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Efficiency in forest management: A multiobjective harvest scheduling model

M. Hernandez [a,*], T. Gómez [a], J. Molina [a], M.A. León [b], R. Caballero [a]

[a] Department of Applied Economics (Mathematics), Universidad de Málaga, Campus El Ejido s/n, 29071 Málaga, Spain
[b] Department of Mathematics, University of Pinar del Río, Pinar del Río, Cuba

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This paper presents a new forest harvest scheduling model taking into account four conflicting objectives. The economic factor of timber production is considered and also aspects related to environmental protection. We also incorporate adjacency constraints to limit the maximum contiguous area where clear-cutting can be applied. The model proposed is applied to a timber production plantation in Cuba located in the region of Pinar del Río. One factor to be taken into account in Cuban plantations is that the forest has a highly unbalanced age distribution. Therefore, in addition to the classical objectives of forest planning, we have the objective of rebalancing age distribution by the end of the planning horizon. Explicitly, the four objectives considered in the model are: (a) obtaining a balance-aged forest; (b) minimizing the area with trees older than the rotation age; (c) maximizing the NPV of the forest over the planning horizon; and (d) maximizing total carbon sequestration over the whole planning horizon. The solution to the proposed model provides a set of efficient management plans that are of assistance in analysing the tradeoffs between the economic and ecological objectives. The model is also applied to randomly generated simulated forests to compare its performance

* Corresponding author. Tel.: +34 952131169; fax: +34 952132061.
E-mail addresses: m_huelin@uma.es (M. Hernandez), trinidad@uma.es (T. Gómez), julian.molina@uma.es (J. Molina), maleon@mat.upr.edu.cu (M.A. León), r_caballero@uma.es (R. Caballero).

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in other contexts. As the problem is a multiobjective binary nonlinear model, a metaheuristic procedure is used in order to solve it.

Introduction

The management of forest resources has become a complex issue that has shifted from its early focus on industrial needs to include other objectives such as environmental protection, recreational value and social demands. This has led to increasingly complex decision-making procedures requiring decision models that have to meet and support the new requirements of the decision-making process. Among the more relevant models are the multi-objective optimization models (Steuer and Schuler, 1978; Bare and Mendoza, 1988; Kazana et al., 2003; Tóth and McDill, 2008, etc.) that try to simultaneously combine several conflicting objectives.

Many techniques are available to address forest management planning with multiple criteria (Diaz-Balteiro and Romero, 2008), depending on the problem to be solved and the data available. In this paper, we focus on harvest planning which involves identifying the stands to be treated, the kind of treatment to be applied, and the schedule. Management planning endeavours to simultaneously fulfil different types of objectives, while taking into account certain environmental considerations such as the maximum adjacent area in which clear-cutting can be conducted. This involves using a multiobjective model whose resolution provides a set of efficient solutions (an approximation of the Pareto frontier) to the problem. The approach selected does not demand too much information from the decision-maker (DM), and the analysis of the efficient set allows us to compare tradeoffs between different objectives to gain greater understanding of the situation being addressed. As Tóth and McDill (2008) stated, better decisions can be made if the DM understands the tradeoff structure between competing objectives. The model presented in this study includes economic as well as silvicultural and ecological objectives.

Given the key role of forests as climate regulators, it is relevant to include ecological objectives in forestry management (Bateman and Lovett, 2000; Couture and Reynaud, 2011). In this regard, the Kyoto Protocol was a significant step forward that recommended forestry as a means to offset industrial carbon dioxide emissions (Platinga et al., 1999). This was emphasized at subsequent Kyoto Protocol meetings (Montreal (December 2005), Nairobi (November 2006), Bali (December 2007), Copenhagen (December 2009), Mexico (December 2010)). Some studies have included carbon sequestration as an additional objective when planning forest harvesting. Hoen and Solberg (1994) suggested a two-criteria model that analysed the trade-off between the net present value (NPV) of the harvest and the present carbon sequestration value over the planning horizon. On the other hand, Díaz-Balteiro and Romero (2003) developed different goal programming models that included an operational measure of carbon sequestration together with other economic and silvicultural criteria. In this line, the present study includes maximizing net carbon sequestration during the planning horizon as an objective.

The model proposed is applied to a Cuban plantation for timber production. One feature of Cuban plantations is that their age distribution is very unbalanced. Therefore, in addition to the classic objectives of forest planning, the age distribution of these plantations has to be balanced by the end of the planning horizon to obtain a constant flow of timber. This objective has been modelled in the present study by following the fractional formulation provided by Gómez et al. (2006). In the literature, usually, rebalancing the forest area by ages is modelled as a set of constraints that must be satisfied (Buongiorno and Gilless, 2003; Díaz-Balteiro and Romero, 2003; Tóth et al., 2006). But in lots of cases, mostly when the forest is organized by units or stands, if the forest is not initially age balanced, to impose these constraints might be very restricted and might lead to unfeasible solutions. With the new formulation proposed in this work, this age balance requirement is treated in a more flexible way, because we add this requirement as an objective instead of a set of constraints. So, the unfeasibility problems are

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