Restoration of a degraded dry forest using nurse trees at Dambulla, Sri Lanka

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SUMMARY

We determined the effect of over-storey nurse tree cultivation on species composition in a naturally regenerated dry forest in a dry zone arboretum in Sri Lanka. The forest had previously been abandoned shifting cultivated land. One area was restored using nurse trees, one area was restored without nurse trees, and one area was left unmanaged as a control. Species dominance, richness and diversity of regenerated trees were assessed within random plots in the three treatment types. Regenerated tree species richness and diversity were greater in the restored land with nurse trees than in the restored land without nurse trees or in the control area. Dry forest tree species were dominant in the plots with nurse trees, while light-demanding and competitive pioneer scrubland species were dominant in the plots without nurse trees and the control area. We suggest that monospecific tree plantations that have been established for reforestation or agroforestry purposes could be used as nurse trees for dry forest restoration.

BACKGROUND

Forest agrarian systems (shifting, swidden or slash and burn cultivation) are ancient, popular and widely distributed practices, especially in Asia, Africa and Latin America (Teegalapalli *et al*. 2009). Such practices have degraded several thousand hectares of tropical dry forests in Sri Lanka (Perera 2001). Recovering these forests to their natural condition, with dominant primary forest species, is a serious challenge to forest managers and conservationists (Lamb *et al*. 2005). Although seeds are available in the soil seed bank, rapid colonization by light-demanding and fast-growing early pioneer species and alien plant invaders suppresses or delays the natural regeneration of late-successional tree species seedlings through above and below ground competition (Weerawardana 1999, Perera 2001).

To combat these problems, Popham (1993) introduced a sustainable, low-cost silvicultural method to encourage the growth of seedlings of forest tree species. Previous studies in the tropics have indicated that late-successional tree species grow better under the favourable microclimatic and soil conditions created by nurse tree plantations than under pioneer species (Ashton *et al*. 1997, Perera 2001, Carnus *et al*. 2006). We therefore test whether Popham's method could be combined with the use of mango *Mangifera indica* as a nurse tree to aid dry forest restoration. This study evaluated the effects of over-storey nurse tree cultivation on the natural regeneration of dry forest tree species at Dambulla, Sri Lanka.

ACTION

Study site. An arboretum was established by Mr. F.H. Popham in 1963 on 7.5 ha of degraded scrubland, abandoned after shifting cultivation. It is located in Dambulla, Central Province of Sri Lanka (07°51'34''N, 80°40'28''E), in the dry zone of the island. The area receives an annual average rainfall of 1250 mm, mostly during the northeast monsoons (November to January), and five months of windy drought conditions during the southwest monsoons (May to September). The arboretum currently consists of 50-year-old forest vegetation growth in the late stage of forest succession (A1 & A2), unmanaged degraded scrubland (B) and mature native woodland (C) (Figure 1).

Restoration intervention: In 1963, 1.5 ha of degraded scrubland in the arboretum was cultivated with mango nurse trees at a density of 50 trees/ha (area A1, Figure 1). Two years later this cultivated land and 2.2 ha of degraded scrubland (area A2) were gradually converted to a forest arboretum by adopting the Popham method. In the meantime, 3.1 ha of degraded scrubland were left unmanaged (area B) and the remaining area was managed as woodland (area C). Popham's arboricultural approach to restoration was to facilitate the emergence and growth of seedlings of forest tree species. The first step involved clearing away creepers, vines, shrubs and grasses (early pioneers) from around the emerging forest tree seedlings. Once freed from competition, the seedlings eventually grew into trees. The young trees (≤ 3 m in height) were then stem pruned to gain height above their competitors, and saplings were thinned where necessary. To reduce the loss of moisture from the soil during the annual drought period, the clearing of early pioneer species was limited to the emerging tree seedlings. Ongoing annual clearance of the early pioneers just before the rains enabled the germination of new seedlings with the onset of the rains (Popham 1993).

Monitoring: Plant communities in the restored areas with nurse trees (A1), restored areas without nurse trees (A2), and the unmanaged land used as a control (B) were surveyed in 2013 (Figure 1). Seven 10 x 20 m quadrats were randomly placed in each of the three treatments. The map area was blocked out into plots and numbers assigned to each plot; plots were then selected using a random number table and GPS to locate in the field. The number and diameter of trees of 1-20

