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Ecosystem-based Disaster Risk Reduction (Eco-DRR) Assessment Tool for Mangrove Ecosystem Services

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Abstract:- The Ecosystem-based Disaster Risk Reduction (Eco-DRR) Framework focuses on managing, restoring, and conserving the environment for the purpose of integration in the Disaster Risk Reduction (DRR) program. The leaders and managers around the world utilized the intrinsic services provided by the ecosystem as reinforcement to reduce the impact of disaster brought by natural hazards. However, in spite of their significance in superseding disastrous natural events and policies protecting them, anthropogenic activities continually exploit the resources of the environment for development. This turns out that the challenge of this approach in DRR program is the insufficiency of techniques to measure and describe the intervention done by a specific ecosystem to reduce the damage of natural hazards and for humans to realize its importance. In this case, the study formulated an assessment tool to measure the value of one of the most exploited biomes globally, the mangrove ecosystem. The assessment tool concentrated on the DRR services of the studied ecosystem using two (2) types of approaches: a) the Ecological Assessment; and, b) Social (Community) Assessment. These approaches contain different parameters to be used as DRR evaluation instrument and their implementations are guided by the proposed assessment framework for Eco-DRR. This framework serves as a guide in the selection of parameters in the formulation of the Eco-DRR Assessment Tool for Mangrove Ecosystem Services. After the selection of the parameters to be used both for Ecological and Social Assessment, these were grounded in the study site to test their reliability, compatibility, and accuracy before and after data collection. Moreover, the formulated assessment tool was reviewed by the experts working in mangrove ecosystem and related disciplines incorporated in the study. The process and data collection during the pre and post testing were analyzed and discussed to understand their significance in the creation of Eco-DRR assessment tool for the target ecosystem. Finally, the substantial parameters were selected to be included in the final draft of the Eco-DRR tool. The Eco-DRR tool showed promising results after testing it in the selected study site. Each parameter provided data that can reflect the significant role of the mangroves in terms of climate change mitigation, prevention of coastal erosion, tsunami or extreme tidal wave energy reduction, flood or storm surge barrier, and biodiversity protection. These interventions are connected to the different frameworks working in Ecosystem-based Solution similar to the Sendai Framework. The results and analyses of the parameters proved their relevance in managing the impact of natural disasters through their application and relationship to the Sendai Framework. Later in the analysis, the parameters used to evaluate the DRR capacities of mangroves are consolidated to comprise the "Ecosystem-based Disaster Risk Reduction (Eco-DRR) Assessment Tool for Mangrove Ecosystem Services" as fulfilment to the core objective of this study.

Keywords:- *Eco-DRR Framework, mangroves assessment tool, ecological assessment, social assessment.*

I. INTRODUCTION

Ecosystem-based Disaster Risk Reduction (Eco-DRR) is a solution that recognizes the ability of the environment to minimize the adverse impact of natural hazards. This strategy is a part of the Ecosystem-based Solution that deals with the action of reducing the impact of climate change and disasters through the proper management, restoration and conservation of the environment. Various countries initiate Eco-DRR and legal implementations relative to the approach. Researches are being conducted to ensure the effectiveness of every project intended for this strategy. However, challenges in the implementation of environmental protection to support the concept of Eco-DRR are massive instead of declining the degradation. Hence, humanity has to understand their relevance in the ecological balance. Several studies show that many developing countries already have environmental policies, legal frameworks and economic instruments that are considered highly sophisticated by international standards yet still confronted with deterioration of environmental conditions (Huber et al., 1998). The major challenges faced by these countries are not only the lack of a legal and economic environment protection framework, but also the lack of public participation in pro-environmental behavior. People are aware that ecosystems of the environment support the resiliency of all the biotic and a biotic factors from the impact of natural hazards. They understand that these biomes provide numerous ecosystem services that secure lives and properties against natural disasters. Despite this knowledge regarding the importance of the environment in buffering natural hazards, anthropogenic activities continue to degrade the ecosphere for development.

The abovementioned scenario shows that there is a problem in disseminating the effectiveness of the environmental services over natural hazards because of the sustained destructive activities of humans. There is slackness in describing the capacity of nature in buffering natural hazards. There are insufficient written accounts that describe the Eco-DRR value both quantitatively and qualitatively. If these DRR capacities of the different ecosystems are transpired in an apparent manner, beneficiaries like humans will involve themselves in preserving the environment.

Eco-DRR existing frameworks focus on the management, restoration and conservation of the environment. Projects and policies protecting the ecosystems are the priorities of the participating nations (Estrella & Saalismaa, 2013). This is in consideration of the fundamentals of the Ecosystem-based approach on which DRR is a driver that provides good quality healthy environment and appropriate measures to safeguard and rehabilitate the ecosphere (Prieur, 2012). An example of these projects is the Reducing Emissions from Deforestation and Land Degradation (REDD+) mechanism which provides incentives to countries reversing their loss of forest carbon. The participants are paid to follow the REDD+ mechanism in response to the emission reduction of the project (Epple et al., 2011).

The above situation is just one of the copious projects under this kind of Ecosystem-based approach. There are many strategies implemented to meet the concept of an Ecosystem-based approach, particularly for DRR. However, the scheme of implementation focuses only on the fortification of the environment; this only encompasses the idea of restoring and conserving the environment through sound management. Actions undertaken by the manager and other players in discussing environmental issues are the projects that help mitigate the depletion of ecosystems. Limited data show the efficiency of ecosystem services that support the concept of Eco-DRR. Usually, the available data to measure the effectiveness of the ecosystems are acquired through the valuation method which focuses mainly on the monetary value. However, environmental issues differ qualitatively from individualistic consumer choices on commodities creating discrepancies in the results of the approach. In the end, the capacities and features of a certain ecosystem are not specifically discussed by the valuation method. There is a lack of elaboration on how a particular ecosystem works to assist their networks (McCauley, 2006; Vatn, 2005; Sagoff, 1998; Taylor, 1992).

