Promoting wild mushroom yields by forest management

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The issue is …

Annual production of wild mushroom varies considerably due to different factors. The prevailing weather – rainfall and temperature – is one of the key factors, but for example watering for promoting mushrooms is infeasible. Also, local site characteristics such as elevation, aspect, soil type and site quality are mostly uncontrollable. On the other hand, stand characteristics, and hence also forest management, affect the yields of mycorrhizal mushrooms as they are in a symbiotic relationship with the trees. Thus, identifying those stand characteristics and treatments most suitable for mushrooms would help promoting wild mushroom yields.

From a StarTree perspective

Currently in Finland and Spain, wild mushrooms are principally opportunistically harvested and can therefore often be considered side-products of forestry. However, increasing opportunities to obtain monetary and other benefits, such as recreation or picking for personal consumption, can have an effect on forest management as well. Therefore we need to understand the factors affecting the variation in yields in order to enable forest managers to coproduce timber and mushrooms.

The long-term monitoring of mushroom yields and the use of modelling techniques were used to identify key considerations for controlling the yields of mushrooms. Most importantly we wanted to know which kinds of forest stands (tree species, stand age, density, etc.) are most suitable for good crops. It has been suggested that the fruiting body production of the mycorrhizal fungi is linked to the photosynthetic activity of the host tree, and thus ensuring the vitality of the stand would lead to greater mushroom yields. For example, thinnings are one way of increasing the growth of trees.

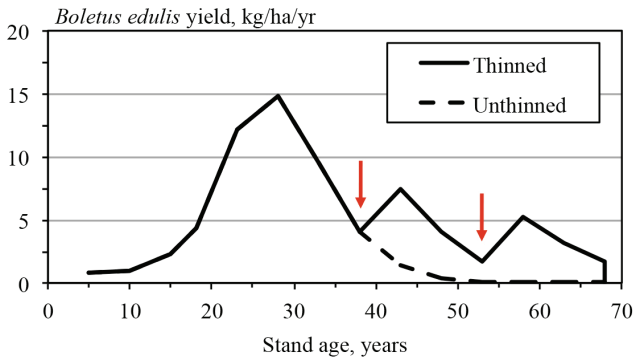
The aim of the following two case studies was to prepare empirical models for predicting the annual yields of wild marketed mushrooms in spruce stands in Finland and in pine stands in Spain. These two examples on different tree species, as well as climatic and site conditions will highlight possibilities to enhance mushroom yields by forest management.

Case 1:
Mushroom yields in spruce forests (Finland)

Boletus spp. and *Lactarius* spp. are among the most marketed wild mushrooms in Finland. These species are also appreciated in international markets, especially *Boletus* spp. The official list of marketed mushrooms comprises 31 edible species, of which we studied only mycorrhizal fungi.

Mycorrhizal ceps (*Boletus edulis*) growing in a Finnish 30-year-old spruce stand which produced high yields (23–46 kg/ha) few years after the first commercial thinning. Photos: Kauko Salo

A total of 56 sample plots were established in planted Norway spruce (*Picea abies*) stands in eastern Finland and inventoried since 2010. The special aim was to study the effects of thinning on mushroom production in young thinning stands therefore several sample plots were located in stands approaching the first commercial thinning. The study area is located at the boreal coniferous zone where the effective temperature sum (lower threshold +5°C) during the growing season is 1100–1300 d.d. on average and rainfall 340–360 mm. The growing season starts in the beginning of May and lasts about 160 days.



Thinning treatments (arrows) improve slightly the simulated yields of *Boletus edulis* in a spruce stand with good mushroom yield in eastern Finland. Unthinned regime is shown by dashed line (Tahvanainen et al., 2016).

Fact Box Finland

Based on the inventory data, the mean annual yields of *B. edulis*, *Lactarius* spp. and all marketed mushrooms were 5.4 kg/ha, 16.4 kg/ha and 28.3 kg/ha, respectively. On average, *B. edulis* and *Lactarius* spp. contributed respectively 23% and 50% of all marketed mushrooms.

