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THE EFFECTS OF BIODIVERSITY CONCERNS ON ECONOMIC PROFITS OF TIMBER IN FOREST MANAGEMENT

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Abstract

The changing demands of today require a widened scope of forest management. Society is asking for sustainable forestry emphasizing biodiversity. Maintaining, improving and also integrating biodiversity into forest management plans have been a challenging task over the last decade. Biodiversity can be decomposed into measurable characteristics of individual stands by diversity indicators. Some examples of the indicators are; mean volume of deciduous trees, mean volume of deadwood and proportion of Old Growth Forests (OGF). OGF, play an especially important role in maintaining biodiversity having large living and dead trees. Also high variability of tree sizes is an important diversity feature.

In forest ecosystems, there are tradeoffs between timber production and habitat for old growth dependent species. The purpose of this study is to estimate economic effects of ecological concerns on Net Present Values (NPV) of timber harvest in the Mustafa Kemal Paşa Planning Unit. To achieve this aim, distribution of age classes and the amount of the area of OGF are considered. A Linear Programming (LP) model was built maximizing the Net Present Value (NPV) of timber production and solved by a commercial LP solver.

The model built for a 100 year planning horizon generating even age class distribution. Then, the amount of OGF was increased 5%, 10% and 15% respectively and the effects of these differences on NPV were analyzed. The results show that, if the forests are managed for maintaining biodiversity, the NPV of the profits of timber production is considerably reduced. In this way it would be possible to measure the opportunity cost of biodiversity in terms of financial returns.

***Keywords**: Forest Planning, Biodiversity, Old Growth Forests, Net Present Value*

1. INTRODUCTION

The forest management paradigm has changed dramatically over the last few years. This is due to the fact that modern societies are demanding from forests not only private goods sold on the marketplace, but also public goods and services without established markets. Society is asking for sustainable forestry emphasizing biodiversity and in forest management. Thus, the modern view of sustainability comprises not only the classic timber production persistence, but also the sustainability of many attributes demanded by society and produced by forests. This change of perspective implies a complex integration of such attributes. Incorporating biodiversity into forest management planning in conjunction with other environmental and economic criteria is a challenging task. This task presents two problems, each one at a different conceptual level. First, the definition of biodiversity itself is not exempt from difficulties and ambiguities. Second, the concept of biodiversity chosen has to be not only biologically sound but also computationally operational in order to be efficiently incorporated into a forest management optimization model [1], [2].

Forest management affects biological diversity on various levels: genes, individual organisms, species, populations, biotic communities, ecosystems, landscapes and regions. As forest management affects directly the composition of structural species such as trees, shrubs and herbs, it affects mosaic patterns of forests in various development stages, the amount of dead wood in forests, the vertical structure of habitats, and forms edge habitats. Unfortunately only limited information about composition, structure and function of forest ecosystems is available on a large scale. Assessment and planning forest diversity requires a set of new methods that provide sound information on the current state of forests and their reactions to management activities. Currently, the implementation of management concepts is difficult because it is not easy to plan for aims that cannot be measured adequately. It is assumed that forest structure such as tree species composition, tree age composition and standing woody biomass have strong impact on biological diversity and forest resistance [3], [1], [2].

Some authors express diversity by; i) using analytic hierarchy process for analyzing decision problems with multiple criteria in strategic management planning of a forest area, ii) establishing quality levels for biodiversity objectives. These levels play the role of targets that forest plans should satisfy. Some examples of quality levels are: a given width of the buffer strip on each side of forest streams, a certain percentage of broad leaf species in a conifer forest, a minimum volume of deadwood, etc., iii) managing the structural diversity of the forest. The structural diversity of a stand is described by the diameter distribution, classifying the number of trees according to species and size classes, iv) decomposing biodiversity into measurable characteristics of individual stands, called diversity indicators. These indicators are considered as critical factors with respect to the occurrence of rare, threatened, and endangered species in the forest area considered. Some examples of the indicators used are the following: mean volume of deciduous trees, proportion of old forest, mean volume of deadwood, etc. [4], [5], [6], [7], [9], [9], [10].

