On behalf of:

Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety

of the Federal Republic of Germany

Mangrove restoration on degraded, barren land

Approach, results and lessons learnt from Bac Lieu Province

Implemented by

Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

GIZ in Viet Nam

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The project “Adaptation to Climate Change through the Promotion of Biodiversity in Bac Lieu Province” is funded by the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB) and implemented by GIZ in close collaboration with the Department for Agriculture and Rural Development Bac Lieu. It´s objective is to enhance the protective effect of coastal forests through the sustainable use of resources and the promotion of biodiversity.

Contents

Introduction

The overall objective of the project, "Adaptation to Climate Change through the Promotion of Biodiversity in Bac Lieu Province" is to improve the resilience of coastal ecosystems and coastal communities to the impacts of climate change. Afforestation for protection against coastal erosion, strong winds and storm surges is a key element in improving resiliency to climate change along an exposed and dynamic coastline that historically has experienced considerable erosion.

A coastal planting plan, prepared in 2011, identified the coastline of Vinh Trach Dong Ward as being particularly at risk due to its high rate of erosion and lack of protective forest [1, 2]. This risk has been confirmed by a survey conducted in 2012 which found that the rate of coastal erosion in Vinh Trach Dong, Hiep Thanh and Nha Mat wards was 30 - 70m between 2009 and 2012 [3] (Figure 1). If current rates of erosion persist, it is probable that some parts of the sea dike, particularly in the northern part of Vinh Trach Dong, will be fully exposed to the sea without protection from fringing coastal forest by 2025, unless efforts are made reduce the rate of erosion and stabilise the coastal land seaward of the dike, Qualitative observations also suggest that the rate of erosion in the northern part of Vinh Trach Dong has increased since the commencement of construction of offshore wind turbines for electricity generation.

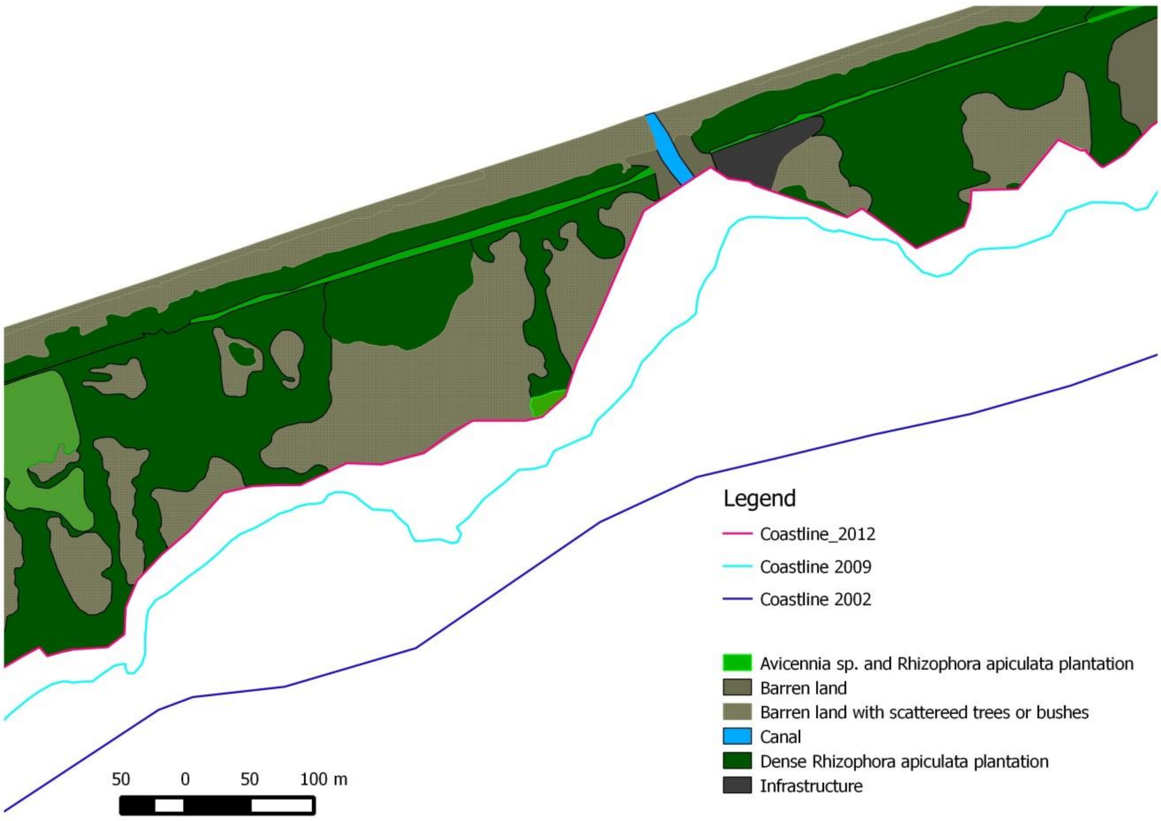

Figure 1: Erosion in Vinh Trach Dong

Considerable areas in Vinh Trach Dong were planted between 2000 and 2006 as part of the World Bank Coastal Wetlands Protection and Development Project, and since then some limited further planting has been carried out by Provincial authorities. However, survival rates have generally been low and the growth of those trees that have survived has been very poor.

