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Analysis of Significant Factors Influencing the Amount of Collected Forest Berries in the Czech Republic

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Abstract: Bilberries (*Vaccinium myrtillus* L.), raspberries (*Rubus idaeus* L.), blackberries (*Rubus fruticosus* L.) and cowberries (*Vaccinium vitis-idaea* L.) are the most important forest berries collected in the Czech Republic (CZ). The average annual value of these collected berry species is estimated to be worth more than EUR 86 million at 2018 prices. The data concerning the collection and use of forest fruits have been systematically collected in a highly detailed structure since 2008, which enables the application of the advanced statistical methods used in this paper. The results of the analyses inter alia demonstrate that collecting forest berries is not only an important recreational activity, but it has an important economic effect. Therefore, this article also deals with the collection of forest fruits, especially bilberries, as a potentially important non-wood forest product (NWFP) for sustainable forest management and also analyses the external factors influencing the total annual amount of collected forest berries. A deeper knowledge of the customer and his or her behaviour—customer insight—are prerequisites for the proactive management of forest ecosystems. The first step to “berry picker insight” is to learn more about the demand, its structure and factors which influence this demand. Thus, one of the research questions concentrates on the analysis of the sociodemographic characteristics of the berry picker that are relevant for explaining the amount of collected forest berries in the Czech Republic. Knowledge of these factors can contribute to a more effective application of marketing methods for shaping and influencing the demand so that, in terms of time and place, it is more in line with the supply, which is limited by the natural conditions, growing season and production potential of forest ecosystems.

Keywords: forest berries; socio-economic importance; customer insight; Czech Republic; ecosystem services

1. Introduction

Forest ecosystems provide a range of services and products that meet the needs of society and individuals [1–4]. As studies have shown [5–9], many ecosystem services are associated with non-wood forest products (NWFPs). Although the economy, forestry, agriculture, rural development and other sectors may address NWFPs, usually, there is not one sector explicitly dealing with these issues [10]. The demand for NWFPs is strongly linked to societal trends and cultural preferences [11]. Due to the role and economic potential in the utilisation of NWFPs, there is a need, and an increasing interest, in monitoring their market volume and values both on a national and an international level [12].

There is also growing concern over the amount of forest crops harvested due to the level of the organic production and the burden on the forest environment in many countries, both in North America and in Europe.

The favourable impact of NWFPs on human health is stressed by [13], and the high content of antioxidants in wild berries is addressed in [14]. Grivins [15] mentioned that the Chinese herbal market demands, for example, large quantities of wild bilberries owing to their beneficial health properties. According to [16], bilberries decrease the risk of cardiovascular disease, diabetes (type 2) and they are helpful in weight maintenance.

According to [17], wild berries are collected by the largest share of European households (20.7%) followed by wild mushrooms (19.7%). Although picking berries could principally be thought as a provisioning service [18], it is often categorised as a recreational forest activity due to the everyman's rights [19]. Some of these services, such as picking berries and mushrooms, may also be regarded as supporting cultural ecosystem services, including outdoor recreation and promoting mental and physical health [20]. Saarikoski et al. [21] emphasised that the aesthetic qualities of forests strongly influence the berry picking experience as well as other recreational activities.

From a geographical point of view [17], the importance of picked NWFPs can be found in some Slavic (e.g., Russia, Bulgaria, Poland, Serbia), Baltic (Latvia, Lithuania, Estonia) or Nordic (Finland and Sweden) nations, which have been accentuated upon in the eastern and northern European countries publications of [22,23] or [24], in which they concentrated on the value of the berries and mushrooms in Slovakian forests. In Finland, wild berry picking has kept its role as one of the most prevalent forest-related activities [25] and large quantities of berries are picked annually; the estimated amount is 42 million kg per year [26]. However, as stressed in [27], for example, the lack of any systematic research concerning the quantities of the harvested wild berries is apparent. According to [28], one of the challenges for internationally comparable ecosystem assessments is that the available data sets and used measures are different in various European countries. Muir et al. [29] directly states: "... information on NWFPs is patchy and incomparable across countries. Undoubtedly, the sheer number of products and different end uses coupled with challenges surrounding non-standard units of measurement and terminology issues all make NWFP quantification problematic."

Berry picking, however, does not provide a similar market value for the forest owner as the wood-based biomass does, but the management of the forests considerably differs between these services and the frequency and intensity of the forest visits [30]. In the situation where the prices of wood products (mainly roundwood) are decreasing [31], especially since 2017, due to the large bark beetle outbreaks in most parts of Central Europe [32,33], forest owners must look for other sources of income, including changing the forest management from wood to non-wood production, or must politically promote the introduction of payments for ecosystem services. Lovrić et al. [17] evaluated the NWFP in 28 European countries and suggested that one should consider the co-production of wood and NWFPs, especially in Central Europe.

At present, the effect by which forest fruits, especially bilberries, respond to changes in forest management is already well described [34–37]. However, such measures can only be realised if the offeror (e.g., the forest owner) has enough information about his/her potential customers (i.e., the pickers). Laughlin [38] refers to the term "customer insight" as "A non-obvious understanding about your customers, which if acted upon, has the potential to change their behaviour for mutual benefit". This paper deals with the collection of forest fruits, especially bilberries, as a potentially important NWFP for sustainable forest management in the Czech Republic (CZ). The first step to "berry picker insight" is to learn more about the demand, its structure and the factors which influence this demand. For the analyses of the significant factors (including the sociodemographic characteristics of the berry pickers) related to the forest fruit collection in the CZ, the following research questions (RQ) are used:

RQ1. How is the total amount of collected forest fruits that are collected each year of the analysed period distributed among the berry pickers?

RQ 2. What are the personal characteristics of the berry picker that are relevant in explaining the amount of collected forest berries in the Czech Republic?

RQ 3. How has the (total) amount of collected forest fruits varied during the analysed period of 25 years?

RQ 4. What are the main meteorological factors influencing the total annual amount of collected forest berries?

2. Materials and Methods

2.1. NWFP in the Czech Republic

According to the Czech Forest Act, the free collection of NWFPs is allowed on 92% of the forest areas (all the forests, irrespective of the ownership, except military forests and strongly protected natural preserves and zones of national parks) [39]. Historically, research on the issue of assessing the socio-economic significance of NWFPs in the CZ was initiated in 1993, as presented by [40]. The popularity of NWFP collecting and especially the consumption of mushrooms and forest berries in the Czech Republic is considerable [41]. The most commonly harvested forest fruits in CZ include mushrooms, bilberries, cowberries, raspberries and blackberries [42].

