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Analysis

Separate or mixed production of timber, livestock and biodiversity in the Caspian Forest

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ABSTRACT

The temperate deciduous forest on the northern slopes of the Alborz Mountains has a high biological diversity and many endemic species. Huge areas are still old-growth forest but logging and grazing have degraded large parts of the forest. These degraded areas have low timber and forage yields and a species composition that differs from its natural state. In this study we present an analytical and a numerical solution to the forest management problem by optimizing the benefits of livestock production, timber harvest and biodiversity conservation. We focus on the ecological interactions rather than on administrative restrictions. Our findings are based both, on theoretical considerations and field investigations of ecological and economic parameters in Azerbaijan and Iran. The results of the numerical optimization suggest that it is optimal to separate timber and livestock production if biodiversity is not valued. Livestock rearing is preferable at high discount rates whereas timber production becomes more profitable at low discount rates. If the valuation of diversity exceeds a certain threshold a combination of timber production and livestock rearing is socially optimal since it yields a high biological diversity.

1. Introduction

Tradeoffs are common in the use of different ecosystem services, such as the production of timber, livestock grazing, and the preservation of biodiversity (Nalle et al., 2004). Sometimes these tradeoffs are so severe that it may be optimal to spatially separate the use of different ecosystem services. This process of land use separation has happened in Central Europe during the last centuries where monocultures evolved from mixed productions. This process was accompanied by an impoverishment of the flora and fauna due to e.g. habitat loss as a result of land use changes. While, by the time that these changes happened, the value of biodiversity was widely neglected, biodiversity is now regarded as one of the most valuable ecosystem services (Millennium Ecosystem Assessment, 2005).

In this study we ask the question how a forest should be used with ecological tradeoffs between its multiple outputs such as timber and livestock if the value of biodiversity is considered. We approach the topic by developing a theoretical model which we calibrate with field data. The field study took place in the Caspian Forest which is located on the northern slops of the Alborz Mountains in northern Iran and southeastern Azerbaijan. The climate in the study area is warm-temperate and humid with annual precipitation ranging from 500 mm to 2000 mm (Sagheb-Talebi et al., 2004). Forests have evolved in this area that survived the climatic oscillations in the Pleistocene and human activity in the Holocene. These forests resemble the Central European forests in terms of floristic composition but additionally they contain a high number of endemic species. Along with the Colchic Forest of Georgia, the Caspian Forest represents the most important remnant of primary deciduous temperate forest in the Northern Hemisphere (Knapp, 2005; Ramezani et al., 2008). The high altitudinal gradient of the Caspian Forest from 25 m below sea level to 2700 m above sea level further supports a highly diverse species assemblage. The area of the Caspian Forest is estimated to be 1.9 million ha in Iran and 0.2 million ha in Azerbaijan (Asian Development Bank, 2005; Sagheb-Talebi et al., 2004).

The forest provides a wide range of valuable goods and services to the human population on different scales. On a regional scale timber and firewood production, forage for wood pasture and other non-timber forest products (NTFP) as well as regulating services might be the most important (Noack and Hidayatov, 2007; World Bank, 2005). On a global scale the biological diversity, the unique integrity and its function as carbon storage might be the most valuable properties. This

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value of global importance has led to the nomination of the Caspian Forest as UNESCO world heritage site (UNESCO, 2009).

The Caspian Forest has been reduced to half of its original size and many of its remaining parts are heavily degraded. The stand volume of the remaining forest has been severely reduced and half of the forest lacks sufficient regeneration as a cause of overgrazing (NBSAP, 2000; Sagheb-Talebi et al., 2004). The combination of logging and overgrazing has led to a strong decline in forest productivity and grazing carrying capacity of many areas.

The governments of Iran and Azerbaijan have both acknowledged the importance of an improvement of forest management. There have been several attempts in Iran to reduce grazing pressure (Shamekhi, 2004) and to implement an ecosystem approach to forest management (Sagheb-Talebi et al., 2004). In Azerbaijan there are programs to reduce deforestation and to promote reforestation but the success is limited so far (Asian Development Bank, 2005).

The different forest uses within the Caspian Forest create a complex system of interactions with positive and negative feedbacks. The combination of uses that might be sensible when considered alone might lead to disastrous consequences if combined. Forestry has focused for a longtime on wood production alone, neglecting the other benefits that forest produce. In forest economics, the seminal paper of Hartman (1976), which included the stream of benefits from a standing forest into the harvesting considerations, received much attention. He found that including services other than timber into the harvesting decision might delay the optimal timing of the harvest (Hartman, 1976). Bowes and Krutilla (1989) gave an extensive treatment of multiple-use forestry and noted that some of the goods and services produced by forests might actually decline with stand age and thus reduce the optimal rotation length.

Swallow et al. (1990) analyzed the impact of different non-timber benefits on the optimal harvesting decision. They showed that several local optima in the rotation length can occur if the non-timber values introduce non-concavities in the objective function. They applied their model to livestock grazing and timber harvesting but did not model the feedbacks explicitly.

