Public perception of the performance of Czech forest ecosystem services

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Abstract

In recent years, there has been growing interest in public valuation for forest ecosystem services in policymaking. This paper investigates the public's perception of the Czech forest ecosystem services, i.e., provisioning, regulating and cultural services, with associated factors (changes in forest cover, production, and respondents' characteristics). The performance perception of forest ecosystem services was gathered from a nationwide survey in 2020. The Coordination of Information on the Environment Land Cover information in 2000 and 2018 was used for observation of forest cover changes. Coniferous and non-coniferous (broadleaved) roundwood, mushroom, and bilberry production data from the observed years were acquired from the Czech Statistical Office and the Ministry of Agriculture's annual nationwide surveys. The Bohemia vs. Moravia study areas were also statistically compared. Predictor analysis of the high score of performance perception from individual and cluster forest ecosystems was also performed to answer the research objectives. The group of forest provisioning services received high scores in public evaluation (from 3.9 to 4.2), followed by regulating services (mean range: 3.7–4.1). The highest score was found in forest as a natural habitat for wild animals and plants (mean: 4.6). However, the lowest value was the esthetic value (mean: 2.3). Both are categorized as forest cultural services. The broadleaved and mixed forest areas in 2018 were significantly higher than in 2000, especially in Bohemia. Meanwhile, the total coniferous forested region in 2018 declined substantially compared to 2000 ($p = 0.030$), especially in Moravian areas. A significantly higher total production of the coniferous and broadleaved roundwood removals in 2018 than in 2000 was reported, in contrast to a marked decrease in collected mushrooms and bilberries. The high score of performance perception of forests as the wood provisioning service was positively and significantly associated with the changes in broadleaved roundwood removals. Older-age and female respondents were the primary predictors of the studied cluster and individual forest ecosystem services. The findings indicate that the social value of the individual forest provisioning services supports the implementation of multi-species and multi-purpose forests; hence, it encourages the implementation of the current Czech forest policy.

Keywords Provisioning services, Forest cover, Roundwood removals, Coniferous, Broadleaved, Non-wood forest products, Mushroom, Bilberry

Background

Forests provide multiple benefits for human well-being, which society has utilized since time immemorial. With growing attention focused on bioeconomy principles in Europe, concerns about the balance of production and consumption in forestry have also increased, making the forest-based sector one of the pillars of the bioeconomy [1–5]. Forests offer wood and non-wood production and other ecosystem services related to cultural (e.g.,

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recreation and esthetic value) and regulatory aspects (e.g., soil and water protection, carbon sequestration) [6–8]. Extreme events and ecosystem disturbances resulting from climate change cause visible changes in the appearance of forests, characterized by an increase of dying trees and young stands, mainly due to the escalation of insect damage, storms, and fires attributed to climate change [9–12]. The destruction significantly impacts the worldwide growth and stability of forests, including European forests [3, 13]. At the same time, the increasing demand for ecosystem services from forests can affect forest health and stability. Ecosystem services within forests can significantly interact with one another [14]. Optimization solely from a wood production perspective can have adverse effects on biodiversity and the fulfillment of water and erosion control services [14, 15]. Conversely, the timber-provisioning service can be adversely influenced, for instance, by game animals [16] and the overabundance of forest tourism [17].

Evaluating forest ecosystem services has provided essential information for policymakers [18]. In a cost-effectiveness and cost–benefit analysis, the ecological benefit from the forest ecosystem services was usually considered non-market goods; thus, the value was sometimes monetized [19–22]. However, more recently, there has been growing interest evaluating ecosystem services rooted in human perception [23–25], which can be verified through different findings, e.g., changes in land use or production services.

Ecosystem services, combined with societal considerations, should be incorporated to ensure the sustainable utilization of European forest resources and the landscapes [26, 27]. Studies examining the perception of forest ecosystem services and their considerable impact on the public's way of life have been conducted in various countries, often focusing on specific locations. These investigations primarily employed a qualitative approach, allowing for a more comprehensive exploration and interpretation of societal perspectives, which facilitated the development of strategic recommendations [28–32]. An online quantitative survey on the societal evaluation of performance in four European countries (Austria, Germany, Finland, and Slovenia) presented the potential gap between the performance of the ecosystem services and the implementation by the relevant stakeholders [33]. Even though a myriad of forestry-related data might be available, there are still limited studies that capture the association between performance perceived by the society and the actual state of the forest ecosystem services at a national level because the indicators used sometimes do not have a close and direct linkage with the evaluated services. However, when data collection and monitoring of the forest-based ecosystem services are continually carried out—such as peer information on the production and consumption of forest-based products, natural water quality, etc. [34]—the public perception of the related service performance can be analyzed to assess its association with dynamic conditions of the forests over the years.

In the Czech Republic, forested regions cover about one-third of the landscape [35]. Forest-based sectors are garnering more attention with increased efforts to adopt the European Bioeconomy principles [36]. Various groups in the country have acknowledged the value of diverse forest ecosystem services [37]. Moreover, public appreciation increased during the COVID-19 pandemic, as restrictions on mobility caused residents to view these natural spaces as their primary options for recreation destinations. Evidence of this was the significant rise in visitors to the studied forests during this period [38]. Similar findings were reported in Slovakia [39] and Germany [40], where they also observed an increase in forest visitation. The results indicate a potentially high interest by the general public to support forest policy in its sustainable utilization. Therefore, this paper aims to identify the public's perception of the Czech forest ecosystem services with associated factors, i.e., wood and non-wood provisioning services, changes in forest cover in the observed years and areas, as well as the respondents' characteristics.

