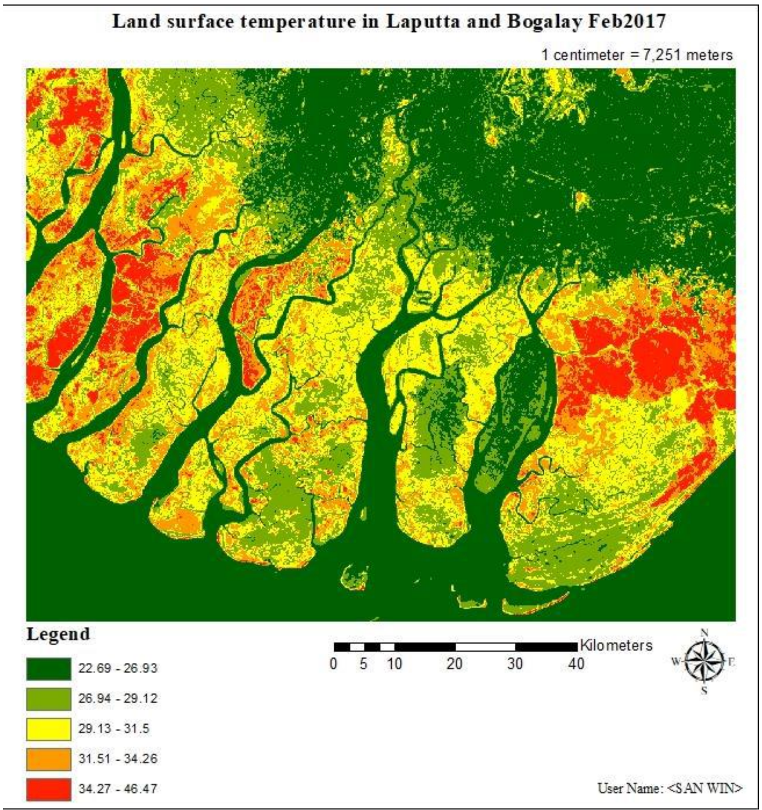

Figure 6: Land surface temperature analysis

The average water salinity ranged from 0.53 ± 0.25 to 28.82 ± 0.55 PSU (Figure 7). The salinity range observed in the study area demonstrated the suitability with the 30 tree species documented in the ADCZ. The mangrove species "*Avicennia marina"* grows well in high salinity environments from 5 to 20 PSU (Pervin et al., 2016; Hastuti et al., 2012).

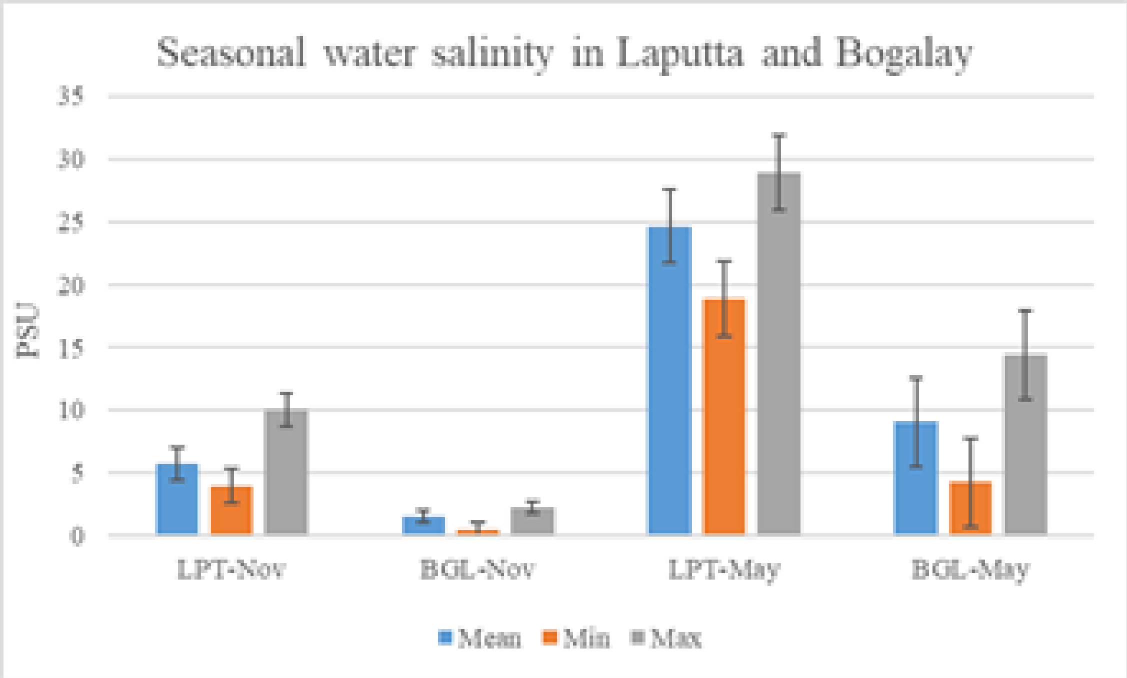

Figure 7: Seasonal water salinity

The mean sea level increases at the rate of 3.917 mm/yr (Figure 8).

