

## Article

# Assessing the Potential of Forest Stands for Ectomycorrhizal Mushrooms as a Subsistence Ecosystem Service for Socially Disadvantaged People: A Case Study from Central Slovakia

Branislav Olah , Vladimír Kunca and Igor Gallay

Department of Applied Ecology, Faculty of Ecology and Environmental Sciences, Technical University in Zvolen, T.G. Masaryka 24, SK-960 01 Zvolen, Slovakia; kunca@tuzvo.sk (V.K.); gallay@tuzvo.sk (I.G.)

\* Correspondence: olah@tuzvo.sk; Tel.: +421-45-5206-506

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**Abstract:** Mushrooming is a widespread leisure activity for a significant part of the Slovak population. From the point of view of the ecosystem services, it combines a provisioning service (mushrooms as food or delicacies) and a cultural service (mushroom picking as physical activity in nature). For urban residents, the forest is a refuge from the daily work routine, and mushrooming contributes significantly to improving their quality of life. For mushroom pickers living in rural areas, the occurrence and availability of mushroom harvesting sites are often even more important since it contributes to their diet or even provides an occasional income. We summarised the ecological preferences of selected ectomycorrhizal mushrooms and applied them as parameters for modelling the potential of forest stands for mushroom growing in central Slovakia. In the second step, we analysed the theoretical demand for wild mushrooms as a subsistence provisioning service for the local population with a special focus on socially disadvantaged inhabitants. The results showed that there is a spatial overlap of forest stands with a high potential for mushroom growing and the districts with the highest proportion of unemployment or of inhabitants receiving social benefits, and the best mushroom forest stands are situated within walking distance from the settlements. This supports the initial assumption that wild mushrooms may contribute to a better life for disadvantaged local communities.

**Keywords:** ectomycorrhizal mushrooms; forest stand; ecosystem services; subsistence; socially disadvantaged; central Slovakia

## 1. Introduction

In general, mushrooms are most often perceived through the picking of their fruiting bodies. Over centuries, they have evolved from the food of the poor to a delicacy, to the position where they have now become mainly a nutritional supplement, often with healing effects [1]. Mushroom picking has increased worldwide and has been increasing since the 1980s [2] and is becoming a recreational activity with regional to local specifics [3]. As reported by [4], based on data from 13 European countries, 152 species belonging to 12 genera of wild mushrooms are collected. Slovakia, together with the neighbouring countries with a predominantly Slavic population, belongs to the so-called “mycophilic” countries [5,6]. Moreover, the overall importance of fungi is increasing so that it is proposed to replace the commonly used term ‘edible mushrooms’ with the term ‘useful mushrooms’ as their use relates not only to their consumption but also for securing mycorrhiza, medical uses, or soil decontamination [7].

At the same time, the perception of the purely timber-production function of forests also changes, with the acceptance of the fulfilment of forest recreational and environmental functions. Traditionally, forest management plans have not considered mushrooms as an economic resource, mostly due to the

lack of data and missing monetary valuation [8]. Besides timber, forests provide several non-timber provisioning services such as material, food, and energetic outputs derived from ‘wild plants, fungi, algae and bacteria’ and ‘wild animals’ respectively [9]. Among those, wild mushrooms belong to the provisioning services, such as ‘wild plants used for nutrition’. In fact, mushrooming is considered an important forest ecosystem service [10]. However, fungi, besides wildlife food, can be used as environmental management agents in weed control or environmental improvement processes as regulation and maintenance services such as bio-remediation, filtration, or decomposition and fixing processes and their effect on soil quality [11,12]. Mushroom-related activities can even evolve into a specialised land use, namely mycotourism, especially if it supports rural areas and sustains local communities [13]. In this way, mushrooms are also becoming an important component of cultural ecosystem services [4].

The assessment of competing for ecosystem services and their trade-off is, in an ideal case, based on a financial quantification of the benefits. However, monetary evaluation is often not easy. More than 1 000 species of edible ectomycorrhizal fungi species are known in the world, and the sale of some such as truffles (*Tuber* spp., *species pluralis*), ceps (*Boletus* spp.) and chanterelles (*Cantharellus* spp.) reaches billion-euro sales in global markets [11]. However, these values range at relatively wide intervals, as the formation of mushroom fruiting bodies often varies significantly from year to year [14,15]. In Finland, picking berries and mushrooms is ranked as a more important forest utilisation than wood products [16]. Measured in monetary terms, mushroom production can be compared with timber production as income associated with mushroom production is equal to approximately 20% of that generated by timber throughout the planning horizon [8]. When evaluating mushroom picking as a recreational service, the value of one mushroom trip could be as much as 39 euros; out of it, only 7 euros is the actual market price of the collected mushrooms [17]. Besides, strictly market-based evaluations of mushroom volume that are being traded for cost and profit of this economic activity, mushrooming plays an important role in the subsistence of the local communities as a considerable part of wild food is home-consumed or informally marketed [4,15]. It is particularly true for the local unemployed or socially disadvantaged communities that live in small or remote villages.