A spectrum of figures to describe the importance of the ecosystem services specifically intended for Disaster Risk Reduction (DRR) must be provided. Consequently, accomplishments in the implementation of Eco-DRR projects recorded for local and international dissemination are general in manner. Often, data being gathered for the reporting are a summary of services provided by a particular ecosystem reinforcing Eco-DRR concept. The discussion of a milestone for the different environmental projects is usually in narrative writing. There's a deficit in translating knowledge and data on Ecosystem-based approaches into measurable run-through. Systematic learning on the impacts and effectiveness of the environment is more easily understood if the variables are more revealing (CBD, 2016). To describe the value of the ecosystems, there should be a systematic accounting method of the different services that they rendered, showing historical trends of Eco-DRR accomplishments. This provides a different method that will serve as a tool for measuring the preventive capacity of ecosystem services in dealing with natural hazards.

The mangrove ecosystem can be used as case scenario to describe the capacities of the environment in reducing the impact of natural hazards. Measuring their Eco-DRR value is beneficial in policy-making and conservation program, and strengthening the Disaster Risk Reduction (DRR) program of a particular coastal community. Eventually, the evaluation scheme of the mangrove ecosystem in terms of Eco-DRR draws out a tool that can be used to create baseline data regarding their abilities to halt coastal natural hazards.

Mangroves are salt-tolerant trees, also called halophytes, and are adapted to live in harsh coastal conditions. They contain a complex salt filtration system and complex root system to cope with saltwater immersion and wave action (Giri et al., 2010). Aside from its capacity to withstand salinity, mangroves have pneumatophores that capture organic materials, roots designed for fish spawning grounds, and intact zonation pattern and numerous species that compliment other biotic factors. Also, this ecosystem buffers hurricanes and tsunamis; harbors masses of floral and faunal biodiversity; provides variety of products in coastal settlements such as food, fuel and building equipment; and provides indirect use value such as water filtration, coastal erosion mitigation and community storm protection (Alongi, 2009). These ecosystems supply trapped nutrients to neighboring habitats in their roots including sea grass and coral reef. As much as 75% of all tropical commercial fish species spend a portion of their life cycle in mangroves. In addition, these shrubs are part of some indigenous culture considering native mangrove extracts for wood, thatch, medications and colors. They are appreciated for ecotourism and as fishing ground for poachers of fish and shellfish. Because of the enormous quantity of carbon sequestration, mangrove forests are significant tropical latitude carbon sinks (Nellemann et al., 2009). They provide the biotic environment within the coastal and intertidal habitat with a broad spectrum of ecological services.

Due to multiple anthropogenic activities, mangrove populations have experienced annual losses worldwide between 0.16 and 0.39 percent over the past two centuries. Extraction, degradation, and failure in the succession process are the critical problems of mangroves (Hamilton & Casey, 2016). Human activities such as wood extraction, aquaculture, housing development, and charcoal production exacerbate the world's mangrove forests without realizing the disadvantages of such actions. Furthermore, natural causes such as temperature, rainfall, typhoons and rising sea level are important variables that threaten the mangrove's biodiversity and ecological equilibrium (Soares, 2009). These scenarios demonstrate how these occurrences decrease the mangrove population and alter their biological process.

In 1920, 400,000 – 500,000 hectares of mangroves covered the Philippines but decreased to 120,000 hectares in

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1994. Over-exploitation by coastal residents, conversion of mangrove areas to agricultural lands, salt lakes, industry and settlements caused this depletion (Garcia et al., 2013). Mangrove evaluation is needed to define species composition of current mangrove structures with an emphasis on species classification for conservation issues. This is important to determine the output of the vegetation stand in order to comprehend the dynamics of organic matter and nutrients cycling in mangroves especially the activity of carbon sequestration. Reliable biomass manufacturing data will serve as an important basis for intervention programs such as initiatives for forest restoration and rehabilitation. In addition, awareness of the structure of species and the variety of current mangrove structures could serve as a basis for the design of an efficient strategy for managing natural resources.

The general objective of the study is to create an Ecosystem-based Disaster Risk Reduction (Eco-DRR) Assessment Tool to measure the Value of Mangrove Ecosystem Services in Reducing Disaster Risk. Specifically, the study aimed:

- to briefly discuss the priorities of the different International Policies and Framework working in the Ecosystem-based Disaster Risk Reduction.
- to apply the selected Ecological and Social Assessment Tools in the studied ecosystem (3) to determine the parallelism of result of the selected Assessment Tools through Mixed Data Analysis.
- to present the final draft of the Ecosystem-based Disaster Risk Reduction (Eco-DRR) Assessment Tool for Mangrove Ecosystem Services.

II. METHODOLOGY

A. Research Setting

This study was done in Sukol River, (121.48935 E,12.74399 N) together with the surrounding communities of barangays Aplaya, sitio K.I. of barangay Poblacion and sitio Asiatic of barangay Ipil, Municipality of Bongabong, Oriental Mindoro. Based on Figure 1, the site is riverine and intertidal in characteristic inhabited by diverse mangrove species. The water river reaches the beach of sitio K.I. and barangay Aplaya, while sitio Asiatic is adjacent to the meander.

