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Challenges and Opportunities for Restoring the Threatened Mangroves

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Authors' contributions

This work was carried out in collaboration between all authors. Authors KN and SM designed the study, wrote the protocol, and wrote the first draft of the manuscript. Author AM managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Restoration of mangrove forests has to be a continuous process. It is important to reverse the loss of mangrove ecosystem worldwide by using various approaches as this ecosystem provides important ecosystem services such as habitat for organisms, recycling of nutrients, controlling floods, trapping sediments, erosion barriers and so much more. This paper addresses issues associated with the ongoing degradation of mangroves, objectives, opportunities well as challenges for mangroves restoration. As far as the restoration of mangroves is concern, it is emphasized to conserve mangrove forest so as to continue benefiting from them. Special emphasis is placed in coordinating efforts between natural and social sciences. However, it should also be noted that, restoring mangroves is only a partial solution, protection and conservation of those important remaining ecosystems, must be a campaign for all nations before too much is lost.

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1. INTRODUCTION

Mangroves are salt-tolerant group of tropical plants that occupy the inter-tidal zones of the sheltered coasts such as estuaries and lagoons. Mangroves have the ability to grow where no other tree can, thereby making significant contributions that benefit the environment. They are variously adapted to cope with the unfavorable environmental conditions for growth and reproduction resulting from inundation with salt water, unstable soils due to tidal flow and lack of freshwater [1-3].

Mangrove ecosystems have been estimated to cover 146,530 km² of the tropical shorelines of the world [4,5]. In 2000 the total estimate for mangrove was 137,760 km^2 [6], this represents a decline from 198,000 km² of mangroves in 1980, and 157,630 km² in 1990 [4], These losses represent about 2.0% per year between 1980–1990, and 0.7% per year between 1990–2000. These figures show the magnitude of mangrove loss, and hence the magnitude of mangrove restoration opportunity. Mangrove restoration involves the re-introduction and re-establishment of assemblages of native mangrove species to sites that can support them to be developed into mangrove ecosystems which perform similar functions as those that were there originally [1]. There are various reasons for restoring mangroves. The reasons are often based on fish habitat value, but include others such as direct wildlife uses and dependence on fisheries production as a source of food, preservation of water quality and reduce pollution by filtering suspended material and assimilating dissolved nutrients [4]. In addition, the restored habitats have potential to increase the species diversity. For instance in Wazo hill Tanzania, restoration of the degraded habitats was observed to increase the abundance and diversity of butterflies [6,7,8].

During mangrove restoration factors for consideration includes the following, soil stability and flooding pattern, elevation of the site, soil/water salinity and freshwater input to the site, tidal and wave energy associated with the site, availability of propagule/seed material, spacing and thinning of plants, presence of weeds, success of nursery techniques, monitoring the progress, incidence of propagule predation, cost of restoration as well as cooperation of the local inhabitants [1].

The objective of mangrove restoration, includes re-establishment of habitats (structure) and functions such as coastal protection, contribution to fishery production, enhancement of, cultural, socials, economical and aesthetic quality of the landscape that have been lost [1]. Apart from having those reasons for restoring mangroves, there are a multitude of opportunities and challenges to restore mangrove forests. The objective of this paper was to highlight the challenges and opportunity of restoring the degraded mangroves ecosystem. The ways forward were also highlighted.

2. OPPORTUNITIES FOR MANGROVES RESTORATIONS

There are many opportunities accompanied with mangroves restorations, to mention few, they includes the following:

Provide economical benefits from the restored ecosystem. The mangrove ecology has potential to provide economic benefits through different activities such as tourism and fisheries. Example the restoration of mangroves in Florida Bay has produced real ecological benefits for as much as US$ 250 ha^{-1} [4].

The continuous deterioration of mangroves provides great opportunity for the restoration project. Local communities around the mangrove resource are highly dependent on natural resources for their survival. The mangrove forests are degraded in their activities of extracting resource for their livelihoods. The local communities are involved in destructives fisheries activities (example dynamites, bottom trawling, poisoning), agriculture activities and deforestation of mangroves for construction which acerbates the mangrove deterioration. Studies in Kunduchi Fishing Village and Mbweni Village in Tanzania showed that these communities due to low education levels, poor infrastructure, and low incomes are largely dependent on natural resources, particularly through fisheries and agriculture leading to declining of the mangroves [9]. This has provided the opportunity for restoration program of mangrove in these areas.

