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RESEARCH ARTICLE

Effectiveness of community participation in Mangrove restoration: the evidence from northern Sri Lanka

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Abstract
As a result of the past failures in centralized management, community-based management approach was evolved as a better alternative in Mangrove management. However, effectiveness of community-based Mangrove management is remained as an important policy question with limited empirical evidence. This study aims to empirically investigate the effectiveness of community participation on Mangrove restoration using the village-level data collected from lagoon-based fishing villages in northern Sri Lanka during 2009–2020. In addition to the field data, this study adopts satellite imagery data of Landsat-7 and Landsat-8 to estimate the extent of Mangrove cover as an indicator of Mangrove restoration performance. The results show that community participation has a significant and positive impact on Mangrove restoration, suggesting the importance of strengthening community management practices for future Mangrove management.

Keywords Community participation · Mangrove restoration · Lagoon-based fishing villages · Satellite imagery data · Northern Sri Lanka

JEL Classification O13 · Q23 · Q56

1 Introduction

Mangroves are one of the most precious and productive wetland ecosystems in the tropical and sub-tropical intertidal environments (Datta et al. 2012; ITTO 2002). They offer a wide array of ecosystem services such as protection of shorelines, mitigation of climate risks by carbon sequestration, maintenance of ecological stability, and support coastal livelihoods through increasing fish production

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(Aheto et al. 2016). Yet, Mangrove forests have been continuously depleted due to intensive human interventions such as aquaculture activities, conversion into agriculture fields and salterns, illegal logging for timber, settlements, and industrial developments (Friess et al. 2019; Webb et al. 2014). During the early years of twenty-first century, global Mangrove forests have experienced an average annual loss of 0.16% (Friess et al. 2019; Hamilton and Casey 2016). Due to the rapid and large-scale degradation, global Mangrove forests have eventually reached to a point where they can no longer sustain themselves unless proper management strategies come in to action. In the past, most of the global Mangroves were brought under the control of governments. However, the history has proven that state-owned management of Mangroves has utterly failed due to lack of resources, weak enforcement of laws, absence of local knowledge, and lack of follow-ups (Aheto et al. 2016; Datta et al. 2012; Walters 2004). This urges the need to find a more inclusive and sustainable management method for Mangrove conservation.

As a result of the past failures in centralized governance, community management approach was emerged as a better alternative in Mangrove management. Subsequently, many countries had switched their Mangrove management strategy from centralized approach in to more inclusive community-based approach with the expectation of achieving sustainable outcomes. On one hand, benefits of community-based management over centralized management approaches are extensively explored. The connection between Mangroves and the livelihoods of the local people is very tangible (Badola et al. 2012). Community members have obvious incentive to take part in Mangrove management as their livelihoods are highly dependent on the benefits received from Mangrove ecosystem services (Arifanti et al. 2022). Decentralization of powers can provide more attachment and a sense of ownership to the locals so that they can pay more attention in protecting their local resources rather than exploiting them for short-term gains (Aheto et al. 2016; Datta et al. 2012). Moreover, local people are well informed with the ground situation than any other external agents and possess traditional wisdom in Mangrove management (Eddy et al. 2016).

On the other hand, in reality, there are many challenges in implementing community-based Mangrove management due to institutional and political barriers, lack of incentives, strategic behavior of the community, and lack of autonomy (Milupi et al. 2017; Aslin et al. 2009; Menon et al. 2007; Bawa et al. 2007; Salam et al. 2006; Agrawal and Ostrom 2001; Sundar et al. 2001; Baland and Platteau 1996). Amidst the existing challenges, whether community-based management approach can be successful in managing the Mangroves has become an important policy question. The existing studies are mainly focused on the factors underlying the successes or failures of community-based Mangrove management and/or the pros and cons of community-based Mangrove management over centralized Mangrove management (Damastuti and Groot 2022; Arifanti et al. 2022; Datta et al. 2012; Walters 2004). However, the studies focusing on effectiveness of community-based Mangrove management is relatively scarce. Therefore, this study intends to provide solid empirical evidence on the effectiveness of community-based Mangrove management in the context of postwar Mangrove restoration in northern Sri Lanka. Through this investigation, this study intends to draw essential policy decisions to navigate future directions in Mangrove forest management in Sri Lanka.

1.1 Study context: Mangrove restoration in Sri Lanka

The condition of Mangroves in Sri Lanka is not an exception from the global context. Although Sri Lanka has over 6000 hectares of Mangroves with high biodiversity, the Mangrove forests were continuously destroyed and misused until recent years as they were de facto open access resources even though they were state-owned (Giri et al. 2015; Karunathilake 2003). Until recently, Mangrove forests were considered as marginal lands and dumping sites of household and industrial wastes (IUCN 2011). It is estimated that more than 70 percent of the Mangrove forest cover in the country were destroyed in the last century (Prakash et al. 2017). Promotion of aquaculture development activities is considered as one of the major factors causing heavy destruction of Mangrove forests in Sri Lanka. Worst effects of shrimp farming activities on Mangroves were realized in the north-western coast (i.e., Puttalam-Kalpitiya lagoon area and Chilaw) where the highest Mangrove density of the country is present. In this region, more than 50 percent of Mangroves were destroyed due to shrimp farming activities between 1992 and 1998 (Harkes et al. 2015). Along with that, rapid expansion of urban settlements in the coastal areas, pollution, and illegal logging also pose serious threat on the existence of remaining Mangroves (Priyashantha and Taufikurahman 2020; Ranawana 2017).

