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Research Article

Sharing or sparing? An analysis of the forest owners' opportunity costs in cultural ecosystem services accounting for the Via Transilvanica outdoor recreational trail

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Abstract

Outdoor recreation is one of the most relevant cultural ecosystem services provided by the Romanian forests. The Via Transilvanica (VT) is Romania's longest marked hiking trail, stretching over 1,400 km from the Danube coast to the Carpathian peaks. Similar to famous routes like the El Camino, it offers diverse landscapes and can be completed in 14 stages, each lasting 3-4 days, on foot, by bicycle, or horseback. The trail has important natural and social impacts, emphasizing the need for environmental preservation. A pilot study was conducted along a trail in 137 km across Bucovina region that accounted for 3699 hectares of forests. The analysis explores three policy scenarios based on land sparing and land sharing frameworks: the first scenario involves complete segregation of forests with high social value (set-aside); the second integrates forest regeneration through active harvesting while protecting forests for social purposes (soft land sparing); and the third focuses on creating buffer zones around the VT trail (strong land sharing approach). Each scenario presents a distinct approach to balancing conservation and social needs. The opportunity cost is calculated from the forest owners' perspective, considering the planned works and timber extraction volumes obtained from the FMPs for each parcel. The opportunity cost calculation showed that the set-aside scenario incurs the highest opportunity cost of an annual value of €1.2 million for the entire assessed area while soft land sparing translates to €0.8 million per year. The cost of establishing buffer zones ranges from €14,000 to €59,000 per year, depending on the zone's width. The study identifies the advantages and shortcomings of each scenario, highlighting the need for a flexible and adaptable management strategy. The study emphasizes the main criteria for a sound, data-driven decision-support system to manage forests with high socio-cultural values taking into account both environmental and economic aspects, as well as the needs of forest owners, local communities, and tourists. Further research is needed as to identify the overall opportunity costs of the three scenarios considering the potential economic benefits of the VT trail at the community level.

Keywords: cultural ecosystem services; decision support system; forest management; land sparing; outdoor recreation

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Introduction

European forests offer benefits to society, considering that they are managed for multiple uses (Forest Europe, 2020). One of these benefits is outdoor recreation, which has become increasingly popular, especially among city dwellers, over the past ten years (Frick *et al.*, 2018). Forest recreation is evolving, with a growing preference for more active experiences, such as mountain biking and running, compared to the more traditional focus on rest and relaxation (Wilkes-Allemann *et al.*, 2017). The COVID-19 pandemic has substantially increased the interest in outdoor recreation visitations (Ferguson *et al.*, 2022). As increasing people start recognizing the importance about the personal and community benefits of spending time in nature, new fields of research and practice are blossoming. These include "cultural ecosystem services" in economics (Chan *et al.*, 2012) and "nature's contributions to people" in biology. Cultural ecosystem service was defined as "non-material benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation and aesthetic experience" (Millennium Ecosystem Assessment, 2005). Within the cultural services' category, a body of literature has developed around recreation as an ecosystem service (Morse *et al.*, 2022), focused on the natural environment as its foundation, what types of systems, and what components of ecosystems contribute to the provision of recreation opportunities (Hermes *et al.*, 2018).

Outdoor recreation has been specifically assessed and mapped as one of the most relevant cultural ecosystem services that can be provided by the European forests (Paracchini *et al.*, 2014). Outdoor recreation management focuses on balancing two key aspects: ensuring people have a fulfilling experience (meeting their expectations) and minimizing the impact of those activities on both the environment and the forest owners. Although nature-based tourism has gained momentum among forestry strategies in recent years, financial incentives are mostly lacking for private owners who allow recreational activities in their forests (Tyrväinen *et al.*, 2021). For example, in Finland the Landscape and Recreation Value Trade scheme has been proposed, where forest owners could be compensated for improving the provision of landscape and recreation values in their own forests (Tyrväinen *et al.*, 2021).

Assigning specific ecosystem services is central to forest management planning (Uhde *et al.*, 2015). However, the trade-offs between these services and the decision-makers involved in this process remain unresolved in current forest policy (Armatas *et al.*, 2018; Schwaiger *et al.*, 2019). Thus, there is a growing recognition among land managers, environmental groups, and local and state governments that current policies and fundings for outdoor recreation on public lands do not fully address the wide range of benefits and challenges this activity creates (Blahna *et al.*, 2020). At the same time, innovative infrastructure projects in forest areas for recreational purposes pose challenges (e.g., liability and costs issues, conflicts) to the owners and forest managers (Wilkes-Allemann and Ludvig, 2019) and thus projects for establishing trails in forests can be highly contested (Chavez *et al.*, 1993; Wilkes-Allemann *et al.*, 2015). The demand for recreation forest facilities highlights the importance of understanding whether landowners are willing to voluntarily improve the forest landscape for tourism and recreation (Bell *et al.*, 2009; Tyrväinen *et al.*, 2021).

However, management with the purpose to increase outdoor recreation management does not occur in a policy vacuum: European forests aim for a multiple integration of ecosystem services (Forest Europe, 2020) and especially the public forest designated for multiple-use should be managed for many public values (e.g., outdoor recreation, conservation, and resource extraction) that are distributed across the landscape (EC, 2021). Moreover, the EU Biodiversity strategy established clear targets for the protection of biodiversity by setting aside forest areas for biodiversity protection. The Romanian National Forest Strategy 2030 recognizes the EU Biodiversity Strategy as a key driver for including forests with socio-cultural value in protected area targets. Consequently, a recent amendment to the Romanian Forest Code has strictly protected over 20,000 hectares of forests around Bucharest, primarily due to their socio-cultural significance. The only planned measure for these areas is ecological restoration to enhance biodiversity protection.

Growing societal demands for forest ecosystem services are pushing for more conservation areas beyond current national and natural parks. A key governance challenge is whether to integrate functions across the

landscape to balance public values like biodiversity and socio-cultural aspects, or to segregate uses by designating specific areas for activities such as outdoor recreation. This debate mirrors the land sharing versus land sparing discussion (Green *et al.*, 2005; Pichancourt, 2024), which has largely focused on biodiversity (Balmford *et al.*, 2012), with limited application to the provision of recreational services in forestry (Gios and Clauser, 2009).

