

Introduction

This special issue of *Forest Ecology and Management* addresses management issues for the tropical timber species of the Meliaceae. The concept for this issue originated from a technical session entitled “Sustainable management of high-value timber species of the Meliaceae: a global perspective”, held at the 2005 World Congress of the International Union of Forest Research Organizations in Brisbane, Australia. With the goal of helping to maintain the world-wide supply of these woods, the papers presented here cover topics that globally affect these species: natural forest management (Grogan et al., 2008; Hall, 2008; Lopes et al., 2008; Negreros-Castillo and Mize, 2008; Norgauer et al., 2008), plantations (Opuni-Frimpong et al., 2008a; Opuni-Frimpong et al., 2008b; Pérez-Salicrup and Esquivel, 2008; Wadsworth and González, 2008); and the conservation and use of genetic resources (André et al., 2008; de la Torre et al., 2008; Ward et al., 2008; Wightman et al., 2008).

The tropical timber species of the subfamily Swietenioideae (the true mahoganies) of the Meliaceae include some of the finest cabinet woods in the world, based on generally shared characteristics such as dimensional stability and workability. The wood of these species is prized for cabinetry, veneers, interiors, and artisan uses. The Swietenioideae includes *Cedrela* and *Swietenia* in the Neotropics, *Entandrophragma*, *Khaya* and *Lovoa* in Africa, and *Chukrasia* and *Toona* in Australia. Genera discussed in this issue include *Swietenia*, *Cedrela*, *Khaya*, and *Entandrophragma*. In this introduction, we provide a brief overview of the general status of these genera and of the papers in this special issue.

1. Current status

High-value Meliaceae have supplied international markets since the Spanish began exploiting *Swietenia* in the New World in the 1500s (Lamb, 1966). Commercial exploitation has intensified in recent decades for all high-value members of the subfamily Swietenioideae. Many species in these genera face intense exploitation pressure across their natural ranges. As local and regional sources are commercially depleted, exploitation has shifted from population to population and from species to species. This is because improving logging technology and expanding transportation networks have made it possible to exploit timber at ever-greater distances from market centers. Decreases in lower diameter limits for cutting have further reduced remaining stocks. For example, valuable Meliaceae in Ghana (*Entandrophragma angolense*, *E.*

cylindricum, *E. utile*, *Khaya grandifoliola*, *K. ivorensis*, *K. anthotheca*) are likely to be exhausted within two to three decades at current exploitation rates (FAO, 1993). In Belize the legal minimum diameter cutting limit for *Swietenia macrophylla* decreased from 106 to 58 cm during the 20th century (Weaver and Sabido, 1997). Today, few populations are undiminished and giant ‘old growth’ trees survive only in remote forests that remain beyond industrial logging’s reach.

Consequently, all three species of the most valued genus, *Swietenia*, are currently listed on CITES Appendix II (CITES, 2007a), restricting their international trade to legally sourced and sustainably managed supplies (Blundell and Rodan, 2003). Spanish cedar (*Cedrela odorata*) and species of *Entandrophragma* and *Khaya* have also been proposed for listing on CITES, while *Cedrela fissilis*, *K. ivorensis*, and *Lovoa* spp. have been found to meet the criteria for listing on CITES Appendix II (CITES, 2000; CITES, 2007b). Moreover, all the high-value timber species of the Swietenioideae suffer from illegal logging (ITTO, 2006).

2. Management issues—natural forests

The high-value Swietenioideae are usually early-to-late secondary, long-lived trees that reach or surpass the canopy of mature forest, and require moderate to high light for successful establishment and vigorous early growth (FAO et al., 2001; Grogan et al., 2008). Regeneration after logging is the main issue for sustaining natural forest populations. Key limiting factors include adequate seed sources and germination, and appropriate sites and light conditions for establishment. Common to most species are insufficient seed trees and natural regeneration after logging (Plumptre, 1995; Grogan and Galvão, 2006).