However, after the Indian ocean tsunami in 2004, the Sri Lankan government realized the importance of protecting Mangrove forests as natural barriers against ocean surges and storms. Subsequently, the government had taken commendable efforts (i.e., establishment of Mangrove nurseries with the support of INGOs, initiate Mangrove restoration activities with community support, opening of world's first Mangrove museum) to protect the existing Mangrove reserves and promote rehabilitation of degraded Mangrove forests in the country. Currently, the Mangrove forests in Sri Lanka are managed by the state-run forest department under Act, No. 65 of 2009. In 2015, Sri Lanka had pledged as the first nation to protect all its Mangrove reserves under the purview of national legal framework (Seacology 2016). After a series of discussions and amendments on the existing regulations, "National policy on conservation and sustainable utilization of Mangrove ecosystems" was formulated by the Sri Lankan government in 2020.

As part of the Mangrove management, large-scale Mangrove restoration activities were started by the central government with the technical and financial support received from international agencies. Although the Mangrove restoration in Sri Lanka is state-driven, community organizations at the village level are one of the key players in the Mangrove restoration activities. Community organizations (i.e., Fishermen Cooperative Societies (FCS)) are mainly involved in mobilizing community labor for Mangrove restoration. FCS connects almost all fishing households in the coastal villages. During the regular meetings held by FCS, activities related to Mangrove restoration are discussed in detail with the local people. Both fishing and non-fishing households including youth and women members who take part in the meetings are engaged in Mangrove restoration activities such as planting Mangrove seedlings, protecting the restored sites, protecting the existing Mangrove reserves, and Mangrove nursery management. Moreover, substantial amounts of valuable inputs i.e., time, labor, money, material inputs, and technical skills are being devoted to the Mangrove restoration activities. According to Seacology (2016), one of the largest Mangrove conservation programs implemented recently in Sri Lanka was launched with the estimated budget of nearly US $ 3.4 million over 5-year period (2016–2020). In this project, Mangrove restoration activities were mainly carried out by the community members and local NGOs (i.e., Sudeesa) using the financial and technical support provided by an international organization i.e., Seacology, with the expectation of restoring Mangroves over 10,000 acres while protecting the existing Mangrove reserves in the country. Despite such large-scale ongoing efforts of Mangrove restoration, the outcomes of Mangrove restoration activities in Sri Lanka are still questionable due to lack of prior assessments on the local conditions, lack of incentives to the local communities, limited access, and lack of coordination between the state authorities and local communities (Kodikara et al. 2017; Ranasinghe 2012).

Initially, the Mangrove restoration was mainly targeted in southern Sri Lanka since Mangroves in the north were remained inaccessible due to the civil war. Therefore, the current status of Mangroves in the northern region is largely unknown. However, after the war, the government put more focus on facilitating community-participatory Mangrove restoration in the war-affected areas, especially in the northern province. Although the Mangrove restoration is state-driven, the success of Mangrove restoration activities highly depends on the active participation of local communities. However, as a war-affected community, whether the local people in the northern region have enough incentive and motivation to take part in the Mangrove restoration is remain unclear as it largely depends on the contextual factors. On the one hand, shared war trauma can incentivize the local communities to work together and exhibit cooperative behavior in postwar environmental restoration. On the other hand, war trauma may also generate anti-social responses among the war-affected communities when the community networks are fully collapsed and the basic needs of war-affected people are unfulfilled. Therefore, effectiveness of community-participatory approach in Mangrove restoration remains as an important policy question. Using a rigorous empirical approach, this study aims to investigate whether community participation in Mangrove restoration has produced any favorable outcomes in Mangrove conservation in northern Sri Lanka.

2 Methodology

2.1 Description of the study area

This study focuses on the four coastal districts in the northern province of Sri Lanka (i.e., Jaffna, Mannar, Kilinochchi, and Mullaitivu) (Fig. 1). Northern province is surrounded by Indian ocean in the north, east and west and only sharing the terrestrial borders with other provinces in the south. Total population of the northern province

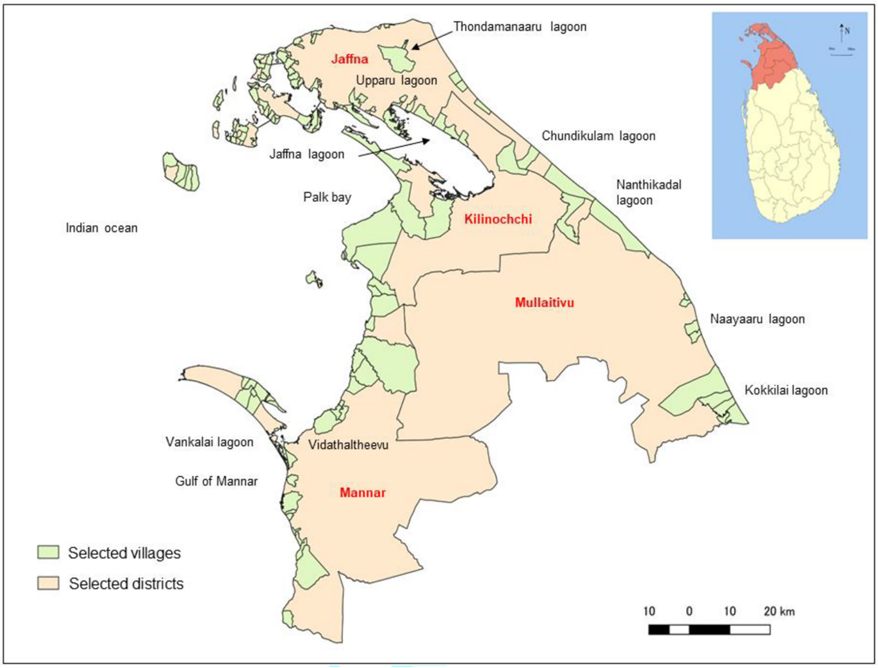

Fig. 1 Map of the Study Area (Source: Authors' construct)

is approximately 1.25 million in which around 80% of the population lives in the rural areas. Agriculture and artisanal fishing are the primary livelihoods of the rural people. Northern province has the longest coastline (431 km) and highest number of lagoons and estuaries which consist abundance of valuable coastal resources including Mangroves, salt marshes, and coral reefs.