One main reason stays on the fact that the conventional forest management considers that if the forests is efficiently managed for wood production, all the other ecosystem services will follow (Nocentini *et al.*, 2017; Buttoud, 2000). Built on the theory of wake effect, the multifunctionality paradigm (Kennedy and Koch, 2004) as a variant of land sharing approach, is largely implemented in Romanian forest management. The principle of forest multifunctionality forms the core of forest management planning in Romania. Forest Management Plans (FMPs) act as key instruments, prescribing management operations at the stand level every ten years being mandatory once the first Romanian forest code, dating back to 1881, has been adopted (Duduman, 2019). These plans are mandatory for all public forests and private estates exceeding 10 hectares. The core role of FMPs is to regulate the type of forest ecosystem services provided at the stand level and link them to forest management measures and allowable timber cuts. FES identification relies on the Romanian functional zoning system, currently comprising 87 categories (Ministry of Environment, Water and Forest, 2022). Selection of the specific function at the stand level follows a legal procedure and is not influenced by forest owner's preferences. Recreational activities provided by forests are considered within nine out of the 87 functional categories that a stand may be assigned to fulfil. Examples include stands designated as parks, educational forests, urban forests, forests near tourist resorts or cultural sites, and forests alongside nationally important roads. However, there is no specific category assigned to forests bordering recreational trails. This omission can limit the normative approach for assigning recreational functions to stands near the tourist paths as well as limited possibilities to address specific management measures in the forest management planning process.

Beyond FMPs, information on cultural ecosystem services associated with outdoor recreation facilities can be found in the management plans of nature protected areas (Nichiforel *et al.*, 2021) and through voluntary certification programs (Scriban *et al.*, 2023). Romania's recently approved Forest Strategy 2030 (Romanian Government, 2022) acknowledges the importance of preserving forests with high socio-cultural value. It aims to identify at least 100,000 hectares of such forests by 2030 and thus contributing to the 10% target of strict protected areas set by the EU Biodiversity Strategy. The strategy emphasizes the need for establishing clear criteria for evaluating, mapping, and managing these high-value forests. These criteria should clarify which forests require exclusion from logging while financially incentivizing their owners. This entails introducing payment systems that encourage sustainable forest management and biodiversity maintenance in forests with socio-cultural significance. Promoting these types of forests can be achieved through developing nature-based tourism activities, thereby unlocking economic potential and generating income from tourists.

Forest trails offer a fantastic way to explore the beauty of nature and enjoy some outdoor recreation. Via Transilvanica (VT) is a long-distance trail established in Romania, a concept known and encountered all over the world, whether it be pilgrimage routes such as the El Camino or North American wilderness trails such as the Appalachian Trail. With its more than 1400 km, VT trail is the longest marked hiking trail that crosses Romania from North to South. The natural and social impact is of greatest importance, considering the variations of landscapes from the Danube coast to the Carpathian peaks. The trail can be covered in its entirety or in 14 stages (3-4 days each), on foot, by bicycle or on horseback. VT trail presents a unique opportunity for a large-scale social experiment to analyse and establish criteria for identifying forests with high socio-cultural importance. The trail traverses numerous forest roads that also serve as timber transport routes. The establishment of the trail was not related to previous studies of the forest characteristics or attractiveness for the tourism-based activities, but rather on connecting existing forest roads and trails amongst different geographical regions and sites of cultural importance. According to existing forest legislation (Romanian Parliament, 2008), public access on these roads is restricted. Exceptions are made for recreational, sporting, and tourism activities, requiring consent from the owner (private forests) or administrator (state-owned forests).

Timber harvesting activities along these roads can impede or even block the VT trail. Logging operations inherently involve felling trees, posing safety risks to both workers and the public. Legally mandated signage warning of falling tree hazards must be placed near logging sites, especially crucial around tourist routes with publicly accessible areas. In October 2020, the VT team raised media attention about a tree with the VT logo on it which was marked and felled by the forest owner, highlighting the potential conflicts in the use of the trail and the logging activities in the surrounding stands. Consequently, the project's founders partnered with the National Forest Administration (RNP Romsilva) and the Ministry of Environment, Water and Forests, advocating for the limitation of aggressive logging near the trail and the preservation of trees along the route. Conversely, silvicultural work is necessary to ensure stand stability, particularly for managing young stands. Additionally, these measures aim to address the needs for the industrial timber, but also the basic timber needs of rural communities residing near the trail. Moreover, it could be a stereotype that any trail or cycling/hiking route should cross "untouched" and quiet landscapes. Cultural aspects like grazing, mowing or wood harvesting may represent educational objectives. Therefore, an active debate regarding the management of these high sociocultural value forests is ongoing within the forest policy arena.

Contributing to this debate, this research aims to provide a pilot evaluation of the opportunity costs associated with the stands located along the VT trails in Suceava County, Romania. Thus, the research objectives are: 1) to analyse the characteristics of the stands along the VT trails as outlined in the FMPs; 2) to identify the planned silvicultural works for these stands, and 3) to assess the opportunity costs of transitioning towards stricter management practices, VT adapted. Opportunity cost analysis is a common method for evaluating the potential impact of alternative planning and management decisions on ecosystem service provision (Ruijs *et al.*, 2017). In this study, the opportunity cost will be assessed from the perspective of forest owners, not of the community at large, by comparing the forest owners benefits under the existing functional zoning system with those obtained in three alternative scenarios that involve different levels of management restrictions of the stands in the vicinity of VT trail. The analysis will focus on the economic value of the harvesting volume in the three projected scenario, compared with the value of the harvesting stipulated in the current FMPs.

Materials and Methods

Data collection

The pilot area for this analysis is Suceava County, encompassing the northern section of the trail called Bucovina Via Transilvanica, which stretches for 137 kilometres (Figure 1). This region was chosen due to the availability of FMPs and the presence of ongoing conflicts related to logging activities that have impacted trail usage.

