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Original article

An interdisciplinary framework to evaluate bioshield plantations: Insights from peninsular India

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ABSTRACT

Bioshields or coastal vegetation structures are currently amongst the most important coastal habitat modification activities in south-east Asia, particularly after the December 2004 tsunami. Coastal plantations have been promoted at a large scale as protection against severe natural disasters despite considerable debate over their efficacy as protection measures. In this paper, we provide an interdisciplinary framework for evaluating and monitoring coastal plantations. We then use this framework in a case study in peninsular India. We conducted a socio-ecological questionnaire-based survey on government and non-government organizations directly involved in coastal plantation efforts in three 2004 Indian Ocean tsunami affected states in mainland India. We found that though coastal protection was stated to be the primary cause, socio-economic factors like providing rural employment were strong drivers of plantation activities. Local communities were engaged primarily as daily wage labour for plantation rather than in the planning or monitoring phases. Application of ecological criteria has been undermined during the establishment and maintenance of plantations and there was a general lack of awareness about conservation laws relating to coastal forests. While ample flow of international aid has fuelled the plantation of exotics in the study area particularly after the Indian Ocean tsunami in 2004, the long term ecological consequences need further evaluation and rigorous monitoring in the future.

1. Introduction

Bioshields are defined as coastal vegetation used or promoted for protection of the coast from extreme events such as storms and tsunamis (Mukherjee et al., 2010). Bioshields range from pristine ecosystems (*e.g.* mangroves) to coastal monoculture plantations (*e.g. Casuarina equisetifolia*) (Feagin et al., 2010). The establishment of bioshield plantations is currently one of the major coastal habitat modification activities in the Asia Pacific region (ITTO/ISME, 2008). In the aftermath of severe natural disasters in the past decade (*e.g.* Cyclone Haiyan in November 2013, Japan tsunami in March 2011, Cyclone Aila in May 2009, Cyclone Nargis in May 2008 and the Indian Ocean tsunami in December 2004), several international organizations (*e.g.* United Nations Environment Programme-UNEP, International Union for the Conservation of Nature-IUCN and Food and Agricultural Organisation-FAO) have suggested that coastal ecosystems need to be restored and rehabilitated for coastal defence against extreme events (Mukherjee et al., 2010). As a reaction to these extreme events, local governments in some Southeast Asian countries have launched large-scale bioshield plantation projects as restoration efforts. Eminent international organizations like the World Bank, IUCN, Asian Development Bank, Overseas Economic Cooperation of Japan have provided enormous funds for such projects (Primavera and Esteban, 2008). For instance, the Indian Government, in association with the World Bank, launched the Emergency Tsunami Reconstruction Project (2006) and National Cyclone Risk Mitigation Project (2004) in tsunami-affected areas, which included the construction of bioshields as one of its major goals (Mukherjee et al., 2009). In Bangladesh, the Forest Department and IUCN have initiated several plantation projects (Biswas

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et al., 2008). Indonesia, Malaysia, Sri Lanka and Thailand have also witnessed the rise of such plantation projects (ITTO/ISME, 2008).

Evaluating the success (or failure) of bioshields is urgently needed given their large spatial scale, the massive funds involved in such projects and the social and ecological consequences of these plantations. Moreover, it is necessary to critically assess past and current plantation projects in order to avoid future failure and improve the ecological functionality of such plantations. This is particularly relevant for bioshields as their efficacy has been the subject of intense scientific and political debate in South and Southeast Asia in the last decade (Baird et al., 2009; Bhalla, 2007; Das and Vincent, 2009; Feagin et al., 2010; Kathiresan and Rajendran, 2005, 2006; Kerr et al., 2006; Vermaat and Thampanya, 2006, 2007).

While mangrove plantation efforts have been reviewed sufficiently (Bosire et al., 2008; Primavera and Esteban, 2008), assessments of bioshield initiatives involving primarily *C. equisetifolia* have seldom been reported in scientific literature. Currently, there is no readily available framework that can be used to analyse these bioshield plantations. Moreover, existing frameworks on mangrove restoration do not consider the long term financial support required for plantation activity (as they are mostly from short term aid projects). This aspect is critical in the post plantation phase *e.g.* in maintaining required hydrological regime through construction of drainage channels for sustained growth of the plantation (Bosire et al., 2008). Given the multidisciplinary context within which such projects are implemented, a multipronged approach may be necessary to create an evaluation scheme.

In this paper, we first discuss insights from published literature on the success or failure of mangrove plantations. We then develop it further and extend it to the context of bioshields and propose a socio-ecological framework for evaluation and monitoring coastal plantations consisting of mangroves or *C. equisetifolia*. In this new framework, we address three aspects of bioshields, i.e. ecological, social and economic (in terms of financial support for plantations) aspects. We then use this framework in a case study in peninsular India to evaluate on-going bioshield plantations. Currently, there is a plethora of interdisciplinary frameworks available in social-ecological systems research (Balmford et al., 2002; Costanza et al., 1997; Ostrom and Nagendra, 2006). These frameworks however differ in their disciplinary background, approach and applicability amongst other things. Binder et al. (2013) provide a comprehensive overview, comparing ten frameworks in terms of their conceptualization, scale, applicability and anthropocentric *versus* ecocentric approaches. In this study, the framework developed is related to the Human Environment Systems Framework though we have used an ecocentric approach in our analysis rather than an anthropocentric one (Binder et al., 2013).