Local communities and institutions are available to provide supports for the restoration programs. The use of local community groups; especially those that are concerned about the environment

can be assigned the task of restoration under the supervision of an expert on the subject. Fishing communities are generally aware of the importance of the presence of mangroves for aquatic life. Members from local community who have no connection to fishing should be made aware of the importance of mangroves [1].

Mangrove Restoration through School. Children in schools close to mangrove restoration sites and their environmental societies can be educated on the importance of mangroves and their restoration and motivated to perform restoration work under the supervision of an expert and experienced person. Such schools can be rewarded by contributing to improvements of the environment by their common facilities/utilities [1].

Availability of international organizations which are interested in funding and providing technical support in the restoration project are also great opportunities. Many organizations are available to provide support in terms of financial and technical support. Example, Wetland International (WI) is interested in wetlands survival, World Wildlife Fund (WWF) is interested in environments and biodiversity conservation and the International Union for Conservation of Nature and Natural Resource (IUCN) is interested in biodiversity conservation, all these can be of great help when dealing with wetland restoration. In the restoration of mangroves in Tsunami affected areas WI, WWF/IUCN provided great support to ensure the success of the mangrove restoration project [1]. However finance opportunity from reducing emissions from deforestation and forest degradation in developing countries (REDD) makes the process ease. Mangrove forests are considered highly productive ecosystems and most carbon is either buried in sediments locally and in adjacent systems or stored in forest biomass as the trees grow [10]. Three different global estimates for carbon sequestration within mangrove systems all converge on a value equivalent to ~18.4×10^{12}g C yr^{-1} when applying a global area of 160,000 km^2. In comparison to tropical forests, mangroves have actually been found to be more efficient at carbon sequestration [9]. Mangroves are thus clearly an option for countries interested in developing REDD+ readiness plans [10,11].

Unfortunately, it is estimated that more than 50 per cent of the world's original mangrove forests have disappeared and the annual global rate of mangrove loss continues to be one to two percent [12]. In order to counteract the loss of mangrove forests and to provide incentives against deforestation, REDD+ projects could finance the protection and restoration of mangroves. When the mangroves are restored, they do provide social, ecological, cultural, and economical benefits including the following: Ecological functions/Environmental services. Mangroves as an ecosystem are capable of performing certain functions or environmental services. Mangrove plants produce organic matter through photosynthesis and this produces the food for most of the fish and shellfish in the coastal waters [13]. Fish and shrimp catch increase with the increasing presence of mangroves in the inter-tidal zone. They also provide habitats and serve as nursery grounds for the juveniles of aquatic organisms on which important fisheries are based on. When these activities are managed appropriately it is possible to derive timber products from mangrove forests without significant environmental degradation, and while maintaining their value as a nursery and a source of food for commercial capture fisheries [1,13].

Erosion barriers. Mangroves with their characteristic root system are capable of reducing erosive forces of waves, tidal currents and consolidating sediment, thus checking erosion. Superiority of mangroves against engineering structures in withstanding high wave energies and protecting coastal areas was evident during the Indian Ocean Tsunami in 2004 [1,13]. On top of that, they act as wind barriers. Mangroves serve the function of wind breakers in the coastal areas that are frequently subjected to monsoon winds [1,13].

Forest products. Mangroves are primarily used for light timber requirements and firewood. Non-wood products, bark (for tannin), leaves (fodder and vegetables), fruits (to make beverages), honey, wax and thatching material as well as finfish and shellfish are also collected from mangrove ecosystems [1].

Reduces salt water intrusion towards land. While reducing the energy in waves, mangroves absorb salt along with water and store them inside their tissues [1]. Mangrove trees are also used for house building, furniture, transmission as well as telephone poles and certain household items.

