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Restoration of rain forest beneath pine plantations: A relay floristic model with special application to tropical South Asia

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ABSTRACT

In the wet forest regions of southwest Sri Lanka and the Western Ghats, India, *Pinus caribaea* was a common tree species for reforestation on public lands that were originally cleared of native forest for agriculture but subsequently succeeded to fire tolerant grasses and ferns. Much of this reforestation occurred during the 1970s and 1980s. The ecological literature suggests that in many temperate broadleaf forest regions pine is an important component of early succession on old fields, beneath which second growth hardwood can establish and eventually dominate. More recent studies have demonstrated the establishment of native rain forest regeneration beneath a variety of exotic tree plantations. We review nearly twenty-five years of research on this topic for South Asia through a series of studies done in southwest Sri Lanka. Results demonstrate that native species recruitment of both pioneers and site generalist late-successional trees grow well beneath exotic pine plantations. Diversity and density increase from plantation interior to edge. Protection from groundstory fire is the single most important component of promoting regeneration recruitment beneath pine. Establishing late-successional site and dispersal restricted species requires planting beneath pine rather than reliance on natural establishment. Best establishment and growth occur in openings where rows of canopy pine have been removed. Species considered for planting comprise the major late-successional canopy tree species of the forest in the genera *Dipterocarpus*, *Shorea* (Dipterocarpaceae) and *Mesua* (Clusiaceae). Native species that produce non-timber forest products (NTFP) need to be planted with best results in canopy openings. The most valuable NTFP's comprise a sugar palm (*Caryota urens*), rattan (*Calamus* spp.) and a medicinal liana (*Coscinium fenestratum*). Financial analyses reveal that pine plantations that are enrichment planted and cultivated with rain forest timber and non-timber species can provide superior economic benefits as compared to land cultivated singly for tea.

1. Introduction

South Asia is one of the few regions in the tropics whereby an indigenous culture, with its religion and property rights on land, have largely withstood the onslaught of monetization, industrialization and land transformation (Gadgil et al., 1993; Berkes et al., 1995). Most regions of the tropics have faced colonization by new peoples, and a transformation of an economy through exploitation and a clearance of forests that have left much of the land in a state of degradation and unstable land tenure (Colchester, 1994; Berkes et al., 1995). This does not mean that South Asia was immune from such impacts but in large part it appeared to avoid much of these processes because populations were already highly dense, forests were already heavily utilized, indigenous private, community and government property rights and uses were well codified and land use practices were ancient and engrained (Gadgil et al., 1993; Berkes et al., 1995).

In the last thirty years forests in South Asia continue to dwindle but rates of deforestation have been considerably slower than most other tropical forest regions (FAO, 2007; Harris et al., 2012). For example, in Brazil the rate of deforestation over the last five years

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has been 313,292,000 $Ha^2\ y^{-1}$ (3.6% loss from 2000 to 2005), and for Indonesia it has been 701,000 $Ha^2\ y^{-1}$ (3.3% loss from 2000 to 2005). In comparison Sri Lanka and India have deforestation rates respectively of 3000 $Ha^2\ y^{-1}$ (1.2% loss 2000–2005) and 206,000 $Ha^2\ y^{-1}$ (2.1% loss 2000–2005) (Harris et al., 2012); though for India FAO data suggest an actual small net gain in forest (FAO, 2007). Much of the deforestation in South Asia can be related to either illegal intrusion by local landless villagers onto neighboring government lands that comprise state owned forest and parks or legally sanctioned government land clearance projects. The incentives are for small-holders to claim land for intensive cultivation of tea, coffee, rubber and other commercial plantation crops that have dramatically risen in market values over the last few decades. In contrast much of the deforestation elsewhere in the moist tropics is from logging concessions (legal and illegal), large colonization schemes to alleviate poverty from other parts of a country, and industrial expansions for land clearing concessions of oil palm, pulp and paper and soy (Hansen et al., 2008).

For South Asia much of the government lands that were formerly cleared by intrusions were reforested by tree plantations in the 1970–1990 period (Nagendra, 2010). Over 30,000 hectares of land were planted with fast growing timber trees by the Forest Department of Sri Lanka (Pereira, 1988). The most important species planted were *Pinus caribaea*, *Acacia mangium* and *Eucalyptus* spp. (Pereira, 1988). Originally these species were planted because of their easy establishment in fire prone and open environments, their known market values, and easy propagation and access to supply of improved seed (Evans, 1992). However, once established, these plantations were poorly managed and did not cater to the needs and values of neighboring communities. National and State governments failed to invest in product and market development for these tree species, and as such, the local populace viewed the plantations as useless.

