# Addressing Multicriteria Forest Management With Pareto Frontier Methods: An Application in Portugal

**Jose G. Borges, Jordi Garcia-Gonzalo, Vladimir Bushenkov, Marc E. McDill, Susete Marques, and Manuela M. Oliveira**

**Abstract:** The practice of multicriteria forest management planning is often complicated by the need to explicit a priori goals and preferences of the decisionmaker. This manuscript aims at describing an approach that may take advantage of a posteriori preference modeling to facilitate the specification of the levels of achievement of various objectives in a typical forest management planning framework. The goal is to provide information about nondominated points in the feasible set in the criteria space (FSCS) so that decisionmakers may take advantage of trade-off information. The emphasis is on demonstrating the potential of adaptive search methods to enhance decisions when three or more criteria are considered. The approach combines the use of mathematical programming and interactive decision maps techniques. It is shown how the estimation refinement method may be used to approximate the Pareto frontier of a typical model I linear programming model. It is further shown how the feasible goals method/interactive decision maps method may be used to retrieve a solution selected by stakeholders from interactive decision maps depicting the Pareto frontier. Results are discussed for a large-scale test application encompassing over 1 million ha of cork and holm oak forest ecosystems in southern Portugal. FOR. SCI. ▮(▮):000–000.

**Keywords:** forest management planning, cork oak, multiple criteria decisionmaking, Pareto frontier methods

ADDRESSING sustainability concerns in forest ecosystem management is a complex task that requires decisionmakers to consider a wide range of often conflicting objectives. Nevertheless, information regarding the impact of forest management options on objectives and conditions of interest is hardly ever perfect. Thus, the efficiency and the effectiveness of such a decision process calls for the use of models and methods as learning devices. The quality of decisions may be enhanced by a learning process that may provide additional insights about the resource capability model and the tradeoffs between objectives.

Over the last decades, the body of literature reporting both exact (e.g., Martell et al. 1998, McDill et al. 2002, Goycoolea et al. 2005, Diaz-Balteiro and Romero 2008, Constantino et al. 2008, Palahí and Pukkala 2003, Bravo et al. 2008, Costa et al. 2010) or heuristic (e.g., Hoganson and Rose 1984, Borges et al. 1999, Borges and Hoganson 2000, Falcão and Borges 2001, Bettinger et al. 2002, Pukkala and Kurttila 2005) approaches to represent and solve multiple-objective forest management planning problems has grown substantially. Nevertheless, the approaches reported in the literature typically require the decisionmaker to either specify the desired level of achievement or specify the preferences for the various objectives (Martins and Borges 2007). As there is often little information about what is possible to achieve (e.g., values of biodiversity and resistance to wildfires indicators), defining a priori the goals and preferences may not be realistic and lead to poor management decisions (Tóth et al. 2006).

Shortcomings of mechanistic approaches to the specification of the levels of achievement of various objectives as well as of the decisionmakers' preferences have been pointed out by Tóth and McDill (2009) and Romero (2004). Tóth and McDill (2009) demonstrated the possibility of developing and displaying a Pareto frontier, e.g., of finding the nondominated points in the feasible set in the criteria space (FSCS) in the case of problems with up to three forest management planning objectives.

Romero (2004) discussed the use of several achievement functions and corresponding assumptions regarding decisionmakers' preferences.

Providing information about the set of efficient solutions can help the decisionmaker understand the tradeoffs between competing objectives. The analysis of these tradeoffs

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Jose G. Borges (joseborges@isa.utl.pt), Technical University of Lisbon, Forest Research Center, School of Agriculture, Lisbon, Portugal. Jordi Garcia-Gonzalo (jordigarcia@isa.utl.pt), Technical University of Lisbon, Forest Research Center, School of Agriculture, Lisbon, Portugal. Vladimir Bushenkov (bushen@uevora.pt), University of Evora, Centro de Matemática e Aplicações. Marc E. McDill (mmcdill@psu.edu), Pennsylvania State University. Susete Marques (smarques@isa.utl.pt), Technical University of Lisbon, Forest Research Center, School of Agriculture, Lisbon, Portugal. Manuela M. Oliveira (mmo@uevora.pt), University of Evora, Centro de Matemática e Aplicações.

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