1.1. Insights from literature on coastal plantations

Lewis (2005) noted that successful restoration projects are frequently reported, while failures are seldom mentioned. In spite of this, there is ample evidence to suggest that majority of past plantation projects, particularly mangroves, have either failed or had limited success (Bosire et al., 2008; Dahdouh-Guebas and Jayatissa, 2009; Hastrup, 2011; Primavera and Esteban, 2008). Though several factors could affect the success or failure of plantations, the foremost ones based on published literature are discussed here in three temporal phases: pre-plantation, plantation and post-plantation.

1.2. Pre-plantation

1.2.1. Assessment of drivers

The success or failure of a plantation is often determined by motivation for the establishment of the plantation, both in terms of their value for stakeholders, as well as for the implementing agency (Bosire et al., 2008; Feagin et al., 2010). Despite the apparent focus on the coastal protection function of bioshields, recent studies have suggested that there might be other drivers for their establishment based on the ecosystem services that such plantations provide (Bosire et al., 2008; Feagin et al., 2010; Mukherjee et al., 2009). For instance, in a detailed review of mangrove restoration efforts worldwide, Ellison (2000) pointed out that silviculture was the prime reason for restoration while Bosire et al. (2008) found that classic mangrove restoration projects were aimed at natural resource production *e.g.* wood products. In the Philippines, where 95% of brackish water ponds were derived from mangroves (1952–1987), massive plantation projects were undertaken to stem the over-exploitation and mangrove loss (Primavera and Esteban, 2008). Assessment of drivers is thereby an essential first step in evaluating a plantation particularly if there are discrepancies between local drivers and the funding agencies. Understanding the motivations behind the establishment of current coastal plantations might also enable future plantation activities to be directed towards more sustainable and ecologically sound drivers. Time of initiation of plantation effort (before or after an extreme event) can be used as a proxy for assessing the underlying drivers for plantation.

1.2.2. Land tenure

Land tenure is one of the most critical factors in driving land use change (Guillerme et al., 2011; Lambin et al., 2001; Ostrom and Nagendra, 2006). In South and Southeast Asia, plantations established on private land or village common lands are subject to land use change based on the discretion of the individual landowners or village leaders (Mukherjee et al., 2009). On the other hand, plantations established on government land may protected by law and are expected to be more secure in the long term and thereby less susceptible to anthropogenic impacts, thought this is not always the case (McElwee, 2006).

1.2.3. Social support for plantations

Long-term sustenance of plantations has been observed to be heavily dependent on local support for such activities particularly when the plantation takes place outside government owned land (Tanaka, 2009). For instance, as pointed out above, plantations on Government land are more likely to be secure in a way even though they have less community participation, buy in and support, whereas plantations in village common land or private land may be more dependent on community support. Community participation is required at the initial stage of identifying drivers for the plantations to ensure continued local support during and after plantation (Biswas et al., 2008). Thereby, documenting community perceptions towards the plantation activity is crucial. However in South and Southeast Asia, plantation establishment is frequently carried out with a top-down rather than a participatory approach (Hastrup, 2011; Mukherjee et al., 2010). Involvement of local communities in the planning and implementation could be used as a proxy for social support for plantations.

1.2.4. Financial resources

Since plantations require maintenance, both in the initial phase of planting and also in subsequent phases to prevent grazing, illegal harvesting, encroachment etc., it is necessary to have financial resources earmarked for monitoring and maintenance. Lack of funding support is known to be a major issue in the sustainability of plantations (Biswas et al., 2008).

1.3. Plantation

1.3.1. Native vs. exotic species

The ecological consequences of the plantation of exotic species have been debated over the past two decades in several countries (Engelmark et al., 2001; Ewel et al., 1999; Knight et al., 2001). Monoculture plantations generally favour fast growing coastal non-mangrove species like *C. equisetifolia*. Such monocultures are often not optimal from a biodiversity perspective and may hinder natural regeneration of native species. For instance, *C. equisetifolia*, a commonly used exotic species for bioshields in India, has a native range extending from Myanmar to Australia and was shown to be invasive in several countries *e.g.* USA, Cuba, Ecuador and Mexico (Global Invasive Species Database, 2005). Moreover, as pointed out by Ellison (2000) most restoration projects are monoculture plantations. Empirical studies based on regeneration experiments to understand the ecology of such plantation initiatives are however lacking in most countries except Kenya (Bosire et al., 2005, 2008; Huxham et al., 2010). Since success is measured at long-term intervals, it is essential to account for the long term biodiversity potential of such plantations *e.g.* recruitment of non-planted mangroves in monoculture mangrove plantations (Bosire et al., 2003).