It is understood that OGF, play an especially important role in maintaining biodiversity having large living and dead trees. Also high variability of tree sizes is an important diversity feature. A universal definition of OGF does not exist because forests differ around the world. OGF are natural forests that have developed over a long period of time, generally at least 120 years (consistent with definitions for the eastern United States), without experiencing severe, stand-replacing disturbance like a fire, windstorm, or logging. Old-growth forests may be dominated by species such as fir, spruce, or beech that are capable of reproducing under a shaded canopy. These old-growth forests can persist indefinitely. Old-growth forest may also be dominated by species such as Calabrian pine, oak, or Black pine that do not reproduce as well under shade and that require disturbance to open the canopy. These old-growth forests will eventually be replaced by the more shade tolerant tree species in the absence of disturbance [1], [11]. Generally OGF include:

1. Trees those are greater than %50 of the maximum known age for a particular species.
2. Large, dead standing trees and branches (snags) are common.
3. Large fallen trees and branches lie on the ground.
4. The forest is a mix of young, old, and middle-aged trees (multi-aged).
5. Small openings (canopy gaps) are visible between the tree crowns.
6. Dirt piles and holes from tipped-over trees (tip-up mounds and pits) dot the ground.
7. Large enough for them to be self-sustaining.
8. Have not been cleared for agriculture or timber harvest [11].

Bertomeu and Romero (2001) argued that the age structure of the forest landscape is determined by the ages of all stands comprising the landscape. The age of a stand can be considered as an index of its successional state, consequently a stand represents a successional stage. The sands, into which the management unit has been divided, have been delimited according to their relative uniformity of site index, species and age. Creating a balance of age classes, in the sense of establishing the same number of stands per age classes will be aim at maintaining biodiversity.

Environmental concerns generally conflict with timber production and incorporating them into forest management would necessarily reduce the income from timber harvest. With ambitious environmental goals, the income reduction can be significant. Important as the environmental concerns are, their effects on timber production need to be carefully evaluated, particularly in regions where timber harvest is important to the local economy.

Some authors evaluate the economic effects of sustainable forest management regimes on timber production. Zhou and Gong (2004a) analyze the trade-offs between different uses of the Swedish mountain region forests. Eid et al. (2001, 2002) evaluate the economic effects of sustainable forest management regimes on timber production in Norway. Carlsson (1999) examines the trade-offs between timber production and biodiversity for a company-owned forest in central Sweden. The models used in these studies are multiple-objective linear programming model [3], or linear programming models [12], [3], [1]. Zhou and Gong (2004b), analyzed the economic effects of environmental concerns in forest management in the Swedish mountain region. The environmental concerns include the amount of deadwood, the area of broad-leaved forest, and the area of old-growth forest. The analysis is performed by formulating a fuzzy linear programming model for the forests in three communes. The model is solved using the modeling to generate alternative approach to generate a number of management plans, which are maximally different from each other in the decision space and are satisfactory with respect to the timber production objective. The results show that, if the forests are managed to meet the interim targets for Healthy Forests, the net present value of the profits of timber production is considerably reduced and this reduction could be as high as 55%. The results also show that among the three environmental goals the increase in deadwood volume is the most restrictive one.

The purpose of this study is to estimate economic effects of ecological concerns on Net Present Values (NPV) of timber harvest in the Mustafa Kemal Paşa Planning Unit. To achieve this aim, distribution of age classes and the amount of the area of OGF is considered. A Linear Programming (LP) model were built maximizing the Net Present Value (NPV) of timber production and solved by a commercial LP solver.

2. MATERIAL AND METHOD

The study is carried out in forests of Mustafa Kemal Paşa Planning Unit in Bursa, in the Marmara region of Turkey. The total area of planning unit is 8692 ha, which includes 6098 ha. productive forested land (Table 2.1). These forests are used for timber production, preservation of biodiversity, different types of recreation. The annual harvest in this region amounts to approximately 7156 ha of forests or 7310 m^3 of timber.