Standiford and Howitt (1993) have approached the multiple benefits of wood, game and livestock production from the perspective of a rangeland manager who searches for the optimal combination of wood, livestock and game production. Their study however has not included the direct feedbacks of game and livestock on wood production. There are other economic treatments of multiple-use forests that include ecological feedbacks like the study of Costanza and Neuman (1997), Crépin (2003), Parks et al. (2002), Touza et al. (2008) and Wam et al. (2005), Wam and Hofstad (2007) but many of these feedbacks remain rather hypothetical due to lack of data. It is widely acknowledged that especially ungulates have an important impact on forest structure and species composition but quantitative data of ungulate–forest interactions are scarce (e.g. Ammer, 1996; Hester et al., 2000; Putman, 1996; Weisberg and Bugmann, 2003).

It is not obvious if these multiple outputs of woodlands should be produced in one area as implicitly assumed in the mentioned studies or if they should be produced in specialized forest stands.

Bowes and Krutilla (1989) used timber benefits and water-flow values as an example to show that the production possibility frontier of multiple forest values can be convex. They concluded that a specialized production of these multiple outputs on separated areas can be optimal. Vincent and Binkley (1993) demonstrated that the multiple uses that forests provide can be more efficiently produced in a specialized forestry if several stands are considered. Boscolo and Vincent (2003) argued that fixed costs of logging and administration might add nonconvexities to the widely assumed convex production possibility set of multiple forest outputs. These nonconvexities in turn make land use separation the most efficient forest use. Swallow et al. (1990) stressed that the shape of the amenity function that impacts the harvest cycle largely depends on the benefits considered.

Our study consists of a theoretical part and an empirical part which is based on several field investigations. This mixture that draws from different sciences and methods permits us to make conclusions that might not have been made with a single perspective. This study intends to help address the urgent problems of forest degradation in the Caspian Forest.

In the following section we propose a modeling framework and in the subsequent two sections we introduce the empirical methods and results. We use these to parameterize and to solve the model numerically. Finally we discuss the results.

2. The Modeling Framework

The Caspian Forest provides a multiplicity of benefits to different stakeholders. We consider a social planner who seeks to maximize the net present value of the forest benefits over an infinite time horizon. This view might be justified since the forest is state owned in both countries.

We assume that benefits of wood production, Ω_w, of livestock rearing, Ω_s, and of biodiversity, Ω_d, are the major benefits of the Caspian Forest.

The local communities keep livestock that grazes in the forest. They receive net revenues from livestock rearing denoted by p_s. The livestock is measured in livestock units per hectare (ha) which we denote by s. The livestock depends on the vegetation that grows on the forest floor. A livestock density that exceeds the carrying capacity for livestock, $s_{\max}$, is not feasible. The forage that determines the carrying capacity for livestock competes with the trees for light, nutrients and water. The trees, w, which are measured in stand volume ($\mathrm{m}^3\ \mathrm{ha}^{-1}$) are the stronger competitors and thus the carrying capacity for livestock becomes a decreasing function of the stand volume, $s_{\max} := S(w)$, with $dS(w)/dw \le 0$. Livestock density cannot be negative and therefore the constraints on livestock rearing are $0 \le s \le S(w)$.

Livestock has several impacts on the forest stand: it reduces the growth and survival rate of seedlings and saplings, leads to stem deformation which reduces the timber value and can finally decrease equilibrium stand volume (Ellenberg, 1996; Gill, 1992). We concentrate only on the impact of livestock on stand growth and maximum stand volume and refer the reader to Wam et al. (2005) for an economic treatment of quality losses due to browsing. We model stand growth, F, as a decreasing function of livestock density with $\partial F/\partial s < 0$.

We assume an uneven-aged forest stand with a constant age structure and density dependent growth.[1] The stand volume cannot exceed the maximum stand volume, $w_{\max}$, and it cannot decrease below zero, $0 \le w \le w_{\max}$. The stand growth is zero where either of the constraints holds with equality. If no harvest, h, occurs, the stand will finally reach its maximum stand volume. To include the impact of grazing intensity on equilibrium stand volume, we assume maximum stand volume to be a function of the livestock density, $w_{\max} := W(s)$.

The management of uneven-aged forests is often analyzed in a Faustmann framework (e.g. Chang, 1981). This formulation of the problem suggests a cyclical harvest strategy. Tahvonen (2009) analyzed a model where no harvesting strategy is presupposed and showed that continuous rather than cyclical harvesting may be optimal. A continuous harvest is more likely to be optimal with low natural regeneration, low wealth, a credit market constraint and a limited harvesting capacity (Tahvonen, 2009). These conditions are

[1] There are sophisticated age structured models of stand growth and age structure (e.g. Salo and Tahvonen, 2002) but for our purpose a simple biomass model may suffice. Studies of uneven-aged beech forests with constant age structures and constant harvests are given in López et al. (2007) and Schütz (2006) and for density dependent growth in Monserud and Sterba (1996).