1.3.2. Site selection

Site selection plays a key role in the success of establishment of a variety of plant species, whether they are natural or planted (Dobkowski 2006; Wang et al. 2009). The suitability of sites for plantation is particularly important for native plants like mangroves (Bosire et al., 2008). Primavera and Esteban (2008) indicated that inappropriate species and site selection have contributed significantly to the failure of plantations in Philippines. They noted that hydrology and soil conditions are key components in site selection but are often not considered. Tidal flushing, salinity of the site and protection from strong winds or tides are particularly important for mangroves. Abandoned shrimp farms could also be particularly interesting for facilitated colonisation by mangroves, not through plantation, but through the restoration of natural hydrology (Di Nitto et al., 2013; Stevenson et al., 1999).

1.3.3. Employment opportunities for local communities

Conservation or restoration activities that have involved local communities have been successful in several parts of the world (Cao et al., 2009; Gómez-Pompa and Kaus, 1999; Huang et al., 2012). Restoration projects that have not addressed the problem of the 'ecology poverty-trap' are particularly prone to failure in developing countries (Cao et al., 2009). On the other hand, projects that have included employment opportunities in the implementation phase had a higher chance of being viable over a span of 25 years (Huang et al., 2012). Since 68.7% (as of 2010) of the population live below the poverty line (below USD 2 a day) in India, regular engagement and employment of local communities in the plantation process is essential.

1.4. Post-plantation

1.4.1. Monitoring

It has been noted that several ad-hoc bioshield plantations have mushroomed after a natural disaster. However, they lack long-term sustainability focus or planning (Biswas et al., 2008; Elster, 2000; Mukherjee et al., 2009). In Bangladesh for instance, it was observed that most mangrove restoration efforts have adopted a trial and error method instead of following a systematic interdisciplinary framework (Biswas et al., 2008). All bioshield project related activity ceases as soon as the funds are exhausted, with little or no attention to monitoring and post plantation care. For instance, grazing has been reported as a major threat to the proper establishment of plantations in such areas (Biswas et al., 2008). Hence, fencing could be critical for the survival of the plants in the initial stages, but it is not always used, as there are no clear plans or resources following the initial establishment. Funds earmarked for monitoring could be used as a proxy for assessing the commitment towards post plantation care.

1.4.2. Policy

The establishment of plantations involves considerable costs. In the absence of adequate policy and implementation to protect plantations from human impacts, such efforts may not be viable in the long term. It has been reported that local communities often do

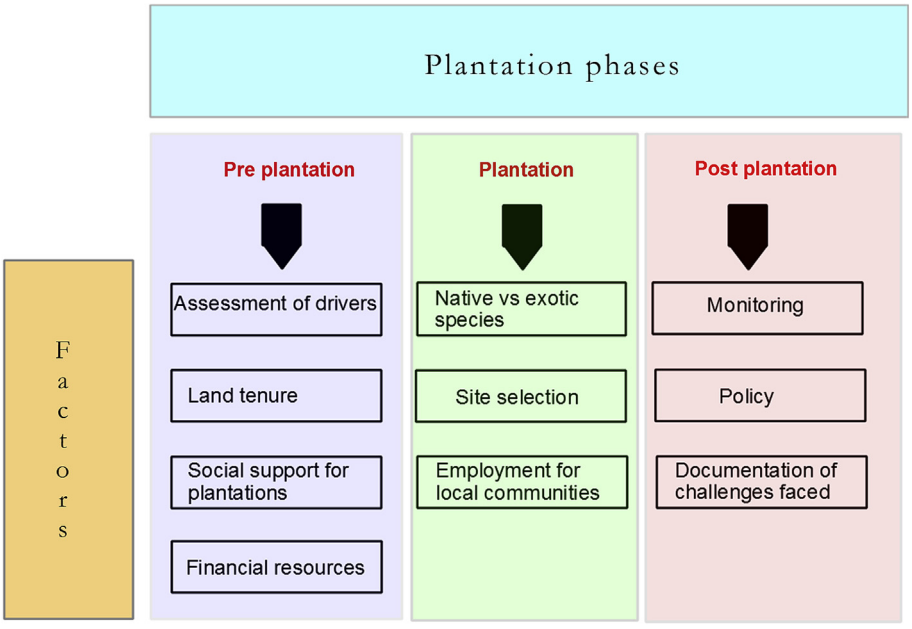

Fig. 1. An interdisciplinary framework for evaluating bioshields.

not perceive the plantations as ecological, financial or social assets (Mukherjee et al., 2010). In such situations, research may be required to understand why communities do not perceive the plantations as beneficial and how they could be integrated in the process. Awareness about policy issues is also essential in safeguarding plantations.

1.4.3. Documentation of challenges faced

Noting the challenges faced during planning and implementation, monitoring is critical for improving the efficiency of the plantation process (Bosire et al., 2008). It provides a valuable feedback loop to improve the plantation process.

We propose the following framework for the evaluation of socially and ecologically viable plantations based on the above insights (Fig. 1). We have also used this framework in a case study in peninsular India to evaluate bioshields.