Mangrove forests protect all types of coastal communities from the fury of cyclones and storms [14]. The best example is the

super-cyclone which occurred on the 29th October 1999 with a wind speed of 310 km hr^{-1} along the Orissa coast (India) and played havoc largely in the areas devoid of mangroves [14]. On the contrary, practically no damage occurred in regions with luxuriant mangrove growth. Similarly, in the Mahanadi delta, where large scale deforestation and reclamation of mangrove land for other purposes have been undertaken, maximum losses of life and property have been reported from time to time during stormy weather [14,15]. These events beyond doubt prove that mangroves can form the best shelterbelt against cyclones and storms and have generated awareness among the local communities of the importance of mangrove forests as protectors of life and property [14,15].

Controlling the flood. Mangrove ecosystems offer protection to the coastline against the floods which are often caused by tidal waves or due to heavy rainfall associated with storms [14]. The serious flood disaster of 1991 in Bangladesh would certainly have been minimized, had the 300 km^2 mangrove area not been cleared for shrimp farming and rice cultivation earlier. The ability of mangroves in flood control is due to the response of their root system to have a larger spread out in areas prone to tidal inundation, and their roots help to promote sedimentation [14]. One of the important functions of mangrove is to trap sediments and thus acting as sinks to the suspended sediments. The mangrove trees catch sediments by their complex aerial root systems and thus function as land expanders. In numerous cases, there has been proof of annual sedimentation rate, ranging between 1 - 8 mm in mangrove areas. The efficient in sediment trapping has great value in the marine ecosystem. This possible sediments trapping by mangrove depends largely on the complexities involved in the exchange process taking place between mangroves and the adjoining coastal areas [11,14,15].

Trapping and recycling of nutrients. The mangrove sediments have the ability to retain nutrients. This depends on the sediment characteristics and flow patterns of the sites. Mangroves have mechanisms to ensure potential for recycling of nutrients such as, the vegetation itself, they filters nutrients from the water, and the mangrove soil, algae, microbes, and physical processes absorb large amounts of pollutants. Mangroves such as *Avicennia* spp. in general are tolerant to high organic load. In Indonesia, *Avicennia* spp. and *Acanthus ilicifolius* are planted in aquaculture ponds for controlling salinity and pH in rainy season [14,15].

Mangrove sediments have a high capacity for absorbing and holding heavy metals thereby preventing the spread of heavy metal pollution in coastal areas. The sediments contain 90% of Mn and Cu released and almost 100% of the Fe, Zn, Cr, Pb, Cd in the total ecosystem [14]. However, mangrove species (*Rhizophora mangle*) contains less than 1% of the total of these metals. This is due to low bioavailability in the mangal sediments, exclusion of the metals by the mangrove plant itself and physiological adaptations that prevent accumulation of metals inside the plants [14,16].

Supporting the fishes and wildlife populations. Mangrove ecosystems are important for fish production; they serve as nursery, feeding and breeding grounds for many fishes and shell fishes. Nearly 80% of the fish catches are directly or indirectly dependent on mangrove and other coastal ecosystems worldwide [14]. For example, the Pichavaram mangroves alone nurture 30 species of prawns, 30 species of crabs, 20 species of mollusks, and 200 species of fish [14]. Besides fish, the mangroves support a variety of wildlife such as the Bengal tiger, crocodiles, deer, pigs, snakes, fishing cats, insects and birds.

Biomass and Litter Production. Mangroves contribute significantly to the global carbon cycle. Mangrove forest biomass may reach 700t ha^{-1} estimate the total global mangrove biomass to be approximately 8.7 gigatons dry weight (i.e. 4.0 gigatons of carbon) [17]. Mangroves generally grow better in wet equatorial climates than they do in seasonally monsoonal or arid climates and the amount of litter they produce is negatively correlated with latitude [17].

Litter Decomposition and Nutrient Enrichment. Mangrove ecosystems produce large amounts of litter in the form of falling leaves, branches and other debris. Decomposition of the litter contributes to the production of dissolved organic matter (DOM) and the recycling of nutrients both in the mangal and in adjacent habitats [14]. The organic detritus and nutrients could potentially enrich the coastal sea and, ultimately, support fishery resources. The contribution of the mangroves could be particularly important in clear tropical waters where nutrient concentrations are normally low [14].