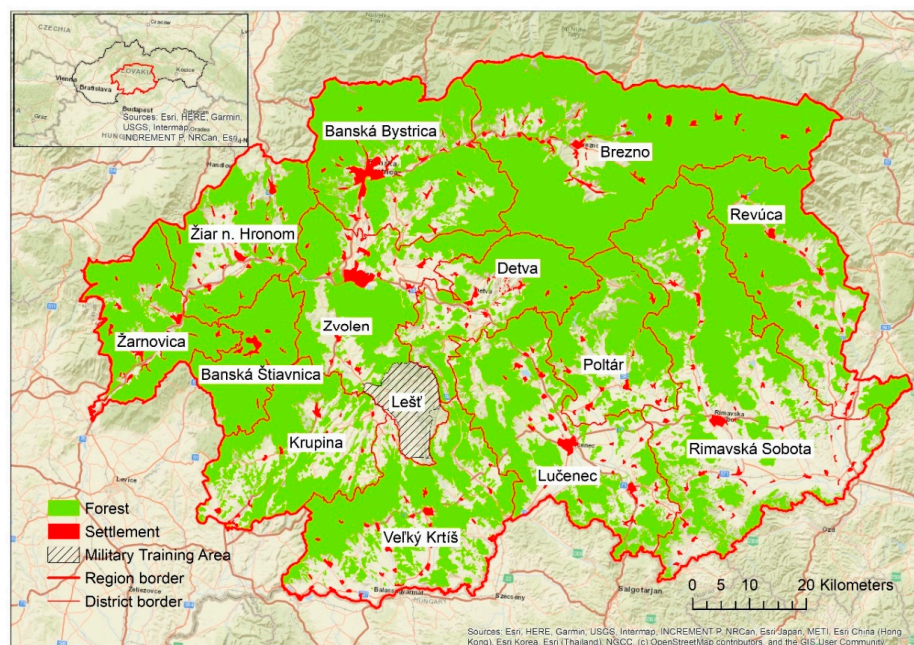
Since mushrooming is a very widespread activity amongst the people, there are plenty of well-known mushroom areas. This knowledge mostly comes from local mushroomers, and they pass it on to their relatives or friends [5]. Even people from larger cities come picking to these places as they have friends or relatives in the area. However, as reported by [18], rural inhabitants have a higher probability of collecting mushrooms because it requires knowledge of the ecosystem and the ability to navigate in the forest. Besides common mushroomers, who pick mushrooms just for food or for leisure and rely on common knowledge, mycologists who collect, survey, and study mushrooms and their ecology are able to formulate scientifically based ecological preferences of mushroom species occurrence in order to locate potentially new mushroom spots. These preferences can be applied as an interpretation key on available information on forest stands in order to assess their capacity for mushroom-based ecosystem services. Despite the fact that ectomycorrhizal fungi populations in forests cannot be inferred from the stand structure alone [19], many parameters influence the occurrence of specific fungi and their fruiting bodies [20] or actual seasonal yields [21]. As noted by [22], spatial distribution models are broadly used to map tree species, plants, and wild flowers, but have rarely been applied to mushrooms. Nevertheless, the knowledge base on the mushroom occurrence and its relation to environmental factors is quite rich [8,23–25]. As many authors agree [14,26–29], the most important factors determining ectomycorrhizal mushrooms are the site’s natural conditions such as soil, water and climate, and the presence and the state of mycorrhizal partners (host tree species). As reported by [22], it is possible to model mushroom habitat with reasonable accuracy in complex landscapes. The modelling of mushroom occurrence is usually based on interpreting natural conditions and actual vegetation according to results from mushroom field surveys or applying expert judgement [8,22,30]. Expert judgement is often applied for assessing the capacity of ecosystems to provide services, especially due to a complex character of the analysed systems [31,32].

The aim of this paper is to assess the potential of forest stands for ectomycorrhizal mushrooms growing in central Slovakia as the basis for a subsistence ecosystem service and to analyse its accessibility for local populations with a special focus on the more socially disadvantaged inhabitants.

## 2. Materials and Methods

### 2.1. Study Area

Slovakia is still considered a rural country where almost half of the population (45%) still lives in villages (2752 in total, 95% of all Slovak settlements). The Banskobystrický Self-governing Region (SK032 NUTS 3) is the largest region of eight designated self-governing regions in Slovakia, and it is situated in the South-Central part of the country (Figure 1). Lešť Military Training Area was excluded from the analysis due to its restricted access. The study area lies in a temperate climate zone, but its natural conditions are strongly influenced by its rich geological development resulting in landscape types such as basins and mountain ranges, including various microrelief forms, with altitudes raising from 120 up to 2050 m above sea level. The region is covered with almost a full spectrum of forest stands occurring in Slovakia, starting from floodplain forests, sub-mountain floodplain forests, oak forests, lime-maple forests, beech forests to spruce forest at the highest altitudes.



**Figure 1.** Study area of the Banskobystrický Self-governing Region.

Compared to the other regions, it is more rural (forests cover almost 50% of its 945,263 ha) and less inhabited as it covers almost 20% of the country but with only 12% of its inhabitants (of which 48% lives in the countryside). It is also a region with such a high rate of unemployment and number of socially disadvantaged inhabitants that five of its districts are officially listed as “least developed districts” [33]. For these reasons, mushroom picking may be an important and feasible way of self-subsistence for the local communities in this region, both as nutrition or even casual income. In fact, it is a well-known and often observed situation that the locals use to sell the harvested mushrooms and berries by the roadside.

