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Integrating monetary and non-monetary valuation for ecosystem services in Piatra Craiului national park, Southern Carpathians: a comprehensive approach to sustainability and conservation

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The concept of ecosystem services and their valuation has gained significant attention in recent years due to the profound interdependence and interconnectedness between humans and ecosystems. As several studies on valuation of forest ecosystem services have stressed the human-nature interactions lately, in the research study area, the environmental conditions shows rapid changes while human pressures on forests intensify. Thus, the research questions are as follows: (i) what are the the monetary and non-monetary value of ecosystem services provided by forests in Piatra Craiului National Park and (ii) their relationship with other variables, focusing on identifying differences and resemblances between each approach. The R PASTECS package was utilized to analyze primary statistical indicators for both monetary and non-monetary values, revealing significant variability in the results (s% monetary 141% and s% non-monetary 62%). Both monetary and non-monetary assessments were computed at the management unit level and the data used was provided by the Forest Management plans and photograph analysis which have significant value as indicators of ecosystem services. The correlation between nature and culture was assessed through social-media based method, highly known to stimulate participant engagement while the quantitative data was assessed through forest data computation and PCA method for visualization. The research highlighted that, in monetary terms, the minimum value of identified ecosystem services was €34 and the maximum value exceeded €570,000 at management unit level and in non-monetary terms, the values ranged from 1 to 5 (kernel score). The research reveals a substantial variability in both types of valuations. Strong associations between certain variables (monetary value with carbon stock and stand volume), moderate connections (slope with stand productivity), and weaker relationships (non-monetary value with altitude, age with slope, type of flora with altitude, and altitude with stand productivity) were revealed. The findings provided valuable insights for policymakers, land managers, and stakeholders involved in natural resource management and conservation, emphasizing the importance of considering both economic and non-economic benefits in decision-making processes. The integrated approach of this study shows how we can better assess the mixed value of ecosystem services, contributing to the ongoing actions of raising awareness and social responsibility.

KEYWORDS

biophysical and socioeconomic valuation, mixed-methods approach, environmental policy insights, conservation strategies, Southern Carpathians

1 Introduction

The concept of ecosystem services has garnered significant attention in recent years due to its recognition of the profound interdependence and interconnectedness between humans and ecosystems (Zhang et al., 2021), which plays a vital role in supporting human wellbeing and sustainability (Costanza et al., 2014). Moreover, this concept has been emphasized in the past by the Millennium Ecosystem Assessment (MEA), in 2005, which sought to alter public perceptions of natural ecosystems by raising awareness and enhancing knowledge about the services they provide. This breakthrough not only showed us the value of nature but also highlighted how nature's services directly impact our wellbeing. The MEA aimed at mitigating degradation (Millennium Ecosystem Assessmen, 2005; Carpenter et al., 2009; Reyers et al., 2013) and addressing the impacts of climate change on society as a whole. It emphasized that the emergence of ecosystem services as a framework can serve as a valuable tool in decision-making processes (Martínez Pastur et al., 2016; Bell-James, 2020), reinforcing the need for considering nature's contributions in various policy and management strategies.

Since ecosystem services encompasses the bundles of benefits to humans and society such as provisioning of essential resources and regulating its involved processes (pollination, decomposition, water purification, erosion and flood control, and carbon storage and climate regulation) (Millennium Ecosystem Assessmen, 2005), they fundamentally link ecology, economics and social wellbeing together (Everard, 2013). Nevertheless, researchers such as Luck et al. (2012) and Schröter et al. (2014) have examined various concerns related to ethical perceptions of valuing nature based on its utility rather than its intrinsic value. There is a spectrum of perspectives on the concept of ecosystem services, with some favoring its general application, while others advocate for a distinct approach that involves separation, monetization, and treating it as a commodity, as discussed by Bell-James (2020). Even though the concept of ES framework has been shown to emphasize the multiple ways of dependency between humans and nature, the framework is believed to have failed due to continuous ecosystem loss and ecological breakdown, attributed to the core foundations of modern Western culture (Muradian and Gómez-Baggethun, 2021).

To highlight the role of ecosystem services, for a correct valuation Spangenberg and Settele (2010) suggested the use of adequate methods integrating monetary and non-monetary valuation of ES (traditional economic valuation techniques such as cost-benefit analysis and stated preference methods for monetary valuation, alongside qualitative assessments, multi-criteria analysis, and integrated models to capture non-monetary values).

Monetary valuation has been widely utilized as a direct method to assess the economic value of ecosystem services (Baveye et al., 2013). This approach involves assigning a monetary value to goods and services provided by ecosystems, based on market prices or other valuation techniques (Turner et al., 2003; Baveye et al., 2013; Selivanov and Hlaváčková, 2021). It provides policymakers with quantifiable information that can be integrated into cost-benefit analyses and policy-making processes, providing a deeper understanding of the real contributions of nature to human wellbeing (Balmford et al., 2002; Jiang et al., 2021). Nevertheless, monetary valuation often overlooks the inherent non-monetary aspects of ecosystem services, such as cultural and social values, which are challenging to capture in monetary terms. Thus, methods are often pondered, and a combination of them might provide greater reliability (Daily et al., 2009; Custódio et al., 2020). The dimension of knowledge regarding ecosystem services as a means of a possible non-monetary evaluation depends on the values of the civil society correlated with certain locations or environmental areas (Paracchini et al., 2014; Martínez Pastur et al., 2016; Sharma et al., 2022). However, cultural ecosystem services are tricky to address, requiring a multidisciplinary and comprehensive approach because, ultimately, it is about the access right and right to nature as some argue (Tenerelli et al., 2016; Kosanic and Petzold, 2020). Thus, establishing a comprehensive approach toward the space of cultural ecosystem services (CES) has to take into account the connectivity between capacity building and raising awareness, besides the evaluation per-se (Scholte et al., 2015).

To capture the diversity of values correlated with nature, the non-monetary approach looks into the values, preferences, perceptions, demands, and experiences of the people who benefit from ecosystem services, demonstrating the pluralistic value of nature and its close connection to the ES framework (Chan et al., 2013; Custódio et al., 2020). These methods typically involve surveys, interviews, social-media based approaches, or other concepts from the citizen science principles to collect data on people's perceptions and willingness to pay for ecosystem services (Boyd and Banzhaf, 2007; Cabana et al., 2020; Isse et al., 2021; Peri et al., 2022; Sharma et al., 2022). Non-monetary valuation recognizes the diverse range of values (biodiversity conservation, cultural significance, aesthetic enjoyment, recreational opportunities) associated with ecosystems and offers a more comprehensive understanding of the benefits they provide (Díaz et al., 2018; Sharma et al., 2022).

For the area where the research was carried out, respectively, Romania, several studies have been conducted to assess forest ecosystem services, including carbon sequestration (Chivulescu and Schiteanu, 2017; Dobre et al., 2021; Nichiforel et al., 2021; Pache et al., 2021; Pitar et al., 2021; Chivulescu et al., 2022) water purification (Petz et al., 2012; Platon et al., 2015), and recreational value (Hartel et al., 2014; Bogdan et al., 2019; Tudoran et al., 2022). However, as environmental conditions evolve and human pressures on forests intensify, further research is necessary to comprehensively understand the changing dynamics of these services and devise effective conservation measures (Chivulescu et al., 2020; Leca et al., 2023).