Tourism, food and scientific studies. Mangrove forests are also important in terms of aesthetics and tourism. Many people visit these areas for sports fishing, boating; bird watching, snorkeling, and other recreational pursuits In addition to those, Mangroves also provide opportunities for education and scientific research. It is essential to systematically conserve the biodiversity in the mangrove ecosystem and manage well for the use of mankind [4].

3. CHALLENGES FACING MANGROVES RESTORATION

Failure of achieving the restoration goals. However while great potential exists to reverse the loss of mangrove forests worldwide, most attempts to restore mangroves often fail completely. Restoration has, unfortunately, emphasized planting mangroves as the primary tool in restoration, rather than first assessing the causes for the loss of mangroves in an area, then assessing the natural recovery opportunities, and how to facilitate such efforts [18]. In addition, few restoration efforts are embedded in a larger framework that also consider the fate of the planted mangroves, in terms of stand structure and regeneration, return of biodiversity and recovery of other ecosystem processes [18].

Sometimes, the human dimension is ignored as an important consideration in mangrove restoration projects resulting in failure [14].

Achieving sustainable funding is a challenge. Most of the mangrove restoration projects are not self funded, they do depend on outside funders for almost all the projects activities. In addition to that, restoration programs are continuous processes which require constant supply of fund at all stages starting from the planning phase, implementation phase of the restoration projects and post management of the projects. At each level, the funding is required to sustain the mangrove restoration. However funding scarcity can hinder continuation of the restoration project. In additional to that, each donor has his own interest and duration of funding, but not according to the need of the mangrove ecosystem to be restored.

Disease and pests to mangrove is also a challenge in their restoration. Diseases also cause devastating damages to mangroves. For example, top dying disease has damaged about 45 million *Heritiera fomes* (Sundari) trees. The top dying disease is believed to be caused by an array of factors increased soil salinity due to reduced water flow, reduction in periodic inundation, excessive flooding, sedimentation, nutrient imbalances, pathogenic gall cankers, and cyclone–induced stress [19,20]. Biological pests and parasites also have serious impacts on mangroves. Significant damage is caused by grazing of buffaloes, sheep, goats and camels in dry coastal areas of Asia and the Middle East [19].

Young plants are damaged by barnacles and leaf eating crabs of the sesarmid family. Some caterpillars are parasites of the fruits of *Rhizophora*, and these inhibit seed germination. Mangrove species like *Nypafruticans* sometimes poses a problem, when it is introduced as an exotic species [19]. For example, the Nipa palm, (*Nypafruticans*) was introduced from Singapore to Nigeria in 1906 to control coastal erosion. However, the palm spread extensively and replaced the native mangrove species like *Rhizophora* in Nigeria [19,20].

Creation of database of all the failures and successes. Too often personnel working in mangrove restoration project change project, without considering the magnitude of their work. This has a negative impression on the restoration process in a long run. Sometimes a final report is required by contract or as a permit condition [21]. Even if it is not, preparation of a final report is warranted to serve as an archival record of the project. The public deserves to be informed of a completed project and the benefits that accrue from it. News releases, media events, and public celebrations are vital all in order to keep aware on the progress of the projects [21]. Popular articles for public consumption can be prepared in non-technical language. Such publicity keeps ecological restoration in the public eye. If policy makers and politicians are aware of successfully completed projects, they will be more inclined to promote and fund new projects. Technical accounts of the project are equally important. Case histories become a treasure trove of information for all restoration practitioners who want to improve their professional proficiency. Case histories can be published in technical journals, trade journals, and posted on internet sites. Papers and posters can be presented at conferences [21].

Lack of long term monitoring. Most of the Mangrove restoration projects are time bound while restoration is a continuous process.

Monitoring of the mangrove restored is required from time the projects starts, during the projects and even after post project. Post projects involve the maintenance and protection from vandalism and other stress. Hence lack of proper monitoring of the mangrove restoration in all phases can led to failure of the projects.

Following principle of ecological restoration. During restoration process, there is a need to adhere with all the ecological restoration principles. These principles consider how the ecosystem components interact and dependent on each other, for example, mutualism, ecological succession, primary succession versus secondary succession and primary productivity. In this case, any restoration program which ignores these principles during restoration programs is likely to fail. This is the great challenge in mangrove restoration.

