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Restoration and Conservation Benefits of Mangrove Forest to the Coastal Communities: A Review on Sri Lankan Perspective

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Abstract **- Mangrove forest plays a vital role to enhance the standard of living in coastal communities by providing a variety of products and services. However, the mangrove forest cover was 0.2% which is much less than other existing forest types. The objective of the study was to conduct a review of mangrove forest resources and their associated benefits to coastal communities through conservation and restoration in Sri Lanka. This study reviewed secondary data such as peer-reviewed published research papers and reports for this study. The present extent of mangrove forest cover is increased to 16,000 ha between 2015 and 2016. Notably, the Puttalam district has the highest extent of mangrove forest. 10% of mangroves are cleared for prawn farming in the Chilaw and Kalpitiya. Mangrove forests provide vegetables, fuelwood, timber, and seafood to local communities to accomplish their subsistence and commercial uses. The restoration project has been initiated by the Sri Lankan government with the partnership of non-profit organizations and Seacology. *Rhizophora*and *Avicinnia* was the main species used for replanting. Community-based restoration and conservation approaches are widely considered and implemented for replanting mangroves. This study recommends that future researches need to be focused more on the mangrove forest in each province, and their values to empower the livelihood, and more in-depth scientific studies regarding the effective mangrove restoration, conservation, and quantification of mangrove forests carbon stocks through REDD+ scheme to obtain incentives to improve the living standards of the mangrove-dependent community.**

Keywords: **Coastal community, Conservation, Restoration, Benefits, Livelihoods, Mangrove forest, Sri Lanka**

I. INTRODUCTION

The mangrove forest is one of the wealthiest hubs of genetic and biological diversity on the earth. Many coastal residents are depending on mangroves for their well-being, fishery activities, and income generation. It provides countless ecosystem services to ensure the well-being of human survival. Mangroves can be categorized as trees and shrubs which are growing between the intertidal zone of land and sea. The intertidal zone environment has high salt concentration, frequent inundation, high wave action, strong wind waves, and muddy soils. However, the organisms are well-adapted to live in this inhospitable ecosystem. Mangrove trees have developed with several adaptations such as regulation of salt, nutrient retention, providing a strong supporting, viviparous method of offspring production, and aerial root system [1], [2]. This is a rare type of forest in the world and is constructed by 73 species of trees and shrubs. The estimated global mangrove forest cover was 15.2 million hectares in 123 nations and territories. Around 39% of mangroves are located in Asia, followed by Africa (21%), North and Central America (15%), South America (12.6%), and Oceania (12.4%) [3]. The Food Agriculture Organization (FAO) in 2007 stated that the global mangrove forests declined by 1% per annum over two decades from 1980 and the severe destruction rate has been recorded in South Asia between 3.58% and 8.08% [4].

Natural calamities and human interventions are threatening this valuable ecosystem. The deforestation and degradation of mangrove forests are mainly rooted in the purpose of coastal development projects, extraction of timber and fuel, and aquaculture. These activities have threatened the provision of many valuable ecosystem services and affected the livelihoods of the coastal communities [5], [6], [7]. Mangrove forests provide a habitat for fish, crustaceans, molluscs, birds, reptiles, and mammals [8].

Sri Lanka is a tropical island in the Indian Ocean comprising about 19,500 ha of mangrove forest according to the Forest Department and experienced losses of mangroves due to various reasons including the Asian tsunami of 26th December 2004 [9]. Mangroves are acted as a protective barrier during the tsunami. The areas with highly dense mangrove forests can reduce property damage by sucking the tidal waves.

However, natural coastal vegetation is destroyed due to the post-tsunami resettlements such as reconstruction sites and the removal of tsunami-related debris [10]. Sri Lankan coastal communities depend on mangrove-originated produce for their commercial and subsistence uses. Loss of mangroves has severely affected the livelihoods of local communities because many mangrove forest resources are harvested for fulfilling basic needs such as fuel wood, medicines, fish, vegetables, poles, posts for temporary fences, timber, and other raw materials for the production of handicrafts. The coastal residents are engaged in fishing, shrimp farming, and the extraction of timber for generating income at the commercial level. The major causes for mangrove exploitation in the country were commercial

activities, expansion of aquaculture, coastal zone agriculture, the establishment of residential sites, mining, tourism, and industrial development [11]. The importance of mangrove forests could be assessed by ecological sustainability, environmental security, and provision of the economy [1], [12]. The restoration and conservation activities are very minimal because of the less attention regarding the importance of receiving benefits and lack of understanding about the key role mangroves play for climate mitigation, national economy, and development of local livelihood standards.