A detailed analysis on the socio-economic effects of the non-market non-timber forest products in the CZ has been presented by [43]. The main data serving as the basis for a more detailed statistical analysis of the collection of forest berries and their harvesters, for our article, have been obtained using the same methodology (more details can be found in Section 2.2: Data Collection) as that of the data on mushroom collecting in the article by [43] and have been extended by the data from 2014 to 2018. Figure 1 shows the total amount of harvested forest berries in the years 1994–2018.

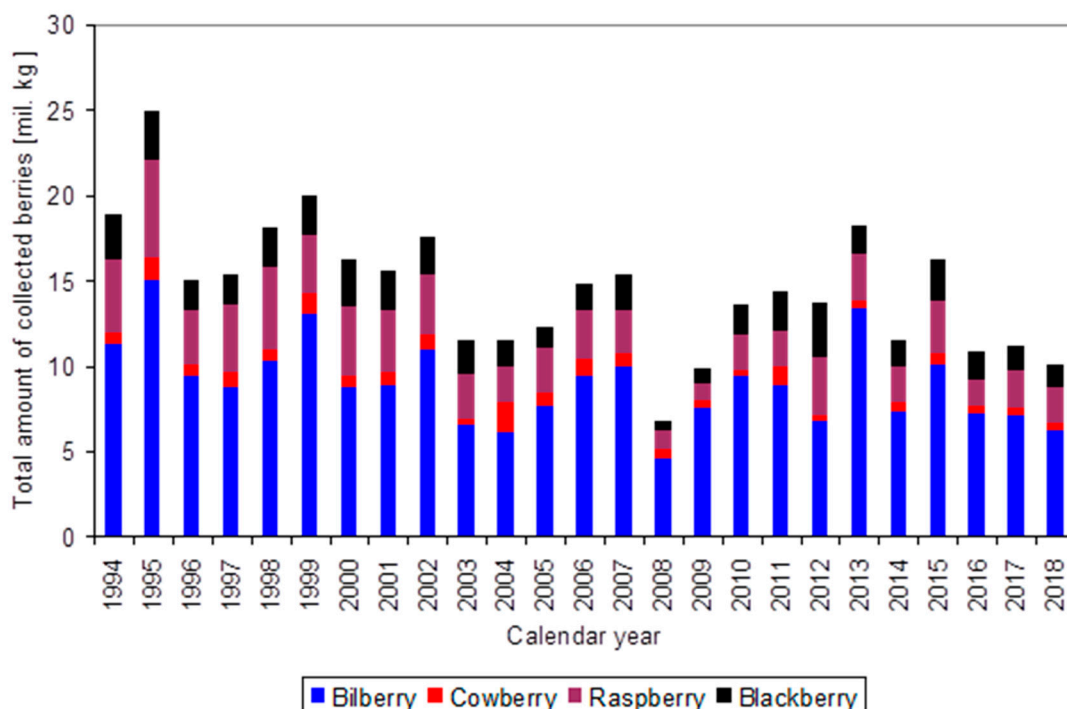


Figure 1. The total amount of the collected forest berries (bilberries, cowberries, raspberries and blackberries) in the Czech Republic (CZ) (millions of kg) in the period 1994–2018 (Sisak et al. 2016 [43], extended).

The coefficient of variation, also known as the relative standard deviation, mathematically defined, in statistics, by the ratio of the standard deviation by the mean value (standard deviation/mean),

is considered to be a normalised measurement of the dispersion of the data, see, e.g., [44]. In Table 1, the coefficient of variation is calculated for each time series shown in Figure 1. The values of the variation coefficient that approach 30% indicate considerable variability in the analysed data, see [45].

Table 1. The coefficient of variation of the total amount of the collected forest berries (bilberries, cowberries, raspberries and blackberries) in the CZ in the period 1994–2018.

	Bilberries	Cowberries	Raspberries	Blackberries
Mean (millions of kg)	8.972	0.720	2.928	1.912
Standard deviation	2.462	0.352	1.141	0.609
Coefficient of variation (in %)	27.4	48.9	39.0	31.9

2.2. Data Collection

The research area covers the whole of the Czech Republic, a Central European country. The CZ occupies an area of 78,863 km². The CZ forestland covers 26,717 km², i.e., 33.9% of the total area of the CZ. For further details about the natural conditions of the CZ, see, e.g., [46]. The extent of the forest area accessible to the public and the number of inhabitants basically stayed the same during the analysed period of 1994–2018. According to the Czech Statistical Office [47], there was a 2.81% increase in the number of inhabitants during the whole 25-year period, which is negligible.

Over the whole period of 1994–2018, standardised questions related to the amount of harvested wild berries and mushrooms were used in personal interviews. For the period of 1994–2007, only the aggregated data estimating the total amount and the total value of the collected forest berries are available. This means that for the period of 1994–2007, the data are not available from the individual respondents, but only the calculations of the total value and quantity for each species of collected forest berries are available. Since 2008, the survey has been conducted by the hired research agency Stemmark, which, as a member of European association research agencies (ESOMAR), meets its strict criteria regarding ethics and a professional approach to market research. So, for the period 2008–2018, the socio-economic data of the individual respondents including the collected amount and price per kg of the collected forest berries are available. The questioning was conducted using a computer-aided personal interview method (CAPI) on a representative group of respondents as a part of the omnibus research. A network of approximately 250 trained interviewers allowed one to achieve the desired representativeness of the research sample using the original standardised questionnaire [43]. In the individual years of the period 2008–2018, there was a regular change in the respondents in the omnibus research. The description and advantages of the omnibus research method are explained, e.g., by [48]. The respondents were selected on the basis of their gender, age, education, size of the municipality and region of residence (a so-called quota sample) which ensures the representativeness of the sample with respect to these criteria and which is also an important prerequisite for the subsequent statistical analyses. Between 2008 and 2018, the number of respondents in the annual survey ranged between 1000 (2013) and 1087 (2011). For the entire monitored period, more than 1000 respondents were interviewed annually. The total number of respondents for the period 2008 to 2011 was 11,254, which makes this research unique on a global perspective. The standard error estimate [49] associated with this sample size is 0.47%. The data contained within are the main source for the analyses and graphs presented in this paper. The estimates concerning the total quantity of the collected berries are derived from the results of these surveys and have been published in yearly reports on the state of the forest and forestry of the Czech Republic [50]. Although the division of the Czech Republic into regions has changed several times over the last 25 years, the division used since the beginning of the research in 1994 has been retained (Figure 2).