Methodology

Study area

Located in Central Europe, the Czech Republic's forested landscape covers about 34% of the country's total area (Fig. 1). Even though there was an increased share of church forests from the early 2000s as a result of a national law that urged the return of the property to the churches, the Czech forests still predominantly belonged to the state (about 54%) [35, 41]. Of the entire Czech forested region, about 74% were dedicated to production forests [35, 42]. The broadleaved forest tree composition gradually increased over the years. More recently, the forest vegetation composition consists of 69.6% and 28.7% coniferous and broadleaved trees, respectively. The remaining 1.7% is the forest land without trees, primarily comprising clear-cut areas designated for reforestation. Among the total forest vegetation, Norway spruce (*Picea abies*) stands out as the most abundant forest tree species, accounting for 48.1% of the total, followed by pine (*Pinus* spp.) at 16%, larch (*Larix* spp.) at 3.9%, fir (*Abies* spp.) at 1.2%, and other coniferous trees at 0.4%. Beech (*Fagus sylvatica*) takes the lead among broadleaved species, constituting 9.3% of the total forest vegetation, followed by oak (*Quercus* spp.) at 7.6% and birch (*Betula* spp.) at 2.8%. Additionally, other various broadleaved
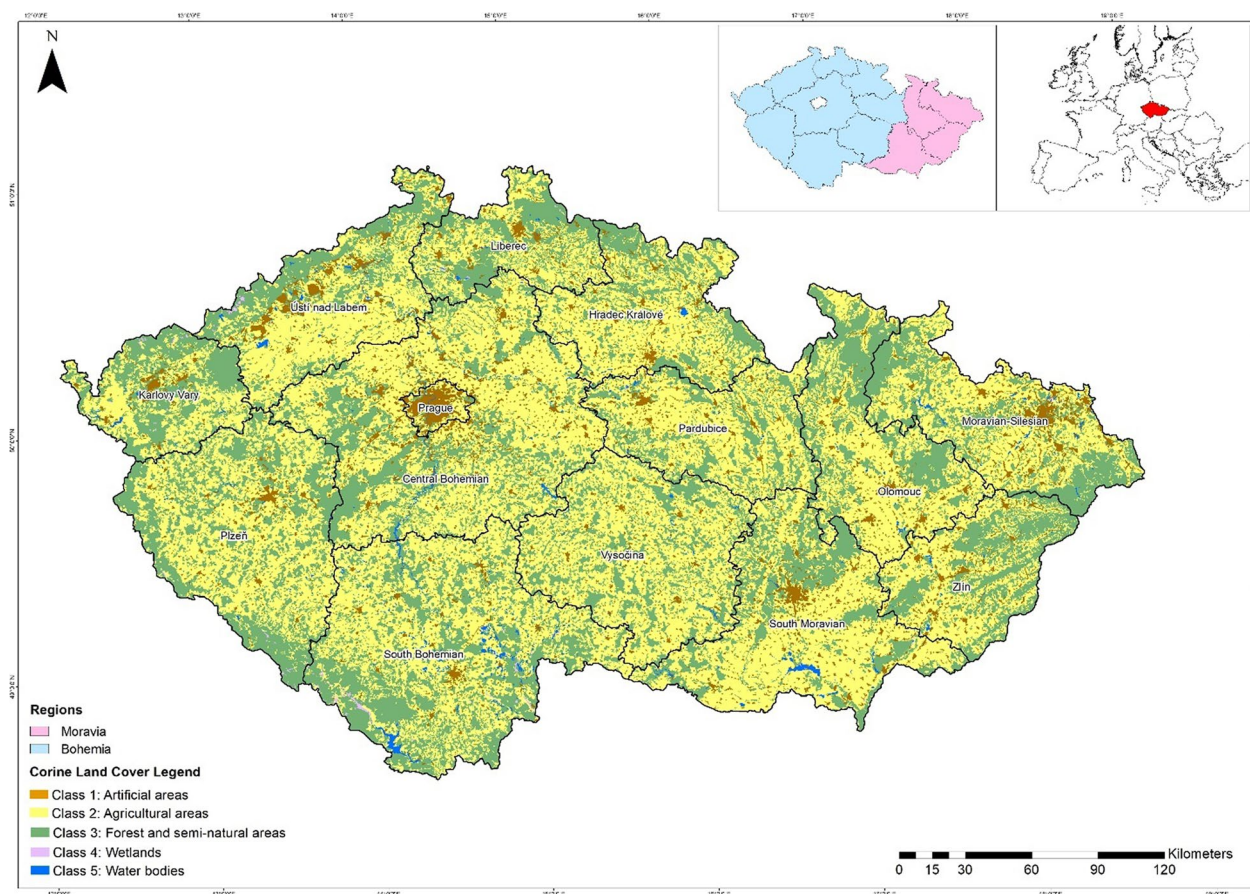
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Fig. 1 Map of the Czech Republic with main land cover classes (based on CORINE Land Cover in 2018)

trees, including species within the genera linden (*Tilia* spp.) and more than 15 additional species, collectively account for 9% [35].

For this paper, we divided the Czech Republic into two historical Czech lands, i.e., Bohemia and Moravia. The country comprised 14 regions or '*Kraj*" (Nomenclature of Territorial Units for Statistics/NUTS 3 level), which were presented as two study areas in some of the analyses. The Bohemian study areas encompassed ten regions that, historically, were part of ancient Bohemia. Moravia comprised four additional Czech regions, which encompass three historical Moravia and Moravia-Silesia [43]. Studies have indicated that Bohemia and Moravia display unique habits and preferences regarding collecting non-wood forest commodities [44, 45] and varying patterns of roundwood removals [46].

Conceptual framework of the forest vegetation cover changes

The conceptual framework, according to a model developed by Gingrich et al. [47] of the interaction between expectancy and public valuation, was modified (Fig. 2) to investigate the link between performance perception and the Czech forest products and ecosystem services [24, 48, 49]. The framework included the pathway of forest transition. Groups of the studied forest ecosystem services based on the CICES classification [50] were:

a) Provisioning services, i.e., wood products, non-wood commodities, and clean water source.
b) Regulating services, i.e., flood protection, erosion prevention, and carbon sequestration.
c) Cultural services, i.e., natural habitat of animals and plants, recreation, and ecotourism, as well as esthetic value.