Sri Lanka has a few scientific studies in the current status of mangrove forests, economic and environmental valuation, benefits related to conservation and restoration of mangrove forests to empower the living standards of local livelihoods including coastal communities and hand-full research have identified the valuation of mangrove ecosystem services to the coastal community. Therefore, this review study aimed to provide insights on mangrove forest resources, existing and ongoing protection and restoration activities, and their benefits to coastal communities.

II. MANGROVE FORESTS IN SRI LANKA

Sri Lanka is a tropical island consisting rich in floral diversity and many lagoons, wetlands, and estuaries are along the coastal region which is a host place for the mangrove ecosystem [13]. The country has around 8,718 hectares of national mangrove forest in 2014 based on the estimation by the Coastal Conservation and Coastal Resource Management Department [14]. The present extent of mangrove forest cover is increased to 16,000 ha between 2015 to 2016. The Puttalam district has the highest extensive mangrove forest area in the country as above 2,000 ha, which is followed by Trincomalee, and Batticaloa districts contained over 1,000 ha. Sri Lanka has 82 lagoons which were suitable harbors for mangrove forests [15].

Table I shows the extent of mangrove forests in major lagoons. The largest mangrove forests have consisted mostly of riverine and fringing mangrove types in the northeast region of the country. The salinity condition is a major factor that can differentiate the fringing and riverine mangrove types and the distribution of mangrove species caused by the seasonal rainfall and discharge of freshwater in the wet zone and dry zone. Low-saline mangrove forests are mostly located in the river estuaries where salinity is below 10 ppt.

These mangrove types showed luxuriant growth when compared with high-saline mangroves. Low-saline mangrove forest is enriched with freshwater communities of phytoplankton, zooplankton, macrofauna, and macrophytes. High-saline-type mangroves are hosted on the shores of lagoons and islands within lagoons with a salinity level of above 25 ppt. High-saline mangrove forests are contained marine plankton and sea grasses [16]. This potential unique system is a home for 23 mangroves and around 18 associate species in Sri Lanka [17], [18].

The species *Avicennia, Rhizophora, Bruguiera, and Sonneratia* represent the major genera of mangroves. There are three categorizations of mangroves based on their abundance and distribution, as very common, common, and rare. The very common species are *Avicinia marina, Bruguiera gymnorhiza, Excoecaria aggalocha, Rhizophora mucronata, Rhizophora apiculate,* and *Sonneratia caseolaris.* These mangrove species are widely distributed in a various range of soil and hydrological conditions [10]. Most of the Sri Lankan wetlands are covered by mangrove forests with various species of mangroves. Figure 1 shows the distribution of the mangrove forests map of Sri Lanka in 2015 developed by the Forest Department, Sri Lanka. The mangrove forests are playing a vital role to empower aquaculture production, reduce the impacts of natural disasters, and enhance the livelihood of coastal communities.

TABLE I EXTENTS OF MANGROVE FORESTS IN SRI LANKAN LAGOONS

Lagoon	Mangrove Extent (ha)
Puttalam lagoon [19]	2,197
Kala Oya Estuary [19]	1,200
Negombo Lagoon [20]	108
Kadolkale [21]	10
Panama Lagoon [22]	83
PambalaChilaw [23]	209
Trincomalee [24]	2,595
Ampara [24]	816
Batticaloa [24]	2,071