The poor survival and growth in past planting efforts can be attributed to a number of factors, but mostly to the high elevation of the coastal fringe in Vinh Trach Dong, which means that many areas are flooded only a few times a year on the highest astronomical tides. This is exacerbated by the presence of small embankments along the edges of canals and as a result of former shrimp pond development in the area, which also serve to prevent tidal flooding. As a consequence, the soil is too dry for good survival and growth, particularly of young seedlings during the dry season. Neither of the two most common species that have been planted in the past, *Rhizophora apiculata* and *Ceriops tagal*, are well-suited to these hydrological conditions.

A total area of 450 ha of higher land in Vinh Trach Dong is in need of planting [1, 2]. Given the lack of success of past planting and the high cost of planting this area, estimated to be around USD 300,000 [2], it was decided to carry out smaller trial plantations in selected areas to assess a different planting design with alternative species, which would serve the dual purpose of coastal afforestation with a more diverse range of species, and a model for future planting on difficult sites with high elevation which are very common along the whole of the Bac Lieu coastline.

Site Preparation and Planting Design

Planting was carried out at two sites, Site 1 and Site 3 (Figure 2) in 2011. Both sites had been planted with either *Ceriops tagal* or *Rhizophora apiculata* during the World Bank Coastal Wetlands Project, but survival and growth rates were poor. A third and fourth site (Site 2 and 4, Figure 2) were selected for planting in 2012.

Prior to planting, the sites were prepared by digging canals of about 0.5 m in depth and 2-3 m wide to supply water to the sites on normal high tides, resulting in a parallel sequence of canals and embankments with a range of micro-tidal environments (Figure 2). This approach was based on the view that some degree of tidal flooding was needed to make the hydrology of the sites more suitable for mangroves, and on observations in a number of areas, notably at Site 3, of well-developed mangroves in canals of former shrimp ponds.

Species Selection

Four local species of mangrove were selected for planting based on their potential suitability for the sites; *Ceriops tagal*, *Intsia bijuga*, *Lumnitzera racemosa* and *Xylocarpus moluccensis*. It should be noted that *C. tagal* is not a particularly good species for planting for coastal protection because of its very slow growth rate; even under relatively favourable conditions it grows much more slowly than most other mangrove species.

Planting with non-mangrove species such as *Casuarina* was also considered. However, non-mangrove species were not thought to be viable in the long-term owing to their intolerance to regular flooding by seawater, which is almost certain to be a consequence of rising sea levels in the future.

Planting

Fruits of the four species were collected locally or from elsewhere in the Mekong Delta in 2010 and 2011 respectively, germinated and grown in a nursery for about 12 months before planting at the field sites. Planting was carried out in September 2011 and 2012 respectively, when the nursery-grown seedlings were about 12 months old. At that stage, *Intsia*, *Lumnitzera* and *Xylocarpus* seedlings were about 50-60 cm in height, but the *Ceriops* seedlings were only 20-30 cm tall. Seedlings were planted about 1 m apart, giving an overall average planting density of about 20,000 per hectare. A summary of the area, number of seedlings and cost of planting carried out in 2011 are given later in Table 2.