Empirical models were prepared for predicting the annual yields of wild marketed mushrooms. Separate models were fitted for the yields of *B. edulis, Lactarius* spp. and all marketed mushrooms. The mushroom yields were predicted along with the development of a spruce stand with a good mushroom productivity using the estimated models.

Mycorrhizal fungi suffer from regeneration cutting, but mushroom yields increase along with stand age. The highest yields of *B. edulis* were obtained just before the first thinning phase of stand development i.e. at the age of 25–30 years and the stand density of 25 m^2/ha. In old stands, *B. edulis* was rare. The peak in the yields of *Lactarius* spp. and all marketed mushrooms was slightly later. The mushroom yields were promoted by a warm pre-season (in July) and wet conditions during the fruiting season (in August). In Finland, the growth of spruces mainly happens in late June and July and the fruiting bodies of mushrooms are appearing primarily from the end of July onwards. This would support the theory suggesting that a good fruiting of mushrooms coincides with a good growth of trees.

In a good mushroom stand, the contribution of the yields of all marketed mushrooms to the total net present income (with a 3% interest rate) during the entire rotation is 25%. Mushroom incomes are based on the prices paid to pickers: 3.4 €/kg for *Boletus spp.,* 1.5 €/kg for *Lactarius* spp. and 1.2 €/kg for other marketed mushrooms.

Thinnings seem to improve slightly and temporarily the *B. edulis* yields. However, using the inventory data, we were not able to separate the effects of thinning from the effect of stand density. Thus, in the simulations, the effect of thinning on mushroom production is described through the change in stand density, and interpreting the effect of thinning should be regarded as preliminary. Thinning opens up the canopy and rainfalls are more likely to wet the forest floor, which may promote mushroom yields after thinning.

Case 2:
Mushroom yields in pine forests (Spain)

Wild mushrooms are probably the most popular non-wood forest products in Spain. Picking mushrooms is typically seen as part of the cultural heritage of the country with different traditions concerning the fungal species collected in different regions. Hence, the Spanish legislation authorized 93 fungal species for commercial trade of which *Lactarius* group *deliciosus* and *Boletus* group *edulis* are the most marketed mushrooms.

The interest of forest managers in responding to the increasing societal demand of mushroom picking drove the establishment of a long-term set of permanent plots in pine forest ecosystems in Catalonia (Northeast Spain). The first set of 24 plots were established in 1995 in *Pinus sylvestris* forests. Since then, new plots have been established amounting to 107 plots in pure and mixed *P. sylvestris, P. nigra* and *P. halepensis,* as well as in *P. pinaster* ecosystems where a thinning experiment was established. The permanent plots are monitored on a weekly basis during the autumn season aiming to identify the fungal diversity and measure the productivity of wild mushrooms.

Saffron milk caps (*Lactarius deliciosus*), a highly appreciated fungal species that grows symbiotically with pine trees, being positively affected by thinnings. Photos: Juan Martínez de Aragón