The aim of this research is to valuate ecosystems services in Piatra Craiului National Park, using both monetary and non-monetary valuation methods, harmonize quantitative data [obtained from forest management plans for monetary valuation, incorporating market prices and other economic indicators (Costanza et al., 2014)] and qualitative data [collected from the general public visiting the national park, capturing their perspectives and preferences regarding ecosystem services (Vedeld et al., 2004; Sharma et al., 2022)], and to explore relationships among identified ecosystem services indicators and different characteristics of ecosystems.

Consequently, the research paper answers to following research questions: (i) which are the ecosystem services provided by a national park (Piatra Craiului National Park-Southern Carpathians Mountains), and which is their monetary and non-monetary value and (ii) which is the relationship between values obtained from monetary and non-monetary valuations and other variables (ecosystem characteristics), with a specific focus on identifying dissimilarities and resemblances between each approach.

2 Materials and methods

2.1 Location and description of the study area

The study area is located in the Southern Carpathians Mountains, specifically in Piatra Craiului National Park (**Figure 1**) part of the Romanian Long Term Ecological Research Network (RO-LTER) (Badea et al., 2012; Badea, 2021). This area is characterized by a temperate continental climate, with slightly small topo climates typically found at medium and high altitudes. The annual rainfall ranges between 800 and 1200 mm, while the annual temperature averages from 3 to 4 degrees Celsius, with a high annual variation (± 3 degrees Celsius). The park encompasses a forested area of over 11,400 hectares, consisting predominantly of spruce, beech, pure and mix stands. Historically, the National Park was designated a nature reserve in 1938, and the management practices at that time focused on preserving the constituent habitats. Moreover, in 1990, it was designated as a national park, and the current management plan focuses on the conservation of representative ecosystems in their natural state, as well as the establishment of the prerequisites for recreational activities, visitation, and education while ensuring minimal impact on these ecosystems.

Currently, the study area is divided into 4 different areas: a strict protection zone, which covers 43% of the total area; an integral protection zone occupying 1%; a sustainable conservation area of 46%; and a sustainable development zone on the remaining 10%.

This zonal configuration within the park is the focal point of a comprehensive management investigation, which involves stratification of the woodland based on forest management methods, topographical attributes, climatic conditions, and ecosystem classification. Two types of management practices are distinguished based on the forest management plans information and the designated management areas: forest conservation and forest wood production.

2.2 Models and methods

2.2.1 Analytical frameworks and contextual insights

The Forest Management plans rely on international terminology as outlined by Carcea and Dissescu (2014) and encompass various parameters essential for effective management. These parameters include stand productivity (indicative of potential wood volume production and yield class), stand density (standing volume per unit area), slope (average land slope or gradient), altitude (average elevation above sea level), type of flora (plant species characteristic of the forest type), age (average age of component trees at the management unit level), forest type (homogeneous forest parts requiring consistent silvicultural measures), annual stand growth (current yearly volume increment of the stand), and stand volume (total timber volume of the stand). Both Monetary and Non-monetary assessments were computed at the management unit level, where a management unit represents a designated area of forest land managed and treated as a single entity for sustainable forest management purposes. This unit serves as a distinct ecological and administrative planning entity utilized by forestry authorities or administrators/owners to implement comprehensive forest management practices. Data used from Forest Management plans and photograph analysis have significant value as indicators of ecosystem services. These variables are related to indicators found in ecosystem service classifications (Haines-Young and Potschin-Young, 2018). In particular, each variable from both sources is associated with one or more ecosystem services. In our study, we selected these variables based on correlation matrix analysis.

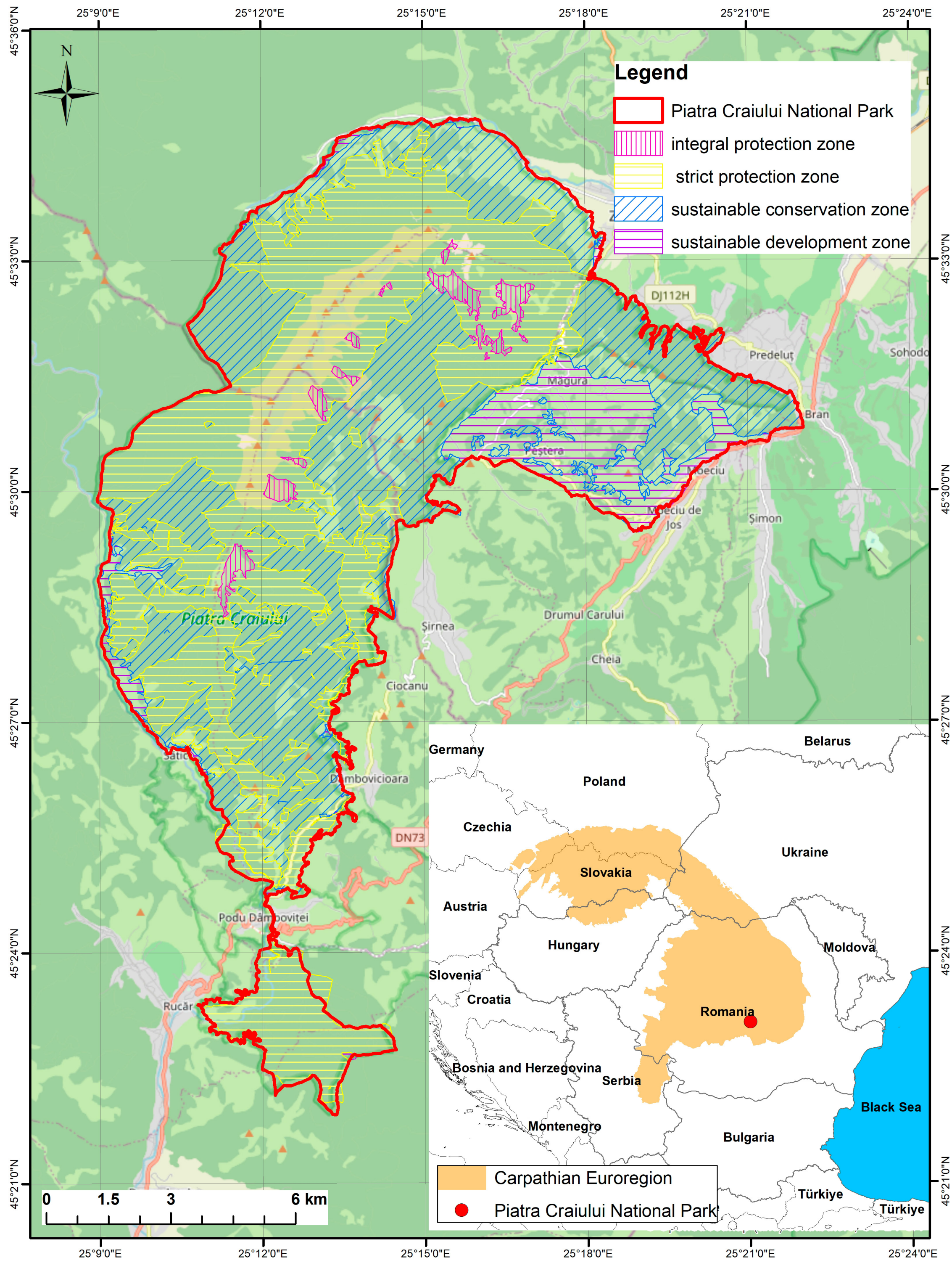

FIGURE 1
Administrative map of the Piatra Craiului National Park. The hatched area indicates the designated management plans for the park. The small square represents the location of Piatra Craiului National Park (red dot) within the Carpathian Mountains (dark yellow).