The fluctuation in provisioning services dynamics, such as net primary productivity and wood production, or value of collected forest bilberries can be influenced by changes in vegetation cover over time [51–54]. In addition to provisioning services, forests also offer regulating and cultural services. Consequently, alterations in their state from external factors, like global warming and forest management, can
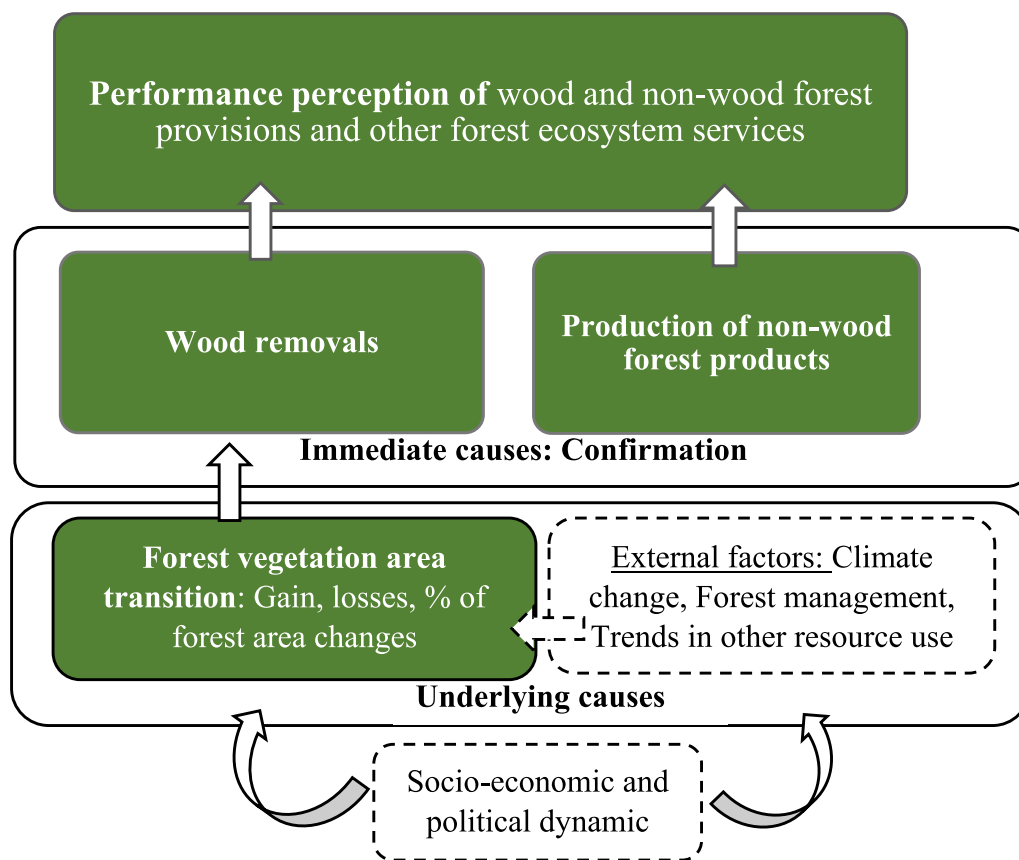
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Fig. 2 Conceptual framework of performance perception from forest provisioning services and the immediate and underlying factors

impact these services [55–57]. In the Czech Republic, sociocultural, economic, and political circumstances play significant roles in the dynamic of forest vegetation area changes [37, 44, 58, 59]. Hence, although we did not include the factors in this study, they were still addressed.

While the previous framework [47] encompassed the dynamics of various land uses, e.g., agricultural regions, we purposely refrained from discussing the latter in this paper to maintain a sharper focus on the topic of forested areas and their associated ecosystem services. Over the last 20 years, the area of forest land has increased by an average of 2000 hectares per year in the Czech Republic. The forested region in percentage has remained relatively stable, with the present value of 34.2% [35, 60, 61].

National survey of forest provisioning services in the Czech Republic

The research was based on the primary function of forest ecosystems. Any product extracted from and provided by the forest is defined as a forest provisioning service, which includes wood and non-wood forest products. The forest ecosystem provides a beneficial regulating service that can moderate natural events, which include carbon stock, climate regulation, decomposition, water purification, erosion, and flood control. Cultural provisions are non-material services that can be obtained from forest ecosystems through spiritual and cognitive development, recreation, and esthetic experiences. In our research, different types of services were selected and included to represent each of the above-mentioned groups [8].

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A national survey carried out by the project "Advanced research supporting the forestry and wood-processing sector's adaptation to global change and the 4th industrial revolution (EVA 4.0)" at the Faculty of Forestry and Wood Sciences (FFWS), Czech University of Life Sciences Prague (CZU), was performed in November 2020 in collaboration with an external market research company, STEM/MARK, a.s. (Prague, Czech Republic). The computer-assisted web interviewing (CAWI) technique was used to recruit the respondents by generating emails and sending the questionnaires via different online platforms. A proportional sampling method was used to recruit the online participants based on age, sex, education level, region, and population size representative for the whole country. General characteristics and sociodemographics are considered factors that influence the variables in the conceptual framework. The respondents were asked to answer a closed-ended questionnaire about their performance perception of the Czech forest ecosystem services. A scoring system with five options was used, from one (1 = "not important") to five (5 = "very important"). It included the option: "do not know" if the respondent was unable to judge it. No identified personal information was attained from the respondents.

Data acquisition, preprocessing, and analysis of forest cover changes

The CORINE Land Cover produced at the national level was coordinated by the European Environment Agency's management and quality control [62]. The forest areas (in hectares [ha]) of the Czech Republic were extracted from the CORINE Land Cover maps in homogeneous landscape arrays using ArcGIS 2020 version 10.8.1 (Tom Sawyer Software, Berkeley, California). The attributes of the tables, which were downloaded from the NUTS 2021 [63], were exported to Microsoft Excel, Microsoft 365 MSO version 2210 (Microsoft Corp, Redmond, WA, USA) for further analysis. Of 29 CORINE land cover categorizations [64], three subclasses from the forest and semi-natural areas (broadleaved, coniferous, and mixed forests) were classified as the studied forested region [65].

The CORINE comprised land cover monitoring data from 1990, 2000, 2006, 2012, and 2018. In this paper, the years 2000 and 2018 were used to examine the changes in forest cover area, as were the wood and non-wood provisioning services.

Data compilation of wood and non-wood forest products

In this paper, we compared the results of public perception of forest ecosystem service's performance with wood and non-wood forest production. Wood production, which was indicated by roundwood removals (for both coniferous and broadleaved species) in the Czech Republic, is defined as the amount of harvested wood (in cubic meters [m^3]) under bark and was publicly available by region from the Czech Statistical Office [46]. This paper compiled and analyzed the coniferous and broadleaved roundwood production data per the study area (Bohemia, Moravia, and the Czech Republic) corresponding to the observed years (2000 and 2018).