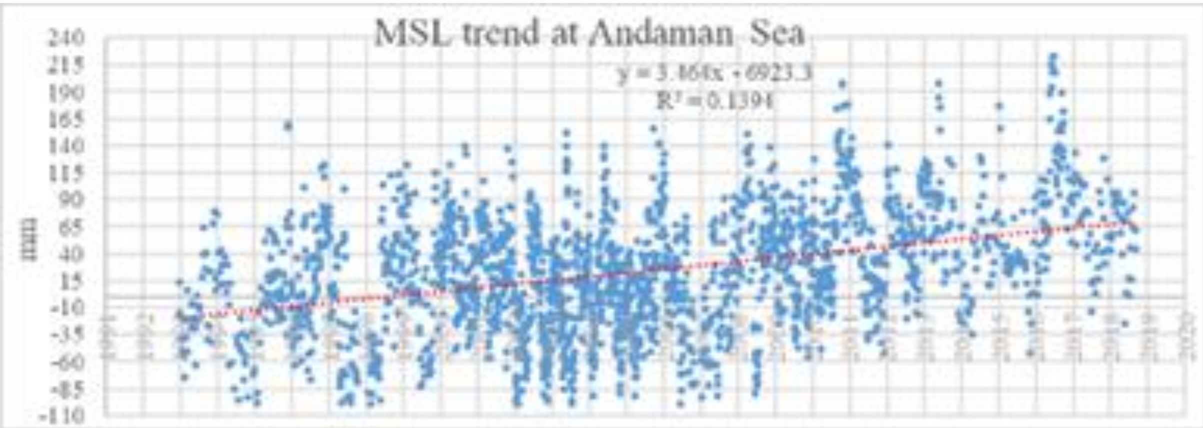

Figure 8: Mean sea level trend

The 30 mangrove tree species including two palm tree species and excluding shrub species were recorded in our study for ADCZ (Figure 9). 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 (Figure 10 and Figure 11). *Aegiceras corniculatum*, *Ceriops decandra* (CD), *Exceocaria agallocha*, *Heritiera fomes*, and *Phoenix paludosa* were not only species that thrive in high salinity environments but also demonstrated the highest adaptive capacity to the widest salinity change range. The wider salinity tolerance of CD proved its least vulnerability to climate change impacts.