2.2.2 Non-monetary valuation

Assessing cultural ecosystem services overall took into consideration the spreading of knowledge based on scientific data (quantitative data) in such a way that any user of such ecosystem services can acknowledge and understand the principles and requirements of CES. For this reason, the correlation between nature and culture was assessed through a mixture between specific communication instruments, easy to understand, regarding the classification of cultural ecosystem services types in the sense of subjective value-based judgments with the help of imagery data.

In order to evaluate CES, using non-monetary methods, social innovations such as the social-media based method were used. This approach was chosen for the non-monetary valuation because of its ability to stimulate participant engagement, obtain qualitative information, overcome language barriers and promote a holistic understanding of ecosystem services. It contributes to a more comprehensive and culturally sensitive assessment, with the added benefit of simplified data collection. With the help of photographs taken by the public and posted on the photograph-sharing platform Flickr (last accessed on 01.10.2019), we assessed each image and its respective correlation with the ecosystem services it offers, following the methodology presented in Tenerelli et al. (2016).

In the present research endeavor, an assemblage of 1288 photographic records, captured within the confines of Piatra Craiului National Park's geographical expanse, was procured from the digital imagery exchange platform Flickr. Among this corpus, a discernment emerged indicating that a total of 998 entries were concomitant with explicit geolocation metadata. Subsequent to meticulous scrutiny, it was ascertained that 489 of these instances delineate instances of non-monetary contributions, thus furnishing pivotal spatial and elaborative data of significance for subsequent analytical undertakings.

The ecosystem services identified in the photographs encompass groups of services like aesthetic, existence, land use/land cover, intellectual, and recreational. Additionally, some provisioning services were observed and various wood and non-wood forest products. After the categorization process, assessments were carried out for each ecosystem service. These results were then digitally represented, taking spatial distribution into account.

Under the classification of ecosystem services (Millennium Ecosystem Assessmen, 2005), photographs were grouped according to their content. The "Existence" group included images of vertebrate wild animals, non-vertebrate wild animals, and vegetation. The "Aesthetic" group comprised visually pleasing photographs. The "Recreational" group contained images depicting various activities such as hiking, mountain walking, freeskiing, biking, camping, barbecuing, picnicking, etc. The "Intellectual" group consisted of photographs related to local identity, cultural heritage, education, and scientific exploration. Similarly, the "Land use/land cover" group encompassed images representing different land types, including forests, sparse forests, transitional woodlands, shrub areas, grasslands, moors, bare rocks, rivers, and streams, among others. Each of these groups facilitated the classification and organization of the diverse photographs based on their respective characteristics and themes.

We utilized Kernel Density Estimation (KDE) to convert point data from photographs into a continuous surface across the Piatra Craiului National Park for comparable results with monetary value ES estimation. KDE provides a non-parametric estimate of the underlying unknown intensity function (Waller and Gotway, 2004). Widely employed in various scientific disciplines, such as fire science for defining patterns of fire occurrence (Kuter et al., 2011; Oliveira et al., 2012; Mallinis et al., 2019), wildlife ecology (Fieberg, 2007; Fleming and Calabrese, 2017), and crime incident analysis (Levine and Associates., 2013), KDE ensures a comprehensive representation of the landscape. In kernel density analysis, bandwidth selection is crucial, often surpassing the significance of choosing the kernel function (Kuter et al., 2011). We determined the optimal bandwidth by calculating the average k-th nearest neighborhood distances between points, using the k-nearest neighbors' algorithm (Williamson et al., 1999). After multiple tests, we identified the optimal k value as 40 through visual examination, ensuring accurate and meaningful outcomes. To treat observations consistently across diverse concentrations, we employed the normal distribution kernel function with a fixed bandwidth, ensuring standardized data handling across the national park.

For each of the 5 ecosystem service categories (aesthetic, existence, intellectual, recreational and land use/land cover), we generated individual kernel density maps. Additionally, a cumulative kernel density map, representing non-monetary values, was produced by spatially intersecting all categories. This map was then overlaid onto forest management units, and the average kernel value for each unit, indicating the non-monetary score, was calculated, and assigned to all 1127 management units.

Subsequent to conducting an analysis employing kernel functions, an allocated kernel score was attributed to individual forest management units situated within the confines of Piatra Craiului National Park. This procedure consequently engendered a model of comparability between the realms of pecuniary and non-pecuniary valuations.

2.2.3 Monetary valuation

To assess the value of ecosystem services that forests have to offer, various methods have been considered according to the area studied. Thus, the methods used (described below) have taken into account reliable ways to evaluate the available harvestable wood volume, the carbon stock in above-ground biomass, and the provision of non-woody products (medicinal plants and berries).

Leveraging data from forest management plans, we assessed wood volume through primary harvesting procedures like shelterwood, conservation, and secondary cutting for stand management. The monetary value of stands with specified logging rules (regeneration felling) was determined by multiplying the average firewood price (Statistics, 2019) with harvestable wood volume. For estimating the above-ground tree biomass carbon stock in the Piatra Craiului National Park, we relied on standing tree volumes, net growth, and national emission factors from the forest management plans. The carbon stock estimation followed the Intergovernmental Panel on Climate Change Guidelines (IPCC, 2006), and the 2019 Refinement on forestland use equations:

$$AGB = AG\ volume * WD\ \ i * BEF \tag{1}$$

Where:

AGB—aboveground biomass, in tones;

AG *volume*—aboveground volume of forest stands provided by forest management plans in m^3;

WD—wood density for each main species expressed, tones/m^3, i represents the main species (**Table 1**);

BEF—biomass expansion factor (1 for broadleaves and 1.15 for conifers).

The biomass expansion factor is needed to correctly add the biomass of branches to the stem to estimate the overall tree AGB. Nevertheless, due to the fact that the volume provided by the management plan is estimated with an allometric equation (Giurgiu, 2004) that estimates the all-aboveground volume in broadleaves species (i.e., BEF equal to one), it was used only for

TABLE 1 Average wood density for the main forest species in Romania (Sp, species; WD, wood density, expressed in T/m^3) (Giurgiu, 2004).

Sp.	WD	Sp.	WD
Picea abies in the areal	0.353	*Quercus petraea*	0.568
Picea abies outside the areal	0.346	*Quercus robur*	0.571
Abies alba	0.335	*Tilia cordata*	0.440
Larix decidua	0.460	*Salix alba*	0.390
Pinus sylvestris	0.406	*Ulmus minor*	0.530
Pseudotsuga menziesii	0.460	*Fraxinus excelsior*	0.560
Pinus nigra	0.466	*Acer campestre*	0.510
Pinus strobus	0.300	*Carpinus betulus*	0.620

conifers. The value of BEF was 1.15 for conifers used for temperate forests by various countries, which have shown to provide reliable results (IPCC, 2006). The root to shoot was considered to be 0.2 for all species (Giurgiu, 2004).