Questions remain regarding requirements for establishment and vigorous early seedling growth of these timber species. For example, does *Swietenia macrophylla* (big-leaf mahogany) require large tracts of land opened by catastrophic disturbance for successful recruitment into the forest canopy (Gullison et al., 1996; Snook, 2003), or can it establish and grow to canopy dominance in much smaller single- or multiple-tree forest gaps (Brown et al., 2003; Grogan et al., 2003)? Grogan et al. (2008) indicate that size–class distributions in Brazil belie the catastrophic disturbance hypothesis of regeneration and recruitment. Norgauer et al. (2008) found greater germination success in the shaded understory, but better seedling growth and survival in canopy gaps. Advanced regeneration was abundant

under a 64-year-old low-density plantation of *S. macrophylla* in Puerto Rico (Wadsworth and González, 2008).

Even when seed production and germination are sufficient, significant loss of seeds and seedlings may occur from predation by small mammals, insect attack, fungi, or drought (Negreiros-Castillo et al., 2003; Grogan and Galvão, 2006). Seed predation on *Entandrophragma* in the Central African Republic eliminated all seeds when other food sources were in short supply (Hall, 2008). Insect and fungal attack killed the majority of seedlings in more mature, humid forests, and small mammals were the most important mortality agents in young secondary forest. Such high mortality suggests that additional plantings in gaps must serve as backup for natural regeneration, although appropriate conditions remain to be determined. For *S. macrophylla*, Negreiros-Castillo and Mize (2008) considered a minimal interference, low-cost technique with direct seeding and no maintenance in the Yucatan Peninsula. In Pará state, Brazil, Lopes et al. (2008) investigated planting nursery-grown seedlings of *S. macrophylla* into logging gaps followed by periodic cleaning. Moderate investment in planting and clearing was economically feasible, yielding higher returns than harvest of other commercial species growing in gaps.

Given sufficient seeds and seedlings, the next question is: where to encourage regeneration? Adult tree distributions can indicate a species' preferred habitat, but we must understand factors that determine species distributions for successful forest management. Although adult *S. macrophylla* occurs at higher density on lower slopes throughout southeastern Pará state in Amazonia, Norghauer et al. (2008) found higher germination on high-ground sites. No differences were found in early seedling growth between upper and lower slopes. These authors hypothesize that differential survival at later stages of the life cycle than those examined probably accounted for observed adult distributions. Thus, it may be necessary to assess multiple phases of the life cycle in order to identify the key factors shaping adult distribution patterns.

As trees mature, what is the required cutting cycle for sustained yield? Grogan et al. (2008) found that the average cutting cycle of 30 years in Brazil does not allow for commercial population recovery of *S. macrophylla* if the time required to recruit from seed to commercial size is 60 years or more. Longer cutting cycles in natural forests or rotation lengths in plantations should result in higher value boles, because heartwood volume growth rate increases after diameter growth slows (Wadsworth and González, 2008).

3. Management issues—plantations

As native stocks of the Swietenioideae are depleted, plantations and agroforestry plantings will become more important in maintaining the worldwide supply of these species. The high light requirement for establishment and early growth of many of these species make them particularly suitable for plantations and agroforestry. However, plantation success is limited by attack from larvae of the shoot borer moth (*Hypsipyla* spp.), which destroys the apical meristem of seedlings and saplings, resulting in excessive branching, poor

form, and reduced commercial value. The shoot borer is a particularly frustrating pest because a single larva can cause significant damage to a tree, and the low density of adults (moths) and burrowing habit of the larvae make it extremely difficult to control. Attempts at management are probably best directed at increasing the tolerance of stock to attack by genetic selection (Newton et al., 1993; Navarro et al., 2004) or silvicultural treatment (Mayhew and Newton, 1998), rather than trying to eliminate attack completely.

Planting trees in mixed rather than pure stands, with lateral shade and overhead light, is regarded as the most promising silvicultural approach to shoot borer control (Newton et al., 1993; Mayhew and Newton, 1998). However, in small (0.5–5 ha) plantations of *S. macrophylla* and *C. odorata* in the Yucatan, there was no difference in attack between mono- and polycultures, nor did attack increase with tree density, although taller trees did suffer more attacks (Pérez-Salicrup and Esquivel, 2008). The usefulness of particular species for inclusion in polyculture needs to be evaluated. In the first rigorous study of shade effects on African Swietenioideae, overhead shade did reduce attack, but also severely limited growth, for *K. anthotheca* and *K. ivorensis* in Ghana (Opuni-Frimpong et al., 2008b). Seedlings and saplings of *K. anthotheca* and *K. ivorensis* were more susceptible to shoot borer attack but grew faster than *E. angolense* and *E. utile* (Opuni-Frimpong et al., 2008a).