### 2.2. Ectomycorrhizal Mushrooms and their Ecological Preferences

This methodological approach to assess the potential of forest stands for wild ectomycorrhizal mushrooms consisted of two main steps. The very first step was to summarise a list of the most commonly harvested ectomycorrhizal mushrooms and their occurrence in Slovak forests based on

the published papers of the second author as well as other Slovak mycologists such as [34–38]. As commonly harvested mushrooms, several species from the following genera of ectomycorrhizal fungi were considered: *Boletus* (formerly, including now new genera of *Neoboletus* and *Imleria*), *Xerocomellus*, *Leccinum*, *Lactarius*, *Cantharellus*, *Russula*, and *Amanita*. Of these genera, the favourite species in Slovakia and as for potential habitat we calculated with *Boletus reticulatus* Schaeff., *B. edulis* Bull., *B. aereus* Bull., *B. pinophilus* Pilát & Dermek, *Neoboletus luridiformis* (Rostk.) Gelardi, Simonini & Vizzini, *Imleria badia* (Fr.) Vizzini, *Xerocomellus chrysenteron* (Bull.) Šutara, *Boletus subtomentosus* L., *Leccinum albobostipitatum* den Bakker & Noordel., *L. pseudoscabrum* (Kallenb.) Šutara, *L. scabrum* (Bull.) Gray, *L. aurantiacum* (Bull.) Gray, *Lactarius deliciosus* (L.) Gray, *L. deterrimus* Gröger, *L. salmonicolor* R. Heim & Leclair, *Cantharellus cibarius* Fr., *C. pallens* Pilát, *C. amethysteus* (Quél.) Sacc., *Russula cyanoxantha* (Schaeff.) Fr., *R. virescens* (Schaeff.) Fr. and *Amanita rubescens* Pers.

The considered species of edible mushrooms were linked to specific site conditions and forest ecosystems in order to specify the ecological preferences of the most preferred and collected ectomycorrhizal mushrooms and the occurrence of their fruiting bodies. The ecological preferences covered both abiotic conditions such as soil, hydric, climate as well as natural biotic conditions such as the tree species of the forest stand. The ecological preferences were translated into a set of variables and their parameters as prerequisites for mushroom growing (Table 1).

The parameters represent an expert judgement of the second author based on systematic mycological research within the study area that was combined with papers documenting the mushrooms occurrence or the fruiting bodies production in Europe and fine-tuned in several iterations during the research. General ecological requirements for *B. edulis* were adopted from [27], soil conditions for *B. edulis* (*Boletus* spp.), *L. aurantiacum* (*Leccinum* spp.), *C. cibarius*, *Russula* spp., *Amanita* spp. and *L. deliciosus* from [28], meteorological variables for *L. deliciosus* from [29], and climatic variables for growth of *B. edulis* from [25]. In order to address microrelief and microclimate conditions, slope and aspect were parametrised for mushrooms in general following [14,24,39]. The actual vegetation of the forest stand, in the sense of tree species mycorrhizal partners, was represented in the assessment by three variables: tree species composition, tree age, and tree cover density. Tree species parameters for *B. edulis*, *B. aereus*, *B. reticularis*, *B. pinophilus* and other evaluated mushrooms were derived from [23,24,26]. Tree age parameters for *B. edulis* and *L. deliciosus* were derived from [8,14,40], and other mycorrhizal mushrooms from [41]. Tree cover density parameters for species such as *B. aereus*, *B. edulis*, *B. pinophilus*, *Cantharellus lutescens* and *L. deliciosus* were derived from [19,25,39,41,42].

**Table 1.** List of variables and their parameters applied in the assessment of the forest stands potential for ectomycorrhizal mushrooms growing.

Variable	Parameter Value	Description
Ac—Abiotic conditions (soil, hydric, climate)	1.0	Types with deep soils, no soil skeleton in topsoils, often with dry topsoils in summer, warm climate
	0.7	Types with deep soils but partially with wet soils, or very acidic soil reaction (pH), or higher soil skeleton occurrence in topsoils, warm climate
	0.5	Types with prevailing moist or wet soils, or stony or rocky soils, in various climate conditions
	0.2	Types on extreme sites with shallow or rocky soils in ravine or mountain conditions, or on limestone bedrock with low water content and retention capacity, mostly warm conditions
	0.0	Other types - floodplains, debris, steep limestone slopes, rocky soils, localities near treeline



Table 1. Cont.