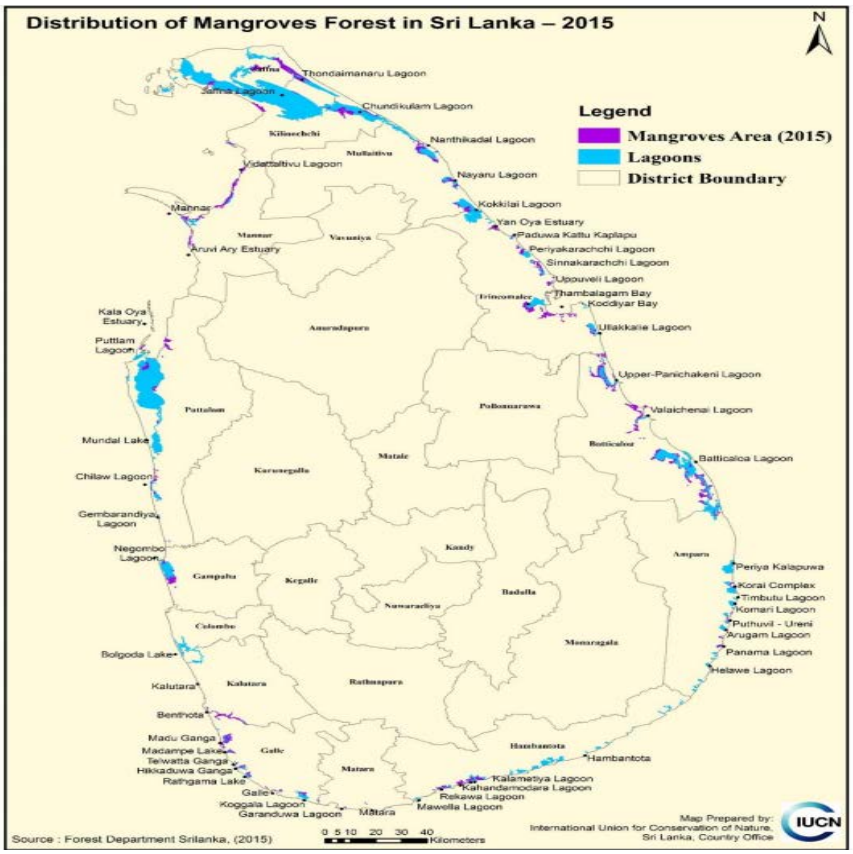

Fig. 1 Distribution of Mangrove Forests in Sri Lanka [15]

III. DESTRUCTION OF MANGROVES

Most of the Sri Lankan mangrove forests are destroyed by human interferences and a certain proportion of damage caused by natural disasters as well. Human activities have reduced the extent of mangrove forests for industrial activities. About 10% of mangroves are cleared for prawn farming in the places between Chilaw and Kalpitiya. The tallest mangroves are logged for various purposes including timber utilization. Furthermore, lack of demarcation and proper zonation of mangrove forests could be induced carbon removal. More than half percent of the mangrove forests have been destroyed in the last 30-year period due to forest clearing and overexploitation of resources. Around 80% of planted mangrove seedlings have been lost due to human disturbances [25]. Sri Lanka has accounted for an alarming rate of mangroves destruction by various anthropogenic originated activities such as illegal construction sites, salt industries, development projects, water pollution, encroachments, improper waste disposal, conversion of mangrove sites into shrimp farming and other aqua cultural locations, mass tourism, the introduction of invasive species, natural disasters, and overexploitation by traditional consumers than commercial users. A huge extent of mangrove forests is cleared in the North-western province due to introduce shrimp cultivation, fishing, fuel wood collection for local industries and household purpose, and infrastructure developments and there were much unsustainable shrimp production and their associated wastewater affect the lagoons [26].

A previous study found serious pressure on mangrove forests because of encroachment, illicit felling, infrastructure development, illegal construction, fuel wood extraction, and infrastructure development [27]. The mangrove forest declined by the rate of 0.08% between 1975 and 2005. About 225,000 metric tons of carbon-capturing potential has vanished with present rates of mangrove destruction [28].The mangrove forest cover declined to 17% in 2012 from 23% in 1992 in Puttalam lagoon. There are many negative effects caused by the destruction of mangroves such as lack of shrimp production, poor support to the local community, loss of breeding places of fauna especially crab, fish, and birds. Mangrove forest area has been transformed to other land-use practices due to the construction of hotels, expansion of tourism, rubber, coconut, and cinnamon plantations, and expanded shrimp cultivation [29]. According to the IUCN red list, five mangrove species listed under the least concerned (*Avicennia marina*, *Excoecaria aggalocha*, *Aegiceras corniculatus*, *Rhizophora mucronata*, and *Sonneratia caseolaris)*, six species were near threatened *(Avicennia officinalis, Lumnitzera racemose, Ceriops tagal, Heretiera littoralis, Rhizophora mucronata,* and *Rhizophora annamalayana),* five species categorized as vulnerable *(Bruguiera sexangula, Nypafruticans, Bruguiera*

gymnorrhiza, *Excoecaria indica*, and *Scyphiphora hydrophyllaceae*), three species were endangered *(Xylocarpus granatum*, *Bruguiera cylindrical*, and *Sonneratia alba)*, and two species listed as critically endangered *(Lumnitzera littorea* and *Ceriopsis decandra)* [30]. Therefore, scientifically and systematically designed plans need to be considered conserving valuable resources as per the level of the risk level.