The total carbon stock, for each forest stand, considering also the below ground biomass was ultimately estimated, using the equation provided by the IPCC (2006) guidelines:

$$C = AGB * (1 + R) * CF \tag{2}$$

where:

C - carbon stock expressed in tones;

AGB—above-ground biomass expressed in tones.

R - root to shoot factor, dimensionless;

CF—carbon fraction.

We used a default factor for carbon fraction of 0.5 (IPCC, 2006). The carbon amount was transformed to CO_2 and expressed in metric tons, which was then multiplied by the pre-established reference value of 42.05 €/tCO_2, which represents the average market value of CO_2 at the time the study was conducted to evaluate the monetary values of existing carbon stock.

For valuing non-woody products, such as medicinal plants and berries, we relied on a methodology guided by expert studies (INCDS Marin Dracea, 2020a,b). This approach establishes permissible harvesting quantities based on forest types (**Table 2**). To assign monetary value to medicinal plants and berries, an average price was applied—0.76 euro/kg for medicinal plants and 0.80 euro/kg for berries—representing reference prices excluding exploitation, packaging, and transport costs (Statistics, 2019).

2.2.4 Descriptive statistics

The statistical parameters to describe both Monetary and Non-monetary values were calculated utilizing the R PASTECS package available in R software (Grosjean and Ibanez, 2004). In the context of ecosystem service valuation, the application of statistical metrics serves the purpose of providing a succinct overview and assessing the quality of monetary and non-monetary values, thereby increasing transparency and even facilitating informed decision-making.

2.2.5 PCA assessment

The Principal Component Analysis (PCA) method was utilized to reduce the dimensionality of the datasets and gain a more detailed visualization (Mudrov and Proch, 2005; Greenacre et al., 2022). The R packages used for this analysis include *corrr* (Kuhn et al., 2020), *ggcorrplot* (Kassambara, 2022), *FactoMineR* (Lê et al., 2008), and *factoextra* (Kassambara and Mundt, 2020) from the R studio application (R Core Team, 2023). In more specific terms, it can be defined that the "corrr" package allows exploration of correlations, "ggcorrplot" facilitates the visualization of correlation plots, "FactoMineR" performs factor analysis and PCA, while "factoextra" aids in extracting and visualizing multivariate analysis results in R.

The PCA analysis utilized primary data from management plans, including stand productivity, density, slope, altitude, flora type, age, annual growth, and volume. Additional data, such as carbon stock and monetary and non-monetary values, were incorporated. Areas in imagery data were digitized using GIS. Qualitative results from social media and Kernel interpolation were compared with monetary valuation at the management unit level. All datasets were standardized using R packages and visually represented. The study employs both monetary and non-monetary methods to offer a comprehensive understanding of ecosystem service values. Valuing services from ordinary people's perspectives through non-monetary methods provides insights into social values. The research assesses the reliability of a hybrid method combining both approaches, contributing to the discourse on comprehensive ecosystem service valuation. A mixed-methods approach combines quantitative monetary analysis with qualitative non-monetary analysis, emphasizing the need for a combined view in forest policy (Krott, 2005). Incorporating qualitative data into decision-making processes, as suggested by (Kenter, 2018) and (Maca-Millán et al., 2021) has proven to be effective. This approach involves meticulous data preparation, using quantitative facts presented in summary tables and graphical representations to emphasize key points, especially as policy-briefs for decision-makers. The use of inferential statistics goes beyond raw data to explore investigative questions based on hypotheses (Smith et al., 2011). The study's findings provide reasonable arguments for policymakers, land managers, and stakeholders involved in park management, emphasizing the importance of combining factual and value judgments for effective problem-solving.

3 Results

3.1 Non-monetary valuation

The photographs extracted from the Flickr proxy were used to represent five distinct groups of ecosystem services, namely aesthetic, existence, land use/land cover, intellectual, and recreational services, as depicted in **Figure 2**.

It should also be mentioned that using Kernel analysis, each management unit in the research area has been assigned a kernel value (score) for non-monetary services.

Since the non-monetary methods have shown a significant increased use in scientific research as compared to the monetary ones, the results in this study reveal high preferences toward the

TABLE 2 Quantity of herbs/berries that can be harvested according to the type of forest (dry quantity expressed in kg/hectare) (INCDS Marin Dracea, 2020a,b).

Forest type	Herbs		Berries	
	Scientific name	Dry quantity	Scientific name	Dry quantity
Spruce	*Sambucus nigra*	48	*Vaccinium myrtillus*	200
	Vaccinium myrtillus	180	*Vaccinium vitis idaea*	100
	Arctium lappa	3.8	*Rubus idaeus*	100
	Taraxacum officinale	0.6	*Rubus fruticosus*	100
Beech	*Achillea millefolium*	0.207	*	*
	Equisetum arvense	2.14	*	*
	Primula officinalis	3.2	*	*
	Hypericum perforatum	3.89	*	*
	Taraxacum officinale	5.4	*	*
	Urtica dioica	9.69	*	*
	Sambucus nigra	9.31	*	*
	Vaccinium myrtillus	29.87	*	*

*No information was available.

aesthetic and existence ecosystem services, as well as land use/land cover (Figures 2A–C). The graphic representation of the most considered non-monetary ecosystem services has shown that they generally overlap in the north part of the National Park in the case of each service. The overlapping is more visible in the case of intellectual, recreational, and land use/land cover ecosystem services.

To this matter, these respective ecosystem services were classified into 5 importance classes, using the kernel function in ArcGIS, resulting in a combined reliable value of them.

According to the Kernel Function classification of the ES, the average combined percentage cover is around 9% in the case of the classes 3–5 (moderate, high, and very high), while in the case of the classes very low and low, respectively, 1–2, the average combined percentage cover falls just a bit under 36% from the total area.

In the case of aesthetic services, the coverage is rather low, most of it being situated in the northern part, covering 14% of the total area of Piatra Craiului National Park from the Southern Carpathians Mountains, the rest being of low interest, especially on 75% coverage in the south of the mountains. Nevertheless, such ecosystem services are predominantly located in the main tourist sites within the area, strategically positioned along the frequently visited tourist routes, and with information easily accessible through online platforms (Figure 2A). Additionally, locations featuring caves or canyons (e.g., Zarnestiului canyon) are highly sought after and greatly appreciated by visitors, due mostly to their scenery and accessibility.

Similar Kernel function coverage can be found in the case of existence services (Figure 2B) where most of its importance is located in the Northern part as well, covering almost 18% of the total area of the park while the remaining area being taken as granted by observers, under the presupposition and believe that the right to nature is equal with other fundamental rights.

Closely related to other services, intellectual (Figure 2D) and recreational (Figure 2E) services cover similar percentages of the total of the park, the former accounting for barely 35% while the latter just topping 24%, perceived to express the low interest in such values of the community and society as a whole.