In the Czech Republic, forest mushrooms and berries are the country's most popular non-wood forest products, and their collection is considered a recreational activity [44, 54, 66]. Every year, the Ministry of Agriculture (MoA) of the Czech Republic reports the compilation of the collected forest mushrooms and berries (in thousand tons) based on annual nationwide surveys [35, 67, 68]. The national forestry report combined and presented only the totals of various forest mushrooms. Meanwhile, the forest berries that are commonly gathered in the Czech Republic were bilberries (*Vaccinium myrtillus* L.), blackberries (*Rubus fruticosus* L.), raspberries (*Rubus idaeus* L.), cowberries (*Vaccinium vitis-idea* L.), and elderberries (*Sambucus nigra* L.). Bilberries were the most collected forest berries in the country, followed by raspberries. In this paper, the 2000 and 2018 raw data of mushroom and bilberry collection from the annual national surveys were compiled and compared with the results of public valuation on non-wood forest commodities.

Data analysis

Descriptive data for the general characteristics of the respondents were grouped based on the study areas. Group comparison of categorical data traits, e.g., the score of performance perception of the forest ecosystem services, gender, and education level of the respondents between the study areas, were analyzed using a Chi-square or Fisher exact tests. The continuous data were first checked for normality using the Kolmogorov–Smirnov normality test. ANOVA test was used for analyzing non-categorical and normally distributed data (i.e., age of respondents). Statistical tests of the respondents' general characteristics served as the preliminary results (Table 1). A total of 1509 online respondents were included in the research. The respondents were primarily from the age group 25–54 years (about 65%). Nearly 60% of the respondents obtained a high school certificate (*maturita*), and about 95% of them visited the forests at least once a year (Table 1).

The non-categorical and non-normally distributed data, such as differences in forest area, roundwood removals, and total mushroom and bilberry collection in the observed years by study area, were analyzed using the Wilcoxon matched-pair signed-rank test. The respective data were arranged according to the areas, so-called

Table 1 General characteristics of the respondents[1]

Characteristics	Bohemia (*n* = 1006)	Moravia (*n* = 503)	Total (*N* = 1509)	*p*-value
Gender (female)	50.0 (503)	49.9 (251)	50.0 (754)	1.000
Age (years)	42.5 ± 13.3	41.4 ± 13.6	42.2 ± 13.4	0.138
Age group				
- 18–24 years	10.1 (102)	14.5 (73)	11.6 (175)	0.043
- 25–54 years	66.1 (665)	63.2 (318)	65.1 (983)	
- 55–65 years	23.8 (239)	22.3 (112)	23.3 (351)	
Education level				
- High school (no *maturita*)	41.0 (412)	40.4 (203)	40.8 (615)	0.917
- High school (*maturita*)	37.1 (373)	38.2 (192)	37.4 (565)	
- Higher education	22.0 (221)	21.5 (108)	21.8 (329)	
Size of the town				
- < 5000 inhabitants	37.7 (379)	40.2 (202)	38.5 (581)	0.003
- 5000– < 20,000 inhabitants	20.5 (206)	14.5 (73)	18.5 (279)	
- 20,000– < 100,000 inhabitants	18.3 (184)	24.5 (123)	20.3 (307)	
- ≥ 100,000 inhabitants	23.6 (237)	20.9 (105)	22.7 (34.2)	
Frequency of forest visits				
- Several times a week	15.7 (158)	10.1 (51)	13.9 (209)	< 0.001
- Once a week	27.7 (279)	24.9 (125)	26.8 (404)	
- Once a month	36.1 (363)	35.8 (180)	36.0 (543)	
- One or two times a year	16.1 (162)	22.1 (111)	18.1 (273)	
- Less than once a year or never	4.4 (44)	7.2 (36)	5.3 (80)	

[1] Data are presented as % (n) or mean ± sd; all group comparisons were analyzed using Chi-square test, while ANOVA test was used for age of respondents (in years), *p* < 0.05: significant level

"kraj", which is the NUTS level 3 in the Czech Republic, and grouped based on the region, i.e., Bohemia and Moravia. The percentage of forest area or production changes was calculated as:

$$\frac{production\ or\ forest\ area(2018) - production\ of\ forest\ area(2000)}{production\ or\ forest\ area(2000)} \times 100\%.$$

Furthermore, K-means cluster analysis was also performed to categorize the areas with high scores of performance perception of the entire forest ecosystem services to determine which cluster/group was to be used for the predictor analysis (Additional file 1: Tables S1, S2, S3, S4, and Figs. S1, S2, and S3).

Binary logistic regression with a conditional forward approach was applied to identify potential predictors of the performance perception (1 = high score) of the selected Czech forest ecosystem services (individual or cluster). The perception of high-performance scores for forest clusters was determined through K-means cluster analysis. Meanwhile, scores of four (4) and five (5) were grouped as indicative of high-performance levels for individual wood and non-wood forest provisioning services. The following covariates associated with the dependent

variables in Table 1 were included in the initial model: age (in years), sex (1 = female), education level (1 = high-school graduates with *maturita* and above), frequency of forest visits (1 = minimum monthly visits), the population size of the residence (1 = 20,000 and above), and study area (1 = Moravia). Additionally, we integrated visual forest views [37, 69] indicated by percentage changes in each forest vegetation area, roundwood removals, and amount of collected mushrooms and bilberries from 2000 to 2018 as independent factors that may influence public perceptions of cluster and individual forest ecosystems' performance. A *p*-value of less than 0.05 was designated as the statistical significance in all analyses. Statistical analysis was performed using IBM SPSS version 26 (IBM Corp., Armonk, NY, USA).

Results
Respondents' perception of forest ecosystem services
In general, the respondents could answer the questions regarding the performance perception of the selected

Czech forest ecosystem services. The scores of selected forest ecosystem service performance from Bohemia and Moravia were combined because no statistically significant difference between the two areas was found (Table 2).

On average, forest provisioning obtained mean scores from 3.9 to 4.2, of which wood production was the lowest. The highest proportion of respondents valued all forest ecosystems in the group of provisioning services as "very important". The mean scores of the regulating services of forests group were between 3.7 and 4.1, of which carbon sequestration had the lowest score. Similar trends were found in the group of regulating services, compared to the provisioning, whereas the highest percentages of respondents positioned all ecosystem services in this group as "very important".

