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Forest production management and harvesting scheduling using dynamic Linear Programming (LP) models

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Abstract

Fuelwood is one of the most widely used natural resources. Its major uses include household heating and energy production (heat energy plants). Its production is expected to increase in order to cover the increased demand, therefore management of fuelwood productive forests should be done in a sustainable way. Two linear programming (LP) models are presented in this work, for the optimal design of production and harvesting scheduling of fuelwood, produced from even-aged (coppice) Oak forests. Respectively, two alternative sustainable management strategies are examined. The first strategy aims at sustainable fuelwood production in the context of area control. The second one achieves maximization of the volume per unit of time and leads to a steady state forest. Actual data from the forest management plan of Achladochori-Aggistro-Sidirokastro forest are used to demonstrate models application. Both models can serve as a "rule of thumb" in the forest management practice.

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Keywords: Fuelwood production; Coppice forest; Sustainable forest management; management alternatives; linear programming (LP)

1. Introduction

Forests produce a great variety of timber and non–timber products and services [1, 17, 18]. Although the importance of non-timber forest services has increased in the last decades, the high oil prices and the current

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economic crisis have turned focus on fuelwood as heating source as well. The increased household consumption of fuelwood in the recent years has developed a fast growing market in Greece [2, 3], with great price fluctuations over time [4, 5]. Moreover, the use of biomass as raw material for energy production in the frame of the European policy objectives 20-20-20 (reducing greenhouse gas emissions by 20%, increasing the share of renewables in energy consumption to 20% and improving energy efficiency by 20%, all by 2020) would demand higher quantities of fuelwood used for this purpose. Consequently, forest management decisions concerning fuelwood production planning is crucial for the sustainable development of the respective fuelwood market.

In the relevant literature, forest production planning is best described by the use of mathematical programming [6]. The aim of such forest production models is to maximize the volume that would be eventually harvested. Furthermore, maximization of harvest volumes may lead to larger marginal profits if it is accompanied by restrictions on harvested quantities in order to increase the total area that would be regenerated at the end of each planning season [7]. In addition to volume control, area control and non-declining even flow of timber are common criteria used in forest management modelling [8]. Besides maximization of harvested quantities, constraints related to ecological or aesthetic reasons [8], as well as to conservation of biodiversity are also examined [9]. Post production problems are usually connected with the distribution of the products to different nodes of a supply chain network (Agriculture Forest Cooperatives, fuelwood merchants, customers) [10]. Extensions of supply chains under stochastic (normally distributed) demand have been also proposed [11]. Due to the multidimensionality of the problems, it is common that single objective function models do not provide adequate description of natural resource problems. When more than one objective is required multi-objective optimization models are used [12].

In this work, a dynamic, linear programming (LP) model is presented, for the optimal design of production and harvesting scheduling of fuelwood, produced from even-aged (coppice) Oak forests, under two alternative sustainable management strategies. Actual data from the forest management plan of Achladochori-Aggistro-Sidirokastro forest [19] are used to demonstrate model's application.

Nomenclature

c	Age class
t	Time period
K	Logged volume of fuelwood (m^3)
V_c	Volume of age class c (m^3)
$F_{c,t}$	Initial area of age class c, year t (ha)
$f_{c,t}$	Logged area of age class c, year t (ha)

2. Fuelwood production and Mathematical mode

The major fuelwood production in Greece comes from Oak coppice forests [13] through clear cutting in relatively small areas, which results in the creation of even-aged stands. The rotation age is 20-25 years, defined as the stand age that maximizes the volume produced per unit of time. To facilitate management planning, clear cut areas are classified into 5-year age classes and treated together as stands with similar characteristics. Assuming a rotation age of 20 years and similar growing capacity (site quality) of the stands, each age class must hold an area equal to ¼ (the so called "normal" area) of the total forest area in order to guarantee sustainable production [14, 15]. That is, the equality of area available for clear-cutting every 5-year periods produces the same fuelwood quantity ad infinitum. Therefore, the first objective of sustainable forest management in this case is the achievement of the area equality between age classes, while maximizing the wood production from the entire forest.

Depending on the initial conditions of a forest, i.e. the distribution of the various stands in age classes, it is possible that the sustainable conditions (equal area among classes) cannot be achieved during a rotation period. Cutting of young immature stands or stands beyond the rotation age are common reasons for such conditions that do not permit application of the above sustainability scheme. In such a case, an alternative sustainable management scheme is to aim at the creation of a steady state in the forest, that is, a state where the initial area in each age class is the same in two successive rotations [8].