Variable	Parameter Value	Description
SA—Slope and Aspect combination	1.0	Slope up to 12° and all aspects, or slope 13°–30° and South or South-West aspect
	0.8	Slope 13°–30° and South-East or West aspect
	0.5	Slope 13°–30° and East aspect
	0.2	Slope 13°–30° and North, North-East or North-West aspect
	0.0	Slope over 30°
Ts—Tree species composition  (for mixed stands it is calculated as the weighted average of tree composition)	1.0	<i>Abies alba</i> Mill., <i>Betula</i> spp., <i>Carpinus betulus</i> L., <i>Fagus sylvatica</i> L., <i>Picea abies</i> (L.) Karst., <i>Quercus cerris</i> L., <i>Quercus robur</i> L., <i>Quercus petraea</i> (Mattuschka) Liebl.
	0.7	<i>Pinus sylvestris</i> L., <i>Populus tremula</i> L., <i>Quercus pubescens</i> Willd., <i>Quercus robur</i> ssp. <i>slavonica</i> , <i>Quercus rubra</i> L., <i>Quercus virgiliana</i> (Ten.) Ten., <i>Tilia cordata</i> Mill., <i>Tilia platyphyllos</i> Scop.
	0.3	<i>Abies grandis</i> Lindl., <i>Larix decidua</i> Mill., <i>Picea omorica</i> (Panc.) Purk., <i>Pinus strobus</i> L., <i>Pseudotsuga menziesii</i> (Mirb.) Franco
	0.0	<i>Acer platanoides</i> L., <i>Acer campestre</i> L., <i>Acer pseudoplatanus</i> L., <i>Acer tataricum</i> L., <i>Aesculus hippocastanum</i> L., <i>Ailanthus altissima</i> (P. Mill.) Swingle, <i>Alnus glutinosa</i> (L.) Gaertn., <i>Alnus incana</i> (L.) Moench, <i>Alnus viridis</i> (Chaix) DC., <i>Carya</i> spp., <i>Castanea sativa</i> P. Mill., <i>Cerasus avium</i> L., <i>Cerasus mahaleb</i> L., <i>Fraxinus americana</i> L., <i>Fraxinus excelsior</i> L., <i>Fraxinus ornus</i> L., <i>Juglans nigra</i> L., <i>Juglans regia</i> L., <i>Malus sylvestris</i> Mill., <i>Negundo aceroides</i> Moench., <i>Padus avium</i> Mill., <i>Picea pungens</i> Engelm., <i>Pinus banksiana</i> Lamb., <i>Pinus cembra</i> L., <i>Pinus mugo</i> Turra, <i>Pinus nigra</i> Arn., <i>Populus alba</i> L., <i>Populus nigra</i> L., <i>Populus x canadensis</i> cv. I 214, <i>Populus x canadensis</i> cv. <i>robusta</i> , <i>Pirus communis</i> L., <i>Robinia pseudoacacia</i> L., <i>Salix</i> spp., <i>Sorbus aria</i> (L.) Crantz, <i>Sorbus aucuparia</i> L., <i>Sorbus torminalis</i> (L.) Crantz, <i>Taxus baccata</i> L., <i>Ulmus glabra</i> Huds., <i>Ulmus minor</i> Mill., <i>Ulmus laevis</i> Pall.
Ta—Tree age class (with 10 years step)	1.0	Older than 60 years
	0.5	20–60 years
	0.0	Younger than 20 years
Tc—Tree cover density	1.0	Tree cover density from 1% to 70%
	0.8	Tree cover density 80%
	0.7	Tree cover density 90%
	0.6	Tree cover density 100%

### 2.3. Spatial Data and Modelling of Potential for Mushroom Occurrence

In the second step, available spatial data that would fit the specified ecological preferences of mushrooms were considered and tested. Its spatial delineation was based on a combination of three spatial databases.

The forest site's abiotic conditions were assessed from the Map of forest types. This map is a result of a complex geobotanical survey that has been realised in all the forests in the Slovak Republic since the 1950s. Forest type represents a complex ecological unit of the site's soil, hydric, and climate conditions and its potential forest vegetation and serves as a reference knowledge base for forest stands' protection and management. The soil, hydric, and climate characteristics of each forest type were interpreted and parametrised according to their potential to support mushrooms.

Since mushrooms' occurrence also depends on local geomorphology, affecting mainly microclimate and soil humidity, slope inclination and aspect were assessed as additional site's variables following [43]. In addition, in this step also practical accessibility for people was considered as slopes steeper than 30° are difficult to access for common mushroom pickers; therefore, they were parametrised as not suitable (value 0). Although ectomycorrhizal mushrooms can grow on such steep slopes, these sites do not

provide the most favourable of conditions for them. The slope and aspect were derived from a digital elevation model (20 m cell size) and combined and parametrised into a single variable.

The actual vegetation structure of the forest stands was derived from a spatial database of Forest Inventory (in the form of Forest Digital Map) containing detailed information of forest stands, tree cover structure, and composition. From the database, the following stand characteristics were selected and parametrised: tree species composition, tree age, and tree cover density.

The potential of forest stands for mushroom growing was assessed by multicriteria analysis [44] following principles of the LANDEP methodology [45]. All evaluated variables (criteria) were considered equally weighted in the calculation. All variants (classes) of the variable were mutually compared and parametrised by expert judgement within an interval ranging from 0 to 1 (0 representing variants with the lowest or close to 0% probability of occurrence of ectomycorrhizal mushrooms, 1 representing the highest or close to 100% probability for mushrooms occurrence). For example, tree species composition was parametrised using the number of mushroom species bond to the host tree species (1.0—more than five mushroom species, 0.7—three to five species, 0.3—one species, 0.0—no mushroom species).

The potential of forest stands for mushrooms growing was calculated as the multiplication of partial variables:

$$PM = Ac \times SA \times Ts \times Tc \times Ta \quad (1)$$

Where:

PM—Potential for Mushroom growing

Ac—Abiotic conditions

SA—Slope and Aspect combination

Ts—Tree species composition

Tc—Tree cover density

Ta—Tree age class

Due to the range of the applied parameters (from 0 to 1), the resulting potential indicating the probability of mushroom occurrence reaches values also within the interval from 0 to 1, similarly as in occurrence probability mapping applied by [22,46]. This is its main advantage as it is always from that interval regardless of the number of applied variables (it may be enriched with more variables if needed), and it is also easy to interpret or to compare with other similar indicators. For the sake of interpretation and visualisation, the calculated potential values were divided into three classes: low potential (0–0.33), medium potential (0.34–0.66), and high potential (0.67–1).