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ISSN 1758-2067

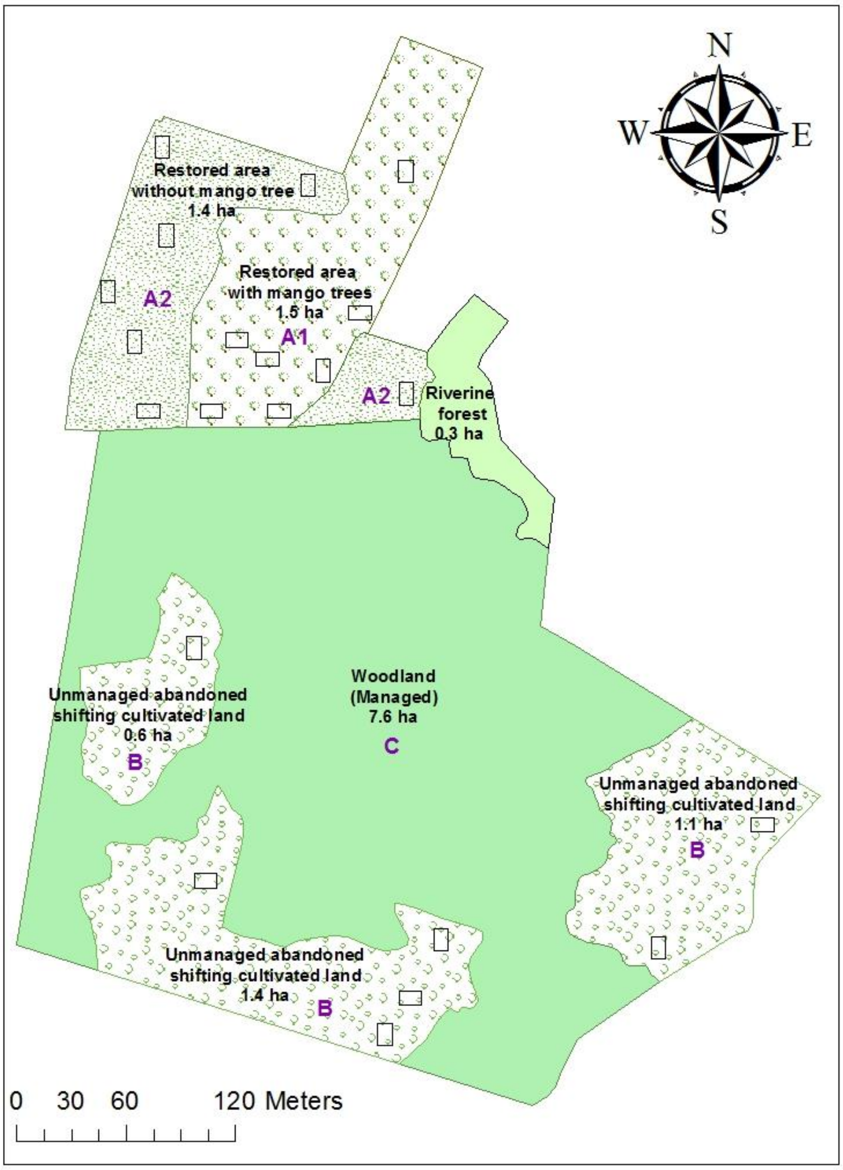

Figure 1. Map of the Popham arboretum with restored and unmanaged control areas. Black boxes show the sampling quadrats.

cm in diameter at breast height of each species in each quadrat was recorded. Example specimens of all unknown species were prepared and their botanical names were verified at the National Herbarium, Peradeniya, Sri Lanka.

Data analysis: The dominance and diversity of tree species within each of the treatments were quantified using the importance value index and Shannon diversity index respectively (Giliba *et al*. 2011). Importance value indexes were calculated from the relative basal area, density and frequency of the tree species:

$$\text{Relative frequency} = \frac{\text{No. plots with species present}}{\text{Total no. plots}} \times 100$$

$$\text{Relative dominance} = \frac{\text{Total basal area of a species}}{\text{Total basal area for all species}} \times 100$$

$$\text{Relative density} = \frac{\text{No. individuals of a species}}{\text{Total no. individuals}} \times 100$$

The importance value index was calculated for each species as the sum of the relative frequency, the relative dominance and the relative density. Ecologically, density and frequency of a species measure the distribution of a species within the population while basal area measures the area occupied by the stems of trees. The Shannon diversity index for an area was calculated as $\sum(Pi*\ln(Pi))$ across species, where Pi is the importance value of a species. Species richness describes the total number of species recorded in a treatment.

Table 1. Tree species richness and Shannon diversity index of restored areas with nurse trees, restored areas without nurse trees and unmanaged control plots in Popham arboretum.

Treatment	**Species richness**	**Species diversity**
With nurse trees	53	3.2
Without nurse trees	40	2.9
Control	40	2.8

ISSN 1758-2067

Table 2. The 12 most dominant tree and shrub species recorded in restored areas with nurse trees, restored areas without nurse trees and control plots in the Popham arboretum (IVI Important Value Index).