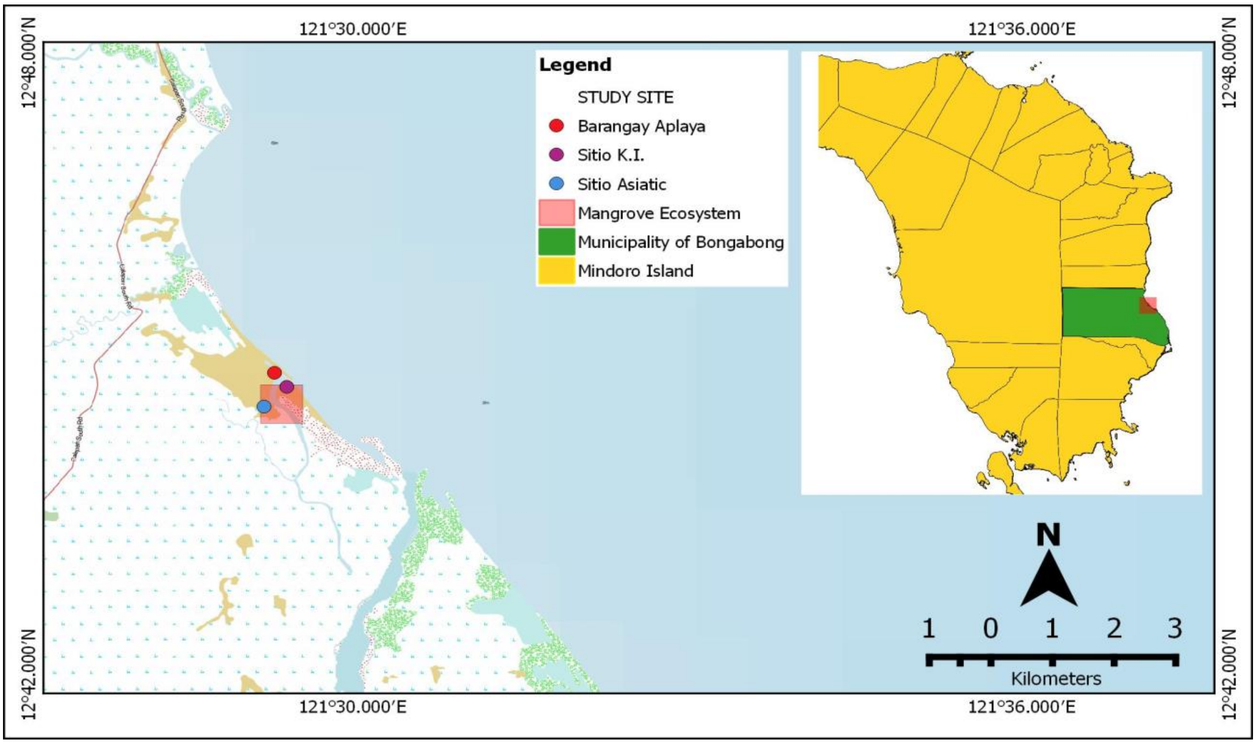

Figure 1. The Map of the Study Area, Municipality of Bongabong, Oriental Mindoro

B. Research Design

The research design of the study was an Outcome-based Research that incorporated Descriptive approach using Ecological Assessment to collect quantitative data and Social Assessment for qualitative data collection. As explained by Shields and Rangarajan (2013), this explores one or more variables using a broad range of quantitative and qualitative analysis. The purpose of using this design was to come up with an output based on the examined group or phenomenon through the validation of the collected data.

C. Research Process

The general research process of the study was to identify the gap in the implementation of the Eco-DRR Framework in dealing natural disasters and discuss the priorities of each International Agreement working in Disaster Risk Reduction (DRR) for the environment. After the identification of the gap and priorities of the DRR policies and frameworks an assessment tool to measure the DRR capacities of the mangroves were selected. The tool was consisting of approaches based on Ecological and Social Assessment Tool. This was done to create an initial list of an assessment tool suited to describe the studied ecosystem in terms of combating natural disasters through quantitative and qualitative data analysis. As the results of the tools have been analyzed, justification of their suitability in the priorities of the different International Agreements mobilizing the Eco-DRR Framework was done. When these assessment tools proved their significance in the objective of the study based on the priorities of the International Policies and Frameworks for Eco-DRR, they served as parameters in showing the effectiveness of the mangrove ecosystem in reducing the impact of natural disasters in the coastal areas. They were deemed included in drafting the assessment tool in measuring the Eco-DRR capacities of the mangrove ecosystem.

D. Research Participants

The respondents of the study based on the assessment were the men and women of the three study sites namely sitio Asiatic and sitio K.I. of barangay Poblacion and barangay Aplaya, who have lived in the communities for at least 15-20 years. In addition, during the implementation of the Social Assessment tool, the researcher included each head of office of the Barangay Government Unit (BGU), Sangguniang Bayan (SB), Municipal Development Office (MPDO), Municipal Disaster Risk Reduction and Management Office (MDRRMO) and Municipal Environment Office (MENRO).

E. Data Gathering Techniques and Analysis

In order to gather relevant data to be used in the analysis of the study, the different approaches in Ecological and Social Assessment research were utilized. In assessing the Eco-DRR capacities of mangroves, the Ecological Assessment was used through allometric data collection, providing numerical results that can be process using numerous equations to obtain the Aboveground and Belowground Biomass for Carbon Sequestration, Carbon Dioxide Equivalent(IPCC, 2014; Kauffman & Donato, 2012; Schöngart et al., 2011) andNet Oxygen Release of this ecosystem(Mitra, 2019). In addition, Inventory of Flora and Fauna, Flood Barrier through Manning's "*n"* Roughness Coefficient, Sediment Accumulation (US Geological Survey, 2012), and Tidal Wave and Tsunami Reduction through Riverine Mangroves (Mazda et al., 1995)were also included in the data collection, administered separately in the study site.

Moreover, in the Social Assessment, the Multi-Criteria Evaluation through Focus Group Discussion was used to measure the opinion and insights of a particular group regarding the Eco-DRR capacities of the mangroves. This approach was used in the study to deliberate information with the involvement of the concerned individuals living near the mangrove ecosystem. The group was composed of 8 to 12 people and led by a moderator in a lightly structured discussion (Krueger & Casey, 2000). On the other hand, for qualitative data collection, a Key Informant Interview was done to collect the ideas regarding the knowledge and experience of the respondents.

F. Mixed Method Analysis

After the separate analysis and discussion of the two data sets, the significance of their relationship was studied through the Convergent Parallel Design as describe in Figure 2, Conceptual Model of the Convergent Parallel Design.

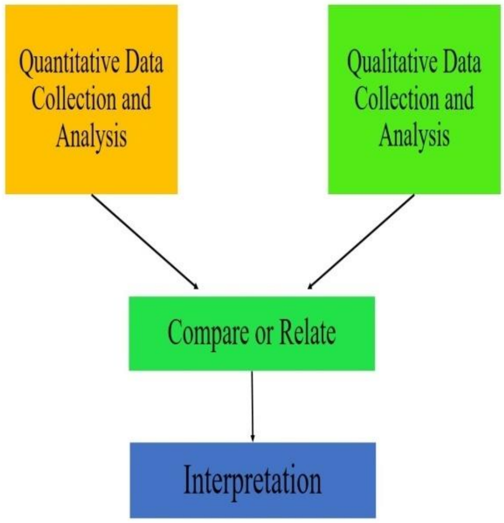

Figure 2. Conceptual Model of the Convergent Parallel Design

A Mixed Data Analysis through Convergent Parallel Design of numerical and non-numerical data was done in the study to validate the results of each major assessment approach of the formulated tool. It is not a part in the formulation of the assessment tool but included in the study to properly interconnect the relationship of the two selected major assessment approaches that composed the Eco-DRR Assessment Tool. This analysis was used to prove that the parameters producing numerical and non-numerical data do not have discrepancies and are well incorporated in times of their application in the mangrove ecosystem and surrounding community.