The method and the applied variables and their parameters were tested and validated in the Zvolen district prior to assessing the potential within the whole study area. The validation was realised on 100 spatially randomly selected forest stands lying within the district. The selected stands were visited in autumn 2018, and the occurrence of ectomycorrhizal mushrooms were recorded. We assessed how many visited stands the modelled potential matched the observed one, and on how many stands the modelled potential was lower than the observed and on how many stands the modelled was higher than the observed. The stand was evaluated as with low potential when there were either no mushrooms recorded or only an occasional occurrence of common species such as *Amanita rubescens*, *Boletus subtomentosus*, *Leccinum pseudoscabrum* or *L. scabrum*, *Neoboletus luridiformis*, *Russula cyanoxantha*, and *Xerocomellus chrysenteron*. As medium potential was considered for stands with the occurrence of common species (listed above) and *Boletus reticulatus* or *B. edulis*, *Cantharellus cibarius*, *Imleria badia*, *Lactarius deliciosus* or *L. deterrimus* but in low abundance. The high potential stands must have a regular occurrence of the species from lower potential classes and other remaining ectomycorrhizal species (according to their specific site's and tree species preferences).

#### 2.4. Demand and Accessibility for Local Communities

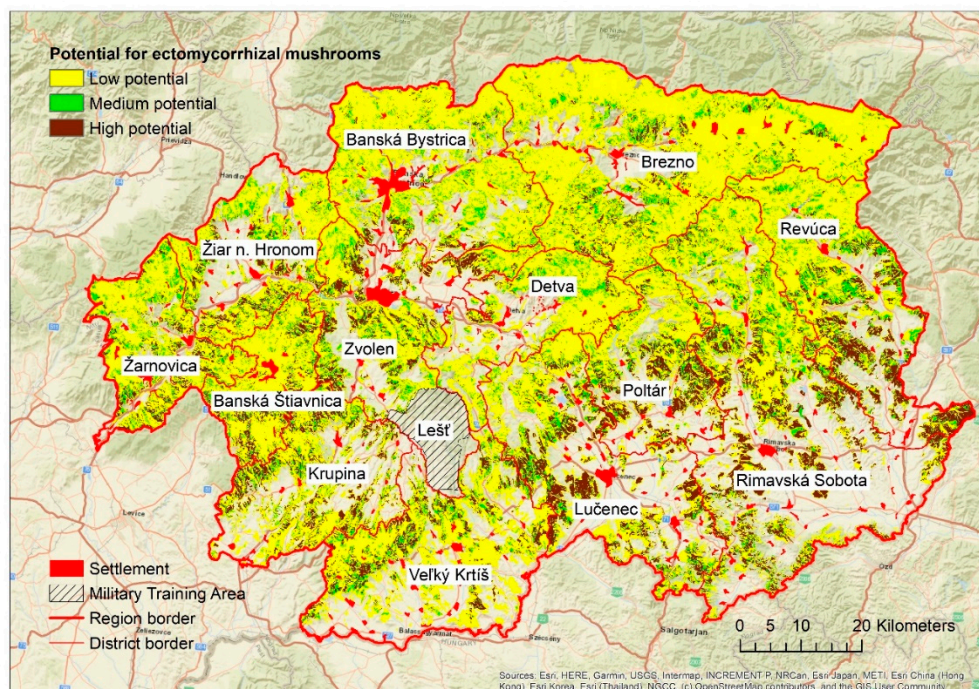
In order to assess the theoretical demand and availability of wild mushrooms for local populations, the official census data (valid for 2019) on the population and its social status per district were applied.

The data is collected, updated, and published by the Central Office of Labour, social affairs and Family [47,48] on a regular basis. The practical accessibility of forest stands with a high potential for the inhabitants was analysed using Euclidean distance zones (with 100 m steps) from the settlements. It was not weighted by slope inclination as this variable was previously applied in the potential calculus (steeper slopes have lower parameters for mushroom growing).

### 3. Results

#### 3.1. Potential of Forest Stands for Mushrooms Growing

Figure 2 shows the potential of forest stands for ectomycorrhizal mushrooms in the Banskobystrický Self-governing Region calculated from the underpinning spatial data. The total area of forest cover is 621,461 ha in the region; out of it, 14.4% are forest stands with a high potential for wild mushrooms. Little less (13.1%) are forests with medium potential, and forest stands with low potential cover the remaining 72.5% of the area (Table 2). From a distribution point of view, stands with high potential are situated mostly in the South and South-East parts of the study region whilst the central and the North parts are covered by forests with low potential. This distribution, observed from the higher perspective, corresponds mostly to landscape types and mesoclimate characteristics with warmer basins and hill lands with dominant oak, hornbeam, and beech forest stands in the South and higher mountains, and inter-mountain valleys with higher coverage of beech-fir and spruce stands in the central part and in the North. When focused from a closer perspective, within the identical landscape types and the mesoclimate zones, the potential classes reflect more the actual forest stands' characteristics such as tree composition, soils, and microrelief.



**Figure 2.** Potential of forest stands for ectomycorrhizal mushrooms growing in the Banskobystrický Self-governing Region.