IV. BENEFITS FROM MANGROVE FORESTS

Mangrove forests play a vital role in the financial status and livelihood of the coastal communities. There are many environmental and socio-economic benefits obtained at the national, regional, and local levels of the country. In terms of socio-economic benefits, mangrove resources have to be obtained for many subsistence needs for fuel wood, aquatic produce for food, shellfish and fish species, medicinal plants, vegetables, and poles for fencing and agricultural activities. Most people are engaged in commercial-scale activities like shrimp farming, fishing, timber collection, raw materials for handicrafts, production of small ornamental items and fishing gears, making mats, batiks, and brooms, and masks. Figure 2 shows the major mangrove-based products collected per household [11]. This finding clearly shows that the scientific-based conservation and management studies could fortify the mangrove products and also improve the benefits for local communities. In addition, the village communities collected and extracted the mangroves for fuel wood, green fodder for goats, leafy vegetables, and construction of the brush piles. The coastal communities who were located in the west coastal line used the branches and twigs of *Rhizophora mucronata*, *Rhizophora apiculate* and *Lumnitzera racemose* for the production of brush piles for fishing. The barks of the mangrove trees can be used to produce tannin [10]. Many ecological functions can be provided by mangroves such as sediment control, pollutant retaining, nutrient and organic matter cycling, reducing the effects of cyclones, floods, tsunami, and greenhouse [2]. The potential of carbon sequestration (blue carbon) is fifty times higher than in tropical forests. Mangroves can be able to store 22.8 million metric tonnes of carbon every year. Mangroves could be supported by biological diversity for providing habitats for many aquatic and terrestrial fauna. Several endangered birds, reptiles, and mammals are survived in this ecosystem [3].