III. RESULTS AND DISCUSSION

I. Priorities of the Different International Framework and Policies Based on Eco-DRR Framework

The different international framework and policies working on Ecosystem-based Disaster Risk Reduction (Eco-DRR) are the Convention on Biological Diversity (CBD) Strategic Plan for Biodiversity, Sustainable Development Goals (SDGs), Sendai Framework, Paris Agreement, United Nations Framework Convention on Climate Change (UNFCCC) Cancun Adaptation Framework, United Nations Convention to Combat Desertification (UNCCD) Decisions, Ramsar Convention Resolution and Policy Brief. They worked and mobilized themselves in the different level and classification of ecosystems for protection, conservation and restoration projects (Renaud et al., 2016). They have their own operational program that reinforces Disaster Risk Reduction (DRR) and Disaster Risk Reduction and

Management (DRRM) actions through Ecosystem-based approach.

According to the report of IUCN (2014b), the CBD Strategic Plan for Biodiversity focuses its program on restoring the natural habitats. Moreover, conservation of areas utilized for agriculture, aquaculture and forestry are given priority. Policies are implemented for the protection of coral reef and other ecosystems. Based on the report of UN (2015), the Sustainable Development Goals focused on providing resilient communities through the restoration and protection of water-related ecosystems including mountains, forests, wetlands, rivers, aquifers and lakes. This also includes resilient agricultural practices that increase productivity and maintain ecosystem. Furthermore, Sudmeier-Rieux (2013) described that the UNFCCC Cancun Adaptation Framework developed and implemented national adaptation plans as a means of identifying medium and long-term adaptation. In addition, Sendai Framework works in the restoration, conservation and protection of the ecosystems in combating the effects of climate change. Meanwhile, according to the study of Renaud et al. (2016), the Paris Agreement supports the enhancement of the sinks and reservoirs of the greenhouse gases identified during the convention of this agreement. In addition, IUCN (2014a), the UNCCD focuses solely on measuring the progress of the land ecosystem.Based on the report of The Sustainable Development Report (2019), the Ramsar Convention Resolutions incorporate Disaster Risk Management and Climate Change Adaptation into development and planning policies at all levels of government including vulnerability analysis, poverty reduction strategies and natural resource management plans (including land-use and water-use plans) and sectors as well as multi-sectoral policies and plans. On the other hand, Policy Brief is the most typical approach in implementing the DRR programs and provides interest merely in the planning process.

II. *Application of the Selected Ecological and Social Assessment Tool in the Studied Ecosystem*

The Ecological and Social Assessment Tool utilized by the study were consisting of different approaches that measure the DRR capacities of the mangrove ecosystem in Sukol River, Municipality of Bongabong, Oriental Mindoro. The assessment tools were delineated to work on the priorities of the Ecosystem-based Disaster Risk Reduction Framework which mobilized by the different International Disaster Risk Reduction and Climate Change Adaptation Agreement. Such priorities are combating climate change, biodiversity loss, coastal hazards, extreme weather condition, livelihood, food scarcity and human welfare. The assessment tools tend to measure the capacities of the mangroves to mitigate the priorities of the abovementioned agreements. The results and analysis serve as justification of their efficiency as parameters to describe the importance of mangrove ecosystem in the coastal area when dealing natural disasters.

A. *Ecological Assessment*

a) Computation of Aboveground and Belowground Biomass

The total estimated biomass of the study site is 5,905.88Mg·Ha^{-1}.The aboveground and belowground live biomass of mangroves is reliable factors to describe the amount of captured carbon and carbon stock of this ecosystem. The higher amount of computed live biomass of mangroves is an implication of their effectiveness in capturing carbon.

The process of achieving the data for biomass computation was effective due to the appropriate parameters used in the study. Moreover, individual biomass results for each mangrove were also presented for sole analysis of the amount of carbon and other organic materials they can capture. The understanding of the capacities of each mangrove species in terms of biomass stocking is an important parameter for analyzing the possible carbons they can store. The process of biomass accumulations in this ecosystem has implication in projecting measures how much possible greenhouse gas are prevented to reach the atmosphere.

The framework of the UNFCCC which provides the opportunity for mangrove conservation and management to mitigate climate change can be supported by using this assessment tool for biomass computation. The aboveground and belowground biomass computation provide data that can be used in annual monitoring of mangrove carbon stock which is essential in describing the DRR capacities of mangroves as climate regulators.

b) Carbon Stock- Computation of Carbon Sequestration and Carbon Dioxide Equivalent (CO2-eq)

The total estimated carbon stock is 2,775.76 Mg·Ha^{-1} which is equivalent to 10,187.05 Mg·Ha^{-1} of absorbed carbon. Highest biomass and carbon stock were exhibited by large girth trees of *S. alba* (total biomass=5,106.74 Mg·Ha^{-1}; net carbon sequestration = Mg·Ha^{-1}) which absorbed an estimated amount of 8,808.62 Mg·Ha^{-1} carbon dioxide.

The carbon captured from the atmosphere by mangrove trees are built into leaves, trunks, branches and below ground, and aerial roots. As reported by the recent study of Murdiyarso et al. (2015), mangroves can store up to 1083 ± 378 MgC·ha^{-1} which are three- to five-fold greater than terrestrial forests. Unlike other research studies of mangrove monitoring with relation to carbon stock that were just utilized to describe the development of mangroves and growth. This study used the difference in carbon stock (net carbon sequestered) of each mangrove species to infer the amount of possible carbon dioxide they can prevent in reaching the atmosphere.