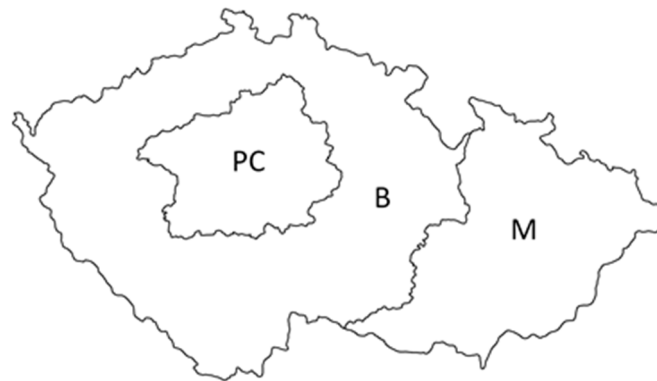


Figure 2. Regions in the Czech Republic. PC—Prague and Central Bohemia, B—Bohemia without the central region, M—Moravia.

2.3. Statistical Methods

The statistical analysis of the data was carried out in 3 steps:

1. The data obtained from the forest berries pickers in each year from 2008 to 2018 were analysed using the Gini coefficient to determine the degree of unevenness in the distribution of the quantity of collected forest fruits between the berry pickers.
2. Using the data for the period 2008 to 2018, the dependence of the volume of the harvested forest fruits on the sociodemographic characteristics of the individual respondents was analysed using a proportional odds model. Graphical methods are also used for clarity—such as a Lorenz curve in the case of the distribution of the collected quantity of bilberries and mosaic displays to show the relationships of the collected quantity and selected sociodemographic characteristics.
3. The total volume of the harvested bilberries, depending on external factors, was analysed using a linear model. In this case, it was possible to use the data for the entire monitored period 1994–2018. In this third step, the collection of bilberries was used for the analysis, due to its importance and the number of respondents stating non-zero amounts of collecting berries (about 38%).

2.3.1. Distribution of Berries Collected in CZ

The Gini coefficient and Lorenz curve were used in order to evaluate the distribution of the berries collected among the respondents' households.

The Gini coefficient [51] is defined as:

$$G = \frac{\sum_{i=1}^n \sum_{j=1}^n X_i - X_j}{2n^2 \bar{X}} \quad (1)$$

where X_i is the amount of the berries collected by i -th respondent, \bar{X} is the average amount of berries collected by one respondent and n is the number of respondents.

The Gini coefficient is a measure of the univariate inequality, which arises as a special case of the concentration index, when the inequality is measured by the same variable that is used for the ranking; see [52]. The statistical conclusions based on the Gini index are often used for measurement inequalities in income distribution [53] or as a poverty measurement [54]. Sadras et al. [55] use the Gini index to assess the yield inequality in yield crops. We employed the Gini index to measure the inequality in the collection of forest berries. The values of the index range from 0 to 1. The larger the Gini index value, the more unequal the distribution of the collected berries is.

Whereas the Gini coefficient summarises the information about the inequality into one number, the Lorenz curve [56] gives one a more detailed insight. The Y axis of the Lorenz curve refers to the

cumulative outcome proportions of the population members ranked by the values of X . Formally, in a finite population, the Lorenz curve of X can be defined as:

$$L_X(p) = \frac{\sum_{i=1}^n X_i I(X_i \leq Q_X(p))}{\sum_{i=1}^n X_i} \tag{2}$$

where n is the number of the observed values, $Q_X(p)$ is the p quantile of the distribution of X , $I(A)$ is an indicator function equal to 1 if A is true and 0 otherwise [52,57].

2.3.2. Analysis of Personal Factors Influencing the Amount of Berries Collected in the CZ

Unlike the amount of collected berries stated by the respondents, many other variables referring to the respondent’s status do not comply with the requirements of a standard linear model. Due to this fact, the sociodemographic characteristics of the individual berry pickers were categorised in Table 2 using the categorical variables: “sex, age, size of residence (res.) or region” as explanatory variables for the dependent variable “the amount of collected berries” in the so-called proportional odds model (3) proposed by [49].

$$\text{logit}(P(Y_i \leq j)) = \log \frac{p_{i,1} + \dots + p_{i,j}}{p_{i,j+1} + \dots + p_{i,J}} = \beta_{0,j} + \sum_{k=1}^m \beta_k x_{i,k} \quad j = 1, 2, \dots, J - 1 \tag{3}$$

where $p_{i,j}$ is the probability that the dependent variable Y_i (of i -th measured object) takes the value j , $p_{i,j} = P(Y_i = j)$, J is the number of possible values of the dependent variable, $x_{i,1}, x_{i,2}, \dots, x_{i,m}$ are explanatory variables for the i -th object and $\beta_{0,1}, \dots, \beta_{0,J}, \beta_1, \dots, \beta_m$ are the regression coefficients.

Table 2. The variables and their values.

Age	Sex	Education	Size of Residence (Number of Citizens)	Region	Collected Amount (in kg/Year)
15–25 years	Male	Ed. 1: Primary	Size 1: ≤ 4999	B: Bohemian without the central region	0
26–55 years	Female	Ed. 2: Secondary	Size 2: 5000–19,999	M: Moravian	0.01–2.00
56–70 years		Ed. 3: College or university	Size 3: 20,000–99,999	PC: Prague, Central Bohemian region	2.01–5
71+ years			Size 4: ≥100,000		5.01–10.00
					≥10.01

Program R [58], namely the polr function in R’s MASS package [59], was used in order to evaluate the model based on Equation (3). The polr function provides both the estimates of the coefficients p and the test statistics for the hypotheses $H_0: \beta_i = 0, i = 1, 2, \dots, k$, testing. The distribution of these test statistics is asymptotically normal [49], therefore, the corresponding significance levels were computed by:

$$p\text{-value} = 2(1 - F(|T|)) \tag{4}$$

where T is the value of the test statistics and F is the distribution function of the standard normal distribution.

The score test for proportional odds (PO Score Test) [60] was used in order to evaluate the significance of the entire model.

All the data regarding the collection of forest berries for the period 2008–2018, i.e., 11,254 entries, were categorised and analysed by the model (3). For this period, the personal characteristics of the berry pickers are available.

The statistical analyses were carried out in the R programming environment [58]. The selected results are illustrated by a mosaic display—a graphical method developed by [61]. In a mosaic display, each of the cell counts of the contingency table is represented by a tile proportional to the cell frequencies. The relative size of a tile becomes an indicator for whether the observed data deviate from the hypothesised mode [62].