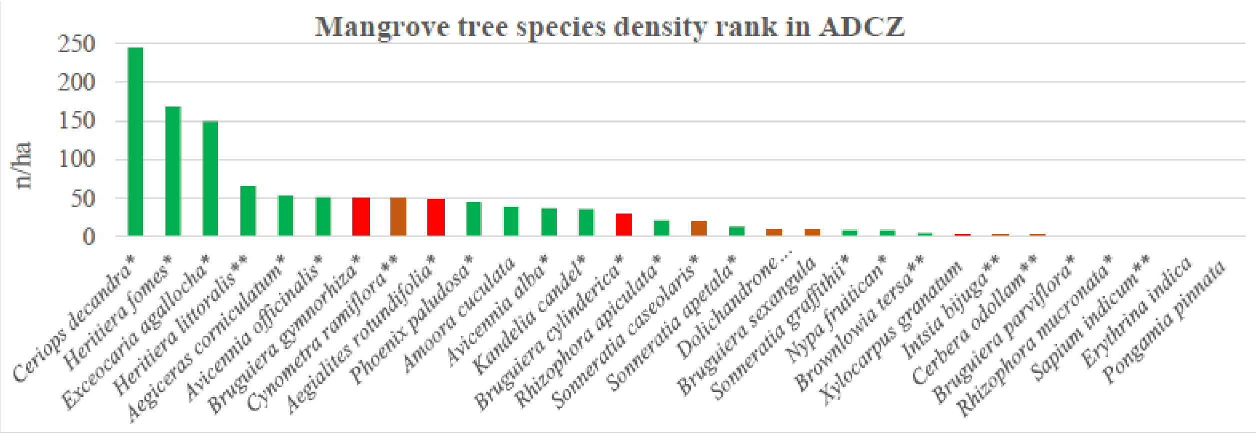

Figure 9: Mangrove tree specie observed by density rank

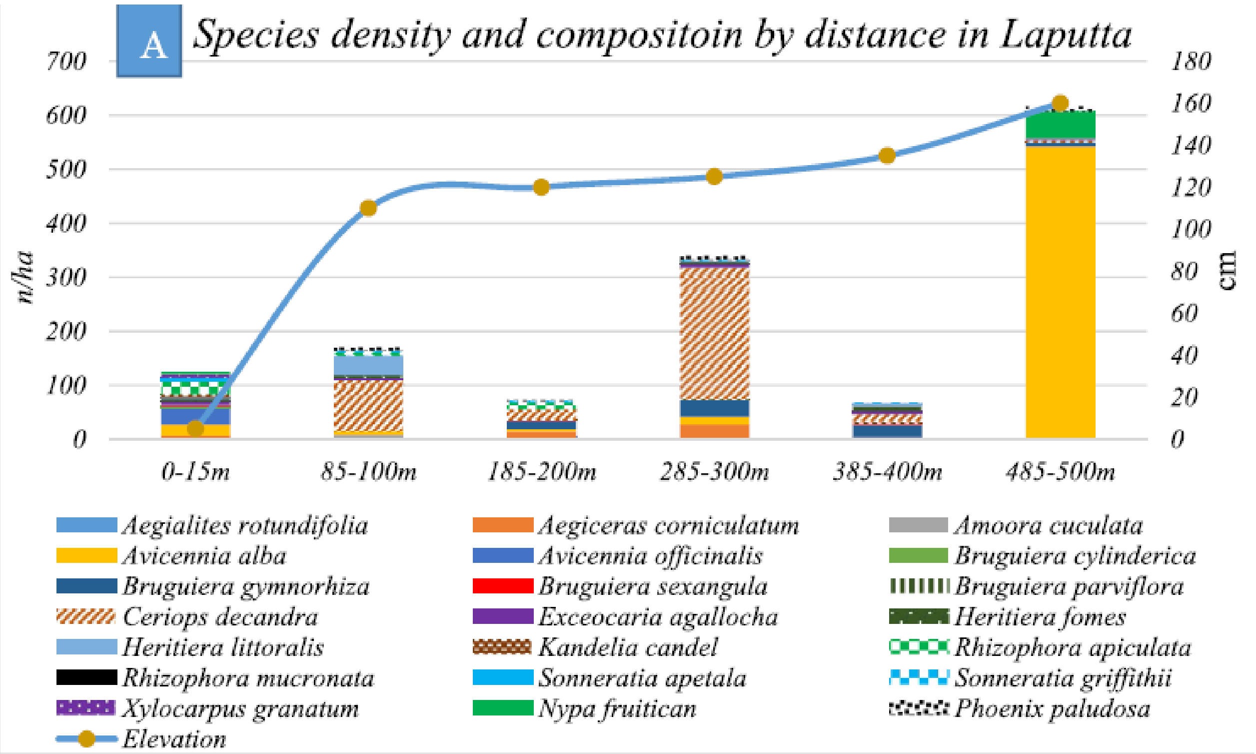

Figure 10: Mangrove species density and composition by distance from seaward edge to landward 500 m in Laputa