Land Use	Area (ha)
Productive Forests	6098.0
Degraded Forests	1049.2
Total Forested Land	7147.2
Bare Land	355.2
Agriculture	1126.5
Settlement	15.0
Water	38.1
Total Area	8692.0

Table 2.1 Land use of the study area

Forest stands in the study area are grouped according to the dominant tree species, development stage and crown closure into 68 stand types. 633 individual stands are available in the planning unit consisting of Oak, Black Pine, Beech, Calabrian Pine and Juniper species. The initial state age class distribution with 20 year internal of productive forests in the study area is given in figure 2.1.

Figure 2.1 The initial state of productive forests in the study area

2.1 TIMBER PRODUCTION

Actual stand parameters like volume, increment and etc. are taken from Mustafa Kemal Paşa Unit forest management plan (2004-2023) [13]. These data were used to build wood production and economic matrixes. Timber yields are estimated using the normal yield tables of Alemdağ (1962) for Calabrian pine (Pinus brutia), the normal yield tables of Eraslan-Evcimen (1967) for Oak (Quercus spp.), the normal yield tables of Kalıpsız (1963) for Black pine (Pinus nigra subp pallasiana), the normal yield tables of Carus (1998) for Oriental beech (Fagus orientalis), and the the normal yield tables of Eler (1998) for Crimean juniper (Juniperus excelsa). An average net income was calculated for 1 m^3 considering yield types for each species. Net income were calculated 41.6 YTL (1 YTL = 1.7 $) for Oriental beech, 43.2 for Oak, 40.3 YTL for Black pine, 38.6 YTL for Calabrian pine and 30 YTL for Crimean juniper for the year 2004 respectively.

Net Present Values (NPV) of timber production was also calculated considering planning periods. The interest rate was determined as % 3.

2.2 THE MODEL

A harvest regeneration schedule covers a 100 year planning horizon with 10 year-periods. The set of feasible management options for stand types are identified based on the following assumptions and regulations.

Harvesting takes place at the middle of each period and each stand will be regenerated immediately after harvesting and that the same tree species will be planted. Thinning is not considered. The minimum ages of final harvest for Oak, Oriental beech and Crimean juniper stands are 100 years for site class I and 120 years for site classes II, III, IV and V respectively. For Black pine, the minimum rotation age is 80 years for site class I and 100 years for site classes II, III, IV and V. For Calabrian pine the minimum age of final harvest is 50 years for site class I and 60 years for site classes II, III and IV.

These age limits are taken from the Turkish Forest Management and Planning Act (1991). There is no limit on the maximum age before which a stand must be harvested. To leave a stand untouched during the planning horizon is another choice. This option is included for each stand.

The model built for a 100 year planning horizon generating equal age classes. First alternative includes only equal age class distribution at the end of the planning horizon. Then OGF were increased % 5, 10 and 15 respectively including equal age class distribution too. Thus, four different alternatives and the effects of these differences on NPV were analyzed. A linear programming model is formulated to represent the forest planning problem. The model maximizes the net present value (NPV) of timber production profits subject to environmental constraints.

Creating old stands by allocating OGF and maintaining a balance of age classes, in the sense of establishing the same area per age class are selected as environmental constraints. In this study, OGF was defined as productive forest older than 60 years for Calabrian pine, 100 years for Black pine, and 120 years for Oak, Oriental Beech and Crimean juniper.

2.3 MODEL FORMULATION

1. Objective Function:

$$Z_{\max} = \sum_{i=1}^{m}\sum_{j=1}^{n} a_{ij} x_{ij} \tag{2.1}$$

2. Constraints:

$$\sum_{j=1}^{n} x_{ij} - A_j = 0 \tag{2.2}$$

$$\sum_{i=1}^{m} y_i - AOGF = 0 \tag{2.3}$$

$$AOGF \geq TOF * 0.0P \tag{2.4}$$

$$\sum_{i=1}^{m}\sum_{j=1}^{n} a_{ij} x_{ij} - NPV = 0 \tag{2.5}$$

$$\sum_{i=1}^{m}\sum_{j=1}^{n} b_{ij} x_{ij} - H = 0 \tag{2.6}$$

$$\sum_{i=1}^{m}\sum_{j=1}^{n} x_{ij} <= T_i \tag{2.7}$$

$$A_j - A_{j+1} = 0 \tag{2.8}$$

$$x_{ij} \geq 0 \tag{2.9}$$

Here,

x_{ij} : Area of stand i to be regenerated in period j (ha).

y_i : Area of stand I not to be regenerated in period j over the planning horizon (ha).

a_{ij} : NPV obtained from regeneration of stand i in period j (YTL).

b_{ij} : Yield of stand i to be regenerated in period j (m^3).

