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Growth and population structure of the tree species *Malouetia tamaquarina* (Aubl.) (Apocynaceae) in the central Amazonian floodplain forests and their implication for management

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ABSTRACT

The long-term success of forest management depends primarily on the sustainability of timber production. In this study we analyse the population structure, tree age and wood increment of *Malouetia tamaquarina* (Aubl.) (Apocynaceae) to define a species-specific minimum logging diameter (MLD) and felling cycle by modelling volume growth. Contrary to other timber species in the nutrient-rich white-water floodplains forests (várzea), *M. tamaquarina* grows in the subcanopy of old-growth várzea forests. The wood of this species is utilized by local inhabitants in the floodplains for handicraft. In 35 plots of 25 m × 50 m we measured diameter at breast height (DBH) and tree height of all trees taller than 150 cm height. From 37 individuals with DBH > 15 cm we sampled two cores by increment borers to determine the wood density, tree age and diameter increment rates. In the management area of a várzea settlement with about 150 ha recently harvested trees of *M. tamaquarina* have been recorded and DBH was measured. The species presents an inverse *J*-shaped diameter distribution indicating that the species is obviously regenerating in the old-growth forests. Tree-ring analysis indicates a mean age of 74.5 years for a DBH of 22.7 cm for a studied population comprising 37 trees with maximum ages of up to 141 years for an individual with a DBH of 45.7 cm. The tree species has low annual diameter increment rates (3.16 ± 0.6 mm) despite a low wood density (0.36 ± 0.05 g cm^{-3}). The volume growth model indicates a MLD of 25 cm and a felling cycle of 32.4 years. In the management area 35 trees with a mean DBH of 24 cm were recorded, similar to the defined MLD. The abundance of trees above the MLD is 2.7 trees ha^{-1}, or 405 trees, when extrapolated to the whole management area. Considering a felling cycle of 32.4 years (annual production unit of 4.63 ha) this results in total of 12.5 harvestable trees, almost three times less than actually harvested. The actual practice of harvesting *M. tamaquarina* risks the overexploitation of this slow-growing species.

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1. Introduction

The conservation of tropical forests has become a huge challenge in our time in the background of global climate change and increasing human populations especially in the tropics with high deforestation rates. A promising way to conserve tropical forests is the development of sustainable management systems which guarantee the long-term use of natural resources such as timber and non-wood forest products (NWFP) and maintain the multiple ecological functions and services of the forests. But a great difficulty for a sustained management of tropical forests is obtaining reliable data on tree growth, which is a prerequisite for determining harvesting volumes and felling cycles (Boot and Gullison, 1995; Brienen and Zuidema, 2006, 2007; Schöngart, 2008).

For centuries, the nutrient-rich Amazonian floodplains (várzea) have been used and settled by a human population of high density that carried out agriculture, pasture, fishing and hunting, as well as the extraction of timber and NWFPs (Junk et al., 2000). Consequently, várzea floodplain forests are one of the most stressed and threatened forest ecosystems in the Amazon. Many várzea trees are utilized and commercially harvested for a variety of different purposes comprising timber and NWFPs (Phillips et al., 1994; Parolin, 2000; Kvist et al., 2001; Bentes-Gama et al., 2002; Wittmann et al., 2009). In general, floodplain inhabitants have preserved an inti-

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Fig. 1. *M. tamaquarina* is a frequent tree species in the sub-canopy of late successional stages of the várzea floodplain forests used for the manufacture of handicrafts by riverine populations.

mate knowledge of the floodplain environment and its resources (e.g., Hiraoka, 1992; Padoch, 1988; Junk et al., 2000), but intensive commercial exploitations of a few tree species, carried out without knowledge of their growth rates, population structures, and regeneration processes, have locally exhausted merchantable stocks and caused already the disappearance of some timber species from local and regional markets within only a few decades (Ayres, 1993; Lima et al., 2005; Schöngart and Queiroz, 2010). The majority of commercially harvested trees in the várzea belong to emergent tree species of the canopy achieving large diameters such as *Hura crepitans* (Euphorbiaceae), *Maquira coriacea* (Moraceae), *Ceiba pentandra* (Malvaceae), *Cedrela odorata* (Meliaceae), *Ocotea cymbarum* (Lauraceae), *Calycophyllum spruceanum* (Rubiaceae) and *Calophyllum brasiliense* (Clusiaceae) (Schöngart and Queiroz, 2010). Molongó, the local name for *Malouetia tamaquarina* (Aubl.) A.DC. (Apocynaceae), however, is a small, abundant evergreen low-canopy tree of várzea's late successional stages (Fig. 1). The timber is used mainly for the manufacture of handicrafts (Cabalzar, 2003).