According to graphical representation, it was found that the most valued services are located in the northern part of the research area, grouped into four cores. The respective cores are close to the main infrastructure road network, allowing fairly easy access to the forest, a fact that might have motivated users to express their interests in such core areas.

For valuing *Natural Capital between currency and intrinsic appraisal*, the multidisciplinary approach was used to provide the reliable outcomes for monetary valuation. The analysis is carried out with high respect to the comprehensive methodology on ecosystem service provision. Monetary values are expressed in euros for each case of provisioning service. The monetary values are represented in fact by: the volume of harvestable wood, stored carbon, harvestable medicinal plants, and harvestable berries, whereas the non-monetary values foresee the cultural ecosystem service categories (aesthetic, existence, land use and land cover, intellectual, and recreational services). Moreover, through the use of Geographic information system (GIS), the values were analyzed and displayed graphically by means of a thematic map (Figure 3A), in which the summed values of these monetary services have been plotted in relation to their geographically referenced information. Simultaneously, non-monetary values, expressed as the sum of Kernel scores, were graphed to illustrate the ecosystem services of existence, aesthetic, recreational, intellectual, and land use/land cover (Figure 3B) for the purpose of comparison.

Thus, for the forests in Piatra Craiului National Park, a value of 2.6 million euros was determined for the harvestable wood, and the value of the carbon stock was 49.7 million euros. Following the application of the methodology for determining the production capacity of medicinal plants and forest fruits in relation to the types of forest, a value of 71 thousand euros and 17 thousand euros was determined. The total value of all these monetary services was 53.2 million euros, calculated with prices at the time of the research in the year 2021. Figure 3A displays a few regions where the

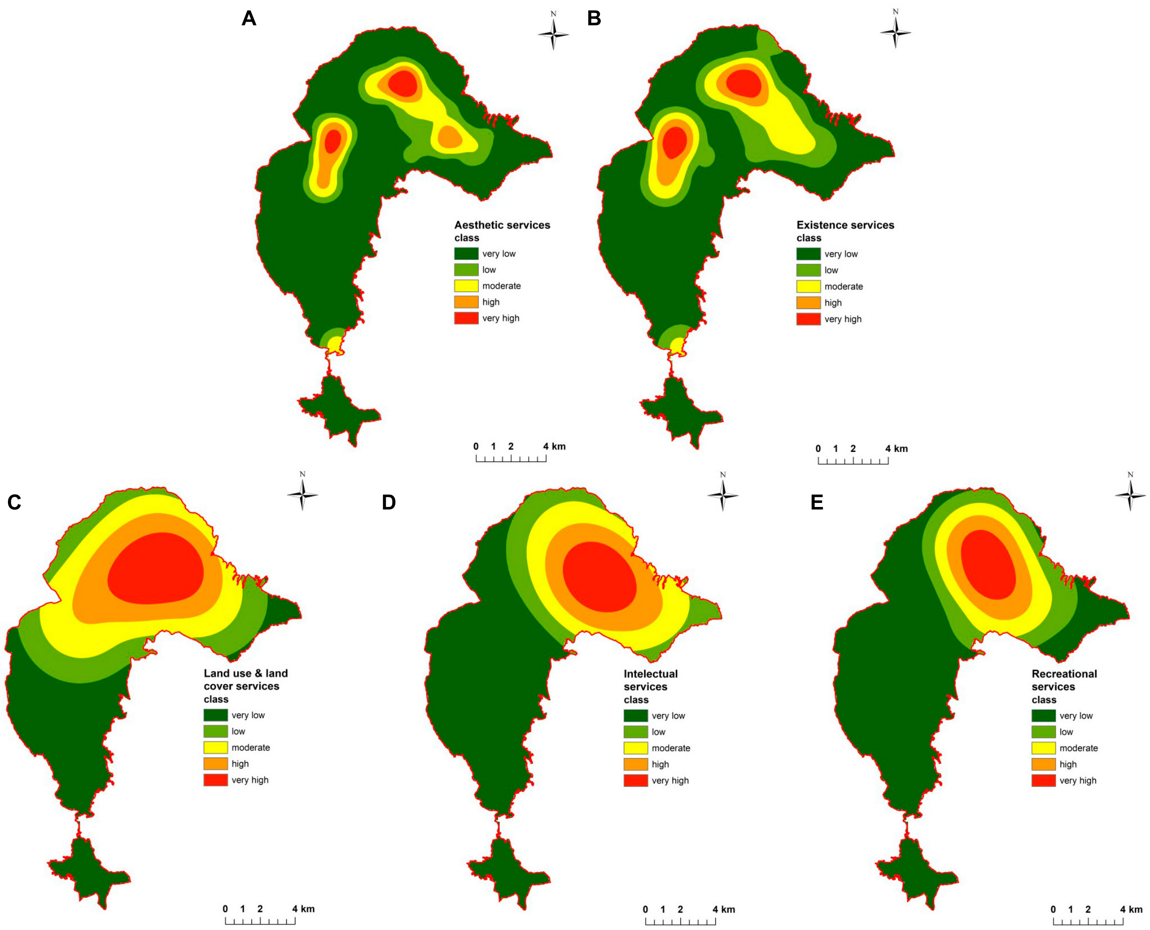

FIGURE 2
Map of Non-monetary valuation [**(A)** aesthetic services, **(B)** existence services, **(C)** land use/land cover services, **(D)** intellectual services, **(E)** recreational services].

monetary value of ecosystem services surpasses 400 thousand euros (evidenced by the red color). These areas predominantly consist of old-growth forests with substantial wood volume, covering extensive plots (more than 30 hectares). Generally, the distribution of monetary values remains consistent across the entire survey area, with the exception of a few "white" areas. These "white" areas represent locations devoid of forest vegetation, such as cliffs and mountain hollows, which were excluded from our analysis.

Forested areas were classified into five importance classes using the kernel function in ArcGIS, resulting in a combined value of them, and after the graphical representation, it was determined that the most important of them are located in the northern part of the research area (Figure 3B), grouped in four cores.

As it is well known, an ecosystem can provide several ecosystem services at the same time, as seen in this research, where more than 2400 records of ecosystem services provided by forests in Piatra Craiului National Park were found. About 25% of these were existence ES, 29% aesthetic ES, 3% recreational ES, 11% intellectual ES and about 32% land use/land cover ES.

For exploring the relationship between currency and intrinsic values, a correlation matrix of the parameters analyzed in this study was built that reveals some significant associations among the variables (Figure 4).

The highest correlation is observed between monetary values, stand volume (0.87), and carbon stock (0.92). This strong correlation is expected, given that wood can be rapidly capitalized, making it economically important in the short term. We also found notable negative correlations between stand productivity and slope (−0.41) and altitude (−0.32), indicating that accessibility and climatic conditions can be limiting factors for forest productivity.

Furthermore, the correlation analysis revealed weak relationships between several variables, including age and slope (0.22) and stand density and productivity (0.17). In addition, the correlation matrix analysis shows a weak correlation between non-monetary values and altitude (0.24), slope (0.14), and age (0.14).

Based on the aforementioned methodology, we also explored the relationship between non-monetary and monetary values. The correlation coefficient of −0.055 indicates a lack of a significant linear relationship between these variables. As expected, we did not identify robust correlations, as there is no direct causality between monetary and non-monetary factors, nor between provisioning, regulating, and cultural ecosystem services.