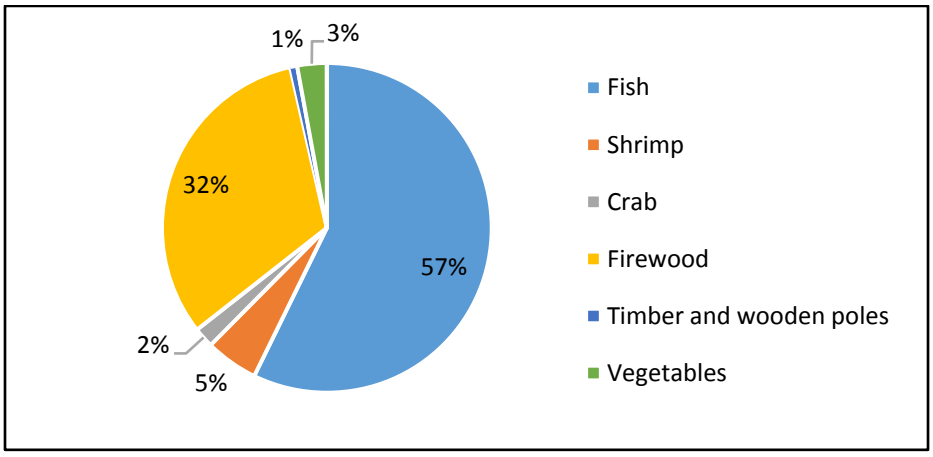

Fig. 2 Average quantity of collected mangrove products (kg) per household

Mangroves are acted as a natural barrier for cyclones, wind currents, water waves, water currents, and natural Mangroves are acted as a natural barrier for cyclones, wind currents, water waves, water currents, and natural catastrophic events. Numerous studies stated that mangroves have the capacity to mitigate the negative effects of typhoons, cyclones, and tidal waves [31], [32]. Mangroves have mitigated the disastrous impact of the tsunami waves in 2004. It can reduce the impacts of climate change issues, and protect from sea-level rise, coastal erosion, and extreme weather events. The trees provide habitat and nesting places to all trophic levels of marine and terrestrial food webs. The soft and smooth soil underneath the roots of mangroves can be enabled the burrowing species such as clams, crabs, shrimp, and snails. The roots of mangroves have collected the sediment and silt where tides carry to the sea. It can stabilize the shoreline erosion by capturing the soil in the surrounding roots [2], [12]. Mangrove forests can provide many natural resources to coastal people who have depended on their livelihood and survival. People have utilized resources where the low tide regions for the capturing of clams, shrimp, and shellfish. Mangroves in Sri Lanka provide timber for housing settlements and charcoal for coastal household needs. Mangroves have facilitated the growth of corals and offer shelter for coral species to reduce the extinction risk from coral bleaching [15], [33]. Overall, mangroves provide many benefits in terms of plants and wood values, recreation and aesthetic values, medical values, aqua food products, biodiversity, ecological and protection values [2], [12], [15], [29], [31], [34], [35].

V. CONSERVATION AND RESTORATION OF MANGROVE FORESTS

Sri Lankan mangrove forests are owned by the government but it has been conserved and managed by various state institutions. Many restoration projects emerged after the tsunami in December 2004 because of the recognition received for the role of the coastal protection barrier. Sri Lanka has served as a member of Mangroves for the future in 2006. This is a kind of partnership between the countries which are affected by the tsunami in Southeast Asia targeted to enhance the well-being of mangrove-dependent communities through sustainable management [36], [37]. Sri Lanka has declared the mangrove conservation and restoration projects to obtain numerous incredible ecosystem services for the well-being of humans and the environment. This project has been initiated by the Sri Lankan government with the partnership of two non-profit organizations known as the Small Fisheries Federation of Sri Lanka (SUDEESA) and Seacology. The government has replanted 35,000 ha of mangrove in coastal regions with the support of 38,000 volunteers. The encouraged volunteers are mostly women and their well-being is empowered by providing microloans to initiate fishing business through mangrove restoration. *Rhizophora* and *Avicinnia* were the main species used for replantation [15]. However, the restoration of mangroves has not been conducted properly to achieve the goal. The success rate of this activity was around 19%. The restoration has been considered the local topographical features, soil pH, disturbance by cattle farms, and local people. Although, this can provide the restoration benefits meaningfully.

In addition, figure 3 explains the project site of mangroves restoration along the coastline of Sri Lankan and their survival level [25]. This shows the restoration as per the bio-climatic zones as wet, intermediate, dry, and arid zone. The dry and arid zones consisted of 52% of restoration, while 30% and 18% restored in wet and intermediate zones, respectively. Mainly these activities were observed in the areas affected by the tsunami in 2004. The planting activities are involved with national and international organizations. This could help to evaluate the project success rates and able to identify the causes for sites with less survival rate and also can be used to plan appropriate conservation and management strategies as per the survival level.