**Table 2.** Potential of forest stands for ectomycorrhizal mushrooms growing.

Potential for Mushrooms	ha	%
low	450,641	72.5
medium	81,278	13.1
high	89,542	14.4
sum	621,461	100.0

### 3.2. Demand and Accessibility of Mushroom Sites

The value of any ecosystem service depends not only on its biophysical presence, but it should also reflect the demand and accessibility for the service's beneficiaries. In other words, a demanded and accessible service is of higher value than service that is less demanded or not accessible to a beneficiary. Following this assumption, the socioeconomic characteristics of the region's inhabitants were analysed. As mentioned earlier, the studied region is rather specific within the Slovak Republic. It is more rural and less populated and less developed. Five (Lučenec, Poltár, Revúca, Rimavská Sobota, and Veľký Krtíš) of its 13 districts are included in the List of Least Developed Districts of the Slovak Republic [33] due to the very high number of inhabitants receiving social benefits and the number of registered who are unemployed (Table 3), which are very much higher than the Slovak average. Moreover, the districts of Revúca and Rimavská Sobota have the highest percentages of socially disadvantaged inhabitants in the whole country.

**Table 3.** The number of socially disadvantaged inhabitants per district in the Banskobystrický Self-governing Region (Source: [47,48]).

District	No. of Inhabitants	No. of Inhabitants Receiving Social Benefits	%	No. of Economically Active Inhabitants	No. of Unemployed	%
Banská Bystrica	110,941	722	0.65	64,411	2087	3.24
Banská Štiavnica	16,103	459	2.85	8334	500	6.00
Brezno	61,630	2565	4.16	31,791	1448	4.55
Detva	32,135	656	2.04	16,895	802	4.75
Krupina	22,225	808	3.64	11,092	642	5.79
Lučenec	73,590	4411	5.99	35,177	2 840	8.07
Poltár	21,545	1180	5.48	10,348	982	9.49
Revúca	39,736	4847	12.20	18,026	2287	12.69
Rimavská Sobota	84,270	9866	11.71	38,826	5795	14.93
Veľký Krtíš	43,683	1815	4.15	21,244	1210	5.70
Zvolen	68,832	1043	1.52	37,400	1302	3.48
Žarnovica	26,193	493	1.88	13,356	873	6.54
Žiar nad Hronom	46,991	703	1.50	24,867	1060	4.26
Slovak Republic	5,450,421	137,985	2.53	2,754,400	136,192	4.94

For this reason, the distribution of the potential for mushrooms within 13 districts of the region was analysed (Table 4). As shown in Table 4, the largest areas of forest stands with high potential are situated in the Rimavská Sobota, Lučenec, Revúca, and Poltár districts. It is also true when comparing the relative proportions of high potential forests stands within the districts (Figure 3). Continuing the analysis, a theoretical availability of high potential stands per capita was calculated. In this respect, the most available picking area per mushroomer is in the districts of Poltár and Krupina. However, this accessibility analysis may be biased by districts' borders' delineation that, in reality, does not present any limitation for crossing those borders. In order to assess accessibility more realistically, the potential

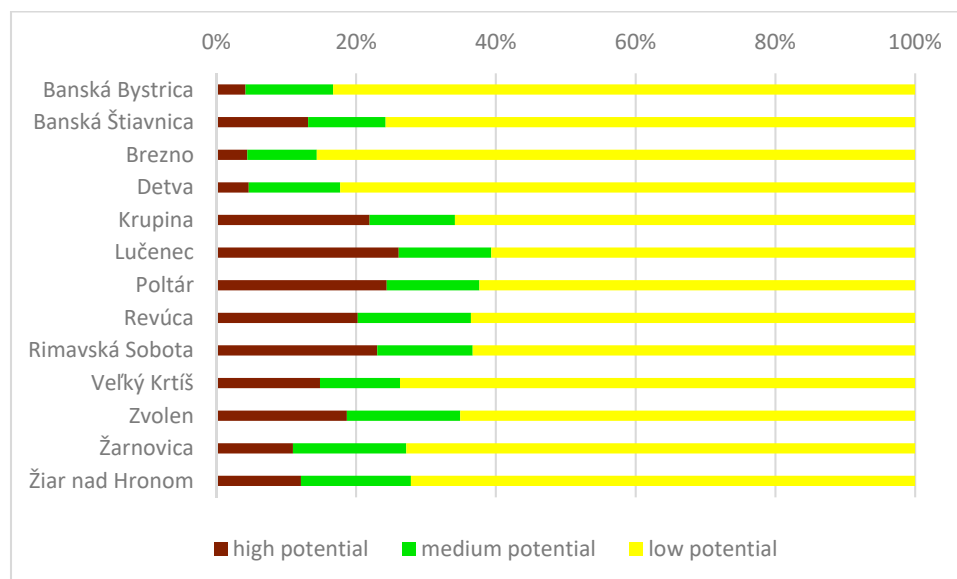


classes' occurrence was analysed within a distance from settlement zones (Figure 4). This analysis revealed that forest stands with high potential lay at distances from 2000 to 2500 m from the nearest settlement. Theoretically, it is approximately a half to one-hour walk (even less when using transport to the nearest forest border).