2. Methods

2.1. Study area

The study area consisted of coastal districts in three states (Andhra Pradesh, Tamil Nadu and Kerala) of peninsular India which were the worst affected due to the Indian Ocean tsunami in December 2004 (Government of India 2005). Andhra Pradesh (AP) is comparable to New Zealand in area, with a population of 84.66 million people (Chandramouli, 2011). Tamil Nadu (TN) is comparable to England (less than half of UK) in area and has 72.13 million people (Chandramouli, 2011). Kerala (KL) is comparable to the Netherlands or Switzerland in area and has a population of 33.38 million (Chandramouli, 2011). The length of coastlines in AP, TN and KL are 960 km, 1076 km and 590 km respectively (see Fig. 2). Each state has a strong identity based on culture, language and history. For instance,

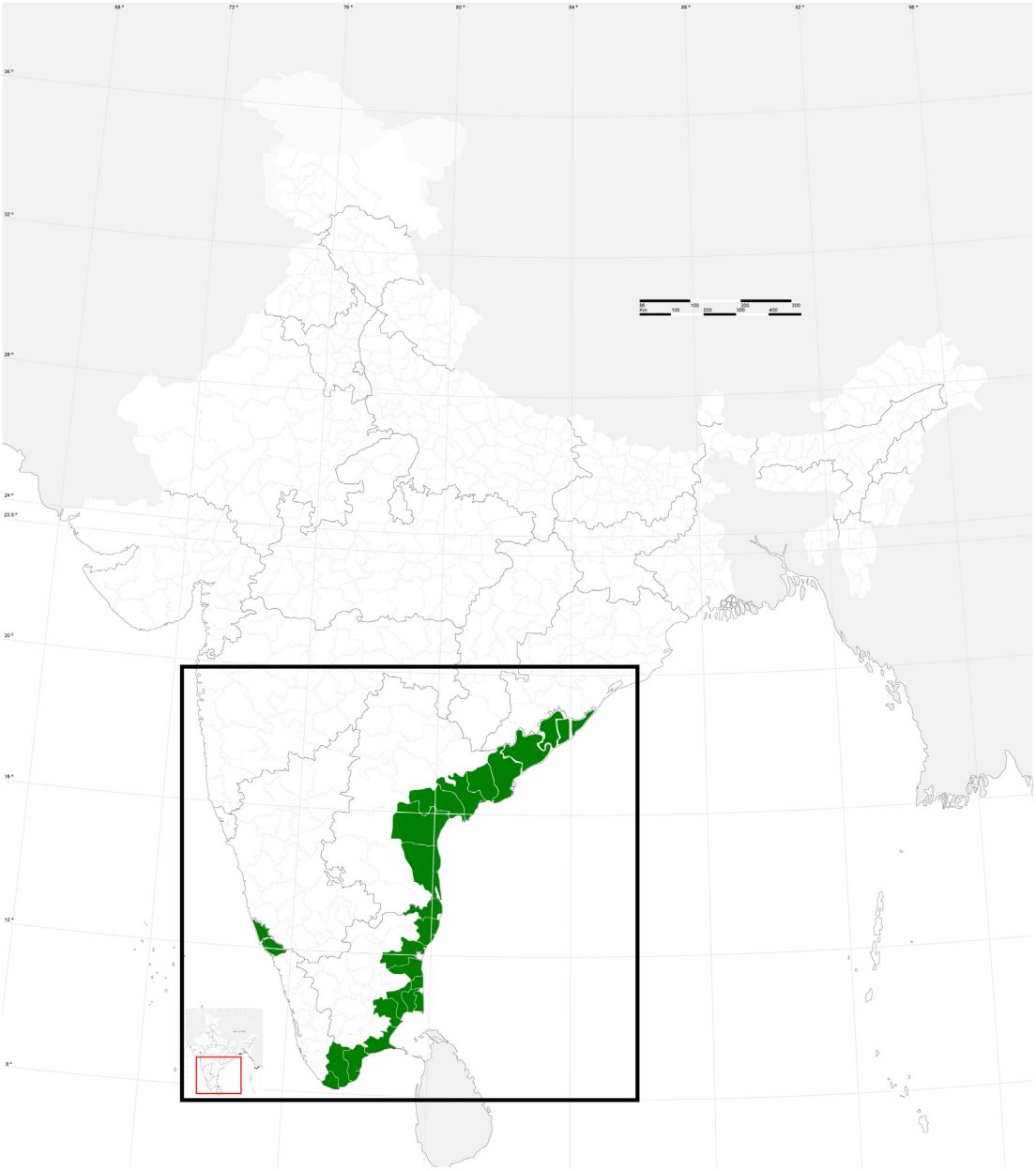

Fig. 2. The area within the thick black frame, demarcated in green are the coastal districts which were included in this study (field survey and secondary information). The state boundaries are indicated by darker lines while the internal districts are indicated by lighter lines. Within the frame, in a clockwise direction, AP is in the top right corner, followed by TN in the bottom right and KL in the bottom left. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

the major languages spoken in AP, TN and KL are Telugu, Tamil and Malayalam respectively. We surveyed six of nine coastal districts of AP, ten of thirteen coastal districts in TN and two out of fourteen districts in KL where coastal plantations were being established.