Land ownership issues. The areas to be restored for mangroves can have the challenges of land ownership. The land can be private owned or public land. Each owner has his priority in the land she/he owns. For example, if the owner is interested in developing that area by building for business, the restoration of mangroves will not be a priority to him/her, hence becoming a challenge in restoration of the mangroves.

Natural processes. Fire, floods, cyclones and drought are all naturally-occurring processes that have the potential to damage mangroves restoration areas. Fire can remove or change habitat available for wildlife around mangrove. Floods, cyclones and drought can impact the natural water regime of the water body and the vegetation of the mangroves in restoration site [22].

Coordination between institutions. Apart from the natural calamities and anthropogenic pressures many of the problems and causes of mangrove loss stem from state level failures in policy, management and enforcement of the so branded protection measures [23]. For example, although there was an instituted government ban on all mangrove forests of mainland Tanzania in 1987 to allow for an inventory exercise of mangrove forests in the country, aiming at preparing a national management plan yet, illegal harvesting continued unabated due to ineffective enforcement [24]. Because there has not been any recent data to indicate the loss of mangrove forests in Tanzania, the difference of an estimated 115-475 ha [24] and that of 108-138 ha [24] remains the only reliable indication of the vast decline of mangrove forests at the national level. The exemplified magnitude of mangrove clearance in Ruvu is just a clue of the lesser known rampant degradation [23]. Loss of mangrove forests is not confined to the disappearance of the mangrove trees, but entail compounded degradation of habitats for other forms of life in the ecosystem under restoration, thus making it a great challenge in restoration programs [23].

Surrounding communities poverty and their daily activities can be a challenge. It is anticipated that there is a clear cause-effect association between poverty and natural resources (mangrove) degradation [23]. The more the people are poor, the more they become dependent to the natural resources and high degradation of mangroves resources that leads to widespread poverty and that poverty is a habitual cause of degradation [23].

Culturally, mangrove forests in rural areas are significantly used for subsistence and provide important inputs to agriculture. While the understanding of most of the rural poor is limited to the simple view of forests supplying goods and services, the realities should gauge our understanding towards recognizing the strategic role that forests play in helping the poor cope with poverty during mangroves restoration projects [25]. It is this traditional dependency at the top of the list of factors that is attributed to degradation of mangrove forests. While struggling for wellbeing, the vicious cycle of poverty-resource degradation-increased poverty is perpetuated [25]. Moreover, Separation of mangrove restoration projects and local communities is also a challenge. The first and foremost challenge and dilemma is when management institutions tend to treat people and the mangroves under restoration as separate ecological entities. This is very characteristic in developing countries where mangrove natural ecosystems have for long been considered to be jeopardized by human use and thus exclusive management thought to be rational [23]. It is important during mangrove restoration to recognize that, restoration and management is pragmatic needing as much to address the human element which either sustain or impede desired functional ecosystem because they are part of the ecosystem and asset for restoration and management of mangrove ecosystem [11].

4. WAY FORWARDS

Revising policy. In many countries including Tanzania, there is an urgent need for revision of the current policy to provide guidance for planned and coordinated institutional action and an organizational set-up which can meet the mangrove restoration tasks [23]. There is a need for more research and information in social economic of mangroves. Since there is still inadequate information about the important socio-economic characteristics, such as trends and patterns in resource use and economic development, land use and ownership and infrastructure, which ruin the integrity of mangrove forests. This entails also the need to develop national and local scenarios of their future development [23]. Research and analysis of policy and institutional frameworks are needed to address these shortcomings. For example, indigenous knowledge and traditional management systems need to be understood and evaluated for an efficient incorporation [23].

Providing and supporting alternative economic to local community surrounding the mangrove restoration projects. Promotion of nationalization of mangrove forests has not solved the problem of resource degradation and overexploitation [23]. It has in essence deprived many rural households of their livelihoods. For this a call is made that alternative development approaches need to be devised so that those societies which are highly dependent on mangrove biodiversity for either subsistence or development are enabled to continue to do so sustainably [23].