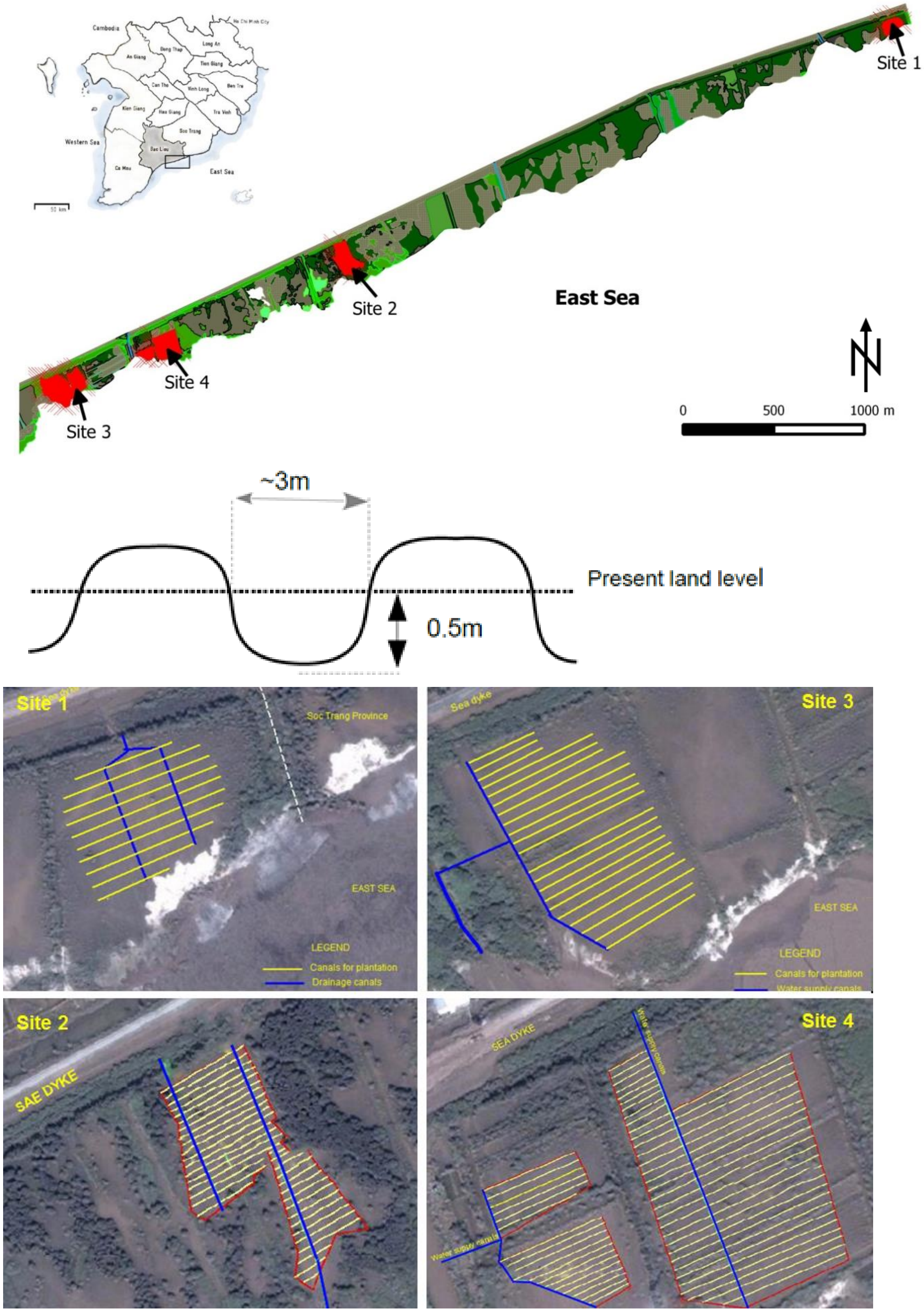

Figure 2: Location, Design and Layout of Alternating canals at the planting sites

Outcomes

Survival Rate

After eight months, the overall survival rate on embankments at both sites, planted in 2011, was more than 70 %. Considerable seedling mortality on the embankments had been expected during the first dry season due to a lack of water, but as shown in Figure 3, most seedlings died during the first two months after planting, before the onset of the dry season. Very few seedlings died during the dry season, implying that their roots were well enough developed to tap sufficient subsurface water to survive over the dry season, even though the top 20 cm of soil was quite dry (around 30 % by weight). However, it should be noted that the dry season of 2011-2012 was atypical in that it was much 'wetter' than average, and this, too, could account for the good survival over the dry season. In addition, although unconfirmed, it is likely that water moved laterally and perhaps vertically from the canals into the subsurface soil of the embankments, thereby supplying water to seedlings with roots deep enough to tap it.

On the other hand, survival was very low in the canals at both sites in 2011 (Figure 3). This was most likely a result of the very high rates of sediment deposition in the canals, which buried many of the seedlings. While some sediment accumulation in the canals was expected, the very rapid infilling around the mouths was not expected. Not only did this bury many of the seedlings, it also prevented the canals from draining fully, thus leading to more or less permanent ponding of the canals, a condition that most mangroves do not handle well. After considerable infilling of the canals with sediment in 2011, *Bruguiera cylindrica* was planted in the canals in 2012. With the experience from sites 1 and 3, no seedlings were planted in the canals in the year of establishment (2012) at sites 2 and 4.