AOGF: Total area of Old Growth Forests at the end of the planning horizon (ha).

NPV : Total NPV at the end of the planning horizon (YTL).

H : Total yield or harvest at the end of the planning horizon (m^3).

m : Number of stands (i=1,...633).

n : Alternative treatments assigned to stand i during the planning horizon (n=1,...11). (regeneration in period 1, 2, ….10 and no treatment is 11)

T_i : Area of stand i (ha).

A_j : Distribution of equal age classes at the end of the planning horizon (ha).

TOF: Total forest area (ha).

P: 5, 10, 15

3. RESULTS AND DISCUSSION

Four planning alternatives (including the initial one) are generated. The total NPV, total harvest and areas allocated for OGF associated with each alternative are presented below (Figure 3.1).

3.1 TIMBER HARVEST VOLUME

Figure 3.1 shows the periodic timber harvest volume associated with each of the four alternatives. The differences among these alternatives with respect to the harvest volumes are notable in period 9. The difference may be explained as follows. The model leaved the regeneration of degraded stands as possible as to the last period because the objective function maximizes the NPV. They could have been regenerated in the last period but some stands that are young at beginning of the planning horizon are matured and reached the rotation age. To get the maximum income degraded or nonproductive forests were regenerated in period 9.

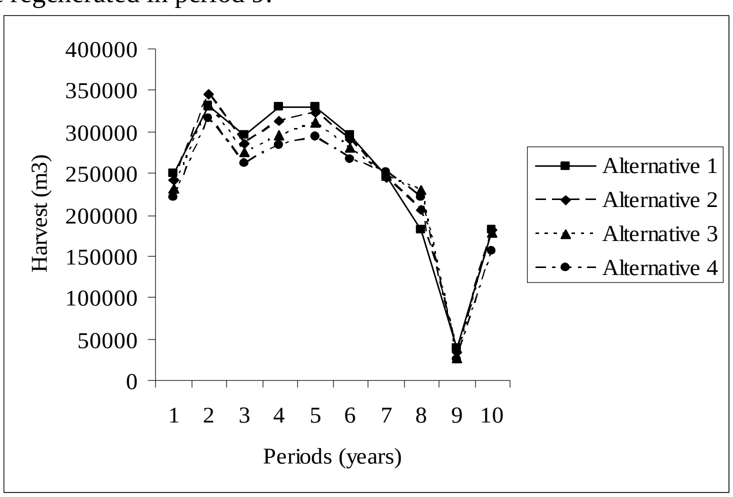

Figure 3.1 Harvest of alternatives according to periods

3.2 COST OF ACHIEVING THE ENVIRONMENTAL GOALS

Table 3.2 shows that, without including the environmental constraint, the NPV is 37.7 million YTL. With the environmental constraints, the NPV would decrease to 37.2, 35.8 and 34.2 million YTL in alternatives 1–3, respectively. The reduction in the NPV is about % 1–9. The reason for this substantial reduction is evident. When the forest is managed without the environmental constraints, all the old stands should be harvested in any period. In order to meet the environmental goals, some of these stands should be left, because they are the primary source of biodiversity. Zhou and Gong (2004b) found in their research that reduction of net present value of timber production could be as high as 55% if the forests are managed to meet the interim targets for Healthy Forests.