Diversification from management alone to include provision of economic alternatives and opportunities for local communities that will discourage them from irresponsible harvesting of the resources is pragmatic to curb the loss of mangrove resources [23]. To efficiently deliver on this, negotiations between the central and local governments on one side and the people on the other must be undertaken to for example, identify suitable alternatives. This is important because, for instance, farming lands in mangrove areas are often regarded as degraded areas which require restoration. So, displacing farmers from these farm lands will require special consideration for those who will continue to rely on mangrove areas for farming as not all farmers can access alternative farm lands [23]. Additionally, involving and providing education to local communities will aware of the functional ecological links between mangrove ecosystems and resources such as fish is crucial to winning management support [23]. The instillation of a sense of ownership of the resources by the local population and their legal empowerment so that they are able to institute and execute control measures on their resources are also essential components in the process aimed at achieving full community support for the sustainable utilization and management of the mangrove resources [23]. Community participatory in restoration and management of mangroves should be considered. It has in essence deprived many rural households of their livelihoods. For this a call is made that alternative development approaches need to be devised so that those societies which are highly dependent on mangrove biodiversity for either subsistence or development are enabled to continue to do so sustainably. Awareness of the functional ecological links between mangrove ecosystems and resources such as fish is crucial to winning management support. The instillation of a sense of ownership of the resources by the local population and their legal empowerment so that they are able to institute and execute control measures on their resources are also essential components in the process aimed at achieving full community support for the sustainable utilization and management of the mangrove resources [23].

Creating alternatives source of income for the local communities. Diversification from management alone to include provision of economic alternatives and opportunities for local communities that will discourage them from irresponsible harvesting of the resources is pragmatic to curb the loss of mangrove resources. To efficiently deliver on this, negotiations between the central and local governments on one side and the people on the other must be undertaken to for example, identify suitable alternatives. This is important because, for instance, farming lands in mangrove areas are often regarded as degraded areas [23].

Revising the mangrove conservation and conservation policy and more research. Policy wise there is an urgent need for revision of the current policy to provide guidance for planned and coordinated institutional action and an organizational set-up which can meet these tasks. There is still inadequate information about the important socio-economic characteristics, such as trends and patterns in resource use and economic development, land use and ownership and infrastructure, which ruin the integrity of

mangrove forests. This entails also the need to develop national and local scenarios of their future development. Research and analysis of policy and institutional frameworks are needed to address these shortcomings. For example, indigenous knowledge and traditional management systems need to be understood and evaluated for an efficient incorporation.

Promotion of nationalization of mangrove forests has not solved the problem of resource degradation and overexploitation [23].

Funding agencies. The funding agencies should *examine* carefully the objectives of NGO's and try to avoid "elaborate dance", support projects that have clear plan and include, consideration of environmental conditions along social ones and support project that aim at long term [23].

Government/Institution. They should ensure that, sustainable management and conservation of existing natural mangrove forests is done to prevent from further degradation. They should invest in research of establishment of ecosystem services, and ecology in restored mangroves, investment in scientific monitoring, cooperation with NGO-s in restoration and monitoring, support educational and awareness programs on mangroves [18].

NGOs should plan their project carefully from the beginning, remove initial problems of degradation, restoration is done for people, therefore learn their preferences, take advantage of the local knowledge, educate communities and facilitate awareness, identify possible future problems and solutions, set clear goals, create sustainable funding for communities, think about monitoring in advance, do not underestimate the role of environmental factors prior restoration, report on success or failure of your project, for others to learn from it [18].

5. CONCLUSION

Prevention is better than cure; we need to protect the available mangrove from being destroyed. Restoration is expensive and some time cannot be achieved to the same level to which the previous mangroves were. Regardless of many challenges in Mangroves ecosystem restoration, still there is a need to utilize all the opportunities available for restoration processes. Local communities surrounding the mangroves have great advantage of benefiting from the mangrove resources, and they are potentially capable of supporting mangrove protection and restoration project. In this case the involvement of these people is vital. In addition the government should be strictly in mangrove conservation policy, EIA and monitoring of the restoration program.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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