Northern province of Sri Lanka has 40–45% of the total Mangrove coverage in the country including the second largest Mangrove forest reserve (Edirisinghe et al. 2012). Small scale fishermen who live in the coastal villages are the direct beneficiaries of Mangrove ecosystem services. They usually engage in the artisanal inshore fishing activities near to the Mangrove areas. In the past, coastal communities were engaged in the extraction of Mangrove-derived products such as firewood, timber, and barks from the Mangrove forests. Currently, extraction of such resources is legally prohibited under the state governance. Also, the locals' access to Mangrove forests is highly restricted except doing the fishing activities in the Mangrove areas. However, still the local communities are supported by the indirect benefits of Mangrove ecosystem services.

2.2 Data collection

This study uses the data collected from 131 lagoon-based fishing villages located in the all four coastal districts of the northern province during 2009 to 2020. Data were collected at Grama Niladhari (GN) level which is the smallest administrative unit in Sri Lanka. Coastal villages that are located near to the lagoon areas with considerable extent of Mangrove patches and consist large number of lagoon fishermen (mainly doing fishing activity in the Mangrove area) were selected for this study. The background information of the current Mangrove management practices was collected from the state authorities which are actively engaged in the Mangrove management in this region. The data were mainly collected through primary and secondary sources. Details on community participation were collected through a village survey done among the community organizations. Also, socioeconomic information of villages was obtained from the annual statistical handbooks provided by the divisional secretariat offices in each target district. In addition to the field data, remote sensing data were collected to estimate the extent of Mangrove forest cover and Mangrove density in the study area.

2.3 Description of the variables

2.3.1 Measures of Mangrove performance (outcome variables)

As shown in Table 1, this study uses Mangrove forest cover, Mangrove density, and the local fish productivity measures such as per boat values of annual fish production, gross revenue from fisheries per boat, per capita values of fish production and gross revenue at village level as the outcomes (Y_{it}) to explain performance of the Mangrove restoration. To control for the effect of increase in fishing effort over the past, fish production values are measured per boat. The data on fish production were mainly collected from the Department of Fisheries and Aquaculture in each target district. Mangroves play a vital role to enhance fish productivity through providing nutrient-rich breeding ground and protective environment for the proliferation and sustenance of fish stock (Barbier and Strand, 2003; Barbier 1998). Therefore, fish productivity in the lagoon areas can be a good indicator of Mangrove conditions.

Estimation of Mangrove forest cover using satellite imagery data and GIS. In this study, Mangrove forest cover and Mangrove density were estimated using cloud-free satellite images of Landsat-7 ETM + and Landsat-8 OLI/TIRS collected from USGS database during 2009–2020. The details of the satellite images used in this study are shown in Table 2. Since each satellite image covers part of the study area, in total, we collected 107 Landsat images to capture all the study villages in four coastal districts. After performing atmospheric correction of the satellite images, the satellite data were used for the estimation of Mangrove cover in the target study villages using GIS. The estimation process is explained as below.

Effective Mangrove mapping requires a tool that can clearly distinguish the pixels of Mangroves from other land features on the satellite images. For this purpose, this study adopts Mangrove vegetation index (MVI). Following Baloloy et al. (2020), MVI was calculated for each satellite image by using the following formula (Eq. 1). MVI values are not directly used in the regression models but they were used to estimate Mangrove forest cover and Mangrove density as measures of Mangrove performance.

Table 1 Descriptive statistics of the variables collected from 131 lagoon-based fishing villages in the Northern province of Sri Lanka for the period 2009–2020

Description of the variables and units	Mean	Standard Deviation	Minimum	Maximum
Outcome Variables				
Mangrove coverage (square kilometers)	0.2161	0.1850	0	0.9974
Mangrove density (Mangrove cover / village area)	0.1046	0.2074	0	2.0780
Fish production per boat (Mt/year/boat)	11.0171	15.5321	0	147.55
Gross revenue from fisheries per boat ('000 LKR/year/boat)	4465.892	6305.143	0	56,004.77
Fish production per capita (Mt/year/person/boat)	0.0018	0.0056	0	0.0785
Gross revenue per capita ('000 LKR/year/person/boat)	0.7443	2.2063	0	30.9722
Key variable of interest				
Ratio of community participation (Number of participants / total village population)	0.144	0.208	0	0.932
Instrumental variable (proxy of war damage)				
Number of forced displacements during the war	1.3206	1.4375	0	8
Village characteristics				
Time-variant variables				
Total village population	1652.777	1041.648	111	5577
Sex ratio (Male:Female)	1.084	0.8	0.13	8.776
Average household size	4.724	0.888	3	7
Number of schools	0.913	0.696	0	4
Population density	919.559	1509.199	1.4947	15,604.03
Household density (per acre)	5.079	3.215	1.333	32
Ratio of lagoon fishermen	0.732	0.138	0.33	0.99
Number of boats with in-boat engines	0.581	2.767	0	34
Number of boats with out-boat motors	23.198	35.125	0	230
Number of traditional fishing crafts	19.464	32.922	0	395
Labor wage_male (LKR/day) (in real monetary terms)	1326.458	514.909	611	2475
Labor wage_female (LKR/day) (in real monetary terms)	945.734	298.611	470	1650
Dependency ratio	0.341	0.081	0.142	0.593
Total number of resettled families	50.539	45.152	0	234
Unemployment ratio	0.139	0.062	0.02	0.35
Fishing expenditure per capita (LKR/month/person)	632,334	223,411.2	200,000	1,125,000
Time-invariant variables				
Village area (sq.km)	8.1682	15.148	0.298	102.15
Distance to district capital (km)	15.586	9.872	0.5	40
Ethnicity_Sri Lankan Tamils	0.874	0.265	0	1.00
Ethnicity_Muslims	0.119	0.267	0	0.995

