Forest Ecology and Management 432 (2019) 376–386

Contents lists available at ScienceDirect

Forest Ecology and Management

journal homepage: www.elsevier.com/locate/foreco

Modelling above ground biomass accumulation of mangrove plantations in Vietnam

Sang Minh Phan[a,b,d,*], Huong Thuy Thi Nguyen[c,e], Trung Kim Nguyen[c,e], Catherine Lovelock[a]

[a] School of Biological Sciences, The University of Queensland, Brisbane 4072, Australia
[b] Southern Institute of Ecology, Vietnam Academy of Sciences and Technology, Ho Chi Minh City, Vietnam
[c] Silviculture Research Institute, Vietnamese Academy of Forest Sciences, Ha Noi, Vietnam
[d] Former Researcher at Silviculture Research Institute, Vietnamese Academy of Forest Sciences, Vietnam
[e] School of Veterinary and Life Sciences, Murdoch University, Perth 6150, Australia

A R T I C L E I N F O

Keywords:
Mangrove
Rhizophora apiculata plantation
Biomass
Growth and yield modelling

A B S T R A C T

In many tropical nations, mangrove forests are essential ecosystems for climate change mitigation and adaptation in coastal regions as they provide important forest resources as well as a suite of other benefits to communities including carbon sequestration. Empirical growth and yield modelling methods derived from terrestrial forestry, which are often robust with respect to forestry forecasting and management, have not often been assessed in mangrove forests yet they are important for underpinning sustainable forest management. We surveyed 89 *Rhizophora apiculata* mangrove plantations with age ranges from 4 to 26 year old in Vietnam, destructively harvesting 25 trees for biomass measurements and 70 for stem analyses, to assess increments in biomass and standing timber. Systems of equations were developed to model site index, mean diameter, dominant height, stocking, biomass and timber volume. We found that conventional forest growth modelling methods fitted the observed data well. Similar to terrestrial forests, stand height is a good indicator of site productivity. Mean errors for stand volume and biomass estimated from yield tables were both less than 5.3%. The root mean square error (RMSE) of the biomass model was 12 and RMSE of the volume model was 10.8, suggesting that these methods are applicable to evenly aged monoculture mangrove plantations in Vietnam. Our research also indicated high variation in mean annual increment of biomass (MAI) in the surveyed plantations due to a wide range of age and site conditions. Some *R. apiculata* plantations in Vietnam can reach a peak aboveground biomass MAI of 22.7 Mg ha^{-1} $year^{-1}$, which is among the highest of published values from plantations of the same species worldwide. Further studies addressing the application of terrestrial forest growth methods to mangrove systems are suggested in order to develop reliable and useful tools for sustainable management of this important ecosystem.

1. Introduction

Mangrove forests play essential roles in tropical coastal environments, supporting fisheries and biodiversity, protecting coastlines from erosion and extreme events, sequestering carbon and supporting human socio-economic activities (Alongi, 2009). Mangrove forests are the dominant vegetation in some of the largest most populated deltas in the world (Spalding et al., 2010; Giri et al., 2011) where they have been degraded and cleared due to conversion for agriculture and aquaculture, particularly in south east Asia (Richards and Friess, 2016). Due to the importance of mangrove ecosystems and in response to losses, extensive mangrove rehabilitation programs have been conducted in South East Asia with the goal of sustaining coastal communities and reducing their vulnerability to catastrophic events and climate change (Saenger, 2002; Mimura, 2008). One of the most common rehabilitation approaches is establishing plantations of mangrove species using genera such as *Rhizophora* on land that was deforested during the war, over-exploited for timber collection and converted to aquaculture (Tri et al., 1998; Mimura, 2008).