2.2. Survey

Using the above three-step framework and a preliminary field survey, we designed a questionnaire to evaluate the on-going plantations in peninsular India. The survey was conducted between October 2006 and September 2008 in two rounds. In the first round, the key stakeholders ($n > 50$) were identified through a combination of methods: expert opinion, preliminary field survey and online search on government websites and donor agency websites. The identified resource persons were contacted electronically and over the telephone. The snowball sampling technique was used to identify further resource persons engaged in plantation activities. In the preliminary survey, the primary stakeholders involved in the plantations were found to be the Wildlife and Social Forestry division of the Forest Department (which is a government organization) and local non-governmental organizations (NGOs) in the study area.

In the second round, the plantation sites were visited and structured interviews were conducted with a subsample of the informants identified in the first round as not all resource persons were available for interview, or did not wish to complete the questionnaire due to privacy issues. The aim here was not to gather a random sample of respondents but to identify the best available and most relevant expertise in order to gain a good coverage of views on bioshields (similar to the expert based Delphi method) (Tapio et al., 2011). Expert based techniques have proved to be very useful in biodiversity management and conservation biology (Gobbi et al., 2012; Gordon and Gallo, 2011; Martin et al., 2012; Moreno et al., 2010; O'Neill et al., 2008; Sutherland, 2006; Swor and Canter, 2011). Most of these expert based studies (*e.g.* Delphi) typically solicit opinion from less than twenty experts (Mukherjee et al., in prep).

We present the results from all the primary stakeholders involved in the plantations from the government and a significant proportion of NGOs in the study area ($n = 17$). Care was taken to ensure the adequate inclusion of government officials in varying positions of hierarchy. Though it is a vast area, a previous study had noted that plantations were mostly established by the government (Forest Department) or by local NGOs with very little involvement of or consultation with the local fisher communities in decision making, implementation or monitoring of coastal plantation projects (Hastrup, 2011; Mukherjee et al., 2009). Therefore, we focused mostly on government officials and NGOs in this study.

3. Results

3.1. Pre-plantation

3.1.1. Assessment of drivers

Coastal protection was found to be as important a driver as afforestation and socio-economic factors combined (42%). Other causes (15%) such as availability of funds, employment of women

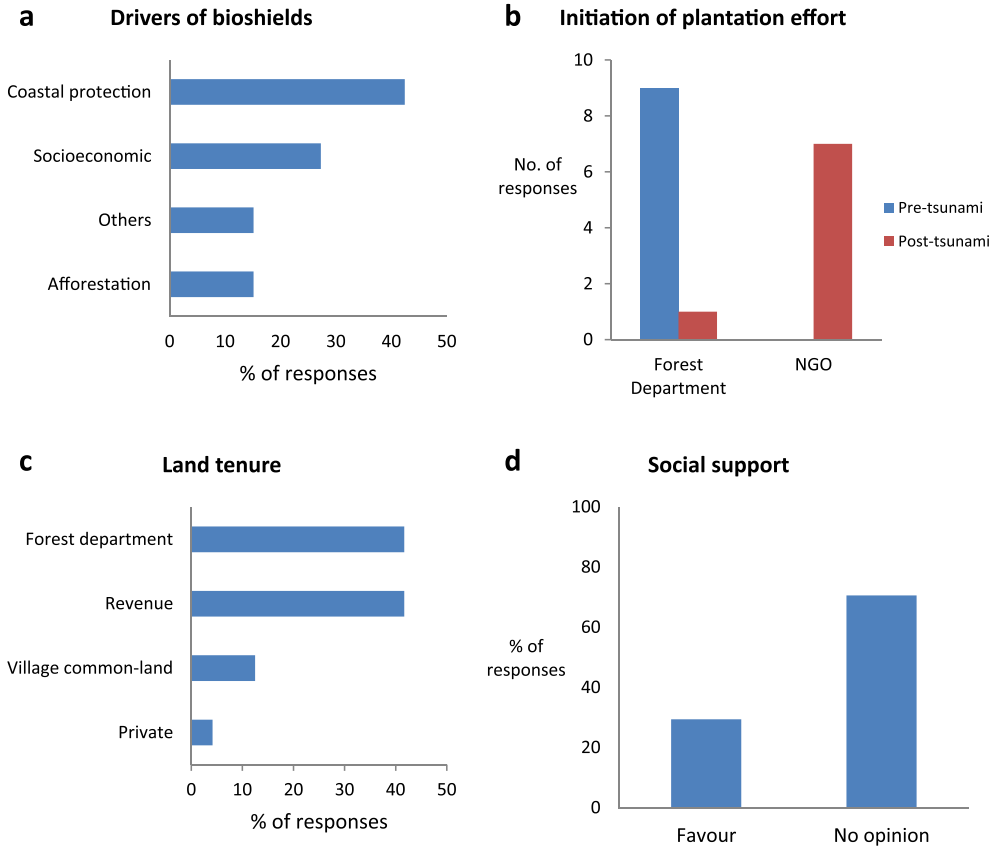

Fig. 3. Pre-plantation phase factors that were considered: a) Drivers: Though coastal protection was stated to be the primary cause, we found that socio-economic reasons were also a major driver for bioshields; b) Initiation of plantation efforts: Unlike the Forest department which had been engaged in plantation activities even before the tsunami, most of the NGO's had started planting bioshileds probably due to the huge influx of international funds; c) Land tenure: Most of the plantations were raised on government land either under the jurisdiction of the Forest Department or the Revenue Department; d) Social support: Since local communities were not directly involved in the pre-plantation phase, their perceptions towards bioshields were assessed by interviewing the two stakeholders engaged in plantation. Majority of the respondents stated that local communities had no opinion.