Timber extraction in Amazonian forests requires a management plan based on legal regulations and normative instructions (IN) established by the Brazilian Institute of Environment and Renewable Natural Resources (IBAMA). The established IN no. 5 (11 December 2006) defines diameter cutting limits (DCLs) and felling cycles (Schöngart, 2008) for regular management plans with a felling cycle of 25–35 years and maximum yields of up to 30 m^3 ha^{-1} or, alternatively, management plans with low yield intensities (<10 m^3 ha^{-1}) applying a shorter felling cycle of 10 years (in várzea floodplain forests yields can exceed 10 m^3 ha^{-1}, but must be restricted to 3 harvested trees ha^{-1}). The IN no. 5 requires the establishment of species-specific diameter cutting limits based on ecological and technical criteria, but if this information is not available for a timber species, a common DCL of 50 cm is applied.

The GOL concept (Growth-Oriented Logging) developed by Schöngart (2008) is an approach to the sustainable management of tropical timber resources in nutrient-rich central Amazonian várzea forests using species-specific DCLs, in term of an optimized minimum logging diameter (MLD), and felling cycles derived from growth models of 12 commercial tree species. Growth modelling is based on tree-rings, which are annually formed in the wood as a consequence of the annual flood-pulse (Worbes, 1989; Schöngart et al., 2002, 2004, 2005). In this study we examine the population structure and tree growth of *M. tamaquarina* using tree-ring analysis to construct models for diameter and volume growth (Schöngart et al., 2007). From these growth models we derive an estimate for a felling cycle and MLD and discuss our results in the background of current Brazilian forest legislation and actually practised resource management in the study region.

2. Methods

2.1. Study area

The study was located in the Mamirauá Sustainable Development Reserve (MSDR) in the Amazonas state located at the confluence of the Solimões and the Japurá Rivers, approximately 70 km northwest of the municipality of Tefé. The MSDR comprises 11,240 km^2 of várzea floodplains. The climate in the study area is characterized by a mean daily temperature of 26.9 °C and an annual precipitation of almost 3000 mm, with a distinct dry season from July to October. Mean water level fluctuation of the Japurá River during the period 1993–2000 is 11.38 m (Schöngart et al., 2005). The várzea is a landscape patchwork of water bodies, aquatic and terrestrial macrophytes and different forests types which cover about 50–75% of the floodplains (Wittmann et al., 2006). Erosion and sedimentation processes continuously rearrange the floodplains, creating a mosaic of small-scale landscapes corresponding to different successional stages with ages up to 300–400 years (Schöngart, 2003).

The MSDR was the first conservation unit in the Brazilian várzea, established in 1990 as an Amazonas State Ecological Station and transformed into a Sustainable Development Reserve in 1996 by the State's Governor as a new category of conservation unit in Brazil. Together with the Amanã Sustainable Development Reserve, Jaú and Anavilhanas National Parks, the MSDR forms the "Central Amazon Conservation Complex" with a total area of about 6 million hectares. This region was declared a world natural heritage site by UNESCO in the year 2000 and recognition was extended in 2003 (Ayres et al., 2005).

Since 1992, a variety of community-based management systems have been implemented in the MSDR based on socio-economic and biological-ecological studies, including fisheries, agriculture, agroforestry, eco-tourism, and forestry (Ayres et al., 1998). Since 1998, several cooperatives have been founded within the MSDR to conduct controlled timber extractions. This forest management aims to keep a multi-aged stand through timber cutting at intervals (felling cycle) by establishing a diameter cutting limit (polycyclic system). The felling cycle defines the return interval in years between timber harvests in the same area. Due to the harvest of only a few selected trees above the defined diameter cutting limit, the uneven-aged structure of the forest is maintained by the establishment of seedlings in small gaps and in the understorey (de Graaf et al., 2003). To achieve a more or less constant annual harvest, the total area for the forest management is divided in several blocks (annual production units) with similar size corresponding to the number of years of the felling cycle. The community Nova Colômbia in the MSDR traditionally uses the wood of *M. tamaquarina* for handicrafts and sells the products at local markets supported by the program for the production of handicrafts of the Mamirauá Institute for Sustainable Development. The semicircular management area comprises approximately 150 ha of forests which the locals can reach within a one hour foot walk (terrestrial phase) or canoe (aquatic phase) from the community (Fig. 2). The annual average income for the seven families of the community Nova Colômbia practising the production of handicrafts was 8845.00 Brazilian Reais (US$ 5025.00) during the period 2007–2009 and contributed considerably to the annual rent and welfare of the local riverine people.

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