With nurse trees			Without nurse trees			Control		
Species	**IVI**	**Habitat***	**Species**	**IVI**	**Habitat***	**Species**	**IVI**	**Habitat***
Ixora pavetta	110	FU	*Memecylon umbellatum*	97	FU	*Catunaregam spinosa*	114	SL
Cassine balae	101	FS	*Glycosmis mauritiana*	91	FU/SL	*Pterospermum canescens*	107	FC/SL
Glycosmis mauritiana	101	FU/SL	*Diospyros ferrea*	82	FU/SL	*Diplodiscus verrucosus*	98	FS
Psydrax dicoccos	96	FS	*Pterospermum canescens*	81	FC/SL	*Memecylon umbellatum*	96	FU
Diospyros ferrea	86	FU/SL	*Phyllanthus polyphyllus*	70	SL	*Maytenus emarginata*	81	SL
Madhuca longifolia	77	FC	*Murraya paniculata*	64	HG	*Diospyros ferrea*	75	FU/SL
Phyllanthusindicus	71	FU	*Manilkara hexandra*	64	FC	*Grewia damine*	67	FG
Memecylon umbellatum	63	FU	*Drypetes sepiaria*	60	SL	*Vitex altissima*	64	FC
Vitex altissima	61	FC	*Eugenia bracteata*	59	SF	*Lepisanthues tetrapylla*	63	FC/SL
Pleiospermium alatum	59	FU/SL	*Gmeliaasiatica*	51	SL	*Syzygium cumini*	48	FC/SL
Chloroxylon swietenia	48	FC	*Pleiospermium alatum*	50	FU/SL	*Allophylus cobbe*	47	FU
Allophylus cobbe	47	FU	*Grewia damine*	46	FG	*Dimorphacalyx glabellus*	45	SL

*Habitat preference of species: FC forest canopy, FS forest sub-canopy, FU forest understorey, SL scrubland, HG home garden, SF secondary forest, FG forest gaps.

CONSEQUENCES

Across all the sample plots (0.28 ha), a total of 73 tree species were recorded, representing 69 genera and 30 families. The overall values of species richness and diversity in the restored area with nurse trees, restored area without nurse trees and control plots are given in Table 1.

Dry forest tree species such as *Ixora pavetta*, *Cassine balae*, *Glycosmis mauritiana*, *Psydrax dicoccos*, *Diospyros ferrea*, *Madhuca longifolia*, *Phyllanthus indicus*, *Memecylon umbellatum*, *Vitex altissima*, *Chloroxylon swietenia*, *Pleiospermium alatum* and *Allophylus cobbe* were dominant in the plots with nurse trees. Light-demanding pioneer scrubland plants of *Catunaregam spinosa*, *Maytenus emarginata*, *Phyllanthus polyphyllus*, *Murraya paniculata*, *Grewia damine* and *Dimorphacalyx glabellus*, as well as a few dry forest species, *Memecylon umbellatum*, *Diplodiscus verrucosus*, *Pterospermum canescens*, *Diospyros ferrea*, *Dimorphacalyx glabellus*, *Manilkara hexandra*, *Glycosmis mauritiana* and *Eugenia bracteata*, were dominant in the control plots and restored plots without nurse trees (Table 2). The total number of forest species in the plots with nurse trees was higher than in the plots without nurse trees and the control plots, and the plots with nurse trees had the fewest scrubland species (Table 3).

DISCUSSION

This study demonstrates that naturally regenerated tree species richness and diversity were highest in areas with nurse trees compared to areas without nurse trees or unmanaged shifting cultivation treatments, supporting the findings of Ashton *et al*. (1997), Perera (2001) and Carnus *et al*. (2006). Nurse tree plantations of mango can therefore increase natural regeneration of light-sensitive dry forest tree species dominance, richness and diversity via effects on the understorey microclimate and soil fertility, as well as suppressing light-demanding pioneer scrubland species (Ashton *et al*. 2001). Also, the effort required to remove the early pioneer species by human intervention is minimum under nurse tree cultivation, since their growth is not aggressive (pers. obs.). The nurse trees also attract animal seed dispersers.

The use of the Popham restoration method in combination with nurse trees is a potentially sustainable, low-cost silvicultural method for converting degraded lands into dry forest in Sri Lanka and elsewhere. Further studies should investigate the consequences of pruning and thinning the nurse trees on the sapling growth of dry forest tree species. We would recommend that monospecific tree plantations that have been established for reforestation or agroforestry purposes could be used as nurse trees for dry forest restoration.

Table 3. The number of dominant tree and shrub species and their habitat in the sample plots. The 12 species with the highest importance value indices (approximately ≥ 40) in each treatment type were considered dominant; some species appear in more than one category.

Treatment	Forest canopy	Forest sub-canopy	Forest understorey	Total forest species	Total scrubland species
With nurse trees	3	2	7	12	3
Without nurse trees	2	0	4	6	7
Control	4	1	3	8	7

ISSN 1758-2067

ACKNOWLEDGEMENTS

We are grateful to Mr. F.M. Popham who established and developed the Dambulla Arboretum to its current condition. We would like to thank Mr. R.B. Hapukotuwa and Miss. R.S.M. Meedeniya for research assistance and the Institute of Fundamental Studies for permission to carry out the project.

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ISSN 1758-2067