Considering that climate change bolsters natural hazards such as extreme temperature, rainfall regime getting heavier frequency of strong typhoon and prevalent drought, these issues become the greatest challenge of nations across the entire planet. The collected numerical data that represent the carbon stock of mangroves are used to validate their role in the climate change mitigation. The harnessed data are suitable parameter in discussing policy enhancement, programs and projects for the mangrove ecosystem with relation to climate change mitigation planning and Disaster

Risk Reduction and Management (DRRM) program. Likewise, the concept of integrating the mangrove protection is in line with the UNFCCC policies which implement ecosystem protection to enhance resiliency against climate change.

c) Computation of Net Oxygen Release

The results for the computation of oxygen release, the dominant mangrove species in the study site can release an average of 7,402.04 Mg·Ha^{-1}·year^{-1}. The overall results for the oxygen released were useful to describe the photosynthetic process, benefits for other living things in two ways. First, the process captured the carbon dioxide in the atmosphere which helps to regulate temperature and contribute in capturing greenhouse gases. Secondly, these communities around the world also contribute oxygen for other biotic components. This released gas was needed by humans and others animals for their cellular respiration for them to produce energy.

The amount of oxygen released by the mangroves of Sukol River was produced from the 2,775.76 Mg·Ha^{-1} of carbon sequestered through the process of photosynthesis. This reveals that the tool significantly describes the importance of understanding the mangroves' Net Oxygen Release because they serve as indicator of effective carbon confinement from different sources. On the other hand, the oxygen being released after post photosynthesis provides life support for the humans and wildlife in the form of breathable gas. Definitely, this specific function of the mangrove ecosystems is an additional factor in climate mitigation and DRRM.

d) Inventory of Flora and Fauna

The results of the study show that the densest mangrove associated plant species in Sukol River is the *Nypafruticans*. Similarly, the recorded faunal organism in the study site were birds observed in the site such as the Blacked-nape Oriole (6 individuals within three stations), Philippine Pied Fantail (two individuals within three stations, White-collared Kingfisher (12 individuals within three stations). On the other hand, various species of insects were seen in the area such as bees (with 18 colonies within three stations) and ants (21 colonies within three stations). Spiders from the Class Arachnids were also observed from the study site with 15 individuals within three stations. There were fiddler crabs (1587 individuals within 36 quadrats), snails (1589 individuals within 36 quadrats), Oysters (940 individuals per quadrats) and mudskippers (61 individuals within three stations).

The result of the inventory for these different species of living things is the reflection of a healthy mangrove ecosystem. The assessment approach to account the living organisms in the mangrove ecosystem was usually done to describe their ecological role in the food web. They are usually used as bio-indicators to describe the health of an ecosystem. The Inventory of Flora and Fauna can be used in the DRR concept. This parameter can serve as basis to describe the prevention done by the mangrove ecosystem to halt biodiversity and habitat loss. Based on the report of CBD (2016), the stake of biotic components other than human beings is considered as disaster due to the deprivation of services brought by these organisms in an ecosystem. The Inventory of Flora and Fauna in the mangrove area is a suitable tool to be used in providing figures regarding the capacity of mangroves in protecting and accommodating different species of living things. Thus, the inventory also produced supporting data in measuring the progress of any restoration or conservation activities done in the mangrove community. The species abundance and richness of the residing biotic factors are reflected during the process of accounting since a healthy ecosystem is an efficient habitat of different living things. The great numbers of biotic components tribe in a specific ecosystem are an indicator of a healthy and resilient environment.

The importance of using inventory approach in assessing the content of wildlife and plants within the mangrove ecosystem is very practical. This simply discusses the efficiency of mangrove ecosystem in supplying the needs of the fringing flora and fauna. The mangroves serve as a support system that remarkably reinforces the conservation and protection of other biotic components associated to them. On the other hand, the collected data from the inventory help policymakers to come up with a novel approach in protecting this ecosystem. The status of abundance and richness of flora and fauna in the mangrove area serves as basis to enhance policies reinforcing this ecosystem.

e) Utilization of Manning's "n" Roughness Coefficient

The "*n*" value of the different channel conditions based on the collected data are: bed material (0.26), irregularities (0.010), sectional variations (0), obstruction (0.004), vegetation (1.00) and meander (1). Based on the results of the study, the Sukol River mangroves of the Municipality of Bongabong, Oriental Mindoro have the capacity to reduce the velocity of river water to 0.57 m/s as they passed through the river channel. The outcome was in consideration to the data collected during the actual test which may vary according to a day-to-day basis condition of the water that pass through the channel especially during typhoon. Noticeably, the "*n*" value for vegetation characteristics reached the maximum value adjustment giving the most significant figure among the other channel characteristics. The vegetation of the Sukol River which are mostly dominated by different riverine mangrove species were deliberative and precise for the designated "*n*" value.

The Manning's "*n*" Roughness Coefficient was usually used in engineering specifically in developing irrigation system in closed or open channel. However, the study utilized the technique to describe the mangroves' ability to act as barrier against flood or surge. Thus, the data collected were based on the normal flow of water during the transition of high tide to low tide instead of the actual flooding situation. This is due to the risk and chance of flooding in the study site especially during typhoon. Nevertheless, the data collected through the approach can be used as baseline data for estimates and comparison regarding the ability of mangroves to buffer the impact of flood water. The Ramsar Convention Resolutions discusses the integration of the wetlands, river and coastal ecosystem in DRRM. The

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abovementioned tool is necessary to provide numerical data to disseminate the effectiveness of the mangrove ecosystem against flooding or surge. This information is useful in putting up hybrid engineering structures to support DRRM programs in mitigating the impact of natural hazards, collaborating with the mangrove ecosystem to reduce the impact of running water which are effective based on the results.

f) Tidal Wave and Tsunami Reduction through Riverine Mangrove Ecosystem

The density of Sukolriver mangroves has the capacity to reduce the wave height of a tsunami or tidal water with 5 meters high into 40% of their original height. This was a clear implication of the shielding done by the mangroves in the riverine system or even in the intertidal zone. When the wave height is reduced, the energy along the tsunami also decreases, causing less damage in the inland environment.