Dynamic scores were revealed in the group of cultural services. Overall, the highest score for the performance of all studied ecosystem services was forests as the natural habitat of animals and plants (72.6% valued it as "very important", with a mean score of 4.6). Meanwhile, the lowest score was on the esthetic value of forests (2.3 ± 1.2), while 42.9% considered it "not important".

Changes in forest cover, roundwood removals and selected non-wood commodities

The total Bohemian forested areas are primarily composed of coniferous trees (Table 3). From 2000 to 2018, the total forested landscape in the Bohemian part increased slightly (+0.76%), contrary to the Moravian region (− 1.97%). This forest area composition indicates that Bohemia is the primary producer of coniferous roundwood. The broadleaved and mixed forested landscapes in Bohemia increased significantly (from 5 to 6.5%, respectively) in 2018 compared to 2000 (both $p = 0.005$).

The Moravian coniferous forest areas decreased from 2000 to 2018 by − 5.9%, which resulted in a significant decline in the total forest area in this part of the country (up to − 1.97%).

In this paper, the wood provisioning services in Bohemian and Moravian forests were indicated by coniferous and broadleaved roundwood removals gathered from the Czech Statistical Office in the observed years (2000 and 2018). Meanwhile, the volume of mushrooms and bilberries collected in the selected years was designated for non-wood forest production (Table 3). A statistically significant increase in the production of both roundwood coniferous and non-coniferous from 2018 compared to 2000 was found in Bohemia and the Czech Republic. Meanwhile, only the coniferous roundwood removals in Moravia escalated significantly in 2018 compared with 2000 ($p < 0.001$). Coniferous roundwood production in Bohemia in 2000 was about two to three times higher than in Moravia. However, the amount of harvested wood in Moravia (approximately 10 million m^3 under bark) approached that of Bohemia in 2018 (about 13.9 million m^3 under bark) (Table 3).

Generally, the mushroom and bilberry volumes foraged in Moravia and Bohemia decreased by about 27 to 30% in 2018 compared to 2000 (Table 3). The amount of collected mushrooms in Bohemia and Moravia declined significantly in 2018 (about 17.5 and 15 thousand tons, respectively) compared to 2000 (25 and 20.7 thousand tons, respectively).

Additional file 1: Figs. S4, S5, and S6 depict the dynamic changes in the clustering of all selected forest ecosystem services, all provisioning services, and combined wood and non-wood products into a high and low score in each category. The group categorization was based on the results of K-means cluster analysis. The evaluation

Table 2 Performance perception of the selected forest ecosystem services ($N = 1509$)[1]

Performance perception	Score					Mean ± sd
Provisioning services	1	2	3	4	5	
- Wood source	2.6 (39)	6.8 (102)	27.7 (418)	26.9 (406)	36.1 (544)	3.9 ± 1.1
- NWFP: berries, mushrooms	1.8 (27)	3.6 (55)	18.7 (282)	27.0 (407)	48.9 (738)	4.2 ± 1.0
- Clean water source	1.1 (16)	55 (3.6)	20.2 (305)	24.7 (372)	50.4 (761)	4.2 ± 1.0
Regulating services	1	2	3	4	5	
- Flood protection	2.1 (32)	6.1 (92)	22.0 (332)	26.6 (401)	43.2 (652)	4.0 ± 1.0
- Erosion prevention	1.9 (28)	3.1 (47)	22.1 (333)	26.9 (406)	46.1 (695)	4.1 ± 1.0
- Carbon sequestration	3.3 (50)	6.8 (103)	34.8 (525)	22.8 (344)	32.3 (487)	3.7 ± 1.1
Cultural services	1	2	3	4	5	
- Natural habitat of animal and plants	1.3 (19)	1.4 (21)	9.3 (141)	15.4 (232)	72.6 (1096)	4.6 ± 0.8
- Recreation and ecotourism	3.6 (55)	6.7 (101)	29.5 (445)	29.5 (445)	30.7 (463)	3.8 ± 1.1
- Esthetic	42.9 (647)	6.1 (92)	25.3 (382)	25.7 (388)	0.0 (0)	2.3 ± 1.2

[1] Data are presented as % (n) or mean ± sd, scoring system: (1 = not important, 5 = very important)

Table 3 Changes in forest area, wood and non-wood forest provisioning services in the Czech Republic in the observed years

Descriptions		2000	Year 2018	2018–2000	*p*-value	% changes 2000–2018
Forest cover, ha						
Coniferous	Bohemia	1,377,468	1,360,854	− 16,614	0.203	− 1.21
Broadleaved		122,939	129,077	6138	0.005	4.99
Mixed forests		379,543	404,261	24,718	0.005	6.51
Total forest area		1,879,950	1,891,192	11,242	0.285	0.76
Coniferous	Moravia	324,186	305,049	− 19,137	0.068	− 5.90
Broadleaved		154,764	154,262	− 502	0.715	− 0.32
Mixed forests		233,825	239,439	5614	0.067	2.40
Total forest area		712,774	698,749	− 14,025	0.068	− 1.97
Coniferous	Czech Rep.	1,701,654	1,665,903	− 35,751	0.030	− 2.10
Broadleaved		277,703	283,338	5635	0.013	2.03
Mixed forests		613,368	643,700	30,332	< 0.001	4.95
Total forest area		2,592,724	2,592,941	217	0.778	0.01
Roundwood removals, m³ under bark						
Coniferous	Bohemia	9,177,628	13,917,143	4,739,515	< 0.001	51.64
Broadleaved		688,467	4,272,216	3,583,749	< 0.001	520.54
Coniferous	Moravia	3,673,392	10,295,367	6,621,975	< 0.001	180.27
Broadleaved		901,503	850,930	− 50,573	0.075	− 5.61
Coniferous	Czech Rep.	12,851,020	24,212,510	11,361,490	< 0.001	88.40
Broadleaved		1,589,970	5,123.146	3,533,176	< 0.001	222.22
Non-wood forest products, tons						
Mushrooms	Bohemia	25,210	17,480	− 7730	0.005	− 30.66
Bilberries		11,490	7870	− 3620	0.005	− 31.51
Mushrooms	Moravia	20,680	14,930	− 5750	0.068	− 27.80
Bilberries		5070	3550	− 1520	0.067	− 29.98
Mushrooms	Czech Rep.	45,918	32,427	− 13,491	< 0.001	− 29.38
Bilberries		16,553	11,431	− 5122	< 0.001	− 30.94

Data are presented in sum; non-categorical group comparisons between selected years were analyzed using the Wilcoxon matched-pair signed-rank test

* Significantly different between the observed years, p < 0.05

of 936, 939, and 986 participants were included into a high-score performance of all selected forest ecosystem services, the provisioning functions, and the combined wood and non-wood products, respectively. These high-score groups were used as the dependent variables in the predictor analysis.

