



Research article

Ranking of industrial forest plantations in terms of sustainability: A multicriteria approach



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ABSTRACT

As forest managers and owners must have precise assessments of sustainability, in this study we have proposed a methodology based on multi-criteria techniques for assessing sustainability in industrial forest plantations and establishing a ranking of these plantations in terms of sustainability. First, we identified and have briefly described a set of sustainability indicators (economic, environmental and social). Next, we developed a statistical procedure to determine if a linear relationship existed between the indicators. With this analysis, the final set of indicators was defined and normalized. Then, we formulated four goal programming models, by which to aggregate the different indicators. In these models, we introduced the preferences of the decision makers for each indicator, using a survey with questions formulated in a pairwise comparison format.

The procedure was applied to 30 *Eucalyptus globulus* Labill. plantations in northwestern Spain and 11 indicators were selected in order to define the sustainability. The results showed several rankings under each goal programming model. Although the results may not be the same in the different models, some plantations are always the most sustainable, while others are always the worst in terms of sustainability. The combination of initial values of indicators, goal programming models and preferences of stakeholders (preferential weights and targets) influence the results, and it cannot be predicted a priori which plantation is the best/worst in terms of sustainability. In our case study, we show how changes in preferential weights and targets substantially modify the results obtained.

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1. Introduction

From its beginnings, when it basically served as a production objective, forest management included a sustainability component, usually comprised of the fulfillment of conditions ensuring sustained yield (Recknagel and Bentley, 1919). Thus, the perfect expression of the idea of sustainability was the ideal of a normal forest. Thus, some authors affirm that sustainability has been the basic idea of forest management for over 250 years (Schraml and Detten, 2010), and it was in the forestry sphere that this concept was born (Carlowitz, 1713 in Pretzsch, 2014). However, in the last few years, forest management has begun to ensure sustainability with other components in addition to the production sustainability

(Bettinger et al., 2009; chap. 9). This idea has gradually been articulated since the initial proposal made in the United Nations Conference on Environment and Development held in Rio de Janeiro in 1992. Nowadays, there are various definitions of sustainable forest management, but they all essentially establish that the latter involves a process of managing forests which is economically viable, environmentally benign and socially beneficial, and which balances present and future needs (Higman et al., 2005). In short, sustainability has been addressed from several viewpoints, and there is a general agreement on the need to identify a multidisciplinary list of criteria and indicators (Raison et al., 2001).

Many studies have analyzed sustainability from a specific set of indicators at different levels, from local to regional and national ones, some of them showing the differences between the criteria and indicators suggested in several national schemes used to monitor sustainability in forest management (Grainger, 2012). Several indicators were initially fixed according to a small number

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of criteria all over the world, resulting in periodic measurements of certain forest attributes. However, with a few exceptions (Wolfslehner and Vacik, 2008; Giménez et al., 2013), most of these efforts have failed to respond to the immediate question of whether, in those cases, forest management is sustainable or not, because the indicators have not been properly aggregated, and for that reason were not able to assess the evolution of the sustainability.

In the case of industrial forest plantations, a correct management should include other spheres apart from environmental, social and economic ones, like long-term biological productivity and the business side of forestry (Poulsen et al., 2001). Thus, forest managers and owners must have precise assessments of sustainability, as well as a capacity to predict the effects of management regimes (Giménez et al., 2013). For this kind of forest system, some studies have defined sustainability incompletely, only focusing on certain aspects without including economic or social indicators (Watt et al., 2005; Evans, 2009; Palmer et al., 2005; Jeffries et al., 2010). An exception to this trend could be the study of Giménez et al. (2013), who propose a sequential procedure under a multi-criteria framework to address sustainable management in industrial forest plantations, using six indicators to define the sustainability of different management alternatives. Finally, Derak and Cortina (2014) have determined 14 indicators for evaluating several ecosystem services in *Pinus halepensis* plantations in Spain.

