

Ecological Restoration on *Leucaena leucocephala* Invaded Stands at the West Coast of Hengchun, Southern Taiwan

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Abstract

Forests at the west coast of Hengchun peninsula, southern Taiwan, have been seriously invaded by *Leucaena leucocephala* which is listed in the world's 100 worst invasive species. To restore the forests as native-species dominated stands, eradication of *L. leucocephala* and planting of 17 coastal native tree species, including 11 pioneer species and 6 non-pioneer species were conducted in June 2008. All *Leucaena* trees were cut and removed in planting strips of 6 m or 12 m, but left all native woody species inside those strips intact to provide shading. In addition, a protection strip of 3 m in width, where no trees were cut, was installed on both sides of each removal strip to serve as windbreaks. There were 5,500 stems of *Leucaena* per ha before the restoration effort. Four years after the operation, saplings and young seedlings of *Leucaena* were reduced to less than 1,000 stem ha⁻¹. Growth of the woody plants that regenerated naturally was enhanced by the removal of *Leucaena*. Basal area increased from 10 to 24 m² ha⁻¹ and density increased from 2,000 to 3,800 stem ha⁻¹. Canopy openness hence reduced from 54% to 8% as monitored by fisheye photographic images. As for the 17 planted coastal tree species, survival rates of *Thespesia populnea*, *Cerbera manghas* and *Pandanus odoratissimus* were higher than 75% after four years of restoration, but overall survival rate was only 53% due to the prolonged dry period (6 months each year) in this region. Mean height growth of pioneer species ranged from 120 to 300 cm, with some fast growing individuals reaching 6 m. Although the growth of non-pioneer seedlings was relatively slow (90-140 cm in average), their existence indeed increased the species diversity of this community.

Keywords: coastal forests, height growth, *Leucaena leucocephala*, native-species dominated stands, restoration efforts.

Introduction

Leucaena leucocephala is a pioneer species with high productivity and fast growing ability. It can dominate an open field or a disturbed land in a very short period. This species is thus listed as one of the world's 100 worst invasive species. In low-elevation areas of southern Taiwan, substantial forest lands were found to have been invaded by *Leucaena*. In order to restore the biodiversity and ecological functions at these coastal forests, all *Leucaena* were eradicated and reforestation operation was conducted in some severely invaded coastal forests, with a goal of recovering the invaded forests to those dominated by diversified native tree species.

Materials and Methods

The study site, about 50 to 100 m to the seashore, is located at the west coast of Hengchun peninsula in southern Taiwan (22°00'01"N, 120°41'59"W) (Fig. 1). Here, the average annual temperature is 25.1°C with annual precipitation 2,020 mm. Dry season lasts from November to April every year, and northeasterly monsoon prevails in the winter.

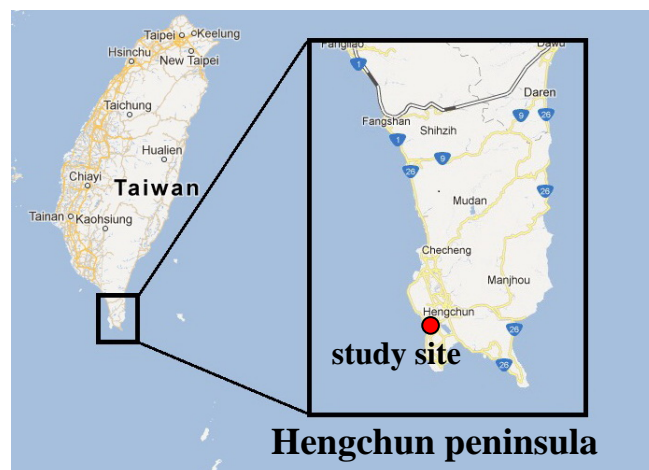


Figure 1. Location of the eco-restoration study site.

The study site was established in May 2008 with a total area of 1.96 ha (Fig. 2). By means of randomized completely block design, four blocks each with two 12 m and four 6 m planting strips were set up where all *Leucaena* stems were cut and removed but all other native tree species were retained. Re-sprouts of *Leucaena* were cut out regularly. In between the planting strips, a protection strip of 3 m wide was also installed where no vegetation was removed to provide shading and as wind-breaks (Fig. 2). Blakesley *et al.* (2002) suggested using framework species method for ecological restoration, where planted trees should include both pioneer and dominate species with characteristics of easy germination, capable of surviving in harsh environments, and attract wild animals for seed dispersal. With these

characteristics, reforestation was more likely to be successful and ecological biodiversity can be quickly restored. According to the principles aforementioned, 17 native tree species were mix-planted in the planting strips, including 11 pioneer species and 6 non-pioneer species (Table 1). Their growth performances were measured in April and in October every year. The dominance of *Leucaena* compared to pre-existed native trees was monitored as well as changes in canopy openness determined periodically by fisheye photographic images.