FMPs were used to collect data for the six state forest districts traversed by the VT trail in Suceava County. The FMPs provide information on stand characteristics (e.g., elevation, soil types, slope, aspect, relief) and structure (e.g., composition, age distribution, regeneration type, standing volume, and current annual increment). Additionally, they specify the functions assigned to each stand and the corresponding Management Type Categories (MTCs). The forest management planner plays a crucial role in identifying the specific functions for each stand based on an evaluation of site characteristics and current forest structure. Functional categories are primarily grouped into two main categories: Group I - forests designated for special protection, and Group II - forests managed primarily for timber production. Subgroups within each functional group provide a clearer reference to the specific forest ecosystem services assigned to each stand during the planning process (as detailed in Table 1).

MTCs define the recommended forest management system for each functional category. These categories range from no intervention (MTC 1) to silvicultural systems that allow for a larger scale of forest practices aimed at increasing stand productivity (MTC 6). Based on the assigned MTC, the forest planner

determines the specific silvicultural work required for each forest stand, along with the planned volume of timber to be extracted. Once established in the FMP and enforced with FMP approval by the ministerial order, the MTC system become compulsory for the forest owner and manager.

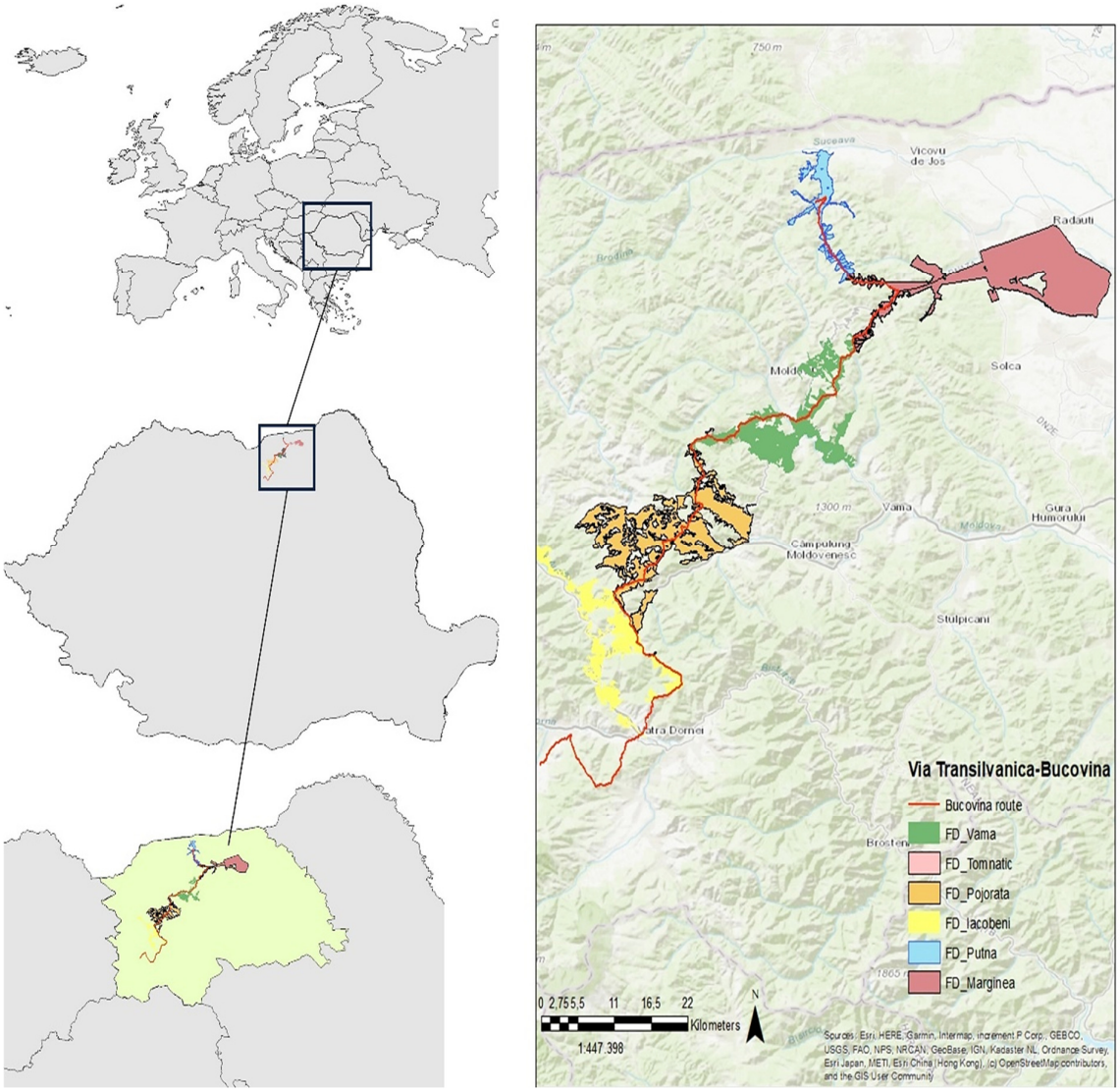

Figure 1. The Bucovina Via Transilvanica route overlaid on the six public forest districts

Geographic Information System (GIS) software was used to collect the data. The VT trail data in shapefile format (*.shp) was obtained from publicly available information on the VT website. This data was then overlaid onto the FMPs available on the public platform "Forest Inspector," provided by the public authority responsible for forest management. Information for each forest district was retrieved from the planning database, focusing specifically on stands located along the VT trail route.

Data analysis

The ArcGIS program was used for data analysis, which involved overlaying the Via Transilvanica route on each forest district and creating an Excel database with the information obtained. The Via Transilvanica

route, in .shp format, was obtained through an agreement between Stefan cel Mare University of Suceava and Tăşuleasa Association, according to a collaboration protocol that supports the objectives of this work. A planning database for the forest District located along the route was also used.