Table 1 (continued)

Description of the variables and units	Mean	Standard Deviation	Minimum	Maximum
Ethnicity_Sinhalese	0.0026	0.0127	0	0.11
Ethnic diversity (Shannon–Weiner index)	0.1236	0.1673	0	0.8868
Community conflict	0.0458	0.2091	0	1
Number of landing sites	1.107	0.483	0	4
Access to market	0.832	0.374	0	1
Access to credit facilities	0.9770	0.1496	0	1
Aquaculture activities	0.099	0.299	0	1
Distance from households to nearest landing site (km)	0.787	0.343	0.25	1.5
Distance from households to restoration area (km)	1.17	0.883	0.2	5
Distance from Mangrove area to the main road (km)	2.445	1.508	0.15	8
Distance from district capital (km)	15.586	9.872	0.5	40
Approx. length of coastline (km)	0.977	0.700	0.2	4
Availability of Mangroves after war (dummy)	0.5190	0.499	0	1
Total number of observations: 1572				

Table 2 Details of the satellite images used for this study (2009–2020)

Serial No	Path/Row	Sensors used	Number of images taken	Districts covered within the study area
1	142/53	ETM+, OLI/TIRS	36	Jaffna, part of Kilinochchi
2	142/54	ETM+, OLI/TIRS	36	Mannar, part of Kilinochchi
3	141/54	ETM+, OLI/TIRS	35	Mullaitivu

Source: United States Geological Survey (USGS) Database (Landsat 7 and Landsat 8 images) http://www.earthexplorer.usgs.gov

$$Mangrove\ vegetation\ index\ (MVI) = \frac{(NIR - Green)}{(SWIR\,1 - Green)} \quad (1)$$

In here, NIR: Reflectance value of Near Infrared band, SWIR1: Reflectance value of Shortwave Infrared 1, Green: Reflectance value of green band.

MVI is known to have important properties that can be used for Mangrove mapping with high accuracy and universal applicability (Prayudha et al. 2021; Baloloy et al. 2020). In here, numerator and denominator of the equation represents greenness and moisture level of the selected pixel range respectively. Shortwave infrared 1 (SWIR1) bands are highly sensitive to water content present within and around the vegetation. As SWIR 1 bands can be largely absorbed by water, the pixels which correspond to Mangroves on the satellite image may show extremely lower reflectance values for SWIR 1 bands, and thus result in higher MVI for Mangroves. Using this unique property of MVI, Mangroves can be easily identified and separated from other land features on the satellite image.

To obtain high precision in Mangrove mapping, we estimated MVI values for different land cover classes using the training data of the study area. Since we do not have ground truth data of the land features, training data representing different land cover classes in the study region were collected from Google Earth. In total, 15 training samples were collected under each land cover class (i.e., Mangroves, irrigated crop lands, terrestrial forests, shrubs, inland water bodies, barren lands, and built ups) for each time period. After obtaining the training data, we estimated mean, minimum, and maximum MVI values for each land cover classes using MVI satellite data. As per our expectation, we found that the minimum MVI threshold value of Mangroves is relatively higher, and not overlap with the maximum MVI thresholds of other land cover classes (Fig. 2). Therefore, minimum MVI value of Mangroves was used as a threshold point to carefully separate the Mangroves from the pixels of non-Mangrove land features. Since the village boundaries are already defined using the shapefiles of administrative boundaries of Sri Lanka, we identified the pixels of Mangroves that come under each target village (Fig. 3). Finally, using GIS, we estimated the extent of Mangrove coverage given by the pixel range within each target village. Estimated Mangrove coverage (in square kilometers) and Mangrove density (Mangrove cover /village area) are used as our outcome variables (Y_{it}) in Eq. 2 to explain Mangrove performance.

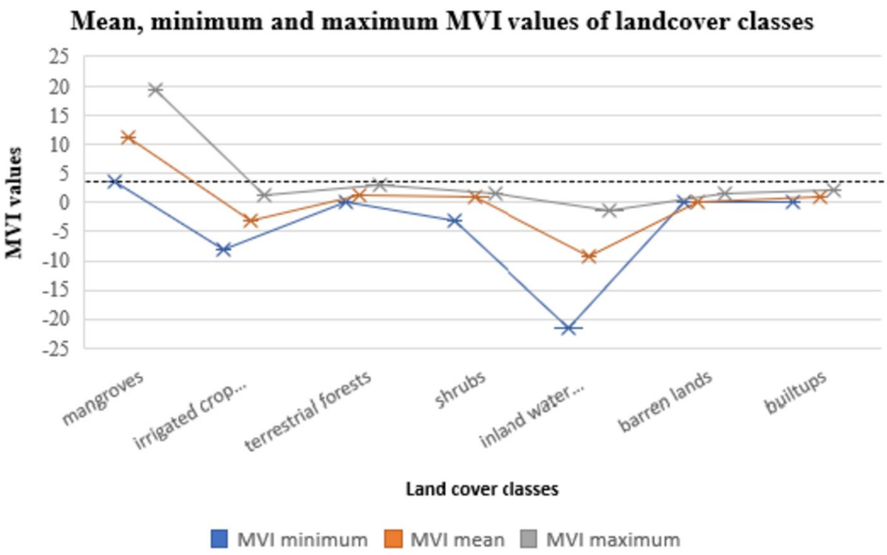

Fig. 2 Mean, minimum, and maximum Mangrove Vegetation Index (MVI) values of training samples representing each landcover class. [a]Minimum MVI value of Mangrove is higher than the maximum MVI values of other land cover classes and not overlapped. [b]Minimum MVI value of Mangroves (3.5) is identified and used as the threshold value for Mangrove separation from non-Mangrove land features. (Source: Authors' construct)