Predictor analysis of public perception on the performance of forest ecosystem services

The results of the binary logistic regression showed that changes of broadleaved roundwood production from 2000 to 2018 were positively and significantly associated with the high score of wood commodity performance perceived by the respondents (*p* = 0.011). The perceived evaluation given by the female respondents had odd ratios between 1.3 and 1.6 times more likely to be included in the high score group of all dependent variables used in the binary logistic regression analysis, except for the wood provisioning services. Respondents

who visited the forests at least once a month had an odd ratio of about 1.3 times more likely to give a high score in the performance of the cluster of all forest ecosystem services. Furthermore, older respondents were positively and significantly associated with high scores of performance perception in all individual and cluster forest ecosystem services (all had *p* < 0.001) (Table 4).

Discussion

Although more services are expected from the forest that benefits the health and well-being of society, forest provisioning attributes were reported as the most favored and usable [70, 71]. In the Czech Republic, wood is still considered a significant forest product for providing economic benefit and the primary forest ecosystem services for forest owners. In 2018 and 2019, the forestry, logging, and wood-processing industries contributed 1.101% and 1.176%, respectively, to the gross value added (GVA) at basic prices, not including the paper and

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Table 4 Independent predictors of high scores in performance perception of selected forest ecosystem services

Predictors	Beta	Standard error	Exp (B)	Confidence interval	*p*-value
Cluster of all forest ecosystem services ($R^2 = 0.069$)					
- Age of respondents	0.034	0.004	1.035	1.026−1.043	< 0.001
- Female respondents (1 = female)	0.242	0.109	1.274	1.028−1.577	0.027
- Frequency of forest visits (1 = frequently)	0.275	0.112	1.316	1.057−1.639	0.014
Cluster of all provisioning services ($R^2 = 0.043$)					
- Age of respondents	0.026	0.004	1.026	1.018−1.034	< 0.001
- Female respondents (1 = female)	0.303	0.108	1.354	1.096−1.673	0.005
Cluster of wood and non-wood forest products ($R^2 = 0.035$)					
- Age of respondents	0.019	0.004	1.020	1.011−1.028	< 0.001
- Female respondents (1 = female)	0.440	0.110	1.552	1.251−1.925	< 0.001
Only non-wood forest products ($R^2 = 0.029$)					
- Age of respondents	0.018	0.005	1.018	1.009−1.027	< 0.001
- Female respondents (1 = female)	0.465	0.122	1.591	1.252−2.023	< 0.001
Only wood production ($R^2 = 0.027$)					
- Percent changes in broadleaved wood production	0.0002	0.0004	1.0002	1.00002−1.0002	0.011
- Age of respondents	0.020	0.004	1.020	1.012−1.028	< 0.001

[1] Values of the final model and R^2 of Nagelkerke of the regression analysis were presented; significant level at $p < 0.05$

furniture industries. The share of forestry, logging, and wood-processing industries to GVA was higher than the agriculture sector in 2018 (1.081%) and other important biogenic resources in the country, yet lower when compared to 2019's share (1.716%). Forests and forestry are essential from the societal perspective—not only in relation to providing ecosystem services but also for providing raw materials and sources for manufacturing and other industries (wood-processing, furniture, paper, etc.). Considering this, the initial low share of forestry of the total GVA would increase significantly if the share from industrial sectors is included. New emerging products made from wood are finding their way to the marketplace, such as wood construction materials and wood-based composites [72, 73].

Public perception of forest ecosystems' performance

This survey revealed that Czechs placed higher scores on all forest provisioning services (on average between 3.9 and 4.2) compared to regulating services (between 3.7 and 4.1) and cultural services (range: 2.3–3.8), except for the value as a natural habitat for animals and plants (4.6 ± 0.8) (Table 2, supported by Additional file 1: Figs. S4 and S6). While another study conducted in Europe revealed that respondents from Austria, Finland, Germany, and Slovenia emphasized the significance of forest ecosystems in regulating and supporting services [33], our findings underscored the significance of provisioning services for the Czech society, as these services offer direct benefits to people. The survey results also revealed that the Czech society values wood forest

products below other provisioning services, i.e., clean water and non-wood forest products, which contrasted with the significant contribution of forestry as one of the bio-based resources to the national economy (Table 2). The 2018 coniferous roundwood production significantly increased compared to 2000, especially in Moravia (more than twice) (Table 3), even though Bohemia has an area of approximately two million ha, which is roughly double that of Moravia's area (± 0.7 million ha). The high roundwood production was the result of bark beetle infection, causing the drying of coniferous trees and subsequent massive logging [57, 60], which led to an oversupply of timber in 2018 (up to 59%) compared to 2016 [74]. These insects have infected the coniferous trees in neighboring countries, such as Slovakia [75], Poland [76], and Germany [77]. With regard to the Czech Republic, the root cause was likely due to vast coniferous monoculture cultivation which substituted natural broadleaved and mixed forests in the Czech lands to enhance wood production more than 100 years ago [78]. The current Czech forests are primarily production forests (about 74%) and consist of mainly homogenous spruce stands and even-aged monoculture stands [42], which makes them less resilient due to lower genetic diversity that fosters resistance to natural disturbances, such as the bark beetle attack. As the changes in the infected trees are visible, the situation predictably caused increased awareness among the general public on the consequences of the coniferous monocultures and their high production.

During the years of the bark beetle outbreak, the perception of foresters and forestry holds somewhat

negative view from the Czechs. This fact highlighted the need to communicate salient topics for non-foresters. A nationwide project funded by the MoA of the Czech Republic entitled "Communication as a tool to harmonize the needs of society and the forestry sector" was implemented in 2019–2021 and reacted to the need to find a communication strategy among relevant stakeholders in the country. A website, www.nekrm brouka.cz ("Don't feed the bug"), was also established as a reaction to present valid information on combating bark beetle infestation. Additionally, finding solutions for prevention and the damaging impact of bark beetle outbreaks are intensely studied [12, 57].