Table 1. Correspondence between type of functions assigned and management types categories

Group	Functional sub-groups	Categories (No)	Management types categories (MTC)
I – Forests providing a special protection role	1.1. Water protection forests	9	MTC 1 - forbids any interventions in the forest ecosystem, including salvage cuttings MTC 2 – conservation works, allowing thin harvests up to 10% of the standing volume MTC 3 irregular shelterwood and single tree selection system MTC 4 uniform and group systems.
	1.2. Fields and soil protection forests	12	
	1.3. Forests with protection functions against climate and industrial harmful factors	14	
	1.4. Forests with social recreational functions	9	
	1.5. Forests with scientific importance for the protection of forest gene pool and ecological diversity	21	
	1.6. Forest with special protection functions for biodiversity conservation	18	
II – Forest with production focus and protection role	2.1. Forest established to produce timber products	4	MTC 5 systems promoting valuable wood assortments (e.g. trees for veneer production) MTC 6 systems promoting common wood assortments (e.g. trees for sawn boards) allowing a larger scale of forest regeneration methods

A dataset was created using remote sensing techniques through the following step i) layers for each stand were loaded separately for the six forest districts: Putna, Marginea, Iacobeni, Pojorâta, Tomnatic, and Vama (Figure 1); ii) for each forest district, a buffer was defined composed from parcels that a) directly intersect the Bucovina VT route, b) are locates at minimum 25 meters from the route and c) are located at minimum 100 meters from the route. The data was then cross-referenced with existing information in GIS databases software on forest management planning. This information included tree species composition, stand structural characteristics, harvesting age, previously executed and proposed silvicultural works, and extraction volumes.

Analysing the centralized data revealed four categories of parcels (Table 2): i) total intersected parcels which includes all parcels crossed by the VT trail, encompassing both forest stands and other land types; ii) parcels with data described in FMPs, implicitly those containing areas with forests; iii) parcels with special designation included in the management planning, e.g. lands for forest administration, forest roads, etc.; iv) privately owned parcels lacking forest management planning data and only containing information related to their parcel origin. Among the 431 forest management parcels, stand-level data was available for 270. The remaining 161 parcels fall into two categories: 60 non-forested areas (roads, constructions) and 101 small private forests lacking data in the FMPs.

In our study, the current forest management is considered to represent a strong land-sharing approach, as far as, except MTC 1, all the other five management types acknowledge the co-existence of multiple protection and production functions for every stand (Ministerial Order 2536, 2022). Based on land sparing versus land sharing potential options in forest management, three scenarios were identified based on existing legal provisions and therefore used to assess the opportunity costs: i) Scenario 1: all stands intersected by the VT trail will be designated as MTC 1, signifying no interventions (and therefore implementing a strong land sparing approach, e.g. set-aside); ii) Scenario 2: all stands that are intersected by the VT trail will be assigned MCT 2 (conservation works, and therefore implementing a soft land sparing approach, e.g. harvesting will continue, but mainly on the purpose of forest regeneration, and sanitation cuttings, as legally set out in the

ministerial order regulating their implementation); iii) Scenario 3: all stands that are intersected by the VT trail will have a buffer zones with no interventions (with two alternatives, a 25 m buffer zone and a 100 m buffer zone along the VT trail). This scenario is supposed to implement a strong land sharing approach, that allows for the continuation of the existing forest management system based on the multifunctional principle in the stands, while providing no intervention zones in the close proximity of the VT trail. The scenarios were created to represent the different policy alternatives: complete segregation, in which no more forestry works are carried-out in the stands intersected by the VT trail (scenario 1), integration of forest regeneration needs with increased recreational use of the forests with high-social values (scenario 2), and integration of current management practices with a reduction of the negative social impact of harvesting in the proximity of the VT trail (scenario 3).

Table 2. Number and area (ha) of forest parcels included in the analysis

Forest District	Total intersected parcels	Parcels with FMP data	Of which no forest land use	Of which in private ownership
Putna	59	49	10	0
	1,021.17 ha	1,013.46 ha	8.31 ha	no data
Marginea	105	70	26	9
	807 ha	795.4 ha	11.6 ha	no data
Iacobeni	29	2	1	26
	3.3 ha	2.12 ha	1.18 ha	no data
Pojorâta	108	51	13	44
	510.08 ha	507.96 ha	8.12 ha	no data
Tomnatic	10	5	1	4
	47.3 ha	47.3 ha	0	no data
Vama	120	93	9	18
	1,353.23 ha	1,333.7 ha	19.53 ha	no data
Total	431	270	60	101
	3,742.08 ha	3,699.9 ha	48.74 ha	no data

Under these three scenarios, the opportunity cost is calculated from the perspective of forest owners. This approach is mainly because the potential economic benefits from tourist activities are most likely visible at the community level and do not directly benefit the primary forest owner (National State Administration). Since the VT trail was recently established, assessing the potential economic benefits at the community level requires further research.

To calculate the opportunity cost from the forest owners' perspective, we have considered the planned works and timber extraction volumes obtained from the FMPs for each parcel. For the third scenario, the buffer zones were designed alongside the VT trails using GIS software. The area of each buffer zone intersecting a specific parcel was then calculated. This area was used as a proportion of the total parcel area to determine the volume of timber that cannot be harvested within the planned harvest volume. Timber prices are those resulting from real public auctions held by the Suceava Forest Department in 2023, with a conversion rate of 1 Euro = 4.96 Ron. The prices refer to standing timber auctions, as this is a usual method of selling timber practiced by the main forest owner (National Forest Administration) and the prices are differentiated by the type of products. The costs of harvesting, transportation, and processing are therefore borne by the harvesting companies and do not impact the profit of the forest owner when using the standing timber selling method.

Results

Stand characteristics along the VT trail

The tree composition of the stands bordering the VT trail reflects the typical mixed forest composition of the Bucovina region, characterized by Norway spruce, beech, and fir (Table 3).