In this paper we review nearly twenty-five years of work in which we experimentally manipulated timber plantations to encourage their transformation to other native tree compositions and structures and to cater to a wider array of social and ecological values. We start with reviewing old-field pine succession as a model system applicable to everwet tropical circumstances. We provide examples where exotic plantations planted on old agricultural lands have served to establish native forests beneath their canopy. We then provide a synthesis of our results on testing restoration applications to *P. caribaea* plantations for a variety of conservation and utilitarian state and local values within the everwet forest zones of Sri Lanka. For this we provide some comparative examples of financial income by using pine as a restoration model as compared to continuing to cultivate tea. We end with a summarization of model prescriptions for different landowner objectives.

2. Plantations as old-field pine analogs

Where forests are impacted by disturbance regimes which are abnormal, or where the regeneration of a forest is maladapted to a particular kind of disturbance, relay floristics can dominate as a successional model (Oliver and Larson, 1996). Examples of such trends were originally observed in the eastern United States with what is defined as "old-field pine" succession (Billings, 1938; Bormann, 1953; De Steven, 1991; Dovčiak et al., 2005). Old field pine is a successional phenomenon that is widespread across temperate forest regions where agricultural lands have reverted back to second growth forestlands. After various forbs and grasses, initial woody colonizers are all conifers that are adapted to dry, hot and open conditions that are often inhospitable to light-seeded broadleaf tree species; or where heavy-seeded broadleaves have poor dispersal because their dispersal agents (rodents) avoid open conditions. However, after the conifers have grown up and shaded out the grasses, and provided cover for the animal seed dispersers, the broadleaf trees recruit beneath, and given cutting or disturbance to the coniferous canopy, the broadleaves usurp the canopy. Such old-field conifer processes have been described widely in North America and Eurasia (Table 1).

However, in South and Southeast Asia, where mixed-dipterocarp forests dominate, no such process exists. When cleared agricultural lands are abandoned, the crop land usually reverts to alang–alang grassland (*Imperata cylindrica*); kekila fernland (*Dicranopteris linearis*); or simpoh thickets (*Dillenia suffruticosa*) that can be continuously perpetuated by fire (Cohen et al., 1996; Garrity et al., 1996). For restoration and reforestation this poses a large and very pervasive problem with old agricultural lands throughout the everwet tropical region. Southwestern Sri Lanka and the Western Ghats of India are no different in this regard as compared to other mixed dipterocarp forest regions of Southeast Asia; in particular the Malay peninsula, Sumatra, Borneo and the southern Philippines.

Many tree plantations in the tropics have native second growth forest that have established in their understory. Are these plantations surrogates of the "old-field pine" succession model? Studies on *A. mangium* plantings in Indonesian Borneo (Kuusipalo et al., 1995; Otsamo, 2000; Norisada et al., 2005); *Eucalyptus* in Australia and Brazil (Keenan et al., 1997; Parrotta, 1997; Parrotta et al., 1997; Kanowski et al., 2005); *Eucalytus* and *Pinus* in South Africa (Geldenhuys, 1997); and teak (*Tectona grandis*) in Thailand (Koonkhunthod et al., 2007) have all recorded understory establishment of native rainforest species. Understory recruitment of native tree species has been shown to be associated with a variety of characteristics that plantation tree species may comprise. Studies have demonstrated some plantation trees attract seed

Table 1
A list of examples of old-field succession whereby gymnosperms first establish, grow and provide shade for establishment of second-growth broadleaf (Angiospermous) forests.

Colonizing species	Forest/Geographic Region	Study
(1) North America		
White spruce (*Picea glauca*)	Maritime provinces, Canada	White and Cogbill (1992)
Eastern white pine (*Pinus strobus*)	New England, Northeast, Midwest USA	Dovčiak, et al. (2005)
Eastern red cedar (*Juniperus virginiana*)	New Jersey, Central USA, limestone	Holthuijzen and Sharik (1985)
Virginia pine (*Pinus virginiana*)	Central Atlantic region, USA	Orwig and Abrams (1994)
Shortleaf pine (*Pinus echinata*)	Piedmont, Central and Eastern USA	Billings (1938)
Loblolly pine (*Pinus taeda*)	SE coastal plains and Piedmont, USA	Bormann (1953) and Spring et al. (1974)
Slash pine (*Pinus elliotii*)	Florida, coastal plains, USA	Hedman et al. (2000)
Oaxaca pine (*Pinus oaxacana*)	Oaxaca, Mexico	Asbjornsen et al. (2004)
(2) Eurasia		
Scots pine (*Pinus sylvestris*)	Western Europe,	Picon-Cochard et al. (2006)
Austrian black pine (*Pinus nigra*)	Italy, Central Europe, Mediterranean	Tonon et al. (2005)
Aleppo pine (*Pinus halepensis*)	Mediterranean	Zavala et al. (2000)
Chir pine (*Pinus roxburghi*)	Western and Central Himalaya	Ohsawa et al. (1986) and Singh and Singh (1987)
Blue pine (*Pinus wallichiana*)	Eastern and Central Himalaya	Ohsawa et al. (1986)

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