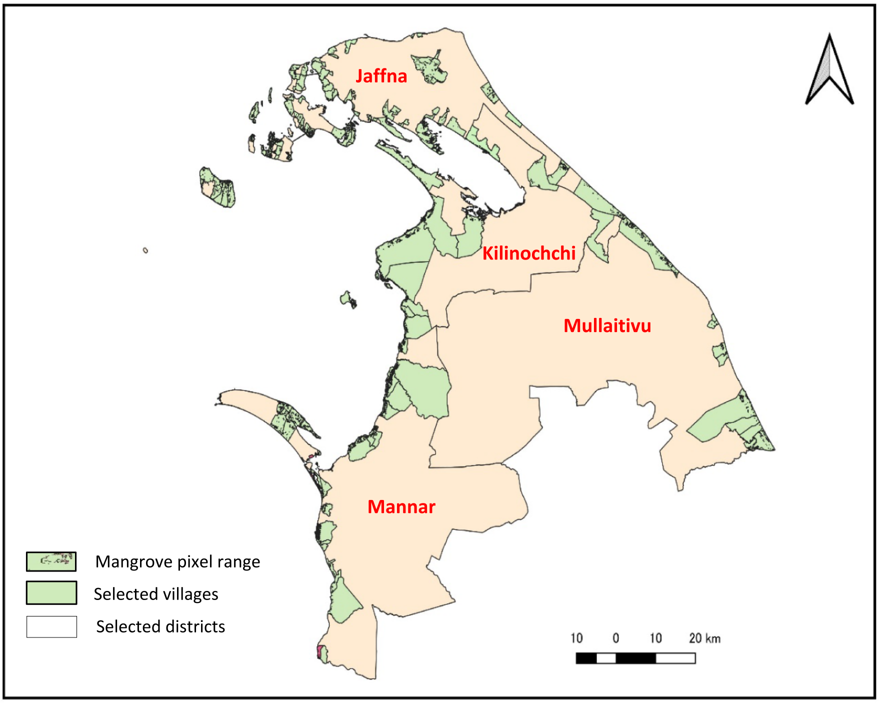

Fig. 3 Identification and separation of pixels representing Mangroves in each target village using the minimum MVI threshold of Mangroves (Source: Authors' construct)

2.3.2 Key variable of interest

In this study, community participation is defined as direct involvement of the local people in Mangrove restoration activities such as planting of Mangrove propagules, protecting the restored areas, protecting the existing Mangroves, and nursery management. To account for the size of villages, we measured community participation as the ratio of total number of participants in Mangrove restoration out of total village population (P_{it}). Community participation data were mainly collected from the community organizations (i.e., FCS) which are actively involved in Mangrove restoration in the study area.

2.3.3 Proxy for war damage

In this study, war exposure (Z_{it}) is measured by the number of forced displacements during the war. Higher the war damage, the more is the chance of being displaced. Therefore, *number of forced displacements during the war* can be a good proxy for war damage. *Number of forced displacements* means how many times the whole village population were forcibly displaced during the war. Such whole village displacements occurred in some of the villages during the entire period of war (1980–2009) in northern Sri Lanka, where the people were forcibly displaced from their native villages by armed forces and were usually stayed in IDP camps till the end of the war. After the war, most of them were settled back to their own villages. The data on the number of forced displacements during the war and other related information were collected using key informant interviews held with the senior members of the village organizations and local authorities.

2.3.4 Control variables

Apart from the effect of community management, Mangrove restoration can be highly influenced by wide range of environmental and socioeconomic conditions. First, increase in Mangrove forest cover may be the result from natural regeneration of the existing Mangrove reserves in the restored areas. To address the effect of the existing Mangroves, we incorporate lagged terms of Mangrove forest cover as controls in our regressions.

In this study, local fish production is used as an indicator of Mangrove performance. However, the condition of Mangroves may not be the only reason to increase fish production. There are various other factors (i.e., fishing effort, number of fishermen, fishing expenditure, and regulatory policies on fish catch) which may also directly affect fish production. Therefore, we control for those factors that can be highly correlated with the local fish production. Fishing effort is proxied by the number of fishing boats owned by the local communities. Since the samples are mainly represented by small-scale (lagoon-based) fishermen, the number of low-mechanized and traditional fishing crafts are relatively higher in proportion than the number of mechanized or in-boat motor boats. Fishing boats are usually registered under fishermen cooperatives. Although there is no clear definition of fishing territory for each community, villagers usually keep their boundaries while engaging in nearshore or lagoon-based fishing activities so that the externalities imposed on the fishing activities of other villagers are relatively small. Fishing expenditure includes paid out costs incurred for fishing gears, maintenance, fuel, and labor charges. Also, we control for the socioeconomic conditions that could be highly correlated with fish production such as size of fishing villages, proportion of lagoon-based fishermen in the village, access to landing sites, access to marketing and credit facilities. The data on fish production and other related information were collected from the annual statistical reports of the local authorities i.e., divisional secretariat offices and the department of fisheries and aquaculture.

In addition, village-level socio demographic characteristics can also influence community attitudes towards Mangrove management. Therefore, we include village-level socio demographic information as controls in the regressions. Villages with high population density may often encounter the problems of unsustainable resource extraction due to increase in demand for local household needs. Likewise, accessibility to Mangrove forests, access to other resources, and daily wage rates for hired labor can affect the opportunity cost for community participation in Mangrove management. Moreover, the factors which may affect social cohesion can also determine the cooperative action of community members in Mangrove restoration. To account for this, we have included variables such as sex ratio, ethnic diversity, ethnic composition of villages, and community conflict. The summary statistics show that the villages are relatively homogenous, and predominantly occupied with Sri Lankan Tamils who are ethnic minorities and the mostly affected people during the civil war. Sinhalese and Muslims are in fewer proportions. Finally, socioeconomic status of the local communities can also have a huge influence on social engagement of the local communities. For example, the community members with low social status may less likely to engage in community development activities due to low self-esteem and fear. This data includes dependency ratio, and unemployment ratio to capture the effects of social status. The data on village-level socioeconomic characteristics were obtained from the annual statistical records of the divisional secretariat offices.