Due to the lack of strong correlations found between monetary and non-monetary values, we do not have sufficient evidence to make robust predictions or draw significant conclusions.

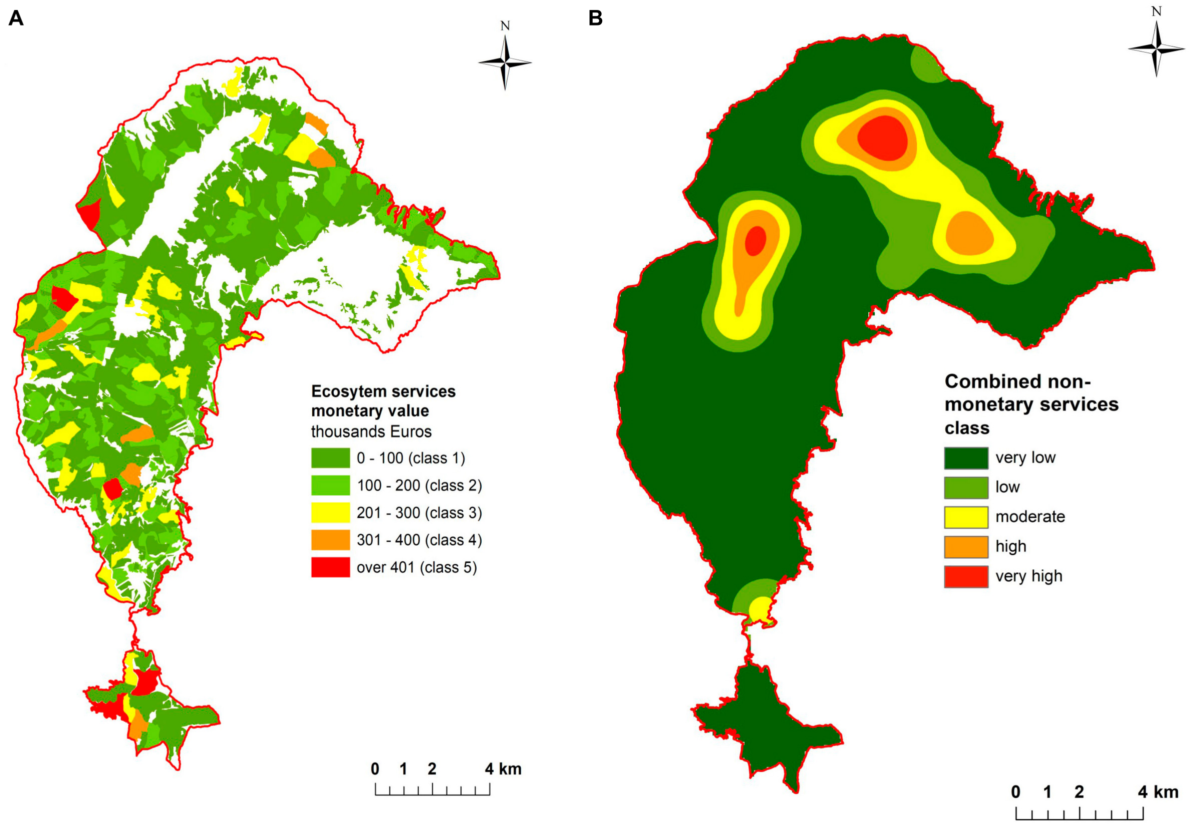

FIGURE 3
Compared monetary and non-monetary evaluation [**(A)** monetary evaluation, **(B)**- non-monetary evaluation summarized].

Therefore, further investigation and consideration of other factors are necessary to gain a more comprehensive understanding of the relationships between these variables.

The examination of the primary statistical indicators for both monetary and non-monetary values of selected ES reveal a substantial amount of data for both types of assessments (Table 3). The minimum value for monetary valuations is 34 euros, while for non-monetary valuations, it is 1 (kernel score). On the upper end of the scale, the maximum values slightly surpass 570 thousand euros for monetary valuations and 5 (kernel score) for non-monetary valuations. The average for monetary valuations exceeds 47 thousand euros, whereas for non-monetary valuations, the average stands at 1.38 (kernel score).

The significantly high standard deviation values reflect a high level of variability in the monetary values across the research area. In contrast, the standard deviation for non-monetary valuations indicates a more moderate level of variability in the dataset. Furthermore, the coefficient of variation reveals very high values, emphasizing the pronounced variability in both the monetary and non-monetary values of ES.

Considering the absence of strong correlations between monetary and non-monetary relationships, we pursued a *Principal Component Analysis (PCA)* as the next step. PCA analysis (Figure 5) was employed to reduce data dimensionality while retaining a substantial portion of the variance. According to PCA analyses, the first two dimensions explained 43.3% of the total variability. The first component (Dim 1) accounts for 26.5% while the second component (Dim 2) accounts for 16.8%.

In PCA analysis, the first dimension of the data is represented by a linear combination of the monetary value, carbon stock, and stand volume (Figure 5). Also, the uniform angle index between them indicates a maximized variance, suggesting that they are well-distributed and effectively contribute to the formation of the first principal component.

The total variance of the second principal component exhibits positive loadings for slope, altitude, age, and non-monetary value. On the other hand, stand density, stand productivity, type of flora, and annual stand growth have negative loadings in Dim 2. This means that higher values of these variables are associated with lower values of Dim 2.

The absence of correlation between monetary-related values loaded by Dim 1 and the second principal component related to aesthetic or cultural aspects (Dim 2) suggests that Dim 1 and Dim 2 represent distinct patterns of variability in the data. This highlights the independence of the two principal components based on the information analyzed in the present study.

4 Discussion

The values provided by ecosystem services play a crucial role in fostering awareness within society (Daily et al., 2009; Badea et al., 2013; Kosanic and Petzold, 2020; Tsirintanis et al., 2022). To achieve