After eight months the survival rate of the seedlings planted in 2012 was lower than of the 2011 sites. This may be due to a dryer dry-season or due to other factors, such as seedling care before planting and transportation. Nevertheless, as seen in Figure 4, the average survival on the embankments of all four sites after (up to) 24 months is still above 50 %.

Since planting was carried out during the wet season, seedling death on embankments in the first two months after planting is unlikely to have been because of lack of soil water. The more likely explanation for this early mortality is root damage or desiccation during seedling transfer from the nursery to the planting site, and/or root damage during planting. As an example, seedlings on the roadside prior to planting at Site 2 in 2012 were observed to be extremely desiccated, which is likely to have some impact on their subsequent survival during the first few weeks after planting.

Differences in the survival rate of different species between sites cannot be easily explained. All sites had similar soil water contents in the top 20 cm of soil throughout the first eight months, and there were no significant differences in soil pH between sites. However, there may be differences in soil texture and structure between the sites. These soil parameters were not measured during the monitoring program.

In 2012 *Bruguiera cylindrica* was planted in the canals of the 2011 planting site 3. The survival rate after 12 months was observed to be rather low at around 40 % with steady growth as shown in Figure 5. The survival rate is much higher than that of the seedlings planted in 2011 (compare Figure 3) which can be explained by the decreased sediment deposition in the 2nd year after site preparation.

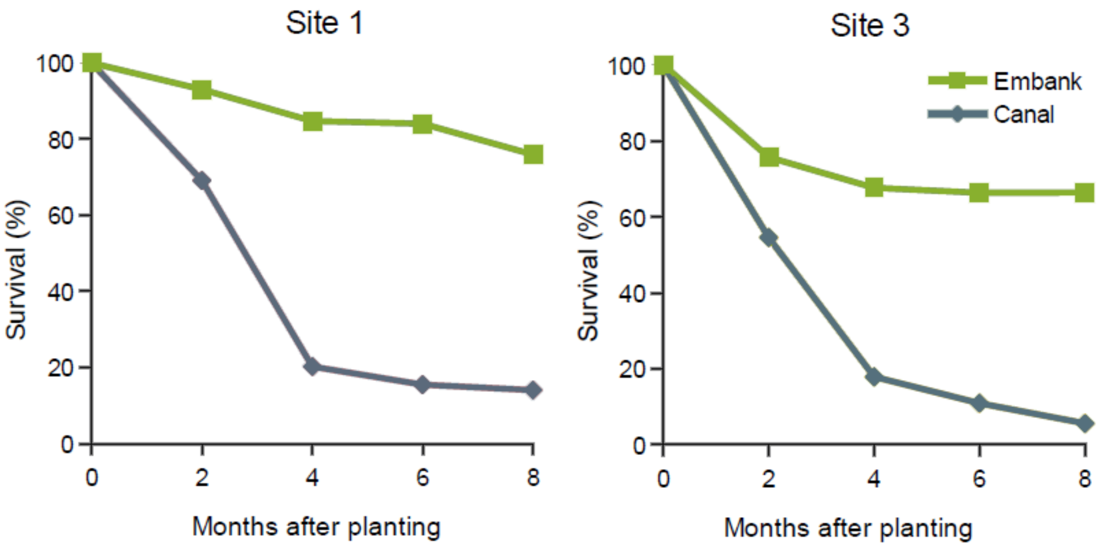

Figure 3: Overall survival rates in canals and on embankments over the first eight months after planting at site 1 and site 3.

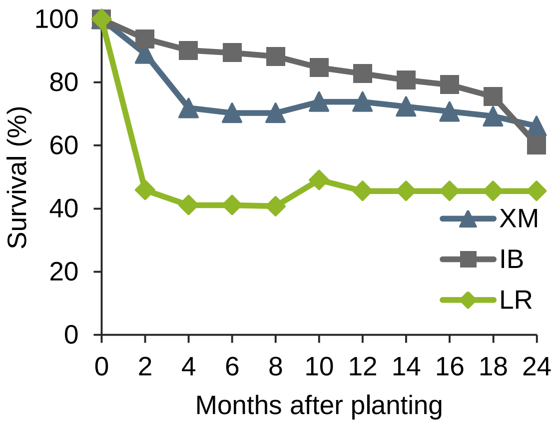

Figure 4: Average Survival of individual species on embankments over the first 24 months after planting at Sites 1, 2, 3 and 4. (CT = Ceriops tagal; IB = Intsia bijuga; LR = Lumnitzera racemosa)