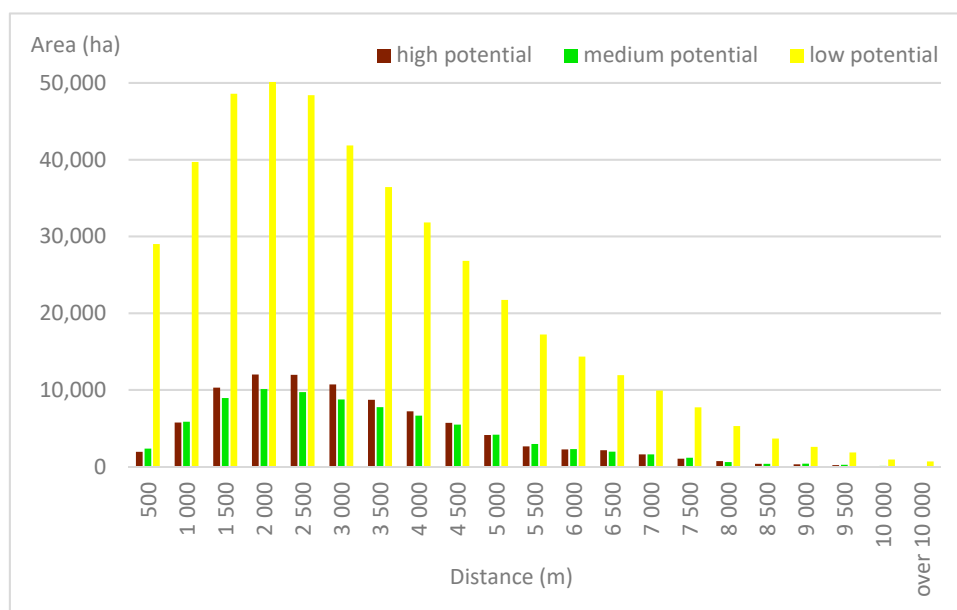
The distribution analyses confirmed the assumption that forest stands with a high potential for mushroom growing are relatively abundant within the districts with a high number of socially disadvantaged inhabitants. In addition, these stands lay within a walking distance, which minimise or may even nullify any travel costs. The results thus may lead to the conclusion that mushroom picking may indeed be an accessible ecosystem service and potentially a feasible way of complementary subsistence for the local communities in socially disadvantaged districts.

**Table 4.** Distribution of the potential for mushroom classes within districts of the region.

District	High Potential (ha)	Ha per Inhabitant	Medium Potential (ha)	Low Potential (ha)
Banská Bystrica	2560	0.02	7651	50,827
Banská Štiavnica	3817	0.24	3215	21,999
Brezno	4893	0.08	10,971	94,367
Detva	1283	0.04	3604	22,695
Krupina	7681	0.35	4266	23,049
Lučenec	11,265	0.15	5716	26,172
Poltár	7750	0.36	4215	19,811
Revúca	10,669	0.27	8537	33,488
Rimavská Sobota	17,333	0.21	10,278	47,627
Veľký Krtíš	7041	0.16	5435	34,964
Zvolen	7230	0.11	6279	25,202
Žarnovica	3895	0.15	5763	25,882
Žiar nad Hronom	4126	0.09	5348	24,558



**Figure 3.** Relative proportions of potential for mushrooms within the districts.



**Figure 4.** Occurrence of the potential for mushrooms within distance zones from the settlements.

## 4. Discussion

### 4.1. Modelling and Parameters

The method applied for assessing the potential for ectomycorrhizal mushrooms in the study area was based on the set of variables on a site's natural conditions and forest stand's structure and the available national Forest Inventory database. The main advantage of this database is that it is a mandatory database for all forests in the Slovak Republic serving as the basis for Forest Management Programs; therefore, it is updated every ten years following uniformed structure and quality. This means that the presented method can be rather easily applied for the whole country in case there is a demand for such an analysis. In addition, the applied calculus is rather simple and enables the addition of more variables if needed. Since it is based on multicriteria analysis, it is also compatible with the multicriteria decision analysis method applied in land management studies such as land suitability evaluation [49], land management [50], or flood risk assessment [51]. It is also applied in optimal forest management for competing ecosystem services [52] as mushroom-based ecosystem services represent an important non-timber provisioning service [4,10].

The most significant preconditions for mushroom growing, according to of authors' own research and the literature review [8,22,24,28,30,53,54], were identified as being the soil, hydric and climate conditions of the site and the actual tree species of the forest stand. These conditions were translated into five variables that represent an intersection between the identified theoretical preconditions and the available spatial datasets for the study area (Forest Inventory and Forest Types). Every variable was separately considered, and its variants (classes) were parametrised accordingly to their capacity to support ectomycorrhizal fungi. Although the knowledge base for mushroom occurrence is in general rich, in most cases, the analyses are limited to one or few mushroom species in the regionally specific natural conditions [25–27]. It is, therefore, very difficult to formulate exact parameters that are valid for the whole group of mushrooms, although certain species such as *A. rubescens*, *B. subtomentosus*, *C. cibarius*, *L. aurantiacum*, *R. cyanoxantha* often grow together and thus they have similar ecological preferences [23]. For this reason, the applied parameters represent a rather relative suitability of the class (of the variable) than the exact value determining mushroom species abundance or yields in the stand. This is particularly true for the natural conditions and the structural characteristics of the forest stand. The presence of the tree host partner, on the other hand, is crucial for certain species such as *Leccinum* spp., and *Lactarius* spp., and in this case, the tree composition play a key role in the assessment,

although still only as a qualitative indicator [14,29]. However, the study's aim was to identify the stands with the highest likelihood for mushroom occurrence as a prerequisite for ecosystem service. An assessment of ectomycorrhizal mushroom abundance or quantification of yields was beyond the scope of this approach.