2.3.3. Analysis of External Factors Influencing the Amount of Berries Collected in the CZ

Provided that the total amount of forest berries collected in a given year is affected by the natural conditions, a multi-regression model (5) was used to analyse the total amount of the collected berries, where y is the annual amount of the collected berries and x_1, x_2, \dots, x_k are the explanatory variables reflecting the natural conditions, such as the precipitation and temperature and $\beta_1, \beta_2, \dots, \beta_k$ are the regression coefficients.

$$y = \beta_0 + \sum_{i=1}^k \beta_i x_i \quad (5)$$

In our case, the average temperatures and precipitation in the relevant months during the period of 1994–2018 and the annual amount of salvage felling are used as independent variables. The selection of the relevant months tested in the linear model: April, May, June, July is based on [63], who states that the climatic factors before the flowering season had no significant effect on the yields of the bilberries. A longer time series was used, including the period of 1994–2007, when the estimation of the total harvested amount of forest berries was undertaken by using the same methods as in the period of 2008–2018. (As mentioned above, the personal characteristics of the berry pickers had regrettably not been collected in the period of 1994–2007.) The data on the precipitation and temperatures were obtained from the Czech hydrometeorological institute [64]. To select the most important variables in the model, the method described in [65] was used. First, the potential explanatory variables x_1, x_2, \dots, x_k are defined. By combining these explanatory variables, all the possible models can be created (2^k models can be created from the k variables), one can evaluate them by a certain criterion and select the best model. In our case, the Akaike information criterion (AIC) is used for the evaluation of the models in the way detailed in [66]. The AIC estimates the relative amount of information lost by a given model, i.e., the smaller the AIC value, the more suitable the model is. Specifically, consider a set of m models and denote AIC_{\min} as the smallest value from their corresponding Akaike information criterions. Then, the expression $\exp((AIC_{\min} - AIC_i)/2)$ can be interpreted as being proportional to the probability that the i -th model minimises the information loss. In our case, when $k = 9$ (9 variables are used), the total number of linear models equals 2^9 , i.e., 512.

The most relevant models are ordered according to the AIC. Each model is supplemented by the determination coefficient (R^2) and the statistical significance of the model as a whole (p -value). The calculation was performed by the supplementary functions package MuMIn of the R program [58].

3. Results

3.1. Basic Data on Socio-Economic Importance

Figure 1 shows the variation in the total amount of collected berries. For example, in 2008, an extremely low forest berry harvest is evident. In addition to explaining the influence of the climatic factors (precipitation and temperature), which are analysed below in the linear model of Section 3.4. (in 2008, the precipitation was low—90% compared to the long-term average, moreover, in May and June, it was only 83% and 75% of the average, respectively), another important factor was the fact that, in mid-January 2007 and at the turn of February and March 2008, two extremely strong windstorms:

Kyrill and Emma hit most of the Central European countries [67] including the CZ. It can be reasonably assumed that the consequences of the storms and the ongoing and subsequent felling reduced the public attendance in the forests. This is also the reason why the annual amount of salvage felling is used as one of the independent variables in the linear model (5). Salvage felling is the practice of felling trees in forests that have been damaged by wildfire, insect infestation, or other natural disturbances. On the other hand, in 2013, there was an extraordinary volume of forest fruits, especially bilberries. That year, in June, the above-average precipitation (variable X3 was 164% of the long-term average of 1981–2010, and, in July, the above-average temperatures (variable X8) were 120% of the long-term average of 1981–2010. This apparently had a positive effect on the bilberry production.

In the CZ, there are not any official data about the prices of forest berries tracked by the Czech Statistical Office; berries are not included into the CZ consumer basket. Therefore, the estimation of the value of the collected berries is undertaken by multiplying the total amount of the collected berries and the average price of the forest berries found in a survey in 2018 (Table 3).

Table 3. The estimate of the amounts of the average annual collection and annual value of the four species berries in millions of EUR at the 2018 prices (ČNB, 2020).

	Bilberries	Cowberries	Raspberries	Blackberries
Average annual share of respondents collecting berries	38.73%	6.35%	28.09%	24.43%
Average annual amount collected in million kg	8.9	0.7	2.9	1.9
The average price per kg in EUR in 2018	5.7	6.7	6.4	6.6
Estimate of the average annual value of harvested berries in prices at 2018 (million EUR)	50.7	4.8	18.9	12.5

For comparison, due to the bark beetle calamity and the collapse of wood prices, the state support for private forest owners was as high as EUR 100 million (it is expected to be paid in 2019 and 2020) [68], thus, an average of EUR 50 million per year, which is equal to the estimated annual value of the harvested bilberries. Although forest berry collecting is important for a large part of the population, due to the free access to the forest and the uncontrolled harvesting of the forest berries, it is of no economic importance to the forest owners as of yet.

3.2. Differences in the Income from the Forest Fruits among the Respondents

For studying how the amount of the collected forest berries are distributed among the respondents, the Gini coefficient (1) was calculated for each year of the period of 2008–2018. Only the respondents who collected bilberries are considered. The disparity among the berry pickers is, in some years, even far more significant and relates to all the kinds of collected forest berries. This fact is documented in Table 4, which shows the unequal collection of all the individual species of the forest fruits that reaches high values in some years.

Table 4. The values of the Gini coefficients for the period of 2008–2018.

Year	Bilberries	Cowberries	Raspberries	Blackberries
2008	0.566	0.605	0.621	0.568
2009	0.716	0.515	0.639	0.663
2010	0.767	0.502	0.612	0.629
2011	0.827	0.826	0.744	0.789
2012	0.769	0.659	0.827	0.849
2013	0.868	0.637	0.698	0.712
2014	0.728	0.673	0.629	0.579
2015	0.772	0.676	0.700	0.698
2016	0.859	0.803	0.734	0.820
2017	0.675	0.584	0.634	0.714
2018	0.642	0.510	0.520	0.496

A more detailed analysis of the distribution of these inequalities in the bilberry harvest is provided by the Lorenz curve (2). The cumulative volume of the collected amount of bilberries each year for the period of 2008–2018 is placed on the y axis (first ordered in ascending order) and the cumulative percentage of the respondents is placed on the x axis.

Figure 3 shows the unevenness of the bilberry collection, when, according to Pareto's rule, 20% of the respondents collect more than 80% of the collected amount. Analysing the concentration curve, it can be seen that a relatively very small portion of the collecting respondents (less than 10%) gains more than 50% of the total value of the collected bilberries (in 2013, it was more than 80%). An explanation for the extreme value of 0.868 for the bilberries in 2013 may be that the favourable climatic conditions resulted in an extremely abundant bilberry crop—the total amount collected was 13.4 million kg (Figure 1), as compared to the long-term average of 8.97 million kg (Table 3). Some respondents participated in the very intensive collection either for commercial or personal reasons—they took a holiday to collect bilberries when it was worth it. If we calculate this portion to all the households in the CZ (the collecting households represent about 38% of all the households), it is evident that less than 4% of the population gain more than 50% of the total value of the forest berries. There are several aspects connected with these results:

- Biological factors: The very intensive collection in over-visited areas in the densely populated Central Bohemia, including the method of harvesting (some harvesters even pluck whole plants from the ground and then pluck the berries), has a very negative impact on the quality and sustainability of the forest berry production. On top of that, the most suitable localities for bilberry picking are situated in protected nature areas (national parks and protected landscape areas), where, in addition to the damage to the stands of bilberry bushes themselves, the increased attendance may pose a problem in disturbing the animals living there [69]. For instance, in the Krkonoše National Park, its administration in the years 2000–2017 (e.g., [70]—the so-called “bilberry decree”) restricted access to selected localities mainly due to the excessive collection of bilberries and the related negative impacts. However, an analysis of the administration has shown that this over-collection has increasingly become a smaller and smaller problem over time, which is why the restriction has been lifted since 2018 [71].
- Legal aspects: Ownership rights to the forests, including the possibility of restricting others' access to the forests and exclusion rights, vary widely across Europe [72]. In the CZ, the “everyman's right” applies, i.e., free entry into the forest and the collection of berries is possible. The exact wording of the Czech Forest Act is as follows: “Every individual shall be entitled to enter the forest at their own risk, and to collect any forest products and dry brushwood lying on the ground for their own needs. While doing so, they shall be obliged not to damage the forest, not to interfere with the forest environment and to follow the instructions of the owner or tenant of the forest and their staff.” The question is, if the Act also allows the collection of berries for commercial purpose or not. It speaks about the collection for one's own needs, not about one's self-consumption. The problem is in the terms in the Czech language also—the word “potřeba” utilised in the Forest Act can be translated as *need* (or *use*), but in fact there should have been the word “spotřeba” translated and understood in an economic sense as *consumption*. This shortcoming of the law is known, but there is no political will to change the law for one letter. If the word “spotřeba” (consumption) was used, then it would be clear that commercial picking of berries is not possible; in the current situation, i.e., when using the word “potřeba” (need), the interpretation (even legally) is unclear. Collecting for commercial purposes is, therefore, not explicitly prohibited, and the term “own needs” is not defined in terms of quantity. It is forbidden, however, to collect forest fruits in a way that damages the forest.
- Economic and ethical aspects: Official commercial picking does not exist in the CZ, therefore, it is not possible to analyse the amount. Based on informal telephone interviews with domestic forest berry processors, it was found that the processors mainly import raw materials from Ukraine and Poland. From this, it can be deduced that most berries picked in the Czech Republic are sold

either on the domestic market by direct sales “by the road” (to a lesser extent), or in Germany and Austria on “farmers’ markets”. It was similarly argued in [73] that non-timber forest products (NTFP) entrepreneurs mainly create distant markets, e.g., not connected with the picking locality. Such a collection type and the following transfer could be described as “organised berry picking”. The sale takes place on a grey market, which brings untaxed income only for a small group (collection organisers), which is not related to the forest owners. Moreover, this is occurring in situations when many forest owners are losing money or losing most of the value of the forest property due to the bark beetle calamity and the rapid decrease in the coniferous wood prices from 2017 [74–76].

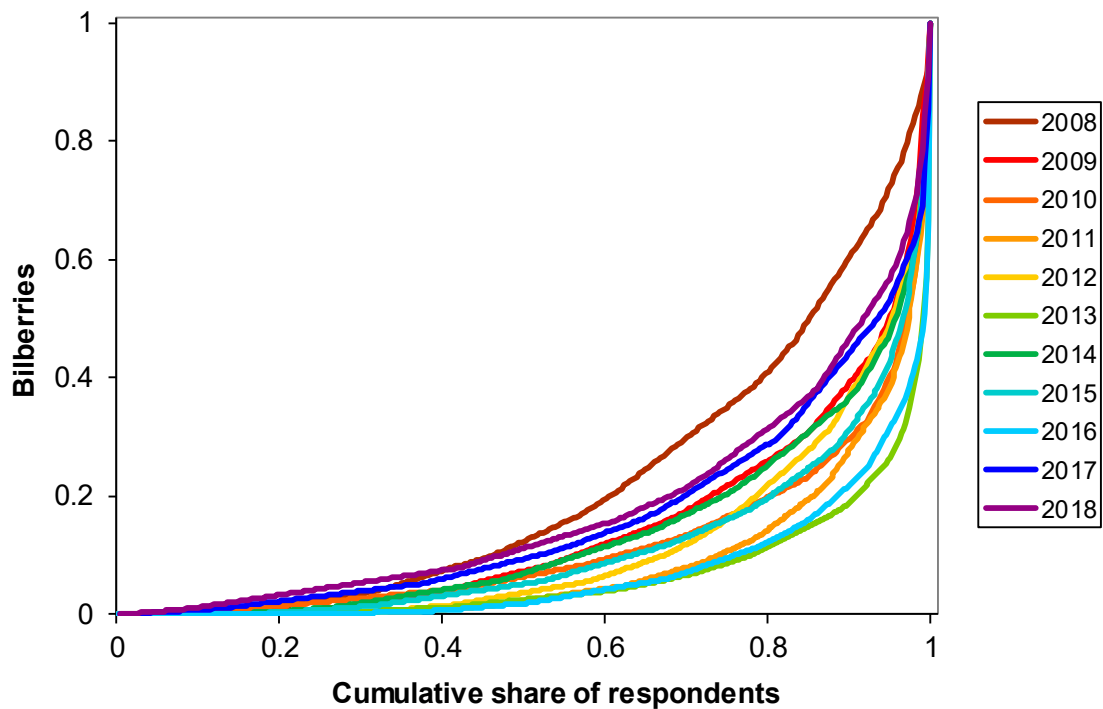


Figure 3. Lorenz curve applied to the bilberry collection.

3.3. Relationship Analysis

A preliminary analysis can be performed by descriptive statistics methods. Mosaic displays are a suitable method for the graphical presentation of contingency tables. The figures below show the selected results, namely, the relationships between the collection of the bilberries and explaining the variables of sex, age, size of residence and region.

The hypothesised model is based on the independency of the variables. It means that, i.e., the cells in the same row should have the same height regardless of the explanatory variable.

The first analysed contingency table is constructed by using the categorical variable of the respondent’s gender and the categorical variable of the amount of bilberries collected. Using a mosaic display (see Figure 4), it can be seen that the proportion of men not collecting bilberries (category 0 on the y axis) is much higher than in the case of women. The significance of the differences can be evaluated by Fisher’s exact test [49]. In this case, the resulting p -value of 0.0005 indicates highly significant differences.

If the age category is analysed (Figure 5), it is evident that the category of non-pickers is higher in older people (71+) and seniors (56–70), the percentage of “occasional pickers” (the category 0.01–2 kg) is highest in the age category of 26–55 years and in the category of 15–25.