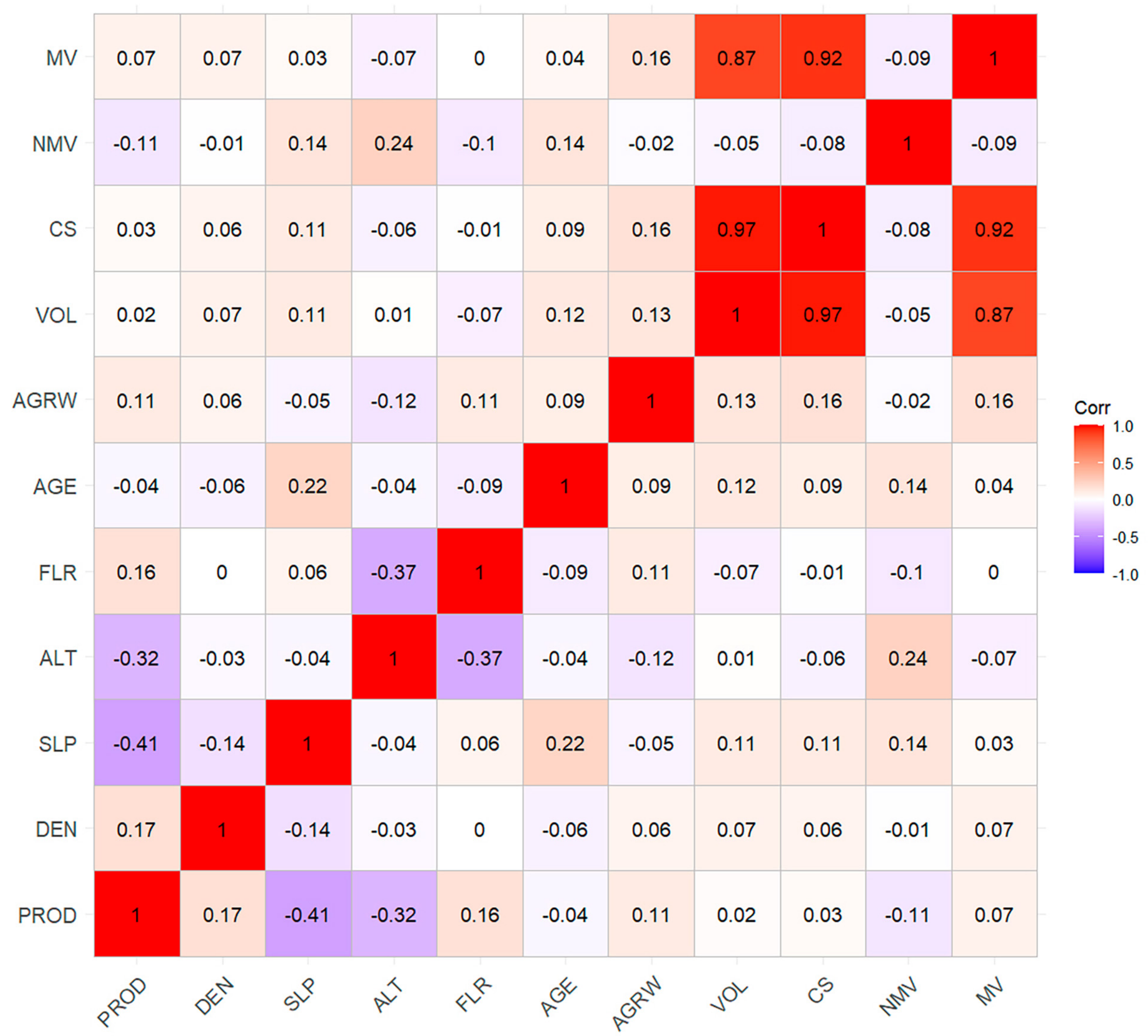

FIGURE 4
Correlation matrix of main variable PROD, stand productivity; DEN, stand density; SPL, slope; ALT, altitude; FLR, type of flora; AGE, stand age; AGRW, annual stand growth; VOL, stand volume; CS, carbon stock; NMV, non-monetary value; MV, monetary value.

TABLE 3 Descriptive statistics of type of valuation method.

Type of evaluation	No. val.	Min.	Max.	Mean	(s)	(s%)
Monetary values	1127	34	571521	47230	67052.40	141.90
Non-monetary values	1127	1	5	1.38	0.86	61.95

(No. val -number of samples, Min–minimum value of monetary evaluation) (expressed in Euro/management unit) and minimum value of non-monetary evaluation (expressed in Kernel score/management unit), Max–maximum value of monetary evaluation (expressed in Euro/management unit) and maximum value of non-monetary evaluation (expressed in Kernel score/management unit), Mean–average value of monetary evaluation (expressed in Euro/management unit) and the average value of non-monetary evaluation (expressed in Kernel score/management unit), (s)–standard deviation value of monetary evaluation (expressed in Euro) and standard deviation value of non-monetary evaluation (expressed in Kernel score), (s %)–coefficient of variance of monetary evaluation (expressed in Euro) and coefficient of variance value of non-monetary evaluation (expressed in Kernel score).

this, a comprehensive and multidimensional approach is essential. This involves integrating social science methods with GIS analysis and statistics to make informed decisions (Apostol et al., 2018; Cabana et al., 2020), especially for policy-makers (Jones et al., 2022).

Given the challenge of economically assessing non-monetary services, the study employed a combination of the "document method" and the "social media-based method" (Cheng et al., 2019). By examining revealed preferences through images and other materials, along with structured identification of ecosystem services using Flickr uploaded images, qualitative insights were captured (Donaire et al., 2014; Barchiesi et al., 2015; Hartmann et al., 2022).

The research identified strong preferences for aesthetic, existence, and land use/land cover ecosystem services in the northern part of the National Park. The reason behind the popularity of the northern area lies in its strong appeal to tourists due to the abundance of natural monuments. This can be

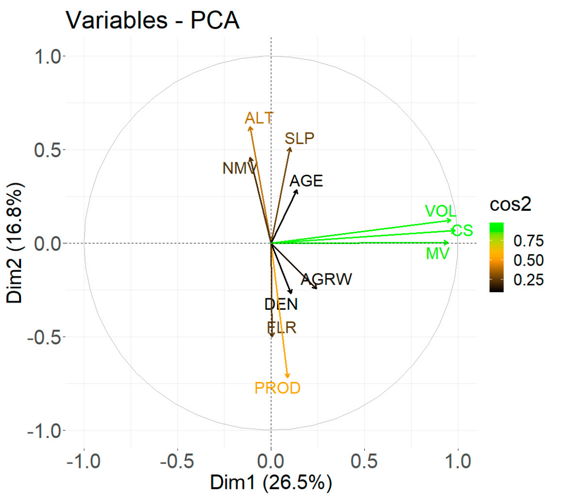

FIGURE 5
Principal component analysis PROD, stand productivity; DEN, stand density; SPL, slope; ALT, altitude; FLR, type of flora; AGE, stand age; AGRW, annual stand growth; VOL, stand volume; CS, carbon stock; NMV, non-monetary value; MV, monetary value.

attributed to the region's excellent accessibility, thanks to numerous access roads and well-established tourist trails. Additionally, its proximity to larger towns further enhances its attractiveness as a tourist destination.

These services were highly valued by visitors for their scenic beauty and accessibility (Parga-Dans et al., 2020; Yang et al., 2022). The Kernel distribution provided insights into the varying degrees of importance and perceived value of different ecosystem services across the research area.

Although recreational and intellectual ecosystem services were less identified by experts (Paracchini et al., 2014; Inácio et al., 2022), their overlapping with other non-monetary forest ecosystem services suggests the complexity of ecosystems (Christie et al., 2012; Raihan, 2023) as a whole. Benefits for recreation were highly correlated with aesthetic and intellectual values (Calcagni et al., 2022) and diverse land use services. This highlights the societal valuation of ecosystem services in the context of climate change and the importance of nature (Daily, 1997; Hermann et al., 2011; Costanza, 2020; Weiskopf et al., 2020).

Also, the identification of substantial monetary values linked to diverse forest-related services in Piatra Craiului National Park is vital for evidence-based decision-making (Maes et al., 2012), public awareness (Acharya et al., 2019), guiding sustainable environmental management practices (Meraj et al., 2022), and fostering a deeper understanding of the economic significance of nature's contributions to society (Sangha et al., 2019). It provides a robust foundation for interdisciplinary approaches to conservation and land-use planning (Delgado-Aguilar et al., 2019; César et al., 2021), encouraging the adoption or redistribution of responsible policies and actions to protect priceless natural assets and promote biodiversity conservation on a broader scale (Ola and Benjamin, 2019).