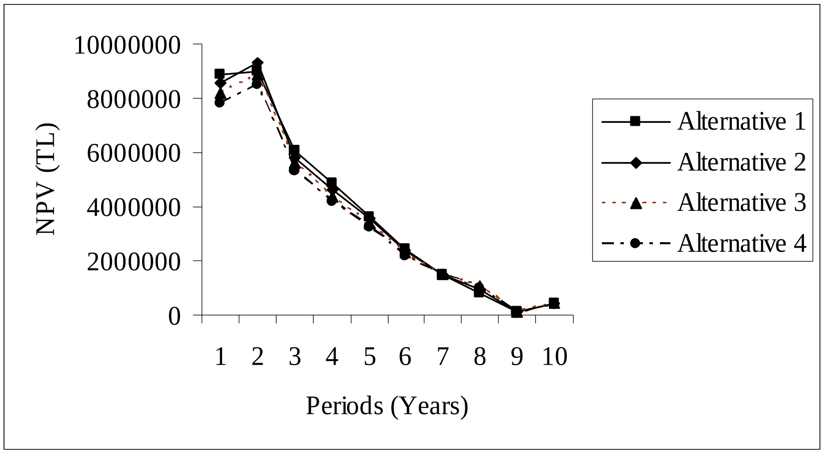

Figure 3.2 NPV of alternatives according to periods

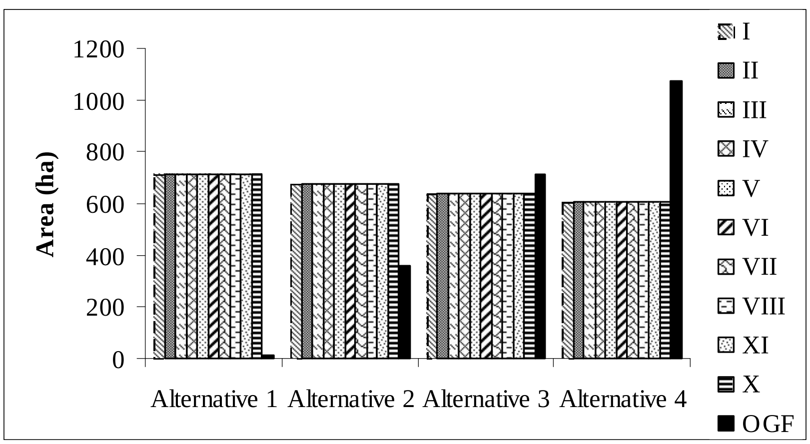

Figure 3.3 Age classes and OGF generated from alternatives

3.3. AGE STRUCTURE OF THE FOREST AT THE END OF THE PLANNING HORIZON

Figure 3.3 shows the age structure of the forest at the end of the planning horizon associated with different alternatives. All alternatives generated equal age class distribution. In the first alternative 15.6 ha of forests are allocated as OGF. Alternative 2 allocated 347 ha (% 5 of the total forested land) area for OGF while alternative 3 and alternative 4 left 715 ha (% 10 of the total forested land) and 1072 ha (% 15 of the total forested land) respectively. 24.2 ha area are not OGF nor they are in age class 10 for each alternative. Thus these areas weren't showed in figure 3.1.

4. CONLUSIONS

Environmental concerns have been a focal point of public interest in sustainable forest management. Preservation of biodiversity is an equally important goal of forest management as timber production. Examples of non-timber forest ecosystem values include biodiversity, visual quality, and water quality and wildlife habitat. In order to quantify the response of these resource values to various spatial, temporal harvest configurations, common indicators are required to evaluate each resource and compare results between resources. Age class structure and patch size distributions are used to represent these values. Because it is the distribution of patch size within different age classes that creates biological and structural diversity at the landscape, it is essential that ecosystem management tools integrate patch and age class management strategies.

To see the effects of biodiversity concerns on economic profits of timber in forest management a model built for a 100 year planning horizon generating equal age classes. Then OGF were increased % 5, 10 and 15 respectively and the effects of these differences on NPV were analyzed. The results show that, if the forests are managed for maintaining biodiversity, the NPV of the profits of timber production is considerably reduced about %1-9. In this way it would be possible to measure the opportunity cost of biodiversity in terms of financial returns.

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