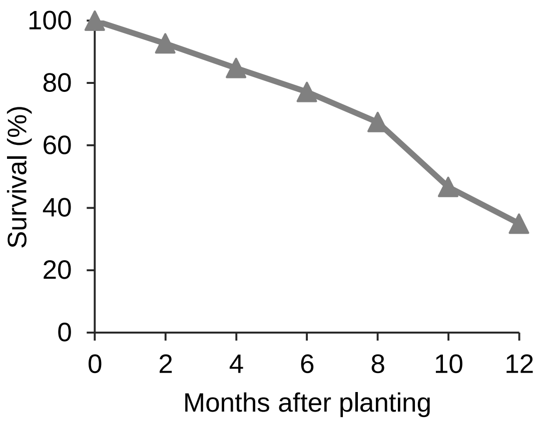

Figure 5: Average Survival of Brugiera Cylindrica in canals at site 3.

Plant development

In terms of height, both *Lumnitzera* and *Xylocarpus* grew well on embankments, but *Intsia* performed poorly (Figure 6). The decrease in the average height of *Intsia* was due mainly to the death of larger seedlings, but even the remaining smaller survivors have very little foliage and seem likely to die or develop slowly. This suggests that *Intsia* is not suitable for planting on these or similar sites.

Of the other two species, over the first eight months, *Lumnitzera* showed the best increment in height (Figure 6) and had a much better developed canopy than *Xylocarpus* (Figure 7). It has been observed that of the three species planted in 2011 on embankments, *Lumnitzera racemosa* is the most suitable for planting at sites that are at or near the upper tidal limits.

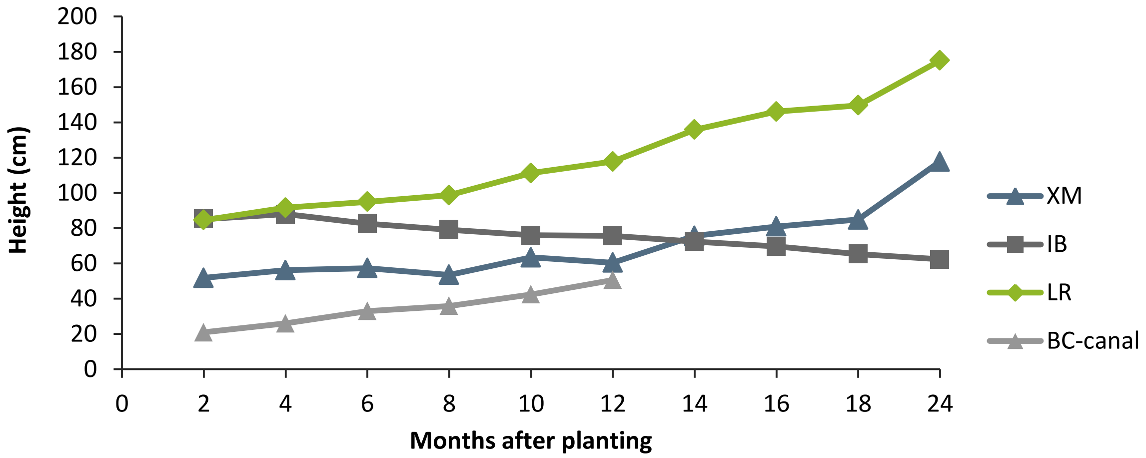

Figure 6: Average Height of individual species on embankments (XM, IB, LR) and Canals (BX) over the first 24 months after planting at Sites 1, 2, 3 and 4. (CT = Ceriops tagal; IB = Intsia bijuga; LR = Lumnitzera racemosa, BC = Brugiera Cylindrica)