The analysis revealed significant variability in both monetary and non-monetary valuations of ecosystem services (Martin and Mazzotta, 2018; Torres et al., 2021). This wide range of values reflects the diverse economic and non-market attributes associated with these services, a situation also found in state forest institutions, where there is a high discrepancy between policy goals formulated in official documents and their on-field fulfillment, many focusing on economic terms rather than non-monetary services (Chudy et al., 2016; Romanazzi et al., 2023). To make well-informed decisions about ecosystem management and conservation, it is vital to consider both monetary and non-monetary aspects (Wanek et al., 2023).

Using correlation matrix analysis, we thoroughly examined the relationships between monetary and non-monetary valuations of ecosystem services. The results indicated a lack of notable connections between these two types of valuations (Acharya et al., 2019; Taye et al., 2021). This observation can be attributed to several factors, including the intricate nature of ecosystem services, making it challenging to precisely quantify their economic value. Additionally, the subjective aspects involved in non-monetary valuations, such as perceptions and preferences of different individuals and communities, contribute to the disparities (Czembrowski et al., 2016). Furthermore, diverse perspectives and purposes from stakeholders involved in the evaluation process can lead to contrasting assessments (Gos and Lavorel, 2012; Vallet et al., 2018; Aryal et al., 2022). Methodological challenges in quantifying and comparing both monetary and non-monetary values also play a significant role in the observed disconnection between these two evaluation approaches.

Our research revealed strong associations between certain variables (monetary value with carbon stock and stand volume), moderate connections (slope with stand productivity), and weaker relationships (non-monetary value with altitude, age with slope, type of flora with altitude, and altitude with stand productivity). This week correlation suggest that mature ecosystems located at higher altitudes are more likely to be positively appreciated by tourists.

These unexpected findings provide valuable insights into ecosystem dynamics and offer important guidance for developing more effective, integrated and sustainable natural resource management policies and practices. Understanding these intricate interrelationships empowers us to enhance our understanding of ecosystems and undertake appropriate and custom-tailored decisions to protect and preserve the environment.

The finding of the Principal Component Analysis (PCA) highlights the independence of monetary and non-monetary values, offering crucial insights into the complex interplay of ecosystem variables, guiding future research for comprehensive ecosystem management and conservation strategies.

While the study offers valuable insights, it has certain limitations. Conducted within a national park, the research's small geographic area may limit generalizability to larger regions or different ecosystems. Quantifying non-monetary values remains challenging due to their subjective nature (Hammermann and Mohnen, 2014; Márquez et al., 2023). The non-monetary valuation approach employed captures qualitative insights but lacks straightforward conversion into monetary values (Christie et al., 2012; Scholte et al., 2015; Hardy et al., 2022).

Despite these limitations, the study has notable strengths. It utilized accurate and reliable field data, ensuring credibility in the monetary valuation results. Additionally, the inclusion of perspectives from ordinary people visiting the park enhanced the non-monetary valuation component. The hybrid approach combining monetary and non-monetary methods allowed for a more holistic understanding of ecosystem services' value (Dunford et al., 2018; Cazacu et al., 2020) and the importance of enhancing, preserving and listening to local communities' wisdom. By capturing the perspectives and preferences of ordinary people, decision makers can align management strategies with stakeholder expectations, fostering a sense of ownership and stewardship.

This research holds practical implications for decision-making in ecosystem management and conservation. By considering both economic and non-economic dimensions, decision-makers can formulate proper policy instruments for well-informed choices (Campbell, 2020) that balance sustainability and societal needs. The methodology used in this study can be valuable for assessing cultural ecosystem services in regions with limited data and challenging field accessibility. Also, the multidisciplinary approach employed in this study demonstrates the potential for a more comprehensive and integrated evaluation of ecosystem services.

Therefore, this study, with its strengths and weaknesses, enhances our comprehension of ecosystem services within a national park context, and beyond. The findings have significant implications for stakeholders and decision makers, empowering them to advocate for conservation, align management strategies with stakeholder preferences, and promote sustainability under a circular economy. Future research should address valuation method limitations to achieve a more comprehensive and integrated approach to ecosystem service assessment.

5 Conclusion

This research provides valuable insights into the valuation of ecosystem services through the integration of monetary and non-monetary valuation methods. By examining a specific national park, this study sheds light on the economic and non-economic dimensions of ecosystem services, contributing to a comprehensive understanding of their value.

While the size of the study may limits its applicability, the robustness of the findings is strengthened by the accurate and reliable field data collected, thus minimizing this limitation. The utilization of actual data from forest management plans and the inclusion of grassroots perspectives ensures a more accurate on-field representation of the monetary and non-monetary values associated with ecosystem services.

The adoption of a hybrid approach that combines monetary and non-monetary valuation techniques presents a practical advantage. This integrated approach allows decision makers to consider both the economic and non-economic benefits of ecosystem services, enabling them to make more informed choices that balance environmental sustainability with social and economic needs.

The findings of this research have important implications for stakeholders and decision makers involved in the sustainable management and conservation of natural resources. The economic valuation results serve as a compelling argument for the preservation and sustainable management of national parks and other natural areas. They provide quantifiable information that can be integrated into cost-benefit analyses and policy-making processes.

In conclusion, this research contributes to the ongoing discourse on the evaluation of ecosystem services by providing insights into the economic and non-economic dimensions of their value. Future research should continue to address the limitations of valuation methods and strive for a more comprehensive and integrated approach to ecosystem service assessment.

Data availability statement

The datasets presented in this article are not readily available because datasets belong to the host institution. Requests to access the datasets should be directed to not applicable.

Author contributions

SC: Visualization, Writing – review and editing, Formal Analysis, Funding acquisition, Investigation, Project administration, Resources, Software, Supervision, Validation, Writing – original draft, Conceptualization, Methodology. MH: Methodology, Validation, Writing – original draft, Writing – review and editing, Conceptualization, Visualization. DP: Funding acquisition, Investigation, Methodology, Project administration, Resources, Visualization, Writing – original draft. AL: Conceptualization, Data curation, Formal Analysis, Methodology, Software, Validation, Visualization, Writing – review and editing. LM: Formal Analysis, Software, Visualization, Writing – review and editing. SL: Supervision, Visualization, Writing – review and editing. RR: Data curation, Funding acquisition, Project administration, Resources, Visualization, Writing – review and editing. RC: Investigation, Methodology, Writing – review and editing. AD: Methodology, Software, Visualization, Writing – review and editing. IP: Data curation, Formal Analysis, Software, Writing – review and editing. CM: Data curation, Investigation, Writing – review and editing. MV: Funding acquisition, Investigation, Project administration, Resources, Supervision, Writing – review and editing. CV: Data curation, Investigation, Resources, Writing – review and editing. TR: Data curation, Investigation, Visualization, Writing – review and editing. OB: Funding acquisition, Project administration, Resources, Supervision, Writing – review and editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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