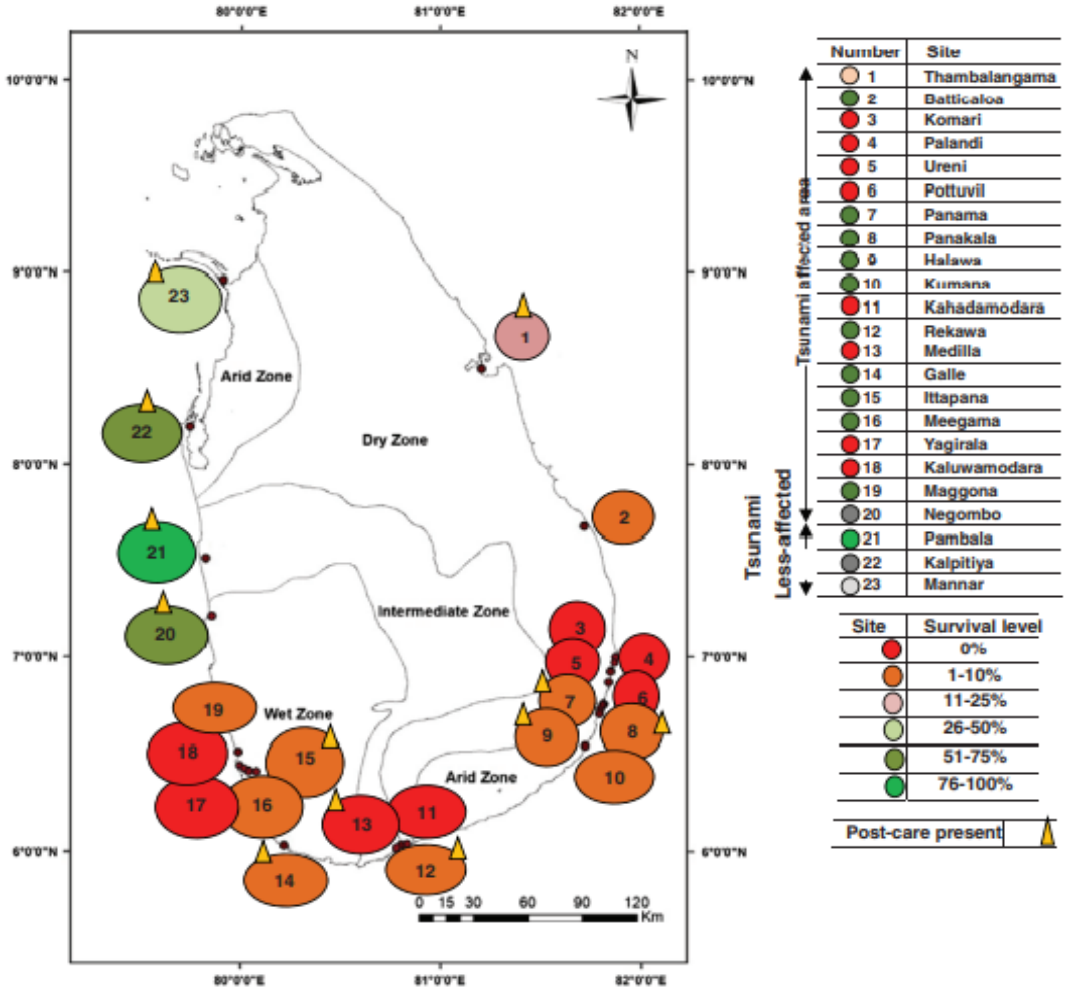

Fig. 3 Project site of mangroves restoration along the coastline of Sri Lankan and their survival level [25]

The conservation of mangrove forests has obtained significant importance by researchers due to their direct and indirect values, multifunction, attributes of mangrove forest, the role of ecological services, and livelihoods for the betterment of mangrove-dependent communities. Mostly, mangroves were destructed due to the poor understanding of the role of mangroves by the public and policymakers in terms of provisioning services to upgrade the national economy. Because of this main reason, mangroves are considered wastelands with little value. There are many awareness programs and education, and training could be provided to the fishing communities located around and nearby mangrove areas. The adjacent community has the responsibility for restoration with external funding support and technical guidance with the necessary advice. Sri Lanka has laws and regulations to safeguard the coastal ecosystems but practically, the enforcement of regulations is very difficult and consumes more money. Considerably, Sri Lanka has enacted to safeguard the mangroves. The existed acts and ordinances were the forest ordinance No. 16 of 1907, the fauna and flora protection ordinance No. 2 of 1937, the national environmental act No. 47 of 1980, the coastal conservation act No. 57 of 1981, the fisheries and aquatic resources Act No. 2 of 1996, the Marine Pollution Prevention Act No. 35 of 2008, and the Conservation of Fish and Aquatic resources within Sri Lankan waters Regulations 2016. The policy plans related to conserve and restore the mangroves were the national forest policy of 1995, the national biodiversity strategy and action plan of 1999, the national wildlife policy of 2000, the environmental policy of 2003, the national policy plan on wetlands of 2006, national fisheries policy of 2006, the national policy on climate change of 2012, and the national adaptation plan for climate change impact in Sri Lanka 2016. The existing national-level policies and ordinances could assist to enhance the conservation and restoration incentives. However, the strategies and management plans have to be well designed for post-care mangrove plantations to achieve successful restoration [38]. Therefore, local communities could play a major role in the effective management of coastal mangroves. The community-based restoration approach can be widely considered and implemented in the replanting of mangroves [11], [39].