2.4 Empirical model

This study analyzes the causal effect of community participation on the performance of Mangrove restoration. However, community participation has serious endogeneity problem due to selection bias and reverse causality. Although we are interested in estimating the effect of community participation on Mangrove performance, community participation in Mangrove restoration is highly depended on the condition of Mangroves. Therefore, the causal effect can go in both directions. To identify the one-way causal relationship (i.e., effect of community participation on Mangrove restoration performance), a rigorous empirical approach is necessary. Fixed effects can control for time-invariant unobserved heterogeneity but it cannot fully address the endogeneity problems. Therefore, following Wooldridge (2010), this study adopts instrumental variable approach (IV) with two-stage least squares technique (2SLS) to control for the endogeneity issues. In the first stage (Eq. 3), ratio of community participation is regressed on the instrumental variable and other exogenous variables. Then, the predicted estimates derived from the first stage is included in the outcome equation (Eq. 2) to obtain consistent estimates.

$$\mathrm{Y_{it}} = \alpha + \beta\widehat{\mathrm{P}}_{\mathrm{it}} + \gamma\mathrm{X_{it}} + \mathrm{C_i} + \delta\mathrm{T_t} + \mathrm{U_{it}} \tag{2}$$

$$\text{First}-\text{stage equation}: \mathrm{P_{it}} = \pi_0 + \pi_1(\mathrm{Z} \times \text{year})_{\mathrm{it}} + \mu\mathrm{X_{it}} + \mathrm{C_i} + \tau\mathrm{T_t} + \mathrm{V_{it}} \tag{3}$$

In here, $\mathrm{Y_{it}}$ indicates the performance measures of Mangrove restoration in village i in year t. Performance measures include Mangrove forest cover, Mangrove density, and the local fish productivity measures such as per boat values of annual fish production, gross revenue from fisheries, per capita values of fish production and gross revenue. $\widehat{\mathrm{P}}_{\mathrm{it}}$ denotes the predicted estimates of the ratio of community participation in Mangrove restoration from village i in year t. Our parameter of interest is given by β. $\mathrm{Z_{it}}$ indicates the proxy for war damage which is used as the instrumental variable. However, the proxy for war damage (i.e., *number of forced displacements*) is time-invariant. Therefore, we use *number of forced displacements* as interaction terms with year dummies. $\mathrm{X_{it}}$ indicates the vector of time-variant controls including the socioeconomic characteristics of the villages. In this model, time-invariant unobserved heterogeneities across the villages are captured by village fixed effects (C_i). Also, time-specific trends i.e., seasonal changes are controlled by year fixed effects (T_t). U_{it} and V_{it} are random errors.

2.4.1 Justification of instrumental variables

Interaction terms between the number of forced displacements during the war (proxy for the war damage) and year dummies are used as instrumental variables (IVs) in our estimation framework.

In Sri Lankan context, Mangrove degradation is independent of the civil war. Mangrove restoration activities were started even before the aggravation of the war, especially after the Indian ocean tsunami in 2004. This implies that our IV can satisfy the condition of exclusion restriction. Furthermore, shared war trauma can cause prosocial changes. The locals who are affected by war tend to develop better social relations as a war coping strategy (Barcelo 2021; Bauer et al. 2014; Bellows & Miguel 2009). Such war-induced prosocial changes can be retained among the war-affected communities even several years after the war, and thus can contribute to their collective action in the postwar community-based environmental restoration activities.

In war-affected villages, they could not fish for several years and hence fish population may have increased compared to villages with less affected by the war. Also, Mangrove condition may be better in villages where the Mangrove forests were remained inaccessible for long period. If it is so, war is related to fish production even if it is not related to Mangrove condition. Therefore, we have addressed this issue by adding the baseline condition of Mangroves as well as the lagged values of Mangrove cover as additional control variables in the regressions.

3 Results and discussion

Determinants of community participation are presented in Table 3. The results show war exposure is significantly and positively correlated with community participation. The positive effect of war exposure on community participation can be explained through two possible pathways. First, war exposure can trigger the development of social capital among the war affected communities. War-affected people tend to have better social connections as a war coping strategy or as an informal insurance so that they can manage the adversities of the war. Such war-induced social connections can persist even several years after the war and foster cooperative action in postwar community development. Another possible reason is that members from the war-affected communities are highly likely to have social interactions among them as well as with the local authorities while receiving postwar livelihood assistance. Having better connections with the local organizations is the only hope for them to express their needs to government officials. This may further strengthen social networks between the local people and community organizations and thereby facilitate their collective community action in postwar development activities.

In here, the war exposure variable i.e., number of forced displacements is time-invariant. Therefore, we use interaction terms between the number of forced

Table 3 Determinants of community participation (results generated using Fixed effects method specified in Eq. 3)

Ratio of community participation	Coefficient
Number of forced displacements × year (base year: 2009)	
c.wvillage_displacement#i2010.year	0.0016 (0.0017)
c.wvillage_displacement#i2011.year	0.0077 (0.0023)***
c.wvillage_displacement#i2012.year	0.0346 (0.0142)**
c.wvillage_displacement#i2013.year	0.0371 (0.0116)***
c.wvillage_displacement#i2014.year	0.0308 (0.0132)**
c.wvillage_displacement#i2015.year	0.0110 (0.0158)
c.wvillage_displacement#i2016.year	0.0300 (0.0167)*
c.wvillage_displacement#i2017.year	0.0530 (0.0137)***
c.wvillage_displacement#i2018.year	0.0381 (0.0107) ***
c.wvillage_displacement#i2019.year	0.0390 (0.0103) ***
c.wvillage_displacement#i2020.year	0.0213 (0.0086) **
Sex ratio	0.0044 (0.0044)
Labor wage (male)	0.00003 (0.00003)
Labor wage (female)	0.0001 (0.00005) **
Ratio of lagoon fishermen	0.1236 (0.1933)
Dependency ratio	− 0.1567 (0.4088)
Unemployment ratio	− 1.5121 (1.1972)
Fishing expenditure per capita	2.19 e-07 (1.73 e-07)
Adjusted R-squared	0.4627
Number of observations	1572
Village fixed effects	Yes
Year fixed effects	Yes
Weak IV test	**13.82**