Table 1
List of bioshield plantation activities in the three 2004 tsunami-affected states in peninsular India. The compiled data clearly indicates that coastal plantations activities were carried out even before the 2004 Indian Ocean tsunami.

State	Name of district	Plantation area (ha) after 2004 tsunami	Plantations before 2004 tsunami (ha)	Total area (ha)	Sources
Kerala		**578,6**		**578,6**	Mangrove notification revenue
	Kannur	308,0			Mangrove notification revenue
	Kasargod	270,6			Mangrove notification revenue
Andhra Pradesh			**33198,0**	**33198**	AP facts and figures 2009
	Nellore	72,7			This study
	Prakasam	486,9			This study
	Guntur		11757,0		AP facts and figures 2009
	Krishna	1840,0			This study
	West Godavari	412,0			This study
	East Godavari		7198,0		AP facts and figures 2009
	Visakhapatnam		11277,0		AP facts and figures 2009
Tamil Nadu		**7840,0**	**2145,6**	**9985,6**	Environment and Forests Department, Policy Note-2009– 2010, Demand No. 15
	Thiruvallur	30,0			This study
	Kanchipuram	363,0			This study
	Nagapattinam	675,0			This study
	Thiruvarur	450,0			This study
	Thanjavur	155,0			This study
	Pudukottai	610,0			This study
	Ramanathapuram	250,0			This study
	Tuticorin	393,5			This study
	Tirunelveli/ Kanyakumari	50,0			This study

(and thereby empowerment), awareness about environment and generating fuelwood were also cited as drivers for coastal plantations (Fig. 3a). Though the responses were nearly equally divided about the initiation of the plantation before and after the tsunami, there were differences between the two stakeholder groups (Fig. 3b). All the forest officers (except one) ($n = 9$) interviewed in this study had begun establishing plantations much before the tsunami while all NGOs interviewed in this study had begun establishing plantations only after the tsunami and had no prior experience in this activity ($n = 8$). Some of the Forest Department records of coastal plantation date to as far back as 1945 (Pichavaram, TN). In Andhra Pradesh, the plantation of exotics in coastal areas date back to the first Government of India five year plan 1951–56 (Table 1).

3.1.2. Land tenure

The responses were classified into four categories viz. Forest Department land, Revenue Land, village common land and private land. The first two categories are government land under the jurisdiction of two agencies (Forest Department and Revenue Department). The majority of the plantations had been established on government land (84%) (Fig. 3c).

3.1.3. Social support for plantations

It was noted that 71% of the respondents offered no opinion about the issue of local perceptions toward plantation efforts (Fig. 3d). However, 29% stated that local communities were in favour of plantations. In response to the question of local opposition to plantations, 24% replied in the affirmative.

3.1.4. Adequate financial resources

We present a list of the funding agencies that have fuelled plantations in coastal areas in peninsular India based on our survey (Table 2). In the case of most NGOs, establishing plantations was a one-time activity and heavily dependent on external funding and mainly aimed at employment generation. For instance, some plantations were established under central and state government schemes like Rashtriya Sam Vikas Yojna (RSVY) (national employment development scheme) or Samporna Gramin Rozgar Yojna (SGRY) (complete village employment scheme). During this study, we came across five such schemes that were funded or supported by the World Bank (Table 2). The Forest Department was the only agency that had funds earmarked for post-plantation care and monitoring.

3.2. Plantation

3.2.1. Proportion of exotic species

In the survey, nearly half of the respondents stated that they were establishing plantations of exotic species wherever possible (due to convenience), while the other half stated that native plants like mangroves were also being planted (Fig. 4a). However, the

Table 2
List of funding agencies that have funded bioshields in the three tsunami affected states in India. Majority of the schemes were funded by the World Bank.

Funding agencies	Percentage of total
Andhra Pradesh Community Forest Management [World Bank]	47
Government of India	24
Forest Development Agency [World Bank]	18
Green Coast	18
ETRP, NCRMP	18
Sampoorna Gramin Rojgar Yojna	12
Environmental Equity Justice Partnership	12
Rufford Foundation	12
SIDA	6
Siemenpuu Foundation	6
Dykona Emergency Aid	6
Hivos	6
Christian Aid	6
Greening Community Land	6
Rozgar Sampoorna Vikas Yojna	6