Currently, the implemented programs in forestry are trying to move towards a more natural and sustainable forest composition [36]. Despite its high productivity and economic consequences, the reduction of the total Norway spruce area in forests has been supported by the MoA of the Czech Republic for approximately ten years. The significant increase in actual broadleaved roundwood production from 2000 to 2018 (Table 3) indicating the potential societal support for increasing mixed-forest areas and producing roundwood non-spruce removals, which encourages the forest policy implementation towards more natural and diverse tree species. In this regard, the results also support the investment in promoting mixed-forest targeting by raising awareness and implementing sustainable mixed-forest management for the forest owners and public utilization for future generations. As the country is located in the middle of Europe, the Czech forests may influence neighboring countries forest well-being, i.e., in Germany, Slovakia, and Austria. Therefore, the country's efforts in reducing the vulnerability of the trees to insect attacks will contribute positively to the adjacent forests. Furthermore, in Central European countries, the Czech Republic is ranked first in roundwood exports as well as one of the top roundwood exporters worldwide, followed by Slovakia [79], which indicates the crucial earlier intervention to maintain the wood quality in the European market.

Among various ecosystem services, forests received the highest rating (mean: 4.6) when serving as a natural habitat for animal and plants, as indicated in Table 2. According to the findings of Hochmalova et al. [37], different segments of Czech society, i.e., tourists, students, and urban residents, highly regarded forests as natural habitats for game animals, with a mean rating exceeding 3 out of a total score of 4. Furthermore, forest plants are traditionally part of the collected non-wood forest commodities, besides mushrooms and berry picking, which are popular recreational activities [44, 45, 54, 66]. The findings underscore the integral role of forest recreational

value in Czech history and culture [44, 80, 81] and the potential as a source of bioeconomy-based tourism [82].

The predictor analysis results (Table 4) did not reveal any significant correlation between public perceptions of non-wood forest provisioning services and various tree cover types (coniferous, broadleaved, or mixed forests), nor with the production of mushrooms and bilberries, which could be attributed to the fact that mushroom and berry picking activities in the Czech Republic are considered part of forest recreational services, often managed without specific production or economic targets [44, 54]. Nevertheless, a decrease in the quantities of collected mushrooms and bilberries over the observed years, as presented in Table 2, aligns with the declining trends in production observed between 2000 and 2018, particularly from 2012 to 2018 [45]. This trend suggests the possibility of a transformation occurring in their natural environments or changes in forest visitors' preferences during the study period. For example, a study reported the Czech forest visitors' preference for a forest with less human involvement [37], contrary to the current extensive logging activities [57].

In Central Europe, e.g., in the Czech Republic, the forest species composition primarily consists of coniferous, predominantly Norway spruce or pine, as well as beech and oak, that foster creating an environment that facilitates the flourishing of various types of berries in different ecological conditions. Bilberries, for instance, are commonly found in coniferous forests, such as Norway spruce silver-fir or pine trees [56, 83, 84], or oak woods [85], while its other closed-family, blueberries, can grow in forests characterized by abundant and diverse vegetation, such as spruce domination, medium-aged deciduous forests consisting of grey alder, birches and aspen, and black alder swamps [86]. Raspberries are associated with fir–beech mixtures [87], and blackberries tend to flourish in silver fir-dominated areas [88]. Meanwhile, cowberries are prevalent in coniferous forests, particularly those with Scots pine (*Pinus sylvestris* L.), light deciduous oak forests [89]. Diverse trees and conditions suggest the potential growth of forest berries according to their natural habitat. However, the production of some berries, e.g., bilberries that has a strong relationship with coniferous forests, e.g., pine are expected to be decreased [56], while blueberries that associated with mix trees are expected to be increased [86]. In the case of mushrooms, the National Report on forest and forestry did not differentiate them into species. Hence, various species of forest mushrooms can grow in multiple forest vegetation types, and can be collected in more seasons than berries.

The esthetic value of the Czech forests earned the lowest score (2.3 ± 1.2). This might be related to the state of the Czech forests, which are currently undergoing

damage from a prolonged drought exacerbated by elevated temperatures combined with low total precipitation and uneven distribution during the last few years. This was followed by exponential growth and infestation of bark beetles [58, 90]. Moreover, based on the results of a workshop entitled "Possibilities of supporting forest ecosystem services from the point of view of the professional public" attended by ten representatives of various Czech forestry stakeholders in November 2019, the respondents did not consider recreation and ecotourism as necessary, especially before the outbreak of the bark beetle infection [91]. During the massive logging activities after the bark beetle infestation and a decrease in coniferous forest areas, the visitors did not favor the appearance of the infected trees that changed the forest view. The findings were per a study in Northern Germany and the USA, which reported the lowest value was given by the visitors on the pictures of forests with dead trees, followed by clear-cutting and deadwood removal due to the insect infection compared to healthier forest stands [69]. Mixed forests are also preferred because of the esthetic values of coniferous and deciduous trees and the variation of stands in all seasons [92].

Czechs also valued the water provisioning forest service highly (on average: 4.2), since trees protect and help provide clean drinking water [6–8]. Forests exhibit improved water quality compared to residential, agricultural, and industrial areas. The intricate tree root network serves as a natural filter, lowering pollutant levels in water [93, 94]. Additionally, forest tree cover composition can significantly influence its impact on water. For instance, mixed forests were reported to have a greater capacity for intercepting and redistributing rainfall [95].

The forest's functionality for flood protection and soil erosion prevention was also highly valued by the Czech society (on average, 4.1 and 4.0, respectively). People in the Czech Republic are generally aware of the flood and soil erosion risks. These concerns can be attributed to several factors, including the personal experience of the impact of a significant natural disaster, such as historical extreme floods in 2002 and 2013 [96–98]. The media's coverage of these natural disasters also appeared to be instrumental in raising public awareness, along with continuous concerns from the national government through the implementation of several strategic measures for risk prevention and mitigation [98, 99]. In contrast to the two previously discussed forest ecosystems, the role of forests in carbon sequestration is considerably lower (mean: 3.7), probably because the adverse effects are not immediately recognized or experienced by the general public, in contrast to the more visible dangers of floods and erosion Nevertheless, the increasing adverse effects related to reduced carbon sequestration and elevated emissions have intensified over the past few decades, largely due to the influence of climate change [9, 98].