4. Conservation of genetic resources and tree improvement

Depletion of the Swietenioideae requires action for the conservation of their genetic resources to ensure the adaptive potential of natural populations in the face of changing environments, as well as to provide genetic material for selection. Individual species require the identification and prioritization of populations for conservation. Progress has been made for *C. odorata* in Central America using a combination of molecular and quantitative traits (Cavers et al., 2004). However, not only is complete removal of populations a threat, but population reductions from logging or forest fragmentation may reduce genetic variation and lead to increased isolation and inbreeding. Several species of *Khaya* and *Entandrophragma* are being harvested at such rapid rates that it is difficult to locate germplasm for *ex situ* conservation (Opuni-Frimpong et al., 2008a). At a site in Brazil, post-logging seedlings of *S. macrophylla* showed reduced genetic diversity compared to the adult population that survived logging (André et al., 2008). The authors consider it critical to plan for genetic conservation in logging operations, and to reduce fragmentation among forest populations by mechanisms such as interspersed agroforestry plantings and reseedling after logging. In contrast, de la Torre et al. (2008) did not find a reduction of genetic variation in certain logged populations of *C. odorata*, perhaps because logging had been less intense.

Trials for genetic conservation and tree improvement have previously been established for *C. odorata* and *S. macrophylla* in Mexico, Central America, and Brazil, and for *Chukrasia* spp.

and *Toona* spp. in Australia, Thailand, Laos, Vietnam, Malaysia, and the Philippines (Kalinganire and Pinyopusarek, 2000; Cunningham and Floyd, 2002). Papers in this issue report on a preliminary assessment of the genetic basis for tree improvement in Ghana (Opuni-Frimpong et al., 2008a) and genetic variation in quantitative traits from extensive trials of provenances and families of *C. odorata* and *S. macrophylla* in the Yucatan Peninsula of Mexico (Ward et al., 2008; Wightman et al., 2008). Genetic variation in susceptibility to shoot borer attack has been observed throughout the Swietenioideae (Newton et al., 1993; Cunningham and Floyd, 2002; Navarro et al., 2004), although this was not found for *C. odorata* and *S. macrophylla* in the Yucatan trials (Ward et al., 2008; Wightman et al., 2008). Results from these trials indicate that to minimize shoot borer impact on stem form, selection might better focus on improving growth than reducing attack.

5. Political will, policy, and enforcement

The papers in this special issue advance our understanding of the key issues for sustaining the valuable timber Meliaceae. However, all the research in the world is of no value if policies for conserving forest cover and threatened species, and for ensuring land tenure or rights to forest products, are ineffective. Non-monetary and monetary returns on time scales longer than a generation become irrelevant when the focus is on short-term economic reward (Rice et al., 1997; Bowles et al., 1998). Maintenance of forests requires societal will, policy support, and enforcement from governments (Reid and Rice, 1997; Blundell, 2007). Some success is accumulating with certification strategies (e.g., Duery and Vlosky, 2005), although many countries within the natural range of these species have insufficient resources for the monitoring required for certification or adherence to CITES regulations. Even recently improved forest regulations for *S. macrophylla* in Brazil, setting higher minimum diameter cutting limits and requiring higher seed tree retention rates, will not sustain Brazil's current supply. Accelerating changes in the timber industry and in land use in the Amazon further complicate prospects for sustainable management (Grogan et al., 2008). These issues apply as well to other high-value members of the Meliaceae.

Acknowledgements

We thank John Parrotta, who planted the seed for the Meliaceae technical session at the IUFRO 2005 World Congress and for this special issue, the participants of the session, and the authors who have contributed to this issue. Special thanks to Nick Brokaw and the reviewers. We thank the University of Puerto Rico-Río Piedras for logistical support. We appreciate the patience of all with the editorial process.

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