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ScienceDirect
Forest Ecology and Management 243 (2007) 39–49
Forest Ecology and Management
www.elsevier.com/locate/foreco

Initial performance and reforestation potential of 24 tropical tree species planted across a precipitation gradient in the Republic of Panama

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Received 12 January 2006; received in revised form 1 February 2007; accepted 1 February 2007

Abstract

Decades of deforestation and unsustainable land use have created large expanses of degraded lands across Central America. Reforestation may offer one means of mitigating these processes of degradation while sustaining resident human communities. However, a lack of information regarding tree species performance has been identified as an important limitation on the success and adoption of diversified reforestation strategies. We analyzed the initial growth of 22 native and 2 exotic tree species planted at three sites across a precipitation gradient in the Republic of Panama (1100–2200 mm year^{-1}), and identify promising species for use in forest restoration, timber production and on-farm systems.

At all sites, *Acacia mangium*, *Diphysa robinoides*, *Gliricidia sepium*, *Guazuma ulmifolia* and *Ochroma pyramidale* rapidly developed large, dense crowns and attained canopy closure after just 2 years. These species might be used in restoration efforts to rapidly stabilize soils and establish crown cover. As nitrogen-fixing legumes, *D. robinoides* and *G. sepium* may also have the potential to increase soil fertility. Several species valued for their timber performed well at all sites attaining high wood volume indices, these species included *Tectona grandis*, *Pachira quinata* and *Tabebuia rosea*. *Albizia guachapele* and *Samanea saman* were among the best performers at the driest site. The most promising species for use in silvopastoral systems varied among sites; *A. guachapele*, *G. sepium*, *S. saman* and *G. ulmifolia* performed best at the driest site, while *G. sepium*, *G. ulmifolia* and *Spondias mombin* were the top performers at the two wetter sites. It is hoped that the results of this trial will improve the success of reforestation efforts by allowing landholders to select species based upon both local site conditions and their specific reforestation objectives.

Keywords: Central America; Forestry; Rainfall; Restoration; Silvopastoral systems; Timber

1. Introduction

Over the last 50 years the Republic of Panama has lost more than 30% of its forest cover (Romero et al., 1999; FAO, 2000). As in much of the Neotropics, the loss of these forests is due primarily to the conversion of forested land to pasture and agriculture (Heckadon-Moreno, 1984; Toledo, 1992). Once forest cover has been lost, tropical lands can rapidly become eroded and infertile (Nichols et al., 2001; Montagnini and Sancho, 1990), and degraded farmland is regularly abandoned. Woody species can be slow to re-establish in degraded pasture (Gerhardt, 1993; but see Griscom, 2004) and the processes of natural succession can be severely impaired by continued soil degradation (Nepstad et al., 1991), dominance of invasive grasses (Hooper et al., 2004; Jones et al., 2004), lack of seed dispersal (Holl et al., 2000) and poor microsite conditions for seed germination (Aide and Cavelier, 1994). Planting trees in degraded tropical landscapes can have positive effects on soil conditions and the regeneration of woody species (Haggar et al., 1998; Lugo, 1997; Ashton et al., 1997; Montagnini, 2001; Jones et al., 2004), and therefore plantations may offer one means to mitigate or reverse the negative impacts of land degradation in the tropics.

Plantation forestry in Latin America has traditionally concentrated on a few well-known exotic species (Evans and Turnbull, 2004). For example, *Tectona grandis*, *Acacia* sp. and *Eucalyptus* sp. represent more than 51% of all plantations established in the Neotropics (FAO, 2000), and *T. grandis* comprised 76% of plantations established in the Republic of

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doi:10.1016/j.foreco.2007.02.001

Panama between 1992 and 2000 (FAO, 2000; ANAM, 2003). Well-managed monoculture plantations of exotic species may be productive under favorable conditions, but these species have often been selected to produce a very limited set of goods and services, and may do a very poor job of achieving other objectives. For example, there is evidence to suggest that plantations of *T. grandis* support low levels of plant biodiversity (Healy and Gara, 2003) and promote soil erosion (Calder, 2002, 2005), and that some exotic species may negatively impact site conditions by reducing soil quality (Berger, 1993; Lugo, 1997). Perhaps most importantly, such a limited number of species cannot be expected to perform equally well across the broad range of climatic and site conditions encountered in Central America's deforested land base, nor can such a small number of species be expected to provide the full range of goods and services landholders seek from planted forests.

