Quantitative Models for Supporting Multipurpose Management Planning of Teak Plantations in Java, Indonesia


Abstract

Current forest management planning of teak plantations in Java, Indonesia, has limitations in supporting sustainable forest management (SFM). It ignores the potential risk of destruction in determining annual allowable cuts, whereas forest destruction seems to be an inevitable problem in teak plantations. In addition, the existing harvest scheduling method only concerns with achieving sustained timber yields, while SFM demands for achieving sustainability of multiple forest benefits. Up to now, however, there is still lack of management planning tools for supporting SFM of teak plantations. This study aimed to develop quantitative models for supporting multipurpose management planning (especially timber production and carbon sequestration) of teak plantations at risk of destruction.

Considering the lack of reliable and practical methods for estimating survival probability and destruction rate of teak plantations, this study proposed an alternative method based on the theory of survival analysis coupled with forest register data. The forest register data were obtained from Kebonharjo forest management unit (FMU), Central Java, for the period 1977–2007. Survival and destruction of the plantations were modeled using probability distribution models. Model parameters were estimated using the maximum likelihood estimation method designed for left-truncated and right-censored data. Results showed that survival probability and destruction rate varied over stand age and planning period. The rates of stand destruction were relatively low (<2% per year) in the period 1977–1987, but increased up to 3% and 14% per year in 1987–1997 and 1997–2007, respectively. The highest rate of destruction mostly occurred in young stands (≤ 30 years old), implying an alarming condition for the sustainability of teak plantations. Survival and destruction models are useful for forest managers to evaluate the risk of stand destruction over a specific planning period and to support the development of alternative harvest scheduling methods for teak plantations in the presence of forest destruction.
Despite a wide array of forest benefits, this study concerned on quantifying carbon sequestration benefits by developing empirical biomass models for teak plantations. Stand biomass and other stand variables were derived from forest inventory data of the FMU. Linear and nonlinear regression models were used to develop four types of biomass models: volume-to-biomass, basal area-to-biomass, age-to-biomass, and age and basal area-to-biomass, which were validated using an independent data set. Results indicated that teak stand biomass was accurately estimated using the volume-to-biomass model. While the accuracy of the age and basal area-to-biomass model was comparable to that of the volume-to-biomass model, the basal area-to-biomass and age-to-biomass models were less accurate. Depending on the availability of input data, at least one of these models will be appropriate for estimating teak stand biomass. These models should prove quite valuable in supporting the multipurpose management of teak plantations.

Furthermore, this study developed an alternative harvest scheduling model for optimizing multiple benefits (i.e., timber and carbon sequestration) of teak plantations at risk of destruction. The proposed model simulated the dynamic of age-class structures from one (a 5-year) period to another and then optimized harvest levels through a planning horizon using linear programming models. The optimal harvest levels were sought for three management scenarios: optimizing harvest volumes, optimizing net present values (NPV), and optimizing NPV while increasing carbon stocks. Each scenario was evaluated using four destruction rates (i.e., zero, low: 4.4–6.3% per period, medium: 9.4–15.9% per period, and high: 18.5–49.6% per period) and three cutting-age limits (i.e., 51, 61, and 71 years). The results confirmed that increasing destruction rates resulted in the reduction of harvest levels, financial benefits, carbon stocks, and led to imbalance age-class structures. Meanwhile, reducing cutting-age limits increased harvest levels and financial benefits, but reduced mature stands and carbon stocks. Although incorporating carbon sequestration benefits into the management objectives resulted in the reduction of financial benefits, such multipurpose management scenario produced better forest structures than timber management. This study suggested that the proposed harvest scheduling model provides greater flexibility for forest managers to develop appropriate management scenarios at risk of destruction; hence, it can be used as an alternative harvest scheduling model for supporting multipurpose management planning of teak plantations.