Table 3. Structural and site-specific characteristics of the analysed stands

1. Forest composition											
Spruce		**Fir**		**Beech**		**Various softwoods**		**Various hardwoods**			
2241.66 ha (59.90%)		414.70 ha (11.08 %)		929.51 ha (24.84%)		27.66 ha (0.75%)		75.89 ha (2.02%)			
2. Altitude		Minimum altitude: 540 m				Maximum altitude: 1350 m					
3. Slope											
<5 degrees		**6-15 degrees**		**16-25 degrees**		**26-35 degrees**		**>35 degrees**			
9.2 ha (0.25%)		175.79 ha (4.74%)		2472.97 ha (66.67%)		899.28 ha (24.24%)		946.59 ha (4.08%)			
4. Canopy coverage											
0.1-0.3		**0.4-0.6**				**0.7-0.9**		**1**			
145.23 ha (3.92 %)		583.62 ha (15.77 %)				2935.77 ha (79.32 %)		36.5 ha (0.99 %)			
5. Age structure (years)											
0-20	20-40	40-60		60-80		80-100		100-120		>120	
280.81 ha (7.59 %)	603.37 ha (16.30 %)	897.92 ha (24.26 %)		520.56 ha (14.06 %)		708.19 ha (19.13 %)		488.93 ha (13.21 %)		201.34 ha (5.44 %)	
6. Functional categories											
2.1B	**1.2A**	**1.2B**	**1.2I**	**1.2L**	**1.4E**	**1.4I**	**1.5C**	**1.5G**	**1.5H**	**1.5I**	**1.5M**
2647.32 ha	183.01 ha	43.94 ha	2.3 ha	0.97 ha	13.5 ha	482.94 ha	4.05 ha	64.17 ha	47.7 ha	24.69 ha	186.53 ha
71.53 %	4.94 %	1.19 %	0.06 %	0.03 %	0.36 %	13.05 %	0.11 %	1.73 %	1.29 %	0.67 %	5.04 %
7. Management types categories											
No intervention (MTC I)		**Conservation (MTC II)**				**Even aged forest management (MTC IV and MTC VI)**					
4.05 ha (0.11 %)		315,14 ha (8.52%)				3381.93 ha (91.38 %)					

Note: Functional category codes: i) 2.1B-forest designated for timber production; ii) 1.2A, 1.2B, 1.2I, 1.2L-soil and terrain protection forests; iii) 1.4E, 1.4I-forests with recreational and cultural functions; iv) 1.5C, 1.5G, 1.5H, 1.5I, 1.5M-forests for biodiversity conservation, old-growth stands, or scientific value (Nichiforel *et al.*, 2021)

Spruce is the dominant species, occupying 59.90% of the area, followed by beech at 24.84%. The stands range in altitude from a minimum of 540 meters, where hardwoods are present, to a maximum of 1350 meters, where only pure Norway spruce stands are found. In terms of canopy cover, 80% of the stands meet the optimal management requirements (values exceeding 0.7). The remaining stands have lower canopy cover due to planned forest regeneration works. This is further reflected in the age structure, with 19% of the stands having reached maturity for harvesting. Slope characteristics play a crucial role in harvesting activities. Notably, 95.2% of the parcels are located on slopes exceeding 16 degrees, which can exacerbate soil erosion, particularly on forest trails used for timber harvesting and transportation. Some of these trails coincide with the VT recreational trail, highlighting a potential conflict between forestry activities and recreational use.

Based on the physical and ecological characteristics, FMPs have assigned twelve functional categories to the stands bordering the VT recreational trail. Timber production is the primary function assigned to most stands (71.5%), highlighting the potential economic impact of implementing harvesting restrictions for

recreational purposes. Among the remaining stands with allocated protective functions, biodiversity conservation is the primary goal for 8.3% (functional subgroup 1.5). Soil protection is another crucial function assigned to 6.3% of the stands (functional subgroup 1.2), particularly those located on slopes exceeding 30 degrees. Notably, recreational functions are already integrated into the FMPs for 13.4% of the stands. These include forests surrounding cultural heritage sites (0.36%) and stands situated along highly touristic trails (13.05%).

Analysing the assigned functions, only 0.11% of the study area falls under the "no intervention" category within the FMPs. For 8.52% of the area, minimal intervention conservation works are planned (MTC II). The remaining stands, including those designated for recreational purposes, are managed under the even-aged system, allowing for the planning of silvicultural activities with varying intensity.

Silvicultural interventions conducted before the establishment of the VT trail

The current FMPS analyse silvicultural works applied in the past decade, reflecting the interventions conducted before the establishment of the VT trail (Table 4). Consistent with the age structure, most interventions (46.6% of the area) focused on young stand management, including afforestation, pre-commercial thinning, thinning, and sanitation cuttings. Regeneration cuts were only implemented on 4% of the analysed area. Notably, windstorms heavily impacted the stands along the VT trail, necessitating timber extraction across over 2800 hectares, representing 76% of the analysed area. Consequently, harvesting activities in most stands precede the official designation of the trail (Figures A1 and A2).

Proposed silvicultural works in the current FMPs

The FMPs currently in effect for the stands bordering the VT trail propose silvicultural works based on the assigned functional categories, without yet considering the existence of the trail (Table 4).

Table 4. Silvicultural interventions applied before the VT trail establishment and proposed in the current FMPs

Type of intervention	Area applied (ha)	Share of total (%)	Proposed area (ha)	Share of total (%)
Afforestation, reforestation, seeds care	112.5	2.0	103,5	2.80
Pre-commercial thinning	230.29	4.1	97.21	2.63
Thinning	1 151.34	20.4	1 389.5	37.56
Sanitation cuts	1 114.59	19.7	1 222.59	33.05
Shelterwood regeneration	192.07	3.4	646.87	17.49
Clear cuts	24.88	0.45	100.5	2.71
Conservation felling	2.6	0.05	136.8	3.70
Unplanned wind storm debris	2 814.88	49.88		
Total	5 643.21	100.0	3699.02	100.0

As per the FMPs, 74% of the area is designated for young stand management interventions. These interventions are crucial not only for increasing stand productivity but also for ensuring stand stability and health. Additionally, the smaller tree sizes harvested through these works result in a lower environmental impact compared to harvesting mature stands. On the other hand, these silvicultural interventions are usually planned in the summer and autumn corresponding to the main flux of visitors.

The FMPs propose three distinct regeneration methods for the remaining area. The primary method is shelterwood regeneration, intended for 18% of the area representing 73% of the stands in regeneration phase. This approach involves the gradual removal of the tree canopy to promote existing natural regeneration. The interventions are spread over 15-30 years, fostering the development of structurally diverse stands. Clear cutting, applicable only to pure Norway spruce stands, is planned for 100 hectares (2.71% of the area). Finally,

low-intensity conservation felling is designated for 3.7% of the area with protective functions. This method involves selective removal of trees to maintain the ecological health of the forest.