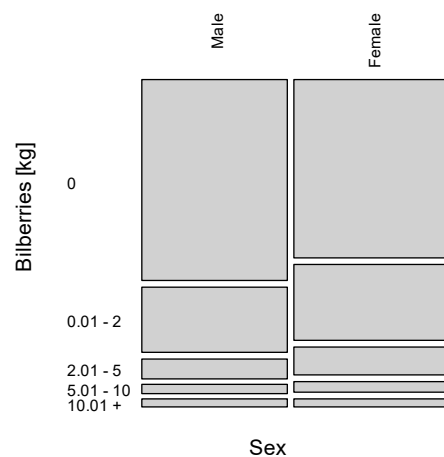


Figure 4. The mosaic display of the relationship between the gender of the respondent and the amount (kg) of bilberries collected.

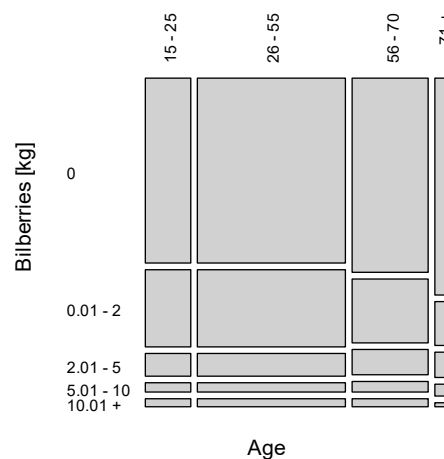


Figure 5. The mosaic display of the relationship between the age of the respondent and the amount (kg) of bilberries collected.

Figure 6 shows that the category of non-pickers (category 0 on the y axis) is lower in villages and small towns (up to 4999 inhabitants). However, the category of non-pickers has a surprisingly lower representation in cities over 100,000 inhabitants, whose residents are more likely to compensate for a city life by spending their free time outdoors and on holiday. City dwellers often own weekend houses and cottages in the countryside, which they often commute to. Czech people are “cottage people”; there are 287,000 cottages in the country, and it is said that every fifth Czech house is used for recreational purposes. Only more cottages per inhabitants can be found in Sweden [77]. Cottages are a part of the so-called second housing, which also is included in the work of [78] and [79]. The outdoor stay of these people is often accompanied by a forest visit and “recreational” forest berry collection. These results are consistent with Šišák [41], [80]. Accordingly, Figure 7, where the size of the collection is analysed compared to the three regions: PC (the capital Prague and Central Bohemia), B (the rest of Bohemia), M (Moravia). Again, it is obvious that the Central Bohemia area, with a large number of recreational facilities and large cities, where the inhabitants of Prague are a significant portion of the visitors, which lies in the centre of this area, shows a higher collection intensity than, e.g., Moravia. In the case of Central Bohemia, the number of forest visitors is so high (mostly because of the visitors from Prague, who leave the area of the capital city to go into “nature”) that the volume of forest fruit harvesting approaches the limits of the forest production possibilities.

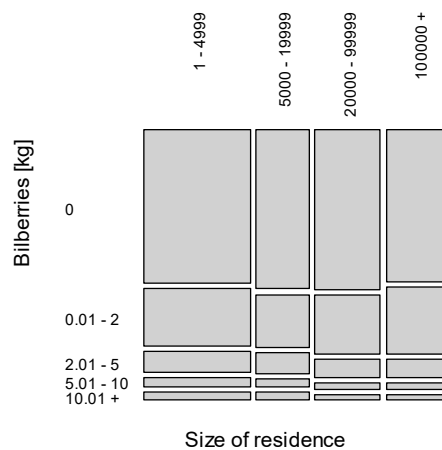


Figure 6. The mosaic display of the relationship between the size of the residence and the amount (kg) of bilberries collected.

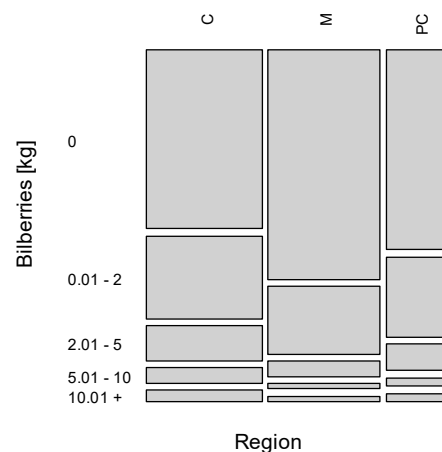


Figure 7. The mosaic display of the relationship between the region of the respondent and the amount (kg) of bilberries collected.

Very intensive collectors (a collected volume of more than 10 kg per year) can mainly be found among women (in the non-central areas of Bohemia) in municipalities with less than 5000 inhabitants. These collectors collect rather close to their place of residence.

The analyses show that women under the age of 55 living in larger cities (100,000 inhabitants) in Bohemia (region PC or region B) are a suitable target group in terms of marketing programmes. These frequent weekend visitors and occasional berry pickers are the most mobile and their flow can be more easily redirected. These people can be the goal of relatively effective and inexpensive explanatory campaigns drawing attention to preventing inappropriate collection methods or to reducing excessive forest attendance in some places.

Mosaic displays are illustrative, but they capture the relationship of only two quantities. In reality, quantities such as the amount of collected berries may be affected by the interaction of many different factors. Their relationship can be evaluated by a proportional odds model.

Table 5 shows the standardised outputs from the polr function, as mentioned in the methodological section, supplemented by the p values obtained from the function calculation (4). If the p -value is less than 0.05 (the difference from the reference category which is considered statistically significant), the values are shown in bold letters. Within a given variable, the other levels of the variable are calculated relative to the first category of the variable (i.e., in the case of the age, 15 to 25 years). So, the categories in the first row of Table 2 are used as a reference to the implicit value equal to 0. That is why they are not displayed in Table 5. See, e.g., [81].

Table 5. The characteristics of the respondents explaining the volume of the collected amount.