The low scores of public valuation in forest ecosystem services, i.e., esthetic value and carbon sequestration emphasize the opportunity to enhance public perception and appreciation for these services through increased awareness of the comprehensive role played by forest ecosystem services. Additionally, follow-up research is recommended to conduct forest cover monitoring combined with surveys to gain a deeper understanding of the reasons behind the low performance scores, and for better strategic measures and recommendations, supporting the Czech Forest Policy that aims for "Forest for Society."

Factors affecting performance evaluation of the Czech forest ecosystem services

Our findings also highlighted that the respondents' socio-demographic information significantly influenced the valuation of the forest ecosystem service's performance in clusters or individual provisioning services. Female respondents in this survey were more likely to value the ecosystem services highly for clusters of all forest ecosystems, combined provisioning services, and individual non-wood commodities. A study in Spain supported our results, in which female respondents reportedly have a higher probability of perceiving an ecosystem's capacity to provide services [28]. In Switzerland, more women utilized non-wood forest products than men [100]. Based on a review study on gender perspective in forest ecosystem services, women also perceived greater importance of domestic food consumption (like wild mushrooms and berries) and herbs. Meanwhile, regarding wood provisioning services, the women appreciated the importance of fuel woods, while men showed a better understanding of timber production [101].

Older respondents perceived clusters of all forest ecosystem services better than the younger ones, with both cluster and individual wood and non-wood provisioning services receiving high scores. Despite the importance of wood production for the national economy, the low evaluation indicates that forestry jobs might be less popular among the young generations, similar to Sweden [102]. The reasons included low competitiveness compared to other industries and lack of financial reserves of the sector linked to natural emergency conditions [103]. Meanwhile the low score of non-wood forest provisioning services by the younger respondents indicates the potential drop in appreciation for this activity in the future, similar to the situation among mushroom pickers in Finland [104], presumably because the picking of mushrooms might require skills and experiences to recognize edible mushrooms and their habitats. The declining trend of forest berry foraging activities, especially among the

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young generation, was also reported in Sweden, ostensibly due to urbanization and a decreased connection to nature [105]. The findings suggest the importance to increase awareness and education in essential roles of forest ecosystem services to the young generations.

Visitors to the Czech forests were driven by multiple motivations, from receiving direct benefits from forest production to enjoying the non-material gains, such sport and enjoying the nature [106]. Frequent forest attendance (at least once a month) also had odd ratio of 1.3 times more likely to give a high value for all forest ecosystem services. Regular visits to forests have evidently played a role in the growing preference for utilizing various non-wood forest products [45]. Our findings suggest the significance of focusing on these groups (older-age respondents, female and regular forest attendance) and their counterparts (i.e., the younger generation, male, and less frequent forest visitors) in enhancing knowledge related to the sustainable production and utilization of forest ecosystem services tailored to their respective characteristics. While our analysis did not reveal any significant disparities in the association between public perception of forest ecosystems' performance in the study regions (Bohemia vs. Moravia) and the dependent factors, it's worth noting that significant changes occurred in the forest vegetation area and roundwood removals between 2000 and 2018, especially in Moravia. The results suggest that future findings may diverge; hence, emphasizing the importance of continuous monitoring that incorporates these variables.

Conclusion
Our survey results found that Czech society placed high scores for the group of forest provisioning services, suggesting the public valued direct benefits from the Czech forests. Regulating services were valued slightly less than provisioning services, but the majority of the respondents perceived them as "very important". Meanwhile, dynamic results were revealed in the cultural services, whereas the highest score from all studied ecosystem services was for forests as a natural habitat for animals and plants, which might connect it with the role as a provisioning service. Furthermore, the lowest score of all ecosystem services under study was in esthetic value. Our findings in positioning also revealed the significant contribution of female and older respondents groups/clusters and individuals forest ecosystem services in high scores, in addition to frequent forest visits.

The results of this paper are used as part of the baseline assessment for embracing the bio-based economy and support for sustainable forest production and consumption in the country.

Abbreviations
CAWI	Computer assisted web interviewing
CORINE	Copernicus Land Monitoring Service
CZU	Czech University of Life Sciences Prague
FAO	Food and Agriculture Organization of the United Nations
FFWS	Faculty of forestry and Wood Sciences (CZU)
GVA	Gross value added
MoA	Ministry of Agriculture of the Czech Republic
NUTS	Nomenclature of Units for Territorial Statistics

Supplementary Information
The online version contains supplementary material available at https://doi.org/10.1186/s12302-023-00802-8.

Additional file 1: Table S1. Descriptive information of the public perception on forest ecosystem services (*n*=1509). **Table S2**. Initial and final cluster centers of all forest ecosystems. **Table S3.** Initial and final cluster centers of all previsioning services. **Table S4.** Initial and final cluster centers of wood and non-wood forest previsioning services. **Figure S1.** Results of K-means Cluster Analysis for Public Perception of All Forest Ecosystems' Performance (Cluster 1 = Low Score (*n*=525), Cluster 2 = High Score (*n*=984). **Figure S2.** Results of K-means Cluster Analysis for Public Perception of Forest Provisionings' Performance (Cluster 1 = Low Score (*n*=525), Cluster 2 = High Score (*n*=984). **Figure S3.** Results of K-means Cluster Analysis for Public Perception of Wood and Non-wood Forest Provisioning's Performance (Cluster 1 = Low Score (*n*=523), Cluster 2 = High Score (*n*=986). **Figure S4.** Flow of respondent's cluster of all forest ecosystem services. **Figure S5.** Flow of respondent's cluster of forest provisioning services. **Figure S6.** Flow of respondent's cluster of wood and non-wood forest provisioning services.

Availability of data and materials
The CORINE land cover dataset analyzed during the current study are available in the Copernicus Land Monitoring Service repository, https://land.copernicus.eu/pan-european/corine-land-cover. Roundwood removal data are available at the Czech Statistical Office website, https://vdb.czso.cz/vdbvo2/faces/en/index.jsf?page=home. Additionally, the mushroom and bilberries aggregate data are published annually in the national forestry report (Green report) and publicly available from the Ministry of Agriculture of the Czech Republic website, https://eagri.cz/public/web/mze/lesy/lesnictvi/zprava-o-stavu-lesa-a-lesniho/.

Declarations

Ethics approval and consent to participate
Not applicable.

Consent for publication
Not applicable.

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