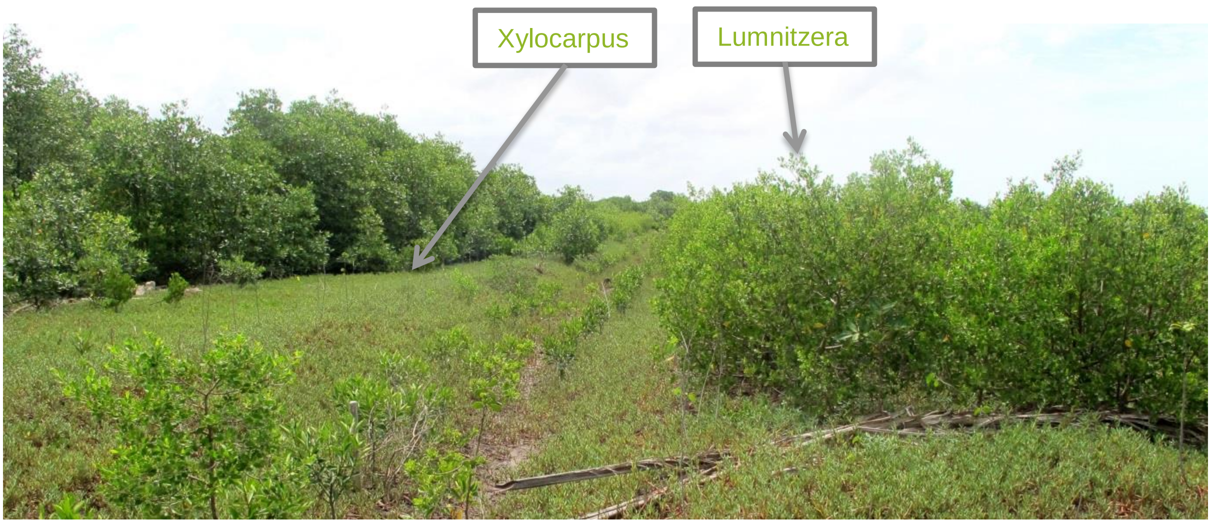

Figure 7: Comparison of canopy development in *Xylocarpus moluccensis* and *Lumnitzera racemosa* 20 months after planting.

The poor development of *Intsia*, and to some degree *Xylocarpus*, during the first eight months might be due partly to their normal pattern of growth as seedlings, but it could also be linked to water stress associated with poor root development. This is an aspect that has not been fully explored in the monitoring program. However, a selection of *Lumnitzera, Xylocarpus* and *Instia*, growing on embankments were dug up, 18 months after planting. Their canopy and root dimensions are summarized in table 1 and it is evident that *Lumnitzera* shows the best developed root system, both in depth and volume.

Table 1: Selected root system and tree composition of *Lumnitzera* racemosa (LR) *Xylocarpus mollucensis* (XM) and *Intsia bijuga* (IB) at site 4, 18 months after planting.

Site	Species	Height (cm)	Canopy Volume (cm³)	Root collar circle (cm)	Root Depth cm)	Root X (cm)	Root Y (cm)	Root Volume (cm³)	Biomass Fresh total (g)	Biomass Dry total (g)
4	LR	137	434,8	13	92	52	35	588,9	3096,0	1667,0
4	LR	134	588,9	9,6	80	44	40	356,8	2706,0	1285,0
4	LR	130	2395,0	13	88	60	58	904,7	3450,0	1645,0
4	XM	82	4,1	4,2	64	21	18	38,7	80,6	39,7
4	XM	98	9,2	6	57	25	12	65,4	232,8	134,6
4	XM	90	7,2	4,7	39	30	10	113,0	132,3	69,5
4	IB	50	0,9	2,8	18	18	15	24,4	20,2	11,3
4	IB	72	137,2	5,8	62	33	19	150,5	135,3	79,9
4	IB	54	20,5	4,1	52	35	21	179,5	58,0	39,9

Soil salinity

The soil salinity is one of important factors influencing survival and growth rates of planted seedlings. Most of planting sites on barren, degraded land in Bac Lieu province, especially in Vinh Trach Dong commune, exhibit high salinity levels. The land preparation of digging canals before planting showed to be effective in reducing salinity and increasing seedling growth. Salinity was monitored at site 3 from September 2011, just after land preparation, to May 2012, as shown in Figure 8. A severe decrease in salinity was recorded in the first four months which constitute the end of the rainy season. The soil salinity was then recorded to be stable until it increased slightly at the end of the dry season in May 2012.

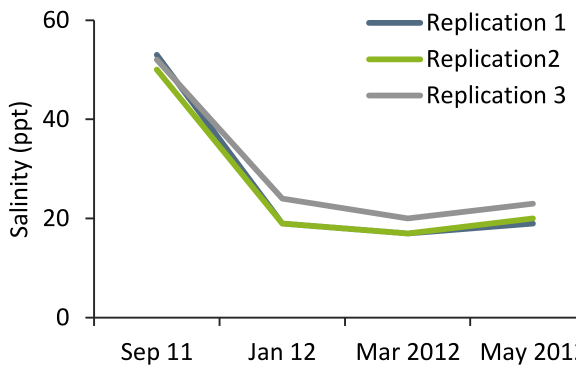

Figure 8: Soil salinity on embankments of planting site 3 between September 2011 and May 2012

In November 2013 salinity was measured at a planting site without land preparation on which seedlings had been growing for 16 months. The salinity was at an average of 51ppt, which is double of what was recorded at a prepared planting site. Comparing these values to the plant development (Figure 9), it can be concluded that salinity highly affects the growth rate of seedlings.

