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How to manage a small-scale multi-use forest?

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ABSTRACT

The management of a multiple-use and small-scale forest generating merchantable household forest amenities, as mushroom amenities, is studied. We consider a wooded mushroom area and a timber area in the forest. An Hartman model, with an environmental dependency of the amenity area is considered. Optimal timber and non-timber cutting ages and optimal proportion of amenity area are derived. Their behaviours in particular with respect to the market amenity unit value are studied. Moreover an oscillating seasonal amenity production, as the mushroom production, is derived and studied in relation with the optimal tree cutting ages.

Introduction

Because forest is a natural habitat of various fauna and flora (e.g. Larrieu and Cabanettes, 2012), forest management could take into account various ecosystem services (e.g. Susaeta et al., 2013). As in the ecosystem approach, the economic representation of a forest by Faustmann (1849) and Hartman (1976) considers various financial forest flows. The Faustmann and Hartman models make it possible to design a silviculture in most European small-scale forests that are under-exploited (Schlueter, 2008). This silviculture will encourage trees and household forest amenities: many trees left standing alone are cleared (without carrying out costly thinning operations done on the whole forest) and are likely to constitute many spots of natural habitats for various forest species, so generating positive and valuable amenities such as mushrooming (e.g. Sourdril et al., 2012; Zotti et al., 2014). Optimal allocation of forest soil for timber production or non-wood production is important in some cases. The owner of a forest specifically dedicated to timber production will not be as sensitive on this question as a non-industrial forest owner. The non-industrial forest owner, specifically farmer forest owner, notably studied by Newman and Wear (1993), Amacher et al. (2003), Lidestav and Nordfjell (2005), Bolkesjø et al. (2007), and Sourdril et al. (2012), will be interested in supporting the forest amenities. This forest owner could preserve and even increase the multi-functionality of his/her forest management by creating, preserving or extending small spots, dedicated to mushrooms or other household and valuable forest amenities. He/she would then design a mixed commercial and household forest management dedicated to additional incomes as in French forest farmers for example, Sourdril et al. (2012). This type of forest is of significant interest in France, Le Jeannic et al. (2015), as well as in Finland, Hyttinen and Kolat (1995), or in Australia, Robins et al. (1996). In this last country, farm forestry is increasingly promoted as a land-use option for "improving the viability of agriculture, developing additional timber resources for industry, and enhancing regional development", Race et al. (1998).

This paper is focused on optimal management of a multiple-use small-scale forest, with a forest land divided into two areas, a mushroom area and a timber area. Many authors considered ecological or amenities benefits in the management of forest as in Bowes and Krutilla (1989), Swallow and Wear (1993), Swallow et al. (1997), Rose and Chapman (2003) or Touza et al. (2008), Amacher et al. (2009,2014). Perrings and Touza-Montero (2004) recalled how the forest ecological interactions were considered in the literature, regarding the benefits from timber harvesting but also the benefits from the non-wood products. Moreover, Vincent and Binkley (1993) but also e.g. Swallow et al. (1997) or Perrings and Touza-Montero (2004) highlighted the importance of spatialization in forest management: Vincent and Binkley (1993) sought

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to prove that an effective forest multi-functionality led to a forest spatialised management. Forest land allocation at the stand level is then a small-scale forest multi-use management topic. So, determining optimal land use allocation between timber and mushroom amenity suggests the need for rational decision making, e.g. Hyde (1980), Parks and Murray (1994).

From the literature, two topics are retained. Firstly, the effect of the market amenity unit value on the optimal timber cutting age is not always taken into account, Brazee (2006). But, Koskela and Ollikainen (2001) studied a first approach of this effect. Secondly, if a forest owner chose an allocation of his forest soil, for the timber production and e.g. the forest mushroom production, the effect of this mushroom amenity value on the optimal tree cutting age must be studied in the timber area and in the amenity area.

The following questions are studied: what are the optimal tree cutting ages in timber and mushroom areas and what are the behaviours of these optimal tree cutting ages with respect to the market mushroom value in the studied multiple-use small-scale forest model? Moreover, what is the optimal proportion of mushroom amenity and timber areas with respect to the market mushroom value? Then, what are the behaviours of the optimal tree cutting ages and of the area proportion dedicated to the mushroom amenity with respect to the total area of the multiple-use small-scale forest?

We consider the case of marketable natural amenities as mushrooms in a multiple-use small-scale forest. Considering the mushroom production, the quality of the biotope will be taken into account: we consider the physical environmental quality which mainly impacts biotope. Due to a supposed good mushrooming environmental quality in a specific area of stand forest, the total forest area is dedicated to timber production and to mushroom production. Moreover, values of timber and mushroom must be considered, Deegen et al. (2011). In the same way, different tree cutting ages also must be taken into account, Coordes (2016). In the first section, we study comparative statics considering the optimal timber and non-timber cutting ages and of the area proportion dedicated to the mushroom amenity with respect to known market value of this amenity. We also clarify the behaviours of the optimal tree cutting ages and of the area proportion dedicated to the mushroom amenity with respect to the total area of the small-scale forest. In the second section, the seasonal characteristic of the amenity is considered to analyse and complete the results of the previous section. Then all results are discussed before concluding.