The assessment tool in computing the energy reduction capacity of mangroves is simple but considerably suiting in terms of descriptive presentation. The parameter's necessary data to generate results are available through online application or anecdotal records from the residents living near the coastal zone of the study site. The results from the simulation of the reduced tidal wave or tsunami impact can be used for comparison of past events. This assessment is useful for Ramsar Convention Resolutions and other related frameworks that support the Eco-DRR program. This is in terms of improving the policies that protect the coastal ecosystems. The numerical data acquired from the tool can be useful during planning, discussion and forums regarding the importance of the mangrove ecosystems in the coastal zone which is not really given importance in the DRRM programs.

g) Use of Sediment Pin to Monitor Sediment Accumulation

In more than a month (December 2019- February 2020) through the utilization of sediment pins, the first station accumulated an average height of 3.125 cm sediment, station 2 gain 2.75 cm and station 3 sediment pins trapped 3 cm. The results of sediment capture justify the effectiveness of the mangroves in the study site to prevent coastal erosion. On the other hand, a historical image of map from Google Earth Pro showing the timeline of sediment build-up along the riverine system of Sukol compliment the possible impact of the mangroves in mitigating the retreating shoreline. The results regarding sediment capture through estimates using pins have a significant relationship along the beach of Barangay Aplaya and sitio K.I., Poblacion.

In terms of sediment deposition, the baseline map of sediment deposit occurrence along the beach of Barangay Aplaya and sitio K.I. Poblacion Shoreline dated November 30, 2010, delineated by a red quadrant, reveals no sediment accumulation in the estuarine along the beach of Barangay Aplaya and sitio K.I., Poblacion (see Figure 3). Then, on December 11, 2014, sedimentary materials started to accumulate in the shoreline of the studied areas. This was prior to the observation during year 2010 where the same area has no sediment deposits. On December 22, 2018, a continuous massive accumulation of sediments was observed in the shoreline of Barangay Aplaya and sitio K.I., Poblacion

The stable condition of the beach along Aplaya and sitio K.I., Poblacionwas shown in map image of the beach dated February 4, 2020, due to the regulated distribution of sediment materials trapped in the mangroves of Sukolriver. They made the substrate materials firm as tides shift and flood passes through the channel.

This event complements the shoreline through the prevention of coastal erosion. The sediment pins make available of a parameter that can present the effectiveness of the mangrove's roots and branches in reinforcing accretion along the beach ecosystem. The approach was practically used for beach monitoring in order to record timeline data regarding the condition of the substrate in the shoreline.

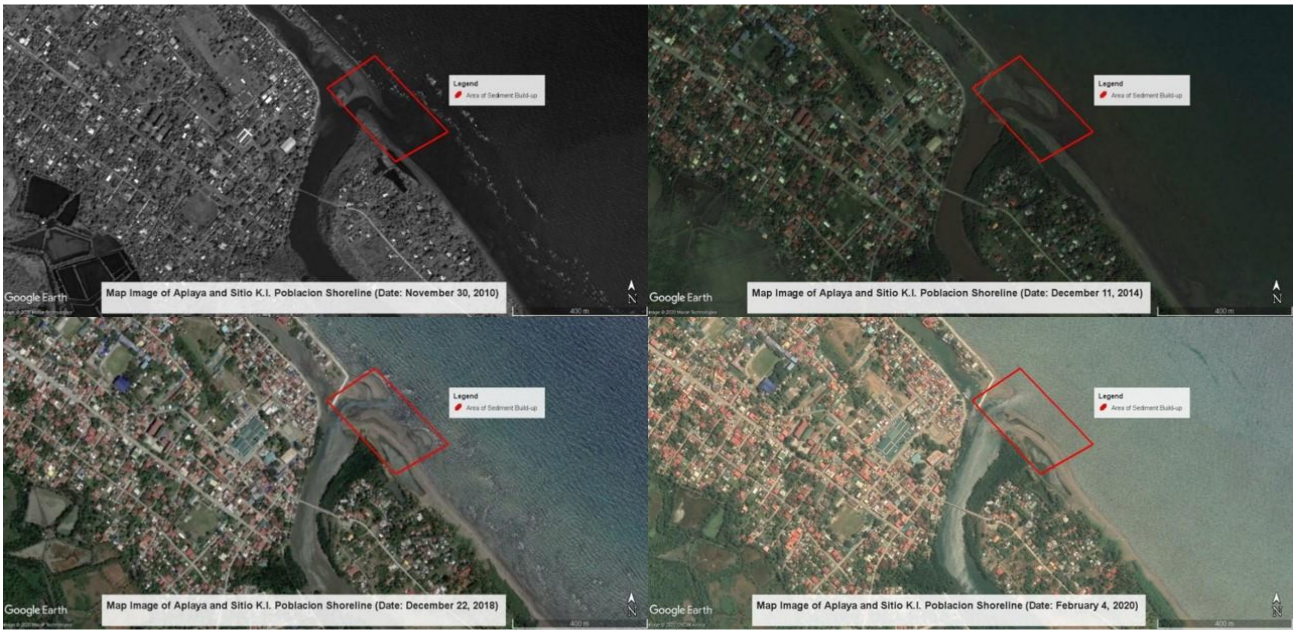

Fig. 3. Map image of Barangay Aplaya and sitio K.I., Poblacion Beach from 2010-2020

Thus, the study inter-connects the relationship of the sediment materials provided by the mangroves in the coastal zone and the accumulated sediments within this ecosystem through the measuring pins. On the other hand, the remote sense image utilized as map is significant in presenting the accretion history of the study site beach area with relation to the mangrove presence near the shoreline. They provide actual visualization of the changes done by the mangroves of Sukolriver in building sand bars as protection for the shoreline of Barangay Aplaya and sitio K.I., Poblacion. The numerical and visual data used in this assessment tool can be a basis of future DRR planning to mitigate coastal erosion; thus, motivating the concerned individuals in policy making for policy brief to enhance the protection program for this ecosystem.

B. Social (Community) Assessment

a. Multi-Criteria Evaluation (MCE) through Focus Group Discussion (FGD)

The value rating provided by the participants regarding the multiple services of mangroves are varied because of the differences in perception of the participants as shown in Table 1, the Result of the Multi-Criteria Evaluation through Focus Group Discussion between the Administration Level and Community Level. The adjective rating of each attributewas also indicated within in the table describing the extent of the value of mangroves to the participants.