The planned silvicultural interventions (Figure 2) will have a direct impact on many parts of the Bucovina VT trail especially for the forest districts Putna, Marginea and Vama. Thus, hikers on the VT trail will inevitable encounter harvesting activities along the route.

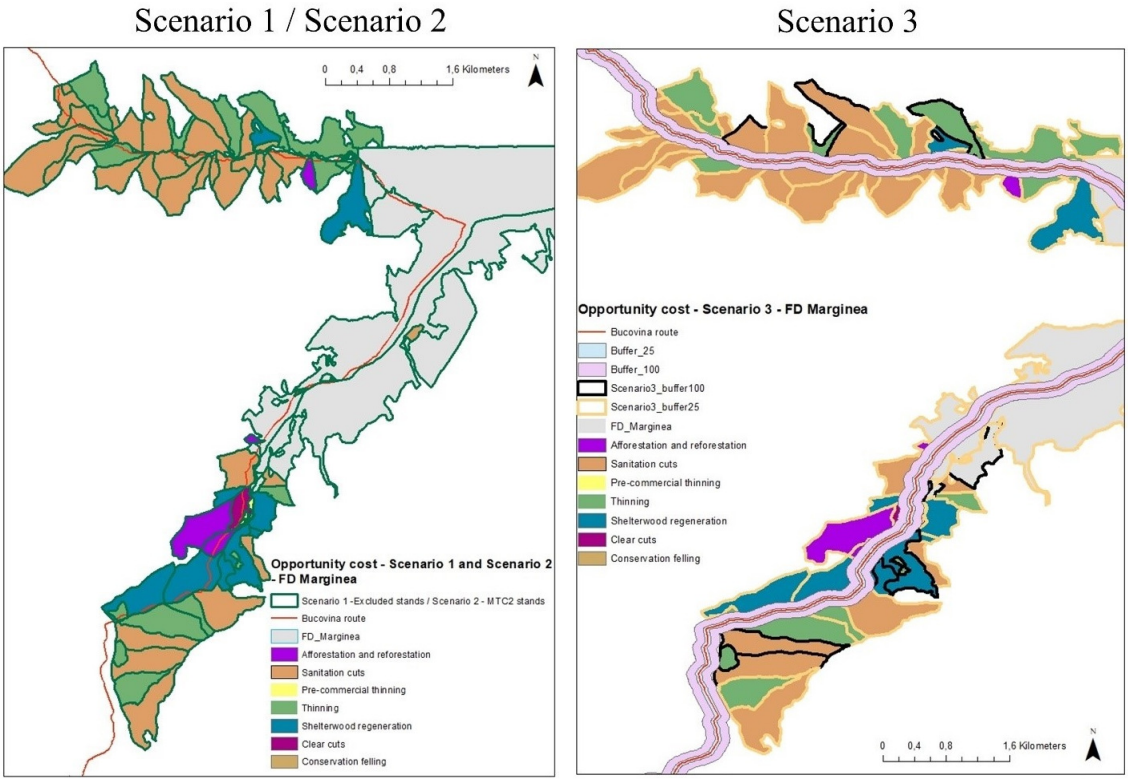

Figure 2. Silvicultural interventions proposed and opportunity cost scenarios – Marginea Forest District

Opportunity cost calculation

Opportunity cost of set-aside scenario

Scenario 1 assumes no harvesting within the forest area surrounding the VT trail. Therefore, the opportunity cost is calculated based on the total volume of timber that could potentially be harvested under this scenario. The data used for this calculation includes the planned harvest volume for each land parcel as recorded in the FMPs and the corresponding silvicultural work type planned for each parcel. Table 5 summarizes the total potential harvest volume under this scenario, amounting to 199,764 cubic meters per decade for the area impacting the VT trail. The stumpage price for timber was set for each type of timber product resulting from the application of the specific silvicultural work.

The results show that the annual opportunity cost of setting aside the stands along the VT trail is €355 per hectare, corresponding to a total annual value of €1.2 million for the assessed area. Stands in the regeneration phase contribute the most to this cost, with a strict protection opportunity cost of €1307 per hectare per year. In this scenario, the reduced impact of harvesting activities will affect 92% of the stands along the VT Trail. Afforestation works, tending of existing regeneration and pre-commercial thinning are still to be applied as they have a minimum impact on recreational activities, yet, they are crucial for establishing new, viable forests. These works bring additional costs on forest managers, which, in the set-aside scenario, cannot be financed anymore from profits made from timber harvesting.

Table 5. Calculation of estimated opportunity cost for set-aside scenario

Silvicultural works	Volume to be harvested (m^3/decade)	Area (ha)	Average selling price (RON/m^3)	Opportunity cost for set-aside	
				EUR/per decade	EUR/year/ha
Thinning	51,038	1,390	200	2,057,984	148
Sanitation cuts	10,295	1,201	200	415,121	35
Shelterwood regeneration	119,816	647	350	8,454,758	1,307
Clear cuts	6,643	38	350	468,760	1,223
Conservation works	11,972	137	300	724,113	529
Total	199,764	3,413		12,120,736	355

Opportunity cost of applying the soft land sparing approach

In the second scenario, the opportunity cost is calculated for the integration of all stands currently included in MTC 4 and 6 into MTC 2 corresponding to the application of conservation works. According to the legal technical provisions, conservation works are meant for maintaining the health and stability of forests and their long-term natural regeneration, by promoting regenerations spots and removing the surrounding trees in a limit of no more than 10% of the existing standing volume per decade (Table 6).