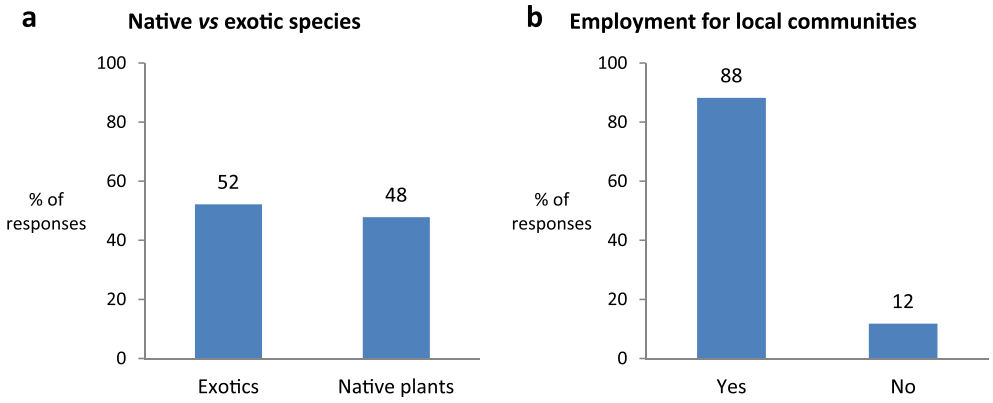

Fig. 4. Plantation phase factors: a) Native *vs* exotic: Both native trees and exotic species were being used in bioshield plantations; b) Employment of local communities: Local communities were engaged as daily wage labour in most of the cases.

funding and area under exotic plantations were much larger than those allocated for conserving and restoring native vegetation like mangroves (see Table 1). Most of the mangrove plantations were monocultures of the mangrove species *Avicennia marina*.

3.2.2. Site selection

None of the respondents had carried out any form of site selection (soil or water quality assessment) prior to the establishment of the plantation. Selection of the site was largely based on availability of land. We found that there was a provision for soil analysis prior to plantation in the management plan of the Andhra Pradesh Forest Department, but in practice, no such analysis was carried out in that state.

3.2.3. Employment opportunities for local communities

The majority of the respondents had involved local communities in the plantation process largely as daily wage labour (Fig. 4b). During the time of the survey, the wage was fixed at 67 INR/person/day (equivalent to 1.23 USD or 0.94 EUR) in Andhra Pradesh.

3.3. Post plantation

3.3.1. Monitoring

Relatively few respondents (24%) had carried out monitoring of plantations after 3 years and only one had fenced the plantation (Fig. 5a). The Divisional Forest Officer of West Godavari district was the only respondent who had taken an active interest in post-plantation care. The planted area was being desilted and channels were being dug to allow inflow of water to reduce the salinity. Post plantation care or monitoring was not included in the design of the project for most of the NGOs. Often, the residents of the village were organized to form Van Samrakshan Samitis (community based forest conservation committees that do not have any funds of their own) and they were expected to take care of the plantations once the external funding ceased. Thus, once funding ceased, there was no post plantation care and this often led to the failure of the plantations.

3.3.2. Policy

Only three respondents out of 17 were either aware of conservation laws or had implemented them, while the rest were unaware of them even though there are laws protecting native trees like mangroves from being felled or damaged *e.g.* the Forest Conservation Act (1980, amended 2002) or the Coastal Regulation Zone Notification (CRZ), 1991 under the Environment Protection Act, 1986; National Forest Policy 1988 (MOEF, 2013). The respondents also pointed to the ambiguities in the coastal policies like CRZ notification and lack of transparency in their implementation (Fig. 5b).

3.3.3. Challenges to plantation activity

The major problems faced by the respondents were grazing, aquaculture and fuelwood collection (15%).

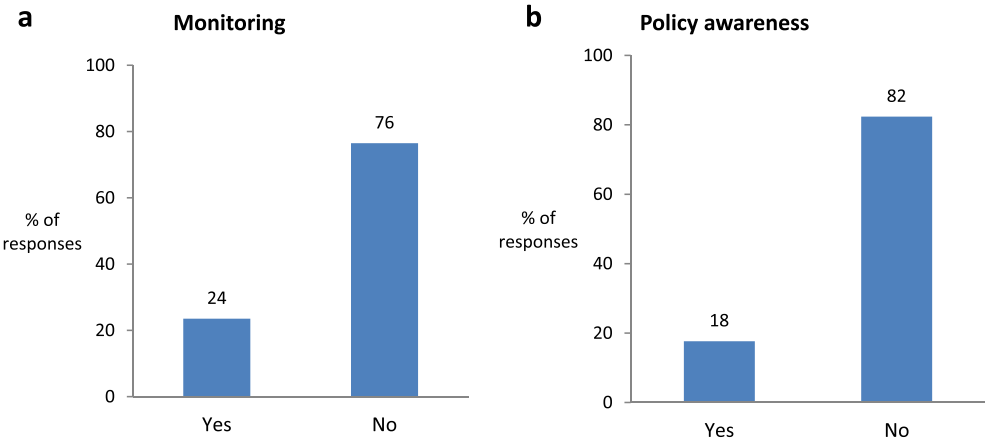

Fig. 5. Post-plantation phase factors: a) Monitoring: Only in 24% of cases, the bioshields were monitored; b) Policy awareness and implementation: In most cases the respondents stated that they were either not aware of the plantation or did not have adequate resources for implementing the policies.