Bold value indicate the F-statistics of the Weak instrument (IV) test (F>10) confirms that the model does not have a problem of weak instrument bias

Significance levels: ***p < 0.01, **p < 0.05, *p < 0.1

Clustered robust standard errors are given in parentheses

2009 is assumed as the base year

displacements and year dummies as a proxy for the war damage. Moreover, the interaction terms can capture the time-dynamic effects of war exposure in the post-war community action. The results show connection between the war exposure and community participation is relatively weak during the initial period immediately after the war, and gradually increased over time. This can be explained by low levels of social connectivity immediately after the war due to low resettlement rate and poor infrastructure facilities. However, the situation has gradually improved over time.

Results in Table 3 also indicate that the postwar community participation is highly influenced by the local conditions. Positive and significant coefficient of female wage can be explained as follows. War-affected villages have large number of women-headed families, and most of them are relied on livelihood assistance support to restart their economic activities. Most of the postwar livelihood assistance programs target women empowerment through facilitating home-based entrepreneurial activities such as coir production, handloom weaving, handicraft production, and food making. The female participation in such entrepreneurial activities may decrease their availability in labor market and thus result in high female wage rate. At the same time, participation in entrepreneurial activities may increase their free time due to flexible time schedules in working hours so that they can contribute more in the community activities.

Although the coefficients are not significant, the results also show proportion of lagoon fishermen has a positive relationship with community participation, whereas high level of unemployment and dependency ratio decreases community participation. The local fish production is highly depended on the condition of Mangroves. Resource dependency may incentivize the lagoon fishermen to be actively involved in the Mangrove management activities. Furthermore, high degree of fishing activities can promote social interactions and mutual trust between the community members and thereby facilitate their cooperative action in the community development activities. On the other hand, low social status i.e., unemployment may reduce social engagement of the community members. Unemployment is considered as a negative social phenomenon. It has serious consequences on the moral and economic well-being of individuals. For instance, opportunity cost for the unemployed people to get involved in the voluntary-based community development activities is high since they are deprived of earnings to satisfy their basic livelihood needs. So, they are more prone to social pressure and thus may result in social exclusion.

To check for the validity of our instruments used in the first-stage, we performed weak instrument test (F test) and found that F-statistics is greater than 10, suggesting the instrumental variable is good enough to explain variation in the endogenous variable (i.e., community participation) and the model does not have the problem of weak instrument bias.

Table 4 shows IV estimates explaining the impact of community participation on Mangrove restoration. In here, Mangrove coverage and local fish productivity measures are used to explain the performance of Mangroves. The results indicate community participation has a significant and positive impact on the performance of Mangrove restoration. According to the results, a unit increase in the ratio of community participation is estimated to enhance the Mangrove forest cover and density in a village approximately by 0.15 sq.km and 0.22% respectively. Likewise, annual fish production per boat and fish production per capita in a village are increased by 31.3 MT/year/boat and 0.12 MT/year/person/boat respectively. Also, the results indicates that a unit increase in ratio of participation leads to an increase of gross revenue from fisheries and gross revenue per capita by LKR 13,567,870/ year/ boat (42,060 USD/year/boat) and LKR 3690/ year/ person/ boat (11.44 USD/ year/ person/ boat) respectively.

The positive impact of community participation on Mangrove restoration can be explained as follows. Since the livelihoods of local people are inter-connected with Mangroves, community engagement in Mangrove management can trigger a sense of ownership among the local people and thereby create more awareness on

Table 4 Impact of community participation on Mangrove restoration performance (Results generated using instrumental variable (IV) method)

	Mangrove forest cover (sq. km)	Mangrove forest cover (sq. km)	Mangrove density (Mangrove coverage / village area)	Mangrove density (Mangrove coverage / village area)	Fish production per boat (Mt/year/boat)	Fish production per boat (Mt/year/boat)	Fish production per capita (Mt/year/person/boat)	Fish production per capita (Mt/year/person/boat)	Gross revenue from fisheries per boat (000LKR/year/boat)	Gross Revenue from Fisheries per boat (000LKR/year/boat)	Gross revenue per capita (000 LKR/year/person/boat)	Gross revenue per capita (000 LKR/year/person/boat)
Ratio of community participation	0.152** (0.0666)	0.256*** (0.0217)	0.216* (0.1289)	0.124*** (0.0218)	31.307* (18.5964)	12.913*** (4.5080)	0.009** (0.0040)	0.0005 (0.0011)	13,567.87* (7804.87)	4782.73*** (1811.761)	3.689** (1.6554)	0.079 (0.4748)
Village FE	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Year FE	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Controls	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Observations	1572	1572	1572	1572	1572	1572	1572	1572	1572	1572	1572	1572

Significance levels: ***$p < 0.01$, **$p < 0.05$, * $p < 0.1$

Robust standard errors are given in parentheses (Standard errors are clustered at village level)

To control for the effects of the existing Mangroves, lagged variables of the Mangrove forest cover (L1, L2, L3) are included in the regression models

Cragg-Donald Wald F-statistics for all the first-stage IV regressions are greater than 10

Local fish market prices are adjusted for inflation using CPI. (Base year: 2009)