Table 6. Calculation of the estimated opportunity cost for soft land sparing approach

Silvicultural works	Volume to be harvested (m^3/decade)	Area (ha)	Proposed volume in MTC2 (m^3/decade)	Volume difference (m^3/decade)	Average selling price (RON/m^3)	Opportunity cost for conservation	
						EUR/ per decade	EUR/ year/ha
Shelterwood regeneration	119,816	647	10,805	109,011	350	7,692,330	1,189
Clear cuts	6,643	38	880	5,763	350	406,670	1,061
Total	126.459	685	11,685	114,774		8,099,000	1,182

For MTC 2 it is assumed that afforestation works, pre-commercial thinning, thinning, sanitations cuts and conservation cuts for assuring forest regeneration will be performed. Therefore, the reduced impact in harvesting is for the stands that have reached the harvesting age and that will be regenerated by using a lower intervention intensity. The technical norms regulating the application of conservation cuttings limit the intensity of interventions to maximum 10% of the standing volume per decade. The volume used for the calculation of the opportunity cost for conservation results as a difference between the volume proposed to be extracted in FMPs and the reduced volume proposed by the transition to MTC2. The annual opportunity cost of applying the conservation system for the stands along the VT trail is €1,182 per hectare, corresponding to a total annual value of €0.8 million for the assessed area. The value of the soft land sparing approach represents 66% of the opportunity cost of the set aside scenario. Nevertheless, compared with the set aside scenario, the second scenario involves a reduction of the harvesting impact on only 19% of the assessed stands. These stands, that are mainly going to be regenerated by applying the shelterwood system, are those providing the main share of economic value.

Opportunity cost of implementing a stronger land sharing approach

The third scenario proposes a stronger land sharing approach by establishing no intervention buffer zones along the trail, while managing the rest of the stands in the current multi-functionality setting assigned by FMPs. The use of buffer zone near recreational trails is already implemented in practice, particularly within the framework of forest certification programs. The primary functions of the buffer zones along recreational trails are twofold: i) enhanced safety by prohibiting harvesting activities near the trail and minimizes the risk

of accidents for hikers and trail users, and ii) reduced visual impact, as leaving trees standing along the buffer zone helps mitigate the potential negative aesthetic impact of harvesting operations on the recreational experience. In this scenario, trees within the designated buffer zone will be left standing, even if the surrounding area is designated for silvicultural interventions. The width of the buffer zone typically ranges from a minimum of 25 meters (corresponding to the average stand height) to a maximum of 100 meters. The calculated opportunity cost considers these two variations in buffer zone width (Table 7).

Table 7. Estimated opportunity cost for establishing a buffer zone along VT trail

Silvicultural works	Estimated volume to be harvested (m^3/decade)		Average selling price (RON/m^3)	Opportunity cost of the buffer zone (EUR/ per decade)	
	25 m width buffer zone	100 m width buffer zone		25 m width buffer zone	100 m width buffer zone
Thinning	699	3,268	200	28,185	131,774
Sanitation cuts	1,125	4,666	200	45,363	188,145
Shelterwood regeneration	957	3,001	350	67,530	211,764
Conservation cuts	3	1,125	300	181	68,044
Total	2,786	11,060		141,260	599,728

Implementing a 25-meter buffer zone on each side of the VT trail would result in setting aside an area of 139 hectares, representing 3.7% of the total area. A 100-meter buffer zone, in comparison, would require dedicating 610 hectares, or 16.5% of the total area. The annual opportunity cost associated with a 25-meter buffer zone is €14,000 for the assessed area. This cost increases to €59,000 annually for the 100-meter buffer zone scenario.

Discussions

While many studies focus on estimating the demand side for forest ecosystem services (Hochmalová *et al.*, 2022) and recreational activities (Lankia *et al.*, 2020), this study highlights the supply conditions and the trade-offs necessary to balance the application of silvicultural interventions with reducing the negative social impact of harvesting activities and enhancing a positive experience for outdoor recreational activities. With the mandatory application of Forest Management Plans (FMPs) in Romania, requiring detailed stand-level inventory, opportunity cost analysis emerges as a useful tool for the economic valuation of implementing different forest management scenarios. The method's simplicity aligns with recent trends in ecosystem services valuation for decision-making (Primmer *et al.*, 2018). These trends emphasize that simple and well-grounded methods are more useful for assessments (Posner *et al.*, 2016). However, this method's results focus solely on the supply side of the equation, neglecting factors that influence the demand for these services.

The study found that completely separating the functionality of the stands solely to provide cultural ecosystem services through outdoor recreation (set-aside scenario) incurs the highest opportunity cost. This translates to an annual value of €355 per hectare and €1.2 million for the entire assessed area, representing only 10% of the total VT trail length nationwide. From this standpoint, securing recreational activities implies prohibiting harvesting activities in the vicinity of the VT trails. Stopping these activities ensures, in short-term better quality for trails intersecting forest roads currently used for harvesting and timber transportation and in long-term more diverse and structure-rich forests after decades of succession resulting in an increased value of the landscape for tourism. Since accessibility is crucial for participation in active outdoor recreation (Andkjær *et al.*, 2015), stricter forest protection can enhance the recreational potential of the existing network of forest

roads and paths. Economically, the increased recreational potential of the VT trail may be offset by a rise in tourist numbers and economic benefits for the communities along the trail (Ahtikoski *et al.*, 2011).

However, additional to the significant economic impact on forest management, implementing the set-aside scenario faces practical limitations. Firstly, thinning are the most proposed silvicultural interventions in the area and are crucial for managing young stands. Omitting these interventions could negatively impact their stability and structure in the short term. Windstorms frequently affect these stands, as evidenced by the high number of harvesting activities required to remove damaged trees. Secondly, the high likelihood of windstorms in the VT area makes strict protection an unsuitable option. Choosing such a forest landscape (affected by windstorm-destruction) for the VT trail without a preliminary assessment of stand characteristics, limits the representativity of this touristic trail for nature and landscape aesthetics. If the frequency remains consistent with the previous decade, implementing a strictly protected regime will be severely hindered. Removing affected trees is necessary for forest sanitation purposes. Consequently, one potential outcome of strict protection could be the neglect of proper young stand management while still experiencing negative impacts on the trails from harvesting windstorm debris. Thirdly, Romanian rural communities rely heavily on firewood for energy security (Popa *et al.*, 2021). Therefore, including a large area under strict protection could lead to an increase in firewood prices, potentially causing frustration among local communities. Hence, according to the Romanian National Forest Strategy active consultations with local communities strictly depended on forest resources are essential before implementing a strict protection policy (Romanian Government, 2022).