	Bilberries		Cowberries		Raspberries		Blackberries	
	b	p-Value	b	p-Value	B	p-Value	b	p-Value
Age 26–55	−0.056	0.321	0.690	<0.001	0.026	0.673	−0.053	0.416
Age 56–70	−0.143	0.022	0.633	<0.001	−0.163	0.019	−0.171	0.018
Age 71+	−0.463	<0.001	0.436	0.055	−0.315	0.004	−0.368	0.002
Sex female	0.328	<0.001	0.217	0.010	0.284	<0.001	0.266	<0.001
Education 2	0.109	0.012	−0.009	0.925	0.141	0.003	0.172	<0.001
Education 3	0.173	0.003	0.273	0.019	0.156	0.016	0.190	0.005
Size of res. 2	−0.146	0.010	−0.298	0.014	−0.149	0.019	−0.119	0.076
Size of res. 3	−0.154	0.003	−0.246	0.032	0.026	0.647	0.038	0.537
Size of res. 4	0.066	0.235	0.146	0.221	0.133	0.029	0.155	0.015
Region M	−0.768	<0.001	−1.434	<0.001	−0.017	0.734	0.102	0.053
Region PC	−0.400	<0.001	−0.514	<0.001	0.114	0.065	0.072	0.276
Proportional Odds Score test	134.167	<0.001	44.549	0.086	59.288	0.003	48.649	0.039

Table 5 shows a significant age effect for the volume of the collected bilberries. Namely, there are significant differences between the reference age category of 15–25 years and the categories of 56–70 years (p -value = 0.022) and 71+ years (p -value < 0.001). However, there is not any significant difference between the categories of 15–25 and 26–55 years, so the level 26–55 is not bold (also compared with Figure 5).

The b coefficients (estimations of the β regression coefficients) are negative in both cases; this means that the respondents in the age categories of 55–70 and 71+ show a tendency to collect a lower volume of bilberries. There is also a significant difference between genders, where females tend to collect a larger volume of bilberries than males (p -value < 0.001). The effect of age and sex on the collected amount of raspberries and blackberries is similar to that on the collection of bilberries (positive b coefficients in the corresponding cells). For cowberries, the age categories 26–55 and 56–70 predominate. People with a high education use the visit to the forest to occasionally harvest all forest berries (positive and relatively small b coefficients in the Education 3 line). Residents of smaller towns (size of res. 2: 5000–19,999) collect less bilberries, cowberries and raspberries (negative male b coefficients for size of res. 2). Residents of central Bohemia (PC region) and especially Moravia (region M) collect less bilberries and cowberries than the rest of the country (non-central areas of Bohemia—region B)—a negative value of b in the corresponding cells. We can similarly interpret the rest of Table 5.

3.4. Natural Factors—Application of the Linear Regression Model

To explain the changes in the collected amount, a multilinear regression model was used with explanatory variables: the average temperature and the average precipitation in the months of April, May, June and, July and the annual salvage felling (see Table 6). The climatic data in the Czech Republic were selected. The annual amount of collected bilberries in the CZ (see Figure 1) was chosen as the independent variable y in the linear model Equation (4). The temperatures and precipitations in the relevant months and the amount of salvage felling, see Table 6, were chosen as the explanatory variables reflecting the natural factors. For technical reasons (the length of the time series is 25 years), the number of explanatory variables in the model (1) must be limited. Each variable is a vector with 25 components, each of which corresponds to the values observed in each single year of the 25-year period of 1994–2018.

Table 6. The basic set of the nine explanatory variables used in the multilinear regression model (5).

	Time Period—Month			
	April	May	June	July
Average precipitation in mm	X1	x2	X3	X4
Average temperature in °C	X5	X6	X7	X8
	Time Period—Whole Year			
Annual salvage felling in mil. m ³	X9			

In Table 7, the top 10 most relevant models are shown ranked according to the Akaike information criterion (AIC). In most models, we can observe a statistically significant positive correlation in the collected amount with the average monthly precipitation in June (X3) and a positive correlation in the collected amount with the average monthly temperature in July (X8) when the bilberries ripen. This result is consistent with the study of [82], which states that berry crops are influenced by the weather conditions during the berry ripening period.

Table 7. The model selection table—the variables (precipitation, temperature, salvage felling) explaining the volume of the collected amount of bilberries.

Intercept	X1	X2	X3	X4	X5	X6	X7	X8	X9	AIC	R2	p-Value
−5.446			0.042					0.675	−0.180	115.2	0.405	0.011
−3.867			0.047					0.498		115.6	0.313	0.016
5.440			0.045							116.0	0.218	0.019
14.870			0.035				−0.522			117.0	0.272	0.030
5.187			0.037				−0.477	0.474		117.1	0.358	0.023
11.360			0.041			−0.423				117.4	0.261	0.036
−1.457			0.048		−0.265			0.483		117.5	0.348	0.027
7.740			0.047		−0.286					117.5	0.259	0.037
6.886			0.041	−0.013						117.5	0.258	0.038
9.648			0.034	−0.022					−0.182	117.6	0.345	0.028

The AIC score shows a significant negative correlation with the annual salvage felling, which is also noticeable (p -value 0.011). Salvage felling may have an impact on both the production of the forest berries and the willingness of the berry pickers to visit the forest. Due to the continuing bark beetle calamity and salvage felling, it can be expected that this factor will play an increasingly important role in the future. In some areas, due to the ongoing felling, people have reduced the intensity of the visits to the forest. In 2016, the total amount of harvested timber amounted up to 16 million cubic metres (less than 60% was represented by salvage felling). In 2018, it was 25 million cubic metres, of which 90% of the wood was harvested due to salvage felling [39,50]. The amount of logged wood is still increasing. In many places where salvage felling has already occurred, the natural conditions are likely to change, and the occurrence of bilberries may be reduced. According to [83], with reference to [84], this exact occurrence happened in Finland, where the bilberry cover decreased due to the intensive forest management.

The other models show a negative correlation with the temperatures in April, in May or in June (variables X5, X6, X7). The influence of a hot spring does not seem to be favourable. The last two models show a negative influence with the precipitation in July, which can be interpreted as that a rainy July prevents the berry pickers from visiting the forest as these factors significantly affect the expected volume of the harvesting, production size and forest attendance, they need to be considered when planning changes in forest management aimed at the potential development of “bilberry management”.

4. Discussion and Conclusions

The most important NWFPs in the CZ are mushrooms and forest berries. However, unlike berries, mushrooms have been observed as one category from the very beginning of the research,

without distinguishing the species (many respondents are not able to name the species correctly). Thus, the results of the annual research on mushrooms cannot be linked to a specific growing season or to a specific management measure concerning the forest. This article, therefore, analysed the significant factors influencing the amount of collected forest berries in the CZ. The analysis has been carried out using four research questions. The answers to them are as follows.

RQ 1. Using a concentration curve and the Gini coefficient, the very uneven distribution of the picked amount of berries among the berry pickers has been proven.

RQ 2. A detailed statistical testing analysed and proved the significance of the demographic and geographic factors of the berry pickers: based on their age, sex, education, size of residence and region, where the picker lives. This analysis has been carried out for each generally picked type of berry, i.e., bilberries, cowberries, raspberries and blackberries. The dependence on the amount of the collected forest berries was demonstrated for all the analysed categorical variables to a greater or lesser extent, e.g., women (in non-central areas of Bohemia) in municipalities with less than 5000 inhabitants are mainly found to be very intensive collectors (a collected volume of more than 10 kg per year).