1 Sri Lankan Rupee (LKR) = 0.0033 USD (Reference year: 2023)

Control variables include: sex ratio, distance from capital, access to market (dummy), labor wage_male, labor wage_female, distance to landing site, ratio of lagoon fishermen, approx. length of coast line, number of landing sites, dependency ratio, unemployment ratio, fishing expenditure per capita, interaction terms between the availability of Mangroves after war and year dummies protection and sustainable use of Mangrove resources. Also, community members can engage in continuous follow-up of restoration activities as they live in proximity to the restoration sites. Engaging local communities may enhance the success rate of Mangrove restoration as the local people have more site-specific knowledge and traditional wisdom in Mangrove management. In addition to that, engaging more local people may help to reduce the problems of information asymmetry and thereby reduce the cost burden of Mangrove management activities. Therefore, it is obvious that community participation in Mangrove management can improve the condition of Mangroves (i.e., Mangrove forest cover and density) in the Mangrove-restored areas through which it may enhance the local fish production. The result implies the importance of strengthening community management practices for sustainable Mangrove management. From the viewpoint of the implementing agencies (eg: state organizations, NGOs), mobilizing the local communities is a vital strategy for the long-term success of Mangrove restoration activities although it is quite challenging to do so unless proper allocation of ownership rights and incentives to the local communities are in place.

As for robustness checks, we run IV regressions without including village fixed effects, year fixed effects, and controls. The results are also shown in Table 4, and we found that our results are highly consistent with the main findings. To verify the validity of instrumental variable, we perform reduced form regression analysis (i.e., regressions that directly link outcome variable with exogenous instrument) for some of the key outcomes. The results of the reduced form equations (Pooled OLS) are presented in Table 5. The results confirm that there is no direct relationship between the instrumental variable and the outcomes, suggesting the validity of our instrumental variable.

4 Conclusions and policy recommendations

Mangrove management is always given a paramount importance in the global policy agendas. However, finding an appropriate management strategy has always been a challenging task. Due to the inefficacies of centralized management, community-based management was evolved as a better alternative in Mangrove management. Subsequently, many countries around the world switched their Mangrove management strategy from centralized approach in to a more inclusive community-based approach with the expectation of achieving sustainable outcomes. However, in contrast to those initial expectations, the outcomes of community-based Mangrove management are far from satisfactory due to institutional and political barriers. Therefore, an important policy question still remains as to whether the community-based management can be a successful approach in Mangrove management.

This study aims to provide empirical evidence on the effectiveness of community-participatory Mangrove management in the context of northern Sri Lanka. The unique setting of community-participatory Mangrove restoration in the postwar setting in northern Sri Lanka makes this investigation more interesting. The main finding of this study shows community participation has a significant and positive effect on Mangrove performance. The finding suggests the government should implement

Table 5 Robustness check for the validity of the instrumental variable (Results of the reduced form linear regressions)

	Mangrove forest cover (sq.km)	Mangrove density (Mangrove coverage /village area)	Fish production per boat (Mt/year/boat)	Gross revenue from fisheries per boat (000LKR/year/boat)
Number of forced displacements (IV)	0.0012 (0.0010)	0.0365 (0.0279)	1.0429 (0.8582)	412.3517 (346.9766)
Controls	Yes	Yes	Yes	Yes
Lagged Mangrove cover (L1, L2, L3)	Yes	Yes	Yes	Yes
Observations	1572	1572	1572	1572

Significance levels: ***$p<0.01$, **$p<0.05$, *$p<0.1$

Robust standard errors are given in parentheses (Standard errors are clustered at village level)

To control for the effects of the existing Mangroves, lagged variables of the Mangrove forest cover are included in the regression models

Local fish market prices are adjusted for inflation using CPI. (Base year: 2009)

1 Sri Lankan Rupee (LKR) = 0.0033 USD (Reference year: 2023)

Control variables include: sex ratio, distance from capital, access to market (dummy), labor wage_male, labor wage_female, distance to landing site, ratio of lagoon fishermen, approx. length of coast line, number of landing sites, dependency ratio, unemployment ratio, fishing expenditure per capita, availability of Mangroves after war necessary policy measures to facilitate community-participatory Mangrove management by addressing the limitations. Devolution of more powers, access, and sharing responsibilities of Mangrove management with the local communities can trigger a sense of ownership among the local people and thereby incentivize them to protect their own local resources. As the Mangrove restoration activities are mainly initiated by the state, facilitating frequent and smooth interactions between the state authorities and local communities can promote community engagement in Mangrove restoration.

This study has also found the positive effect of war on community participation in Mangrove restoration. Because the people were exposed to a prolonged violence, they might have developed better social connections among them as a war coping strategy. Such social connections can remain in the war-affected society even several years after the war and facilitate their cooperative action in community development. It suggests inclusion of the war-affected communities can be a viable strategy to promote Mangrove restoration in the war-affected areas. Also, the finding provides a sense of hope at least after the end of violence, to engage the local communities in postwar community development. This necessitates the need of the state authorities to take necessary actions for strengthening the conflict-induced prosocial changes (i.e., social capital development) in the war-affected society. For example, the government can facilitate the creation of new social networks or revive defunct community centers in the war-torn areas. Also, the state authorities should strengthen the existing community networks by providing financial and technical assistance. On the other hand, war-affected population often face challenges due to sub-optimal living conditions and limited opportunities. Therefore, introducing more eco-friendly livelihood options (i.e., silviculture, eco-tourism development, and collection and selling of non-timber goods) to those target communities may enhance their awareness on protecting the Mangrove resources and promote their participation in Mangrove management. The findings also show that the community participation in Mangrove restoration is highly influenced by socioeconomic status of the local people, suggesting the local authorities should focus more on the existing local conditions as well as the locals' needs before implementing any kind of community development activities.

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Declarations

Conflict of interest None.

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