Discussion

Given that *Lumnitzera,* and to some extent *Xylocarpus,* appear to grow successfully on embankments adjacent to canals, it is fair to question whether they would also grow equally well on high land of a similar elevation without the need to dig canals, thereby reducing the cost of afforestation appreciably? As indicated above, in the 2011 plantings at Sites 1 and 3, it is highly probable that water moved laterally from the canals into the subsurface layers of the embankment, which could have been a critical factor contributing to survival over the first dry season. This question is currently being tried to be answer with plantations in 2012 and 2013. In 2012 *Lumnitzera* was planted on a small patch of elevated, barren land without land preparation. The survival rate is slightly lower than at the reference sites with land preparation, but the canopy and overall plant development is much worse as seen in Figure 9.

Figure 9: Left: Canopy development of Lumnitzera at site 3 (with land preparation) after one year; and right: Canopy development at a site without land preparation after one year

In 2013 further 3 ha of barren, elevated land (Site 5) were prepared with smaller canals, only 50 cm deep. After one year the seedlings show similar survival rates to the sites with deep embankments but the seedlings seem weaker. Figure 10 shows a comparison of this planting site (with smaller canals) and the control site, at which no planting too place, after three months. It is apparent, that *Lumnitzera* had higher survival rates even with small canals, compared to the site without land preparation. The overall seedling development was also much better on the drained site for which reason it can be concluded that the investment of dredging at least small calas can increase survival rates and plant development incrementally.

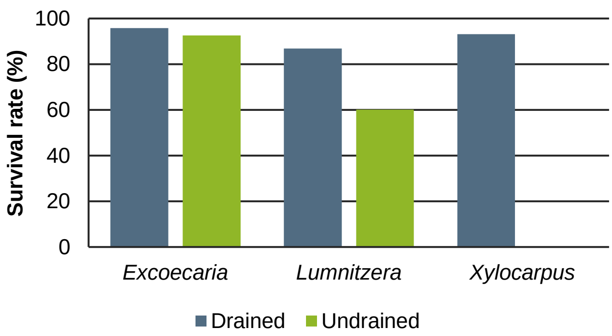

Figure 10: Survival rates of *Excoecaria*, *Lumnitzera* and *Xylocarpus* on planting sites with smaller canals (drained) and without canals, (undraine) three months after planting.

Finally, planting on elevated barren sites requires seedlings that have been grown in a nursery for at least nine months. This adds significantly to the cost of planting such sites, with or without canals. For the planting at Sites 1 and 3 in 2011 the nursery costs were about 25 % of the total cost of around USD 6,830 per hectare. Canal construction and other site preparations accounted for 38 % of the total cost, and transportation and labour for planting about 37 % of the total cost (Table 2). These figures serve to illustrate the need for a proper site assessment prior to planting in order to have a high chance of success and avoid wasting funds on unsuccessful plantations.

Table 2. Average cost per hectare of planting at Sites 1 and 3 in 2011. The area planted was 0.8 ha at Site 1, and 2.3 ha at Site 3. A total of about 31,500 seedlings were planted.

Item	VND ha^{-1}	USD ha^{-1} *
Site preparation (mainly canal construction)	57,245,161	2,600
Seedling costs (propagule + nursery costs)	36,834,677	1,670
Planting costs (transport + labour)	56,193,548	2,550
Total cost	15,273,387	6,830

* Based on an exchange rate of USD 1 = VND 22,000 and rounded up or down to the nearest USD 10

Conclusion

In conclusion, while the initial planting in canals was not successful, planting on the embankments, where the survival rate was over 70 %, can be considered a success. At planting densities of 20,000 per hectare, a survival rate of 50% is sufficient to ensure effective coastal protection, provided that the survivors are evenly distributed, and continue to grow and produce well-developed canopies. On the basis of survival and growth over the first 36 months, *Lumnitzera racemosa* appears to be the most promising of the three species for planting on more elevated sites, followed by *Xylocarpus moluccensis*. *Intsia bijuga*, which is less salt-tolerant and perhaps has a less well-developed root system, does not appear to be very promising for these kinds of sites. Brugiera cylindrical planted in the canals did not exhibit very high survival rates but the remaining seedlings developed very well.

The approach of dredging canals to restore, degraded, elevated, barren land can be recommended. If possible the investment of preparing the site with deep canals should be undertaken to ensure high survival rates and good plant development. This is especially important for sites which are close to the eroding shores, as an intact forest will reduce the rates of erosion. For less exposed sites, it can be recommended to dredge smaller and shallower canals to allow for some water exchange and to reduce salinity. The planting of elevated, barren land sites without any land preparation cannot be recommended as the plants develop poorly and can, unlike the saplings on prepared sites, not be considered to exhibit a protection function.