Restoring and protecting mangrove forests is an effective measure for strengthening resilience and adaptability of deltaic regions under climate change and sea level rise (Gedan et al., 2011). Although monospecific plantations may be less desirable than diverse forests in supporting and maintaining biodiversity and resilience (Polidoro et al., 2010; Salmo et al., 2013), plantations provide important benefits for communities, particularly when communities have limited uplands,

* Corresponding author at: School of Biological Sciences, The University of Queensland, Brisbane 4072, Australia.
E-mail address: sang.phan@uq.edu.au (S.M. Phan).

https://doi.org/10.1016/j.foreco.2018.09.028
Received 3 July 2018; Received in revised form 14 September 2018; Accepted 15 September 2018
0378-1127/ © 2018 Elsevier B.V. All rights reserved.

where they provide a suite of ecosystem services, including carbon sequestration, timber production, coastal protection and support of fisheries (Bosire et al., 2008).

Growth and yield modelling methods for terrestrial forests have only been partially adapted for mangrove forests (Saenger, 2002; Alongi, 2009). Biomass increment studies have been successfully conducted for several mangrove forests, notably in Malaysia, Australia, and Thailand where up to 30 years of growth have been monitored (Putz and Chan, 1986; Saenger, 2002; Alongi, 2009, 2012), but apart from these examples there are few assessments of forest development and yields from mangrove plantations. Empirical forest modelling methods have been mainly used to estimate standing biomass of trees and forests using allometric biomass equations (Ong et al., 2004; Komiyama et al., 2008), but could also be used to estimate growth and yields.

Extensive measurement campaigns to develop a system of growth curves and stand attributes for biomass dynamics, similar to the growth and yield tables for timber for terrestrial forests, have not yet been performed for mangrove forests, but would have widespread application throughout South East Asia. Dynamic models developed for the mangrove species *Rhizophora apiculata,* which is a favoured plantation species, are limited because some ecological variables and data from stem analyses are yet to be incorporated (Asaeda and Kalibbala, 2009) or because model's have limited applicability due to limited availability of data from a wide enough range of forest ages or geographical research areas (Okimoto et al., 2013). Stem analysis has been studied for several species of mangrove forests and results suggest it is an applicable approach for estimation of tree and stand growth and climate impacts in this ecosystem (Li, 1997; Menezes et al., 2003; Yu et al., 2004; Verheyden et al., 2005; Yu et al., 2007; Analuddin et al., 2009; Khan et al., 2009; Robert et al., 2011; Santini et al., 2012).

In the Mekong delta region of Vietnam, mangroves are important natural resources and have been widely planted. Over 50 percent of mangrove forests in Vietnam are located in this region (VNFOREST, 2013). However, Vietnam's mangrove area decreased from 409 000 ha in 1943 to only 139 000 ha in 2012 due to losses from agent orange during the conflict with the USA and due to conversion to aquaculture (Do et al., 2005; VNFOREST, 2013; Nguyen, 2014; Nam et al., 2016). Substantial efforts have been made to restore mangroves by planting trees and establishing mixed forestry and aquaculture and agricultural systems using *R. apiculata*. *Rhizophora apiculata* is common in low elevation mangroves of the region (Saenger, 2002) and is favoured in plantations because of its ease of planting (it does not require rearing in a nursery), rapid growth rates and the suitability of the wood for construction and the production of charcoal in this region (Saenger, 2002). As a consequence, the majority of *Rhizophora* mangroves in the Mekong delta are now plantations (Arnaud-Haond et al., 2009).

The aims of this study were (i) to assess empirical modelling methods similar to those used for terrestrial forests and growth and yield models for *R. apiculata* mangrove plantations, and (ii) to apply models for estimation and forecast forest growth and biomass accumulation of *R. apiculata* plantations in the Mekong delta region, Vietnam, providing growth and yield tables for plantations of this species for this region.