VI. CONSERVATION AND RESTORATION BENEFITS TO COASTAL COMMUNITIES

About 33% of the population depends on the coastal zone for their survival. The main problem among the coastal communities is poverty; therefore, the major income is generated through agriculture and fishing activities to lift their livelihoods. Poor income category people have fully depended on mangroves and obtaining 42% of income from mangrove products. Likewise, medium and rich income communities are benefited by 37% and 21% respectively. Fuel wood, herbs, vegetables, and poles are obtained from mangrove forests to accomplish the basic needs of local communities [40]. The fish catches were ranged between 30% and 80% in the southeastern coast mangroves and also benefit value of coastal fisheries is obtained between 178 and 473 USD. The main fish species Godaya, Reththala, Japan Korali, Angulu, and Parava were harvested from the mangrove ecosystem, and the total mangrove product's value per household per year is 1,171 US dollars. It shows that conservation and restoration activities could upgrade social welfare and the national economy in the eastern coastal zone. The average mangrove-related fish catch is 2,478 kg per household per year and the collection of fuel wood from mangrove forests is around 1,440 kg per family per year. Around 140 kilograms of vegetables are obtained per household per year [10]. The coastal zone communities are obtaining the benefits of mangrove forest products from their commercial and subsistence purpose. 75% of the coastal community has extracted firewood from the nearby mangrove forests. Approximately 1.3% of Gross Domestic Product (GDP) is contributed from coastal, inland, and offshore fisheries in 2017. However, the fishery production from coastal regions has been declined by 5.3%, shrimp and prawn production reduced by 23%, and inland aquaculture dropped by 7.9% in 2017 [15].

Local vulnerable communities are obtained protection from mangroves to ensure food security during off-seasons and extreme weather events. Mangrove ecosystem provides fuel wood, vegetables, seafood for cooking purposes. The poor and medium-income category people are dependent on fish, timber, poles, and vegetables. On the other hand, the high-income receiving community has depended on high-value commercial-scale products such as crab and shrimp. Besides the mangrove-based products, the coastal communities are received protection from coastal erosion, wind erosion, nutrient recycling, breeding grounds and nesting places for many species, carbon sequestration to combat climate change issues, tsunami protection, storm protection, and acting as a windbreak. Further, rapid development in salt industries between 2000 and 2015 can accelerate the declining rate of mangrove forests in Puttalam by 7% in 2020 [41]. Therefore, it will have the possibility to reduce further in the future. Due to this, conservation and replantation activities can increase job opportunities, protect from natural calamities, conserve biodiversity, foreign export from shrimp farming, motivation of local people by providing rewarding systems, long-term conservation along with management activities with the aid people, and ecotourism could be developed to obtain further financial support for regional development. The total economic benefit from mangroves was 12,229 US dollars [10]. The fishing communities and mangrove-dependent communities could obtain many ecosystem services and products from the mangrove forest. Therefore, the community-based mangrove forest conservation and restoration activities could be encouraged to obtain the maximum value of benefits to strengthen the wealth of coastal communities through the support of various state and private organizations. Importantly, the country has planned to restore 10,000 ha by 2030 using the strategies of protecting

existing mangroves, converting destructed shrimp farms, and restoring degraded mangroves. This could reduce greenhouse gas emissions and will contribute to achieve the Nationally Determined Contributions (NDCs) by 2030.

VII. CONCLUSION

This study was carried out to conduct a review on the mangrove forest resources in Sri Lanka and their benefits of conservation and restoration to the coastal communities' livelihoods. The mangrove forests have more potential to store carbon as a mitigation measure for climate change. The greatest extent of mangrove forest was damaged during the Indian Ocean tsunami and cleared for post-tsunami rehabilitation activities. The majority of the coastal mangrove-dependent communities are received many mangroves-based products and services to manage the subsistence and commercial needs. Mainly mangrove forests were degraded and deforested by human-induced activities due to the lack of awareness, education, and the poor understanding of its socio-economic and ecological values. The appropriate awareness and training should be implemented at all levels to conserve the existing resources and increase the carbon stock and forest cover by restoration activities with the incorporation of the REDD+ project. The community-based conservation and replantation projects should be implemented effectively to achieve success and to enhance the livelihood status and standards of coastal communities. Most of the studies in Sri Lanka have reflected the status of the eastern province mangrove forest. This study could recommend that future research studies should focus more on the mangrove forest in each province, and their values to empower the coastal livelihood. This study suggested that qualitative and quantitative studies will be required to obtain a better understanding of conserving and restoring mangrove forests for future implementation, monitoring, and maintenance of natural resources. Besides, the mangrove planting guidelines could be revised and formulated, based on the Sri Lankan site conditions, to facilitate natural regeneration.

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