Management of a multiple-use small-scale forest with natural mushroom amenity area

We consider a forest including specified amenity area. Amenity supplies are assumed to be produced in specific and natural weakly wooded area dedicated to mushroom amenity, Sourdril et al. (2012). The forest has a financial timber value (which leads to the classical forest owner's Faustmann value up to the constant regeneration cost) and in addition has at any time the mushroom amenity revenue (which leads to the forest owner's amenity value). We consider a multi-use forest with an area S. We assume that mushroom amenity only depends on forest age and environmental quality.

Let x the proportion of the forest area with mushroom amenity, S the total forest area, $s = Sx$ is the forest area with amenity.

The commercial timber is produced in the proportion $1-x$ of forest area. Due to small quantities of woods harvested in a small-scale forest, harvesting costs and regeneration costs per ha are higher than in a large-scale forest (average fixed costs are supposed large as costs of setting up storage places for timbers, Bourcet et al., 2007; Elyakime and Cabanettes, 2009). So, the financial timber income (the owner's residual timber value) is lower in a small-scale forest. In accordance with the previous hypotheses, the regeneration cost per area unit c in the timber area satisfies $c'_S < 0$, $c''_{SS} = 0$. Moreover, we consider natural regeneration in the mushroom amenity area. The financial timber income per area unit $V(T, S)$ depends on the cutting age and the timber area and satisfies $V'_S > 0$ and $V''_{TS} = V''_{SS} = 0$.

Contrary to the classical Hartman approach, we assume different tree cutting ages, respectively for the wooded mushroom amenity area and for the timber area. Moreover, due to a supposed interdependency between tree and amenity,[1] we consider a stylised Hartmann model: the wooded amenity area is assumed not to produce commercial wood and the timber area is assumed not to produce merchantable amenity. So, the forest is evaluated with an alternative Hartman value, considering specific cutting age T_w for Faustmann value and T_a for amenity value:

$$H(S, x, T_a, T_w) = S\,x\,E(T_a, x) + S(1-x)J(T_w, S(1-x))$$

with the Faustmann value $J(T, s) = \frac{V(T,s) - c(s)e^{\delta T}}{e^{\delta T}-1}$ and the amenity value $E(T, x) = A\frac{\int_0^T F(t,x)e^{\delta(T-t)}dt}{e^{\delta T}-1}$ per area unit, where A is the market amenity unit value, $F(t, x)$ is a marginal characteristic of amenities at time t per area unit (hypotheses on marginal function F will be specified later).

The amenity benefits depend on the forest age and the environmental quality. We assumed that environmental quality has a larger impact on amenity than on timber areas, so we neglect the impact of environmental quality in the timber area. The mushroom amenity area is assumed preferentially located in high environmental quality area. Let Q the distribution of the environmental quality in the total area with support $[\underline{q}, \bar{q}]$, hence the proportion of amenity area x corresponds to area where the environmental quality is greater that a value q_e:

$$x(q_e) = \int_{q_e}^{\bar{q}} dQ(q) = 1 - Q(q_e)$$

Moreover, we assume that each environmental quality q_e leads to a production rate $r(q_e)$ with increasing r with respect to q_e (i.e. $r'(q_e) \geq 0$) and $r(\bar{q}_e) = 1$. We assume that the marginal amenity function is separable in forest age and environmental quality q_e:

$$F(t, x(q_e)) = \Gamma(x(q_e))F_0(t) \tag{1}$$

where $\Gamma(x(q_e))$ is the expectation of production rate: $\Gamma(x(q_e)) = \frac{\int_{q_e}^{\bar{q}} r(q)dQ(q)}{\int_{q_e}^{\bar{q}} dQ(q)}$. With the assumed hypotheses on r behaviour, $\Gamma(0) = 1$, Γ is decreasing, $x\Gamma(x)$ is increasing and concave with respect to the proportion of amenity area x and the amenity production per area unit is also separable:

$$E(T, x) = \Gamma(x)E_0(T, x) \quad \text{with} \quad E_0(T, x) = A\frac{\int_0^T F_0(t)e^{\delta(T-t)}dt}{e^{\delta T}-1}$$

Taking into account the endogenous proportion of amenity area, we consider the forest management with respect to the cutting age and the proportion of amenity area. From the form of marginal amenity

[1] These interdependencies are not explicitly taken into account because we do not study the forest management tree by tree as in Coordes (2016).