2. Material and methods

2.1. Field-based research

2.1.1. Survey of Rhizophora apiculata plantations

The study included 89 *Rhizophora apiculata* plantations located in the six coastal provinces of Mekong delta in Vietnam, ranging from 8°33′N to 10°11′N and longitude range from 103°45′E to 106°46′E (Fig. 1, Table 1). All plantations were established on sites where primary mangroves had been cleared by Agent Orange during the war, or due to aquaculture or timber harvesting. All plantations are within protection forest areas where forests are strictly managed to minimize interventions until they are legally harvested. The plantation lands belong to the government; however, local farmers are granted protection contracts which places the land under the management of farmers. Plantations have silviculture records which have detailed information about the planting year, planting density and other management actions. All plantations were established between 1988 and 2009. None of the plantations were thinned and have seen minimal intervention by forest managers since establishment. The study sites are located in Kien Giang (including Phu Quoc island), Ca Mau, Bac Lieu, Soc Trang, Tra Vinh and Ben Tre provinces. These provinces include most of the mangrove forests in the Mekong delta in Vietnam.

At each plantation, one sample plot with an area of 100 m^2 was surveyed. The location of plots within plantations were selected randomly on the digital map prior to field sampling. Coordinates of the plot's centre were recorded and used to establish the plot in the field using hand-held GPS. Only one plot per plantation was assessed because generally plantations were relatively small (0.5–1.5 ha) and homogenous. Plantations were not disturbed and fully stocked. We increased the size of the sample plot to 1000 m^2 when stocking of the plantation was less than 2000 trees per hectare as was the case in two locations (in Ca Mau and Tra Vinh provinces). The stocking at inventory time of the studied plantations ranged between 1,430 and 10,000 trees per hectare. To obtain reliable data for our project, we collected all relevant information available in silvicultural records, including dates of establishment, and silviculture practices of research plantations. This information was used to place plantations within age classes and to provide the context for understanding variability in plantation characteristics.

2.1.2. Tree volume, growth and aboveground biomass measurements

All trees present in each sample plot were measured individually for diameter at breast height (diameter at 1.3 m above the highest prop root of *R. apiculata*) (Pearson et al., 2013) and top height (stem height from highest prop root to top of the tree). Crown diameter was measured every one in five trees. In 25 plantations, one tree (selected on the basis of quadratic mean diameter) was identified and harvested for destructive sampling for biomass measurements. Trees were cut at ground level and felled onto a large canvas. The 25 harvested trees were of different sizes (DBH from 5 to 20 cm) and ages (14–21 years old). After harvest the biomass of fresh leaves, reproductive parts, branches, stems, and aboveground prop roots were recorded following the prescribed FAO protocol (Picard et al., 2012). Stems were cut into 1 m sections and fresh weight determined. Stilt roots (including aboveground root and stump) were cut from the ground to estimate aboveground root mass. Roots were cleaned of soil with water in the field and weighed. Fifteen samples of all tree's parts (100–200 g per sample) were transported to the laboratory for dry weight determination in order to calculate a fresh to dry weight conversion factor for each tissue type. Woody and non-woody biomass was dried to constant weight at 105 and 65 °C, respectively.

Stem analysis to estimate tree growth has been widely used in traditional forestry growth modelling methods particularly where longitudinal data of permanent sample plots are unavailable (Weiskittel et al., 2011). Seventy trees with DBH ranging from 5 to 18 cm were selected from 20 plantations with ages between 4 and 16 years for stem analysis. There were 40 average dominant trees among the 70 stem analysis trees (the average dominant trees defined were the average tree of 20% largest trees in the surveyed plots). Tree height was measured both prior and after harvest to test accuracy of tree height measurement by the clinometer. Mean differences among the two methods was very small (0.1 m). Tree boles were divided into 0.5 m sections and a stem disk was taken from each section for analysis of the number of tree rings. The wood discs were dried and polished to increase visualization of growth rings (Menezes et al., 2003). Rings were easily identified. Four transects from the centre of the disc to the edges of the stem were randomly chosen and marked with permanent marker and

Download English Version:

https://daneshyari.com/en/article/11028353

Download Persian Version:

https://daneshyari.com/article/11028353

Daneshyari.com