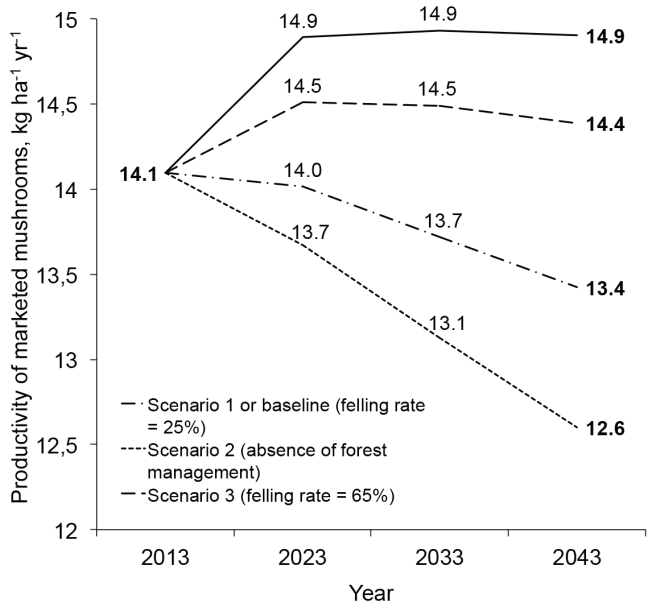
Fact Box Spain

Mushroom yields partly depend on stand species composition (i.e., main tree species). The highest annual mushroom yields were recorded in mixed forests of *P. sylvestris* and *P. nigra* amounting 101.6 kg/ha/yr of which 79.8 kg/ha/yr were considered edible, and 30.2 kg/ha/yr were marketed mushrooms. The minimum production corresponds to the mixed *P. halepensis* and *P. nigra* forest stands with 36.1, 31.0 and 4.4 kg/ha/yr of total, edible and marketed mushrooms, respectively. In pure *P. pinaster* forest stands, average marketed mushrooms yields are approximately 44.5 kg/ha/yr, mainly represented by *Lactarius* group *deliciosus*, which represents around 50% of total mushroom yield.

The modelling of yearly mushroom data records shows that total mushroom yield is significantly dependent on the stand basal area. The same pattern has been observed for all the modelled pine forest ecosystems, so that mushroom productivity increases with increasing basal area until a maximum corresponding to the optimal stand basal area, showing a subsequent decrease in productivity for larger non-optimal stand basal area values. The optimal stand basal area varies from 10-15 m^2/ha in the most dry pine forests (*P. halepensis*) to 35-40 m^2/ha in *P. pinaster* stands, the optimal stand basal area for other pine species being approximately 20 m^2/ha.

Mushrooms yields were predicted for the permanent forest inventory plots of pure and mixed pine forest stands corresponding to the Third Spanish National Forest Inventory (NFI), which represent a systematic sampling of the forest area of Catalonia region. As a result, a mushroom yield map for Catalonia was produced. Furthermore, four different scenarios were simulated with a time frame of 30 years aiming to evaluate the impact of forest management intensity on mushroom yields: (i) Scenario 1 or BAU (business as usual) with a felling rate of 25% of the yearly tree growth, (ii) Scenario 2 with no management, (iii) Scenario 3 with a felling rate of 65%, and (iv) Scenario 4 with a felling rate of 100% of the annual forest growth.

The scenario analysis showed that mushroom yield of marketable species may increase with increasing forest management intensity. The absence of forest management (Scenario 2) or low felling rates (Scenario 1) entail a decrease of 11% and 5% of valuable fungal species respectively. On the contrary, an increase in forest management intensity (Scenarios 3 and 4) may imply an increase in productivity of edible, commercial mushrooms ranging from 2% (Scenario 3) to 6% (Scenario 4), and representing an increase of 100 and 262 tonnes/yr, respectively, at the regional level (i.e. for whole Catalonia).



Evolution of the average productivity (kg/ha/yr) of valuable mushrooms in Catalonia during the next 30 years under alternative regional forest management intensity scenarios (de-Miguel et al., 2014).

Findings

The two cases here have three main aspects in common which are central for promoting mushroom yields by forest management in both Finland and Spain:

The **information on site and stand characteristics** which are most suitable for wild mushrooms **can be used in planning forest management operations** or in searching for potential stands for harvesting mushrooms.

A large annual variation in mushroom yields is harmful for local business relying on the stable supply of mushrooms. Besides promoting yields, **information on how forest management could be used to reduce risk of having no mushrooms has to be gathered**, too.

The **production of timber and wild mushrooms are not competing with each other**, and hence the co-production of these two products is a suitable option. Moreover, the co-production would create significant additional income for forest owners.

Further information:

http://dx.doi.org/10.1016/j.foreco.2015.11.040
Tahvanainen, V., Miina, J., Kurttila, M. & Salo, K. 2016. Modelling the yields of marketed mushrooms in *Picea abies* stands in eastern Finland. Forest Ecology and Management 362: 79-88.

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de-Miguel, S., Bonet, J.A., Pukkala, T. & Martínez de Aragón, J. 2014. Impact of forest management intensity on landscape-level mushroom productivity: a regional model-based scenario analysis. Forest Ecology and Management 330: 218-227.

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