The model, its variables, and parameters were tested and validated by recorded mushrooms' occurrence in forests within the Zvolen district. The main reason being that it is one of the well-known mushroom regions in Slovakia (almost 30% of its forests have high potential for mushrooms) and it lies in the central part of the study area containing almost a full spectrum of forest stands starting from floodplain forests to treeline forests and thus tested results can be extrapolated for other neighbouring districts. It is also familiar to the authors, thus the designed calculus of the potential for mushroom growing, considered variables, and their parameters were fine-tuned in several iterations and validated in the field. The validation that took place in autumn 2018 revealed that, out of 100 visited, 83 forest stands presented a match of the modelled potential with the observed potential in the stand. Nine stands were underestimated (the modelled potential was lower than the observed one) and eight stands were overestimated by the method (the modelled potential was higher than the observed one).

#### 4.2. Mushrooming as an Ecosystem Service

The assessment of wild mushrooms as a provisioning ecosystem service requires an analysis of the service's beneficiaries. As noted by [4], wild food will be collected in areas where there is a supply of it and that that supply is accessible to people who have a demand for collection and consumption. For this reason, mapping of the spatial patterns of supply and demand could include both local landscape characteristics and detailed census data. As documented by several authors, most of the collected mushrooms are self-consumed [8]. In fact, according to the questionnaire realised in Slovakia on the sample of 5 168 random respondents, only 2% of mushrooms were for sale [55]. However, exact data on mushroom harvest and sale are very scarce since the majority of wild mushroom harvesting is not reported [5]. As several authors pointed out [4,8,17,55], there exists a gap between legal regulations on wild mushroom harvesting and commerce and actual mushroom picking and selling. Despite that, wild food collecting is attractive in low-income regions in Eastern and Southern Europe as these products are more easily available and are an important part of the traditional cuisine [4]. In addition, mushroom picking has the potential to compensate for some losses related to unemployment [13] as it can secure a significant additional income for pickers [55]. This was one of the main reasons why the assessment of the potential for mushroom growing as an ecosystem service was considered for socially disadvantaged inhabitants. As reported by [18], most people collect mushrooms within 5 km of their home. This is true for the study area as the stands with the highest potential lay within 2 to 2.5 km from the nearest settlement. It means that they are rather easily accessible for inhabitants as access to the Slovak landscape is free, as well as picking mushrooms and berries, for private use. The potential for collecting mushrooms in Slovakia may be even higher when not mycorrhizal species of fungi are also considered. Slovak mushroom pickers also often harvest other, not ectomycorrhizal, mushrooms as parasols (*Macrolepiota procera* and *M. mastoidea*), oyster mushroom (*Pleurotus ostreatus*), umbrella polypore (*Polyporus umbellatus*) or early false morel (*Verpa bohemica*) [56].

## 5. Conclusions

Forest ecosystems can provide services whose coexistence is mutually supportive. Favouring some services, especially timber provisioning, can lead to the impoverishment of others, particularly regulation or cultural services. This is perceived as a serious issue of the current forest management in many, especially the post-socialist countries. Trade-off analysis of ecosystem services is based on the demand for specific ecosystem services depending on the local situation. Demand can be based on requirements of the population (provisioning or cultural services) or on the exposure of environmental or natural hazards (need for regulation and maintenance services). From an economic perspective, timber production may be considered a priority for the forest owners, but strengthening

local non-timber provisioning services such as forest foods, flood protection, or recreational use of forests is often of higher value for the local communities.

The study presented an approach for identification of forest stands with a high potential for ectomycorrhizal mushrooms growing. Its main advantage, from a practical point of view, is that the methods apply common data as the traditional forest management in Slovakia. The approach can be applied in the planning of forest management, taking into consideration also other than timber-provisioning service. Deciding which services are more relevant and necessary in a particular case will allow them to be prioritised in practical forest management. The presented results can help to support this issue and demonstrate those forest stands that have a high potential for mushroom growing and, therefore, might be managed alternatively. Multifunctional forest management returns manifold benefits—not only ecological and environmental but also social benefits, namely for the disadvantaged local population.

Spatial analyses of forest stands and the human population revealed that there is an overlap of forest stands with high potential for mushroom growing and the districts with the highest proportion of unemployment or inhabitants receiving social benefits. This supports the initial assumption that wild mushrooms may present a subsistence provisioning service and contribute to a better life for disadvantaged local communities even in the economically prosperous countries. This result may highlight the issue and also add a new perspective into the ecosystem services concept of supply and demand.

The applied model, its variables, and parameters are, due to their relatively simple design, open for any further improvements. Especially when considering its application in different study areas with different natural conditions and different available underpinning data. The model may be further developed as it enables adding of new variables if needed. The assessment can be applied even on areas that are currently not being considered forests, although they are covered by woody vegetation. These former fields and pastures overgrowing with secondary succession represent newly formed sites that support several mushroom species. In addition, the model could also address non-mycorrhizal edible mushroom species growing in forest stands, such as oyster mushrooms, saprophyte fungi on dead wood, especially in old forests or true morels (*Morchella* spp.) growing on steep rocky sites.

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