RQ 3. The data obtained over the 25 years of observation indicate a significant variation in the total amount of the forest berries collected, which is also confirmed by the values of the coefficient of variation calculated in Table 1, as values around 30% prove the considerable variability in the analysed data, see [47].

It was possible to perform more detailed analyses of the external factors influencing this variation for bilberries as the most frequently collected forest berry, for which the largest amount of the data is available.

RQ 4. The average temperatures and precipitation in the relevant months and the total volume of the incidental felling in the given year were used as explanatory variables for the external factors. When testing a number of linear regression models, the precipitation in June and the temperature in July proved to be the most important variables.

Based on the above analyses, it is, to some extent, possible to characterise the potential customer (forest berry pickers). Analyses of this type are of great importance for the future application of marketing methods in the development of territorial marketing, in the understanding of the structure of the demand, and, thus, in which direction to orient the supply NWFP as one of the outputs of the forest ecosystem management.

The social significance of our analyses lies in the fact that, due to its popularity, the occasional harvest of forest berries has become an integral part of the recreational use of the forest for the Czech population. A similar conclusion is reached, for example, by [85] on a Finish case. The researchers [86] use the term “multi-objective forest planning” for the approach where several forest outputs and services are considered simultaneously. Promoting the intentional cultivation and production of forest berries in order to make better use of the natural resources, forest land and forests, the diversification of the forestry income needs to be further envisaged. Numerical models are needed to predict the development of different ecosystem services (including berry yields) along with the forest development [87]. The need to model both the timber production as well as the bilberry production is also emphasised by [88].

The current bark beetle calamity in Central Europe is forcing forest owners to reconsider their current forest management policies. As part of the creation of new forest plans, they can also incorporate more production and, subsequently, the NWFP offer. It is logical that the form of ownership and management goals will play a role here. The state, and especially municipalities, as forest owners, can be expected to be very interested in the rural development, including the support of tourism, to choose a form of management that is friendly to forest visitors, including “collectors”. The research [18] considers the optimisation of the wood and berry production as being the most meaningful in public forests. The economic goals of private forest owners may be different [89], an increasing number of those who do not own a forest for economic gain [90] and can, therefore, be motivated to manage forest as public forests. To date, the largest group of private owners—focused on forest profits—still does not

have such a motivation. Although, as our results show, the economic potential of harvesting bilberries and other forest berries is great, it only remains theoretical for owners, due to the legal restriction of property rights in the CZ related to the owner's ability to restrict entry and the free harvest of forest fruits by the public in his or her woods [71]. There is an ongoing debate about the possible solutions in the Czech Republic. There are several theoretical possibilities on how to solve this issue, divided according to the degree of the legislative changes and government interventions. The utilisation of non-fundamental changes (e.g., changes within the traditional arrangement) is more realistic in the CZ. Such slight changes potentially could be of a broad scope: from direct government intervention in timber prices, to small changes in the legislation on the forest berries collection, including the definition of the term "one's own needs" in the sense of "one's own consumption". This issue has already been addressed in other research activities [91]. Similar problems with the commercial picking occur in other countries, e.g., according to [15], Latvia is currently the biggest wild bilberry exporter in Europe. While the sector has grown in recent years, the Latvian government's involvement in regulating it has remained very limited. The utilisation of fundamental changes is unlikely in the Czech Republic. The fundamental changes are considered to be those, thanks to which, where it would be possible to carry out the internalisation of the positive externalities (e.g., on the forest harvesting effects). Such changes are not easy to achieve because they interfere with the belief system of the public (due to the historically used everyman's right system). Such changes may include, for example, the possibility of giving the forest owner the opportunity to charge the public (pickers) for the collection of berries by an amount—a flat rate or for a quantity, and, thus, allow the diversification of the forest owners' income. Such examples are applied, e.g., in the USA [92], Spain [93], Finland [94] or Italy [95]. As mentioned by [96], countries like Italy, France and Spain were among the first to regulate the harvesting rights of wild forest products (WFPs) due mainly to the high anthropic pressure on the WFP resources and consequent depletion due to overharvesting. The harvesting regulation mainly focuses on the promotion of the best harvesting practices and commercialisation rules. The authors of this study [96] emphasised that among all the topics related to the WFP policies, this last part is probably the most debated due to specificities of each area, the species collected and cultural uses; moreover, almost no countries have properly coordinated harvesting rules with their fiscal laws, triggering conflicts between policy makers and wild forest products commercial users.

Thanks to the everyman's right, the prevailing public opinion is that forest ecosystem services are non-tradable public goods. The mentioned types of changes correspond to [97] the theoretical approach, according to which, a higher integration into the market mechanism can be achieved, in practice, in two ways. The first one uses the fact that the degree of rivalry increases, for example, through a significant increase in the demand, and the public good then becomes a collective good. In such a situation, users already compete with each other (e.g., when utilising popular "picker" areas). The second way is a strategy to achieve exclusion, for example, through changes in the legal framework (access rights) or through the enforcement of property rights (e.g., by fencing off the area, entry control together with the payment of entry fees). As long as the customer does not compete, the good is considered a club good; with a growing degree of rivalry, it becomes a private good.

The full internalisation (e.g., privatisation) is but a very sensitive issue, because such privatisation of wild products has had a negative effect on the market, with an increment in the production costs of wild resources, while only a negligible income for the forest owner was achieved [98]. Although the ownership rights of private forest owners are being slightly strengthened, even in the CZ [99], they have not reached the possibilities of other states (e.g., Spain, France or Italy). In these countries, it is possible to find examples of good practices involving the internalisation of positive externalities, in particular, in the form of charging for the collection of forest crops or, at least, the determination of the maximum amount collected. Due to the long-term drought followed by the bark beetle calamity, there is a large surplus of spruce wood on the European market, which is the main economic tree species in the CZ. Its price has fallen sharply, and, at the same time, the area is growing rapidly, which, in the next few decades, was supposed to be the main economic source for the private forest owners.

However, due to the infestation with the spruce bark beetle, it will have almost no economic effect in the foreseeable future. The economically oriented forest owner is, thus, faced with the decision of how to manage these areas in the future. If it were possible (a political effort) to implement at least some of the above-mentioned non-fundamental measures, the practical possibility on how to solve the economic aspect comes into play. Then the forest owner should have the opportunity to incorporate the issue (and therefore also the income) of forest berries into forest management (see, e.g., [100–102]). The Association of Forest Owners has a relatively strong negotiating position in the CZ [103] and can try to move the debate and political negotiations aimed at increasing their exclusion rights [104] or reducing the amount of forest crop collection. Focusing their management on the “bilberry” management can, thus, be a potential compensation for the expected losses.

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