Intrinsic features associated with forest plantations, such as single-species and exotic species composition, short rotations, intensive management prescriptions, etc., have caused a considerable amount of conflicts between companies and local populations. These problems have increased in the case of *Eucalyptus* plantations in several countries (Gerber, 2011). These plantations cause a great deal of controversy in some areas due to forest fire policy (Diaz-Balteiro, 2007) or the ecological impacts reported when managed under intensive forestry practices (Lomba et al., 2011; Calviño-Cancela et al., 2012). In short, some authors affirm that sustainable management in these plantations should try to maintain economical productivity while maximizing biodiversity conservation (Calviño-Cancela, 2013). One potential solution for alleviating these problems would be to define a set of sustainability indicators in order to know which plantations are more sustainable and orientate their management towards achieving plantations with a high degree of sustainability. Finally, the ideas expounded here on the sustainability of different forest plantations should not be confused with the concept of certification. The methodology employed has nothing to do with that adopted for certifying these forest systems. Some authors even advocate, for example, the inclusion of indicators associated with financial viability in plantations under certification schemes (van Eijck et al., 2014).

The use of multiple criteria decision making (MCDM) methods to assess sustainability through previously defined indicators has been extended in recent years to diverse fields. Although the literature is already very extensive, three noteworthy papers are those of Brunner and Starkl (2004), in which several applications have addressed the sustainability issue using several MCDM methods, or Herva and Roca (2013) and Ibáñez-Forés et al. (2014) who focus on diverse sectors such as industry.

Given the multidimensional nature of the sustainability concept, several forest case studies have attempted to portray sustainability by means MCDM techniques (Diaz-Balteiro and Romero, 2008), with goal programming being one of those most employed in forestry applications (Diaz-Balteiro and Romero, 2004; Voces et al., 2012; Giménez et al., 2013), and in other studies (Lozano-Oyola et al., 2012). Other references, which use other MCDM techniques in forest sustainability issues, would be those of Balana et al. (2010) Rantala et al. (2012) and Jalilova et al. (2012).

The main aim of this study was to present several models, based on multi-criteria techniques for establishing different rankings of sustainable *Eucalyptus* plantations, and comparing the results obtained with these models. In order to achieve this objective, we have defined a group of indicators and applied them to a set of homogeneous plantations, in terms of ownership, in the northwest of Spain. These methods, based on goal programming, allows owners to find out which plantations are the most sustainable ones. Besides, they can see the effects in the rankings by giving different weights to each indicator or groups of indicators.

The remaining part of the paper is organized as follows. In the next section, we present the case study along with the MCDM framework proposed. Then, Section 3 presents a summary of the results obtained, and, finally, Section 4 provides a discussion on the results and gives the main conclusions.

2. Material and methods

In this section, we present the case study, and describe the sustainability indicators considered. Lastly, we detail the goal programming models used.

2.1. Case study

Eucalyptus plantations in northwestern Spain are some of the most productive forest systems in Europe (Diaz-Balteiro et al., 2009a), as they provide the raw material for an internationally competitive forest industry. Although these plantations are mostly privately owned and belong to non-industrial private forest owners, for our analysis we preferred the selection of industrial plantations in order to preserve a certain homogeneity in their management. Specifically, the study started from a database of forests managed by the firm ENCE in Galicia. This database contains over 200 forests, 29 of which belong to ENCE, covering a little over 10,500 ha. From a management perspective, it should be noted that all these forests are managed in a single management plan, which is divided up provincially. That is to say, there is no individualized management plan for any of the forests.

This firm pays special attention to the management of these forests for the production of pulpwood. For this purpose, in all the plantations, there are stands of *Eucalyptus globulus* Labill. (7.910has) and *Eucalyptus nitens* H. Deane & Maiden (1.570has). In some plantations there are productive species which take up over 400 ha (*Pinus radiata* D. Don, *Pinus pinaster* Ait.), but the firm sells this wood to others. There are also over 1150 ha for protection purposes, i.e. where no final cuts are made.

We took a sample of 30 forests in order to apply the methodology determining which of them was the most sustainable one. We aimed to have a representative sample and, in fact, these forests make up 13.76% of the total forests and 27.28% of the whole forest area managed by ENCE in Galicia, for a total of 2868 ha. Also, we attempted to select forests representing all sizes, as shown in Table 1. 3 of the 30 forests selected presented *Eucalyptus nitens* as their principal species, and the rest *Eucalyptus globulus*. According to the size of these forests, whose classification is displayed in Table 1, we proposed to analyze at least 10% of them in each category. Finally, we opted for forests in which information on all the indicators chosen was available. Namely, in no case did we use a method for imputing values to a plantation when no information was available for obtaining the value of a certain indicator.

2.2. Indicators considered

To select the indicators, we tried to dispose of an extensive set of them: a group with sufficient indicators to apply the methodology

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