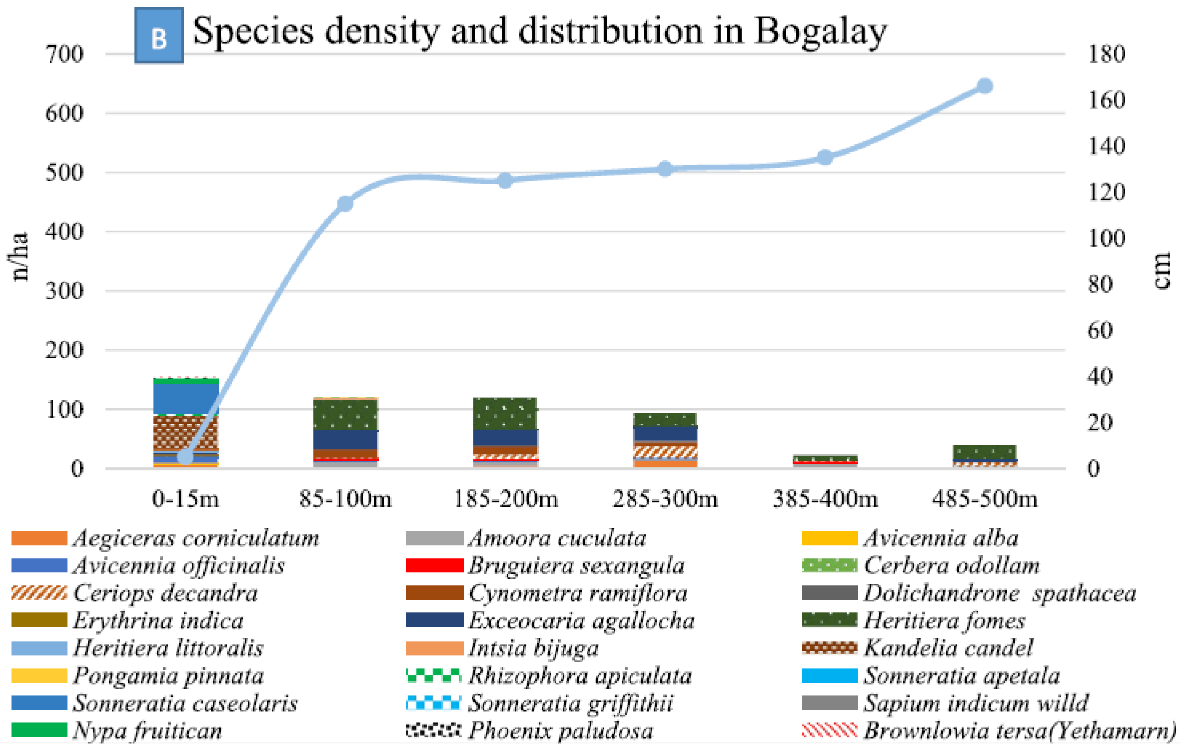

Figure 11: Mangrove species density and composition by distance from seaward edge to landward 500 m in Bogalay

The vulnerability assessment results demonstrated a low adaptive capacity of the integrated mangrove ecosystem and coastal community due to medium adaptive capacity (Figure 12).

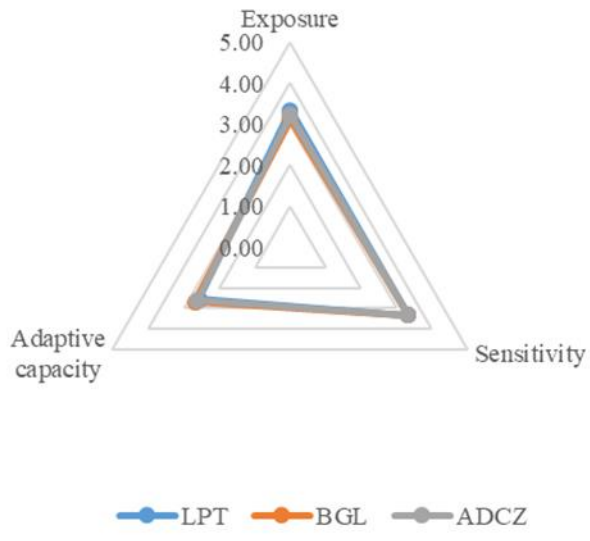

Figure 12: Vulnerability raking

5. Discussion

Accelerated sea level rise and an increase in storm frequency and intensity are two major impacts in coastal ecosystems expected to result from climate change (Ashton, Donnelly, and Evans, 2008; Bender et al., 2010; Harvey and Nicholls, 2008) as cited in (Murdukhayeva, et al., 2013) (Vandenbruwaene, et al., 2011). The climate change impacts may reportedly alter the functions of mangroves such as sediment traps, which promote vertical accretion and seaward progradation to maintain quality of coastal waters, natural breakwaters, natural resource base for silviculture and economic products, habitat for fauna, and nurseries for fish and crustacean species (Ellison, 1994).

6. Conclusion

A high vulnerability of the integrated mangrove ecosystem and coastal community due to medium adaptive capacity was confirmed. The vulnerability of mangrove ecosystems and local communities were expected to have positive correlation. High dependency, such as over extraction of mangrove products for daily income and household use, on mangrove ecosystems are a leading decrease of adaptive capacity (AC) in mangrove ecosystems. The "3P strategy" formulation in terms of coastal resource law development, amendment of existing laws, budget allocation and technology improvement, enhancing community participation, and promoting flora and fauna species richness is recommended. It is critically important to enhance the adaptive capacity of Myanmar mangrove ecosystem for not only to improve the ecosystem quality and expand its spatial extent which enhance greenhouse gas removal and/or sink also to promote the coastal community livelihoods development in a sustainable development manner.

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