Table 1 The Result of the Multi-Criteria Evaluation through Focus Group Discussion between the Administration Level and Community Level

Domain	**Attributes**	**Admin Level-Weighted Average (%)**	**Adjective Rating**	**Community Level-Weighted Average (%)**	**Adjective Rating**
Economic	Tourism Destination	90	Very High	88	High
	Wood Products	84	High	89	High
	Marine Commodities	90	Very High	93	Very High
Social	Source of Income	85	High	95	Very High
	Nature Spirituality, Wellness and Relaxation	97	Very High	94	Very High
	Recreation Activities	90	Very High	87	High
Environment	Protection from Natural Hazard	95	Very High	90	Very High
	Natural Regulation and Maintenance	89	High	86	High
	Habitat	98	Very High	95	Very High

The Multi-Criteria Evaluation was efficient in understanding the thoughts and judgement of the community people by eliciting their knowledge regarding the mangroves of the study site, the Sukolriver. Allowing them to provide their score independently in each attribute prompted them to give their views and contemplations regarding the value of mangroves through an adjective rating via weighted average. The collective score provided by the participating groups represents the shared opinion of the participants that can be used for analysis and discussion with relation to the focus of the study. Using this kind of parameter in the social level achieved chunks of data that can be utilized for further understanding of the studied ecosystem. There was no limit in the discussion of the analyzed data because the items used to solicit the scores for the valuation were capable of addressing different learned knowledge with relation to the studied ecosystem. The study can freely discuss the interpretation regarding the collective thoughts of the participants based on the weight of their scores given to each of the attributes. There were items that can be regarded to have a high or low score based on the learned knowledge of the participants. This helped to discuss the inference in the difference of the scores for each attribute. Moreover, this helps to justify the value of the Eco-DRR services of mangroves in a shared manner essential for relevant presentation of the importance of the mangroves in the coastal zone, policy making and planning. The social assessment strategy used in this study can provide details to the different frameworks that support the existing Eco-DRR frameworks and policies for DRRM policy enhancement and programs.

b) Qualitative Data Collection through Key Informant Interview

The qualitative formulated questionnaire of the study reflected the experience and knowledge of the respondents about their ideas regarding the current condition of the environment. The set of questions for the community people respondents and managers from the Local Government Unit (LGU) of the study site were able to elicit the desired data for each query relative to mangrove ecosystem and natural disasters. Their work and role in the studied community have been the source of their learned knowledge and responses during the process of Key Informant Interview (KII). Their provided ideas during the interview were perceived from the natural occurrences in the environment where they lived and work. This later became the concrete basis of their learned information and understanding within their surroundings. In this manner, when they were asked regarding certain issues and concerns for natural disasters, they hastily express their unpleasant experiences during the onset of the disastrous event. Their opinions associated with natural disasters could be considered as part of the scientific basis or reference in resolving the loopholes of reducing the impact of catastrophic events, both through community participation and intervention of the local government. Eventually, the qualitative data collection through KII searched the most meaningful answers that could provide an efficient solution in reducing the impact of natural hazards with societal consensus.These non-numerical data gathered from the qualitative approach were significant in coordinating the different channels of information from a social point of view in order to realize the importance of a certain thing or issue. As a general opinion concerning the use of qualitative research in formulating the tool to assess the ecosystem services of mangroves with relation to DRR, the approach was very effective in achieving the social judgment in a deeper sense. The respondents have no boundary in terms of providing responses for the questions with relation to the study. As long as they delivered the answers to a particular question, they are considered valid (Long & Johnson, 2000).

III. To Determine the Parallelism in the Results of the Selected Assessment Tools through Mixed Data Analysis

Based on the results of the mixed data analysis, the parameters from the Ecological and Social Assessment are interconnected and reflect each other's point of ideas and discussion. The interesting portion of the two types of data were the way they complement each other. There were times that the quantitative data collection through Ecological Assessment fall short in understanding the perception of the community people regarding the values of mangroves to DRR programs because the technique was much focused on the allometric data collection. Thus, the qualitative approach was focused in acquiring the deeper thoughts and knowledge of the people living near the study site through their experience with relation to the ecosystem services of mangroves. Regardless of their differences in the form of gathered data, their analysis somewhat supported the importance of mangroves in reducing the impact of the studied natural hazards. There were indirect or direct statements from the qualitative data that uplift the quantitative statistical results that made them a significant content for the formulated Eco-DRR assessment tool. Moreover, the parallel features of both analyses reveal their importance in justifying the values of mangroves to DRR.

As an example of indirect statement that support the DRR capacity of mangroves was the regulation of climate near the mentioned ecosystem. There were respondents that said, mangroves provide fresh air and cool climate, as well as making the area relaxing. These testimonials from the respondents were not directly conferring to the climate change mitigation of the saline trees described by statistical data. Most of their answers were according to their perception and senses towards the mangroves. They provide supports to the quantitative analysis of the study in discussing the figures from the gathered allometric data upon answering the questions. This was to describe the mangrove's carbon and carbon dioxide equivalent content with relation to climate change mitigation. The inference in the above statement was that, when these carbon materials were not captured by the mangroves, they add to the greenhouse gases that traps the heat from the surface of the Earth disallowing them to exit the atmosphere. The trapped heat in the atmosphere makes the climate hotter and unpleasant causing feedback to the Hydro-Meteorological Cycle. This only means that the mangroves provide a relaxing climate because they sequester the carbon materials near them that might be converted in to a greenhouse gas that cause extreme heat in the surface of the planet. In addition, mangroves oxygen release made their ecosystem to have a circulating fresh air through the process of photosynthesis. Meanwhile, some respondents also stated that they observed different species of animals, both terrestrial and marine lurking in the mangrove ecosystem of the study site. These were non-numerical data from the interviews and based on the observation of the community people near the mangroves. Still, they justify the results of the inventory of flora and fauna. The said inventory was a quantitative approach in acquiring the richness of biodiversity and population per species of living organisms in the study site. The respondents during the interview did not mention the number of species and species of animals in the mangroves but their statements supported the data analysis from the inventory. This is by means of the illustration of animals they have seen in the studied ecosystem.