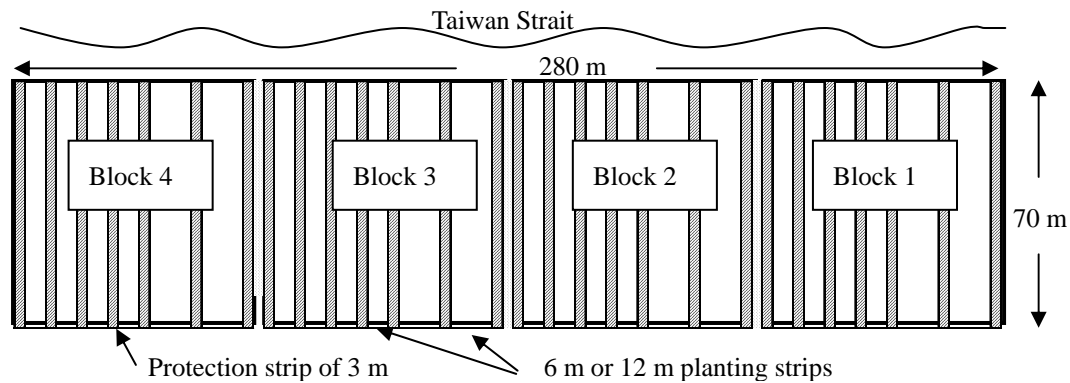


Figure 2. Layout of the study site showing 4 blocks each with 6 planting strips and several protection strips.

Results and Discussion

Density of *Leucaena* in the stand was 5,500 stem ha^{-1} before eradication. Four years after the restoration effort, its density was reduced to less than 1,000 stem ha^{-1} . On the other hand, density of native trees increased from 2,000 to 3,000 stem ha^{-1} with basal area increased from 10 to 24 $\text{m}^2 \text{ha}^{-1}$. As native tree species grew, canopy coverage of the stands had significantly increased while canopy openness reduced from 54% to 8% after the restoration.

The 17 tree species planted showed a mean survival rate of 77% one year after the planting, reduced to 59% in two years (Chen *et al.*, 2011), and 53% in four years (Table 1). Among them, *Thespesia populnea*, *Cerbera manghas*, *Ficus superba*, *Pittosporum pentandrum*, *Pandanus odoratissimus*, *Aglaia formosana* and *Planchonella obovata* had survival rates higher than 70%.

The average height of planted seedlings was about 40 to 85 cm initially. After four years of growth, 11 pioneer species reached 120 to 300 cm. Mean height of *Macaranga tanarius*, *T. populnea*, and *P. pentandrum* seedlings was higher than 200 cm with some reaching 600 cm (Table 1) in the upper canopy. Heights of non-pioneer species seedlings ranged from 90 to 140 cm. This research indicated that reforestation with mix-planted trees could speed up the closure of canopy, hence inhibited the dominance of invasive species along with protecting

both planted and pre-existed species. As the survival rates of planted seedlings stabilized, their height growth showed an increasing trend each year. This project is the first restoration effort which aims at managing the invasive species *L. leucocephala* in Taiwan. The stands were successfully converted from *Leucaena*-dominated ones to species-rich and native-species dominated ones. The goal of ecological restoration in this study has been preliminary accomplished.

Table 1. Sample size (n), survival rate, mean height (HT), and maximum height (HT_{max}) of the 17 planted native tree species after four years of growth

Species	n	Survival rate (%)	HT (cm)	HT _{max} (cm)	Species	n	Survival rate (%)	HT (cm)	HT _{max} (cm)
Pioneer species									
<i>Thespesia populnea</i>	169	86	241±98	614	<i>Terminalia catappa</i>	114	36	166±97	567
<i>Cerbera manghas</i>	63	79	120±53	298	<i>Scaevola sericea</i>	18	19	116±43	192
<i>Ficus superba</i>	61	73	189±80	403	Non-pioneer species				
<i>Pittosporum pentandrum</i>	66	73	208±63	359	<i>Pandanus odoratissimus</i>	68	78	104±37	213
<i>Millettia pinnata</i>	60	58	162±54	326	<i>Aglaia formosana</i>	62	77	127±35	183
<i>Premna serratifolia</i>	43	46	133±57	268	<i>Planchonella obovata</i>	55	73	116±50	229
<i>Hibiscus tiliaceus</i>	121	42	118±70	347	<i>Calophyllum inophyllum</i>	50	53	137±54	318
<i>Macaranga tanarius</i>	79	37	308±115	618	<i>Hernandia nymphiifolia</i>	11	16	93±45	192
<i>Ficus septica</i>	129	45	166±90	451	<i>Ficus benjamina</i>	14	18	144±64	310

References

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