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Annex 1 – Pictorial Sequences

Site 1

May 2011: Before land preparation in. The seedlings visible in the photograph were planted in 2005.

June 2011: The early stages of canal dredging.

September 2011: A few days after planting.

August 2013: 23 months after planting

Site 3

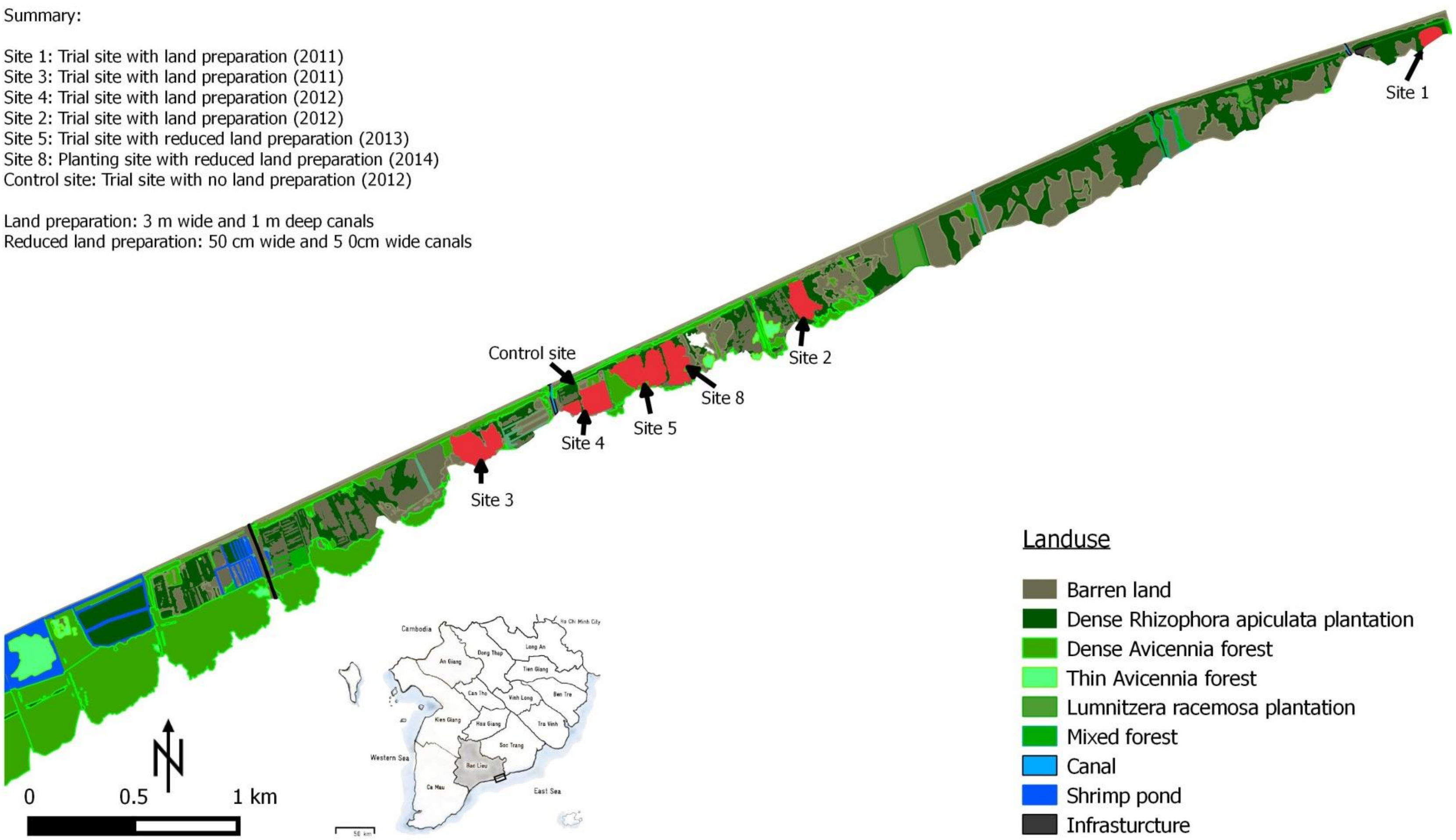
May 2011: Before land preparation. The soil was so compacted that it was impossible to get a soil sample

June 2011: The early stages of canal dredging.

September 2011: A few days after planting.

October 2012: 13 months after planting

Annex II: Location of trial planting sites



Location of trial planting sites at the coast of Vinh Trach Dong, Bac Lieu Province

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