4. Discussion

We found that coastal plantations (particularly of exotics) in peninsular India started more half a century before the December 2004 Indian Ocean tsunami. The Forest Department records demonstrate that current coastal plantations are not a fresh approach for coastal restoration, but a continuation of past efforts aimed at rural employment generation and afforestation. Many plantation schemes funded by the World Bank and implemented by local governments are aimed primarily at income generation as shown in Table 2 and also noted elsewhere (Kareiva et al., 2008). Moreover, in five cases, NGOs undertook plantation activities for reasons that were completely unconnected to coastal protection (*e.g.* availability of funds, empowerment of women and generation of fuelwood) even though they were funded for coastal protection in the wake of tsunami efforts. Some plantations were being established a considerable distance from the coast (>15 km) and thereby could not possibly contribute to coastal protection. The local residents have also voiced their negative opinions regarding the efficacy of the plantations (see Feagin et al. (2010)). Instead of investing more on such plantations, resources and conservation efforts should be directed towards preserving existing natural ecosystems and restoring degraded ones.

However, the intensity and scale of plantation efforts in coastal areas increased dramatically after the December 2004 Indian Ocean tsunami, which affected 2260 km of the coastline in mainland India (Government of India 2005). As a consequence 3,609,000 people were affected, 10,776 lives were lost and 153,226 buildings/houses were damaged (CNN, 2005). The vulnerability of the coast to natural hazards was exposed and the protection of the coast by bioshield plantations gained impetus. In general, these plantations were established despite considerable ambiguity about the role of plantations in protecting the coast (Feagin et al., 2010), and little interdisciplinary research into factors influencing their success (Mukherjee et al., 2010).

Land tenure was found to be an area of concern. While plantations were carried out equally on revenue land and forest department-owned land (both government owned land categories), the future viability of plantations in revenue land is questionable due to changing policies. Moreover, the legal status of the plantations needs to be scrutinized under the new Coastal Regulation Zone notification, 2011 (MOEF, 2013). Any attempt to govern, manage or restore plantations will have to address the issue of land ownership. In this light, land disputes originating out of ambiguity in settlement of land rights need to be addressed immediately.

There is a pressing need to increase community participation in the plantation process. Local communities (primarily fishing communities), who live close to the coast are generally not consulted in the decision-making stage of the coastal plantation projects (Hastrup, 2011). It is hoped that our framework is useful to coastal planners and that in future there is greater interaction and involvement of local communities in such initiatives.

It was noted that along the coast, sand dunes or sandy beaches originally occupied the areas where such plantations were established. These ecosystems are also natural bioshields (Rans et al., 2011) and are currently heavily under threat due to large-scale plantation activities. It is important to view and critically analyse bioshield plantations from the perspective of the ongoing debate on the valuation of ecosystems and implications for ecosystem functioning (Hooper et al., 2012; McDonald et al., 2008; Ochoa-Gaona et al., 2010). Valuing ecosystems and biodiversity could lead to the conclusion that replacement systems, often of lower diversity, have a higher monetary value. In this case, the monetary value of firewood and timber generated from exotic plantations in the short term may be more than the sandy beach or sand dunes. However, in the long term, exotic plantations in the form of bioshields might prove detrimental to the native ecosystems. Often, the damage caused by such interventions are difficult to reverse and the cost of restoration may be prohibitive (Cardinale et al., 2012). It is perhaps detrimental to value the short-term economic gains of exotics higher than the long term ecosystem services provided by the native vegetation or planted vegetation of indigenous composition. Given the current situation, we recommend that financial resources should be allocated to preserve and restore native ecosystems like mangroves in mangrove areas, dune vegetation in sand dunes, etc., which have been destroyed in the past rather than investing in raising exotic or ecologically inappropriate plantations.

Lack of awareness about conservation laws hinders policy implementation. It was noted in this study that, except for a few forest officers, there was hardly any awareness about conservation laws. Policy plays a major role in determining the long-term consequences of such coastal activities. Biswas et al. (2008) suggested that restoration and plantation efforts need a multi-pronged approach with greater emphasis on better implementation of conservation policies. Our results provide further evidence that this is critical to the success of coastal plantations.

In the recent Rio+20 United Nations Conference on Sustainable Development held in Rio de Janeiro, Brazil in June 2012, the first objective in the summary of the global inter-agency paper is: "Actions to reduce stressors & restore the structure and function of marine ecosystems" (IOC/UNESCO; IMO; FAO; UNDP, 2011). Since bioshield plantations are a major activity in the Asia Pacific region, our research is both timely and important within this framework. The framework for evaluating bioshield plantations and our case study will provide a baseline for further investigations in coastal plantation activities.

5. Conclusion

We have provided an interdisciplinary framework to evaluate and monitor plantation efforts in peninsular India, a region heavily impacted by a natural calamity and where such plantations are uncritically presented as safeguarding against future events. Our case study suggests that local communities need to be actively engaged in the decision making process and not only as daily wage labour. We also noted that the pre and post-plantation phases had several lacunae and need further planning and adequate consideration in similar future endeavours. Proper site and species selection before plantation and monitoring after plantation could save precious time, effort and financial resources. Ecological criteria seem to have been undermined during the establishment and maintenance of plantations. While ample flow of international aid has fuelled the plantation of exotics in the study area particularly after the Indian Ocean tsunami, this study clearly shows that long term ecological consequences need further evaluation.

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