More than 100 species of tree native to Panama are known to be used regularly for their timber, fuel wood, fodder and other products (Haggar et al., 1998; Aguilar and Condit, 2001; Love and Spanner, 2005; Connelly, unpublished data). All of these species have the potential to address a wide range of landholder needs. However, relatively little information exists regarding their performance in reforestation projects. For example, tree size, canopy cover and canopy density have been described as the most important characteristics for encouraging soil stabilization and vegetation recruitment to the understory (Montagnini and Sancho, 1990; Parrotta, 1992; Fisher, 1995; Jones et al., 2004), yet most species used for timber production have been selected in part because they allocate a high proportion of biomass to stem wood and have strong apical control (Evans and Turnbull, 2004), and they may therefore be poor choices for reforestation efforts directed at the restoration of ecological function. Some tree species have very specific uses, such as leguminous fodder species that retain foliage during dry periods, readily coppice, have high leaf nutrient content, and are highly digestible by cattle (Chavarria et al., 1997; Jayasundara et al., 1997; Nygren et al., 2000; Dagang and Nair, 2003), or species that are valued for specific properties of their fruits, resins, or bark. Other species may be used to achieve multiple objectives. Studies in Costa Rica have shown that species such as *Vochysia ferruginea* and *Hyeronima alchorneoides* can aid nutrient cycling and encourage land restoration but also have good growth form and high quality timber (Haggar et al., 1998; Carnevale and Montagnini, 2002).

It is well-established that tropical forests in Panama show clear patterns of spatial organization in relation to precipitation (Pyke et al., 2001). Studies of tree species composition across the Isthmus of Panama have shown that Pacific dry forests are quite distinct from the wetter forests of the Caribbean coast (Condit et al., 2004). However, most studies of native species plantations in Central America have been conducted within relatively small geographic areas (Butterfield, 1995; Montagnini et al., 2000; Carnevale and Montagnini, 2002; Piotto et al., 2004; Jones et al., 2004), and it is therefore difficult to extrapolate the results of many of these studies to areas with different climates or soil conditions (though see CATIE, 1986; Piotto et al., 2003; Stewart and Dunsdon, 1994; for regional and pan-tropical comparisons).

For reforestation strategies to be effective at a national and regional scale, and for reforestation to become a viable, widespread activity, landholders must be able to select tree species based both on their specific restoration objectives and on the climatic and other relevant physical characteristics of their landholdings, and it is therefore critically important that the range of reforestation options available to landholders be increased.

Here we present initial results from a long-term study of the reforestation potential of native Panamanian tree species. In the first phase of this study we planted 24 tropical tree species at three deforested sites in the Republic of Panama that span an annual precipitation gradient of 1100–2200 mm year^{-1}. We assess initial species performance across this gradient in relation to three broad use categories:

1. *Restoration potential*: species that rapidly develop wide, dense crowns.
2. *Timber production*: species of known timber value that develop high wood volume indices (VI).
3. *On-farm systems*: fast-growing species useful for silvopastoral or agroforestry systems to increase soil fertility and provide fodder, live fences, and fuel wood.

2. Materials and methods

2.1. Study sites

This study was conducted at three sites in the Republic of Panama: Soberania National Park in the Panama Canal Watershed, Playa Venado in Los Santos Province and Río Hato in Cocle Province (Fig. 1). These sites span an average annual precipitation gradient of 1107–2230 mm, and have varying soil conditions (Table 1). Soberania National Park is the wettest site with mean annual rainfall of 2226 mm and 4.1 dry months annually (defined as months with <100 mm rainfall). Soberania overlies tropical ultisols that are more acidic than those at Los Santos, but have higher concentrations of N and K. Los Santos is the second wettest site with mean annual rainfall of 1946 mm and 5.2 dry months, but has perhaps the richest soils, principally tropical alfisols with the highest concentrations of P, Ca and Mg of the three sites. The soils at both Soberania and Los Santos are

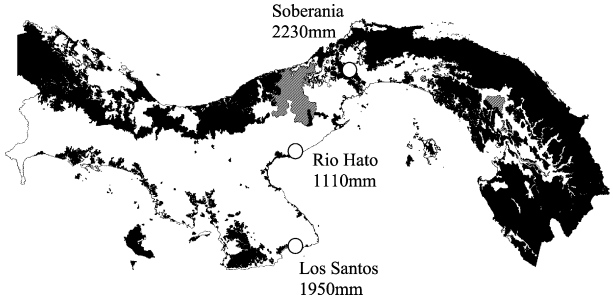

Fig. 1. Map showing forest cover (shaded areas) in Panama in 1992, and the location and rainfall (mm year^{-1}) of each of the three experimental sites: Soberania National Park, Los Santos and Rio Hato (ANAM, 1992; map printed from SIG Republic, Eon Systems, all rights reserved).