Furthermore, some examples of direct statements from the qualitative approach that backed up the quantitative data analysis is the ability of mangroves to act as barrier against the flood. The community people witnessed the flood buffering capacity of the mangroves. They mentioned that the roots, trunks and branches of the mangroves caused the velocity of the flood water to diminish. The quantitative results provided a computation of the estimates of the reduced velocity of the running water entering the mangrove ecosystem. The same idea goes also in describing the tidal wave and tsunami energy reduction done by the mangroves. Lastly, the prevention of coastal erosion was observed in the study through the use of Sediment Pins and remote sensed images. These methods of data collection are in numerical form. Moreover, based on the qualitative data collection, the respondents saw that mangroves trapped the sediment in their roots. The accumulated sediments in the roots were transferred in the beach through tide shift. The statement of the participants regarding the sediment capture of mangroves supported the use of technique in measuring the sediments accrued in the mangroves through the use of sediment pins. The observation of the participants justified the build-up of sediment materials occurring in this kind of ecosystem. The numerical data collected from the sediment pins proved the respondents' statement. Meanwhile, the remote sensed images supported the statement of the respondents that mangroves prevent shoreline erosion through the use of aerial photos where they saw the accretion of beach near the mangroves of the study site.

The overall synthesis for quantitative and qualitative analysis served as basis or reference of the study in selecting the necessary parameters that would comprise the Eco-DRR Assessment Tool. The formulated tool as had been discussed measures the DRR capabilities of the mangrove ecosystem in reducing the risk of natural hazards, both in numerical and non-numerical form.

IV. The Final Draft of the Ecosystem-based Disaster Risk Reduction (Eco-DRR) Assessment Tool for Mangrove Ecosystem Services

Most of the Ecological Assessment results of the formulated tool provides numerical data and requires controlled procedure during data collection. On the other hand, the Social Assessment particularly the qualitative data collection approach, created a non-numerical information that addressed the perceptions, experiences and own knowledge of the participants regarding the subject of the study. Both of these assessment techniques are effective in supporting the purpose of the formulated assessment tool for Eco-DRR to provide measures of the disaster reduction of the mangrove ecosystem.

Specifically, the procedure in collecting the live biomass, is the primary requirement of computing the Carbon Stock or Sequestration, Carbon Dioxide Equivalent, and Net Oxygen Release of the mangrove ecosystem. This used the allometric features of the saline trees. These data were relevant for climate mitigation program considering the parameters have the same necessary data to estimate their values.

Similarly, the resulting figures from the computation of the biomass were prerequisite to get the amount of oxygen released and trapped carbon dioxide within this ecosystem. On the other hand, the inventories of flora and fauna were not much related with the biomass computation and were together administered in the same sampling station. The good thing about obtaining the allometric data from the mangrove ecosystem to compute for biomass was the number of Ecological Assessment that can be associated to them to lessen the workload during data collection. Meanwhile, estimating the sediment accumulation requires extended time unlike any other ecological assessment approaches, sediment build up estimation using pins usually lasts for months or even years depending on the necessary data. Moreover, the Manning's *"n"* Roughness Coefficient was focused only on measuring the buffering ability of mangroves against running water like flood or surge. Likewise, the reduction of wave height simulation by mangroves has the same concept similar to the buffering effect of these trees against flood.

On the other portion of the formulated tool was the assessment for the social aspect. The Multi-Criteria Evaluation, one of the approaches in the Social Assessment was not technically producing qualitative data. Thus, the mentioned technique was the same with the parameters used in the ecological assessment approach providing numerical data through survey using Focus Group Discussion. Meanwhile, the Qualitative Data collection using Key Informant Interview was the only procedure that provides qualitative data based on the learned knowledge and experience of the participants regarding disaster management and mangrove ecosystem.

Generally, based on the gist of the analysis for the results of the data collected, the different approaches composing the Ecological and Social Assessment Tool are suitable to compose the Eco-DRR Assessment Tool. The summary of their DRRM relevance was shown in Table 2, Summary of the Final Draft of the Ecosystem-based Disaster Risk Reduction (Eco-DRR) Assessment Tool for Mangrove Ecosystem Services.

Table 2. Summary of the Final Draft of the Ecosystem-based Disaster Risk Reduction (Eco-DRR) Assessment Tool for Mangrove Ecosystem Services

Eco-DRR Parameters for Mangrove Ecosystem	Eco-DRR Function	DRRM Relevance
1. Aboveground and Belowground Biomass Computation	Collection of data for total live biomass deemed important in acquiring the carbon stock of the mangrove ecosystem.	Climate Change Mitigation
2. Carbon Sequestration and Carbon Dioxide Equivalent	Presentation of the total carbon captured of mangroves and amount of possible carbon dioxide prevented to reach the atmosphere as greenhouse gas.	Climate Change Mitigation
3. Net Oxygen Release Computation	Discussion of the total release of oxygen within the mangrove ecosystem that supports the nutrient cycling process and production of breathable gas for the heterotrophs.	Climate Change Mitigation
4. Inventory of Flora and Fauna	Accounting of wildlife in mangrove ecosystem to be used as parameters with relation to conservation.	Biodiversity Conservation
5. Tidal Wave and Tsunami Reduction through Riverine Mangroves	Simulation of wave height reduction of mangroves ecosystem against tsunami or extreme tidal wave.	Barrier Against Strong Waves
6. Manning's "*n*" Roughness Coefficient	Simulation of mangrove ecosystem capacity to buffer the impact of flood water or storm surge.	Flood and Storm Surge Barrier
7. Use of Sediment Pin to Monitor Sediment Accumulation	Monitoring of accumulated sediment within the mangrove and beach ecosystem.	Monitoring of Coastal Erosion
8. Multi-Criteria Evaluation (Focus Group Discussion)	Presentation and discussion of community valuing for the major ecosystem services of mangroves in terms of DRR.	Environmental and DRRM Policy Enhancement
9. Qualitative Data Collection (Key Informant Interview)	Provide non-numerical data from the social level that discuss the experience of community people regarding environmental issues, natural disasters and importance of mangrove ecosystem.	Environmental and DRRM Policy Enhancement

IV. CONCLUSION AND RECOMMENDATION

The tools used in the study are appropriate to measure and describe the known ecosystem services of mangroves related to DRR. The parameters required by the tools to achieve the necessary data are relevant and free of discrepancies. In totality, the tools provided a spectrum of figures to justify the importance of mangroves in reducing the risks of natural hazards in the coastal areas. Through the use of common ecological and social assessment tool, the study helps in filling the gap of the lack of approach in measuring the DRR capacities of mangroves as reviewed from the past written accounts and literature.

Further study regarding the used of the different tools in describing the relevance of mangrove to disaster risk reduction must be done. There should be an updated knowledge regarding future trends of understanding mangrove ecosystem in terms of their interventions for coastal hazards.

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