Scenario 2, the forest conservation system, addresses some of these limitations by allowing tending, thinning, and sanitation cuttings to enhance stand stability. Public preferences for forest recreation vary widely (Biber *et al.*, 2021). However, a recurring theme in research (Edwards *et al.*, 2011, Paletto *et al.,* 2023;) suggests that most recreational users favour managed forests. The key is that the management practices should be subtle, leaving the impression of a natural forest. This includes features like a mix of tree species and the presence of large trees. Therefore, implementing forestry interventions for young stand management and low-intensity regeneration systems likely maintains the forest's positive aesthetics for visitors. However, this scenario doesn't guarantee a significant reduction in harvesting activities. Most stands will still require at least one intervention per decade.

Promoting land-sparing over land-sharing logging to provide ecosystem services requires either more stringent government regulation or market-based incentive mechanisms (Bousfield *et al.*, 2021). In our case, the previous two scenarios can be implemented through government decisions. In contrast, the third scenario assesses existing practices voluntarily adopted by forest managers and owners to reduce the negative social impact of harvesting activities. This is particularly relevant for FSC-certified forests, which account for over 30% of Romania's forest area. The FSC forest management standard requires assessing all areas providing cultural ecosystem services and addressing the social impact of harvesting through appropriate measures (FSC, 2019). Consequently, during the identification of high conservation value forests, certified forest managers recognized the social significance of the VT trail and established no-intervention buffer zones (Scriban and Nichiforel, 2021). While buffer zones offer a viable solution for trail sections not used for harvesting (e.g., forest paths), their impact remains limited for sections commonly used in harvesting activities, as these will still occur in the remaining parts of the parcels.

Implementing land sparing policy measures necessitates compensation and payments for ecosystem services type arrangements due to the financial burden placed on forest owners. While the Romanian government offers compensation to private landowners with forests categorized as MTC 1 and MTC 2, the actual value falls short of the opportunity costs calculated for our specific areas. State forests receive no governmental compensation, leaving the National Forest Administration to shoulder the entire financial impact of stricter regulations. New initiatives entailing payments for ecosystem services and ecological compensations placing the costs of conservation on private-sector actors (Muys *et al.*, 2022) can provide an alternative solution to alleviate pressure on the state budget. In our case, leveraging private funding through corporate social responsibility initiatives could help compensate for the opportunity costs associated with

stricter protection or forest conservation. The VT team's success in attracting significant sponsorship for trail development suggests a potential avenue. The next step could involve creating a more positive visitor experience in areas prone to conflicts with harvesting activities by providing financial support for more forest protection.

Over the past 30 years, advanced forest decision support systems have been developed to analyse complex forest management challenges (Vacik and Lexer 2014). However, most of these systems lack the ability to directly model recreational and aesthetic values. To address this gap, a pragmatic approach has emerged that focuses on analysing relevant forest attributes as proxies for these values (Nordström *et al.*, 2019). Our study emphasizes that choosing the appropriate management system should consider forest attributes related to: (i) forest management data on specific site-vegetation conditions, age structure, young stand management requirements, and forest regeneration patterns; (ii) estimation of past and anticipated hazards affecting the forests; and (iii) the importance of the forest in ensuring the crucial needs of local communities for their energy security and traditional uses.

The VT trail presents a valuable opportunity for forest owners, managers, and timber harvesting companies to enhance communication with the general public regarding their activities. On-site communication measures are gaining traction in outdoor recreation management, with research indicating that visitors are more likely to adopt pro-environmental behaviours when messages address psychological factors such as identity, emotions, and social influence (Selvaag *et al.*, 2022). Promoting the role of silvicultural interventions in sustainable forest resource management, which benefits both local communities and society at large, ranked highly among strategic options outlined by stakeholders during the development of the Romanian National Forest Strategy (Romanian Government, 2022).

This pilot case requires further research from the perspective of demand for recreational services, specifically to identify recreational users' satisfaction (or dissatisfaction) with the current situation. This research is crucial to understand tourist preferences regarding encountering harvesting activities along the trails. Reviews of existing studies suggest that preferences related to trails, compared to park-based outdoor recreation, appear to be more diverse and context-dependent (Andkjær *et al.*, 2015). While conflicts between different user groups can arise on trails, the connection to the natural environment and local cultural experiences seem to have a greater influence on people's participation in physical activity than potential conflicts. Gathering empirical data on outdoor recreation can help forest managers make more informed decisions by increasing their awareness of potential conflicts.

Furthermore, we recognize that this analysis presents only the forest owners' perspective on opportunity costs, neglecting the broader community. Due to the VT trail's recent launch, no studies currently quantify its potential benefits. Therefore, future research should complement our findings by estimating these benefits using methods that value cultural ecosystem services like recreation and forest aesthetics (e.g., the travel cost method).

Conclusions

This pilot study provides valuable information on the actual effects of forest management practices outlined in FMPs and recreational activities on the VT trail. Managing the forests near the VT trail requires balancing the economic benefits of forestry with the recreational experience for tourists. Rather than as a tool for balancing ecosystem service provision, the opportunity cost valuation analysis, even though realised solely from the perspective of forest owners, should be promoted as necessary background knowledge for policy-making.

This empirical insight of the study proves that all proposed scenarios, derived from current active policy debates, involve important economic, social, and ecological trade-offs. A strong land sparing approach (set aside) offers the most significant environmental protection by reducing the negative impact of harvesting operations. However, it incurs high costs and limits interventions crucial for forest health. The soft land sparing

approach (forest conservation) allows essential interventions but maintains a high economic impact on forest managers and a constant presence of harvesting activities in the VT trail area. The requirements of the FSC forest management standard offer a compromise in their practical implementation, with buffer zones around the trail minimizing negative impacts on the tourist experience. By being made aware of their importance, forest managers can apply additional measures to reduce the social impact of the silvicultural interventions. These measures include scheduling harvesting activities to avoid peak seasons when visitors frequent the VT trails and providing on-site communication regarding the role of silvicultural operations.

The study highlights that a singular, rigid approach (like set aside) is not suitable for managing the VT trail, especially since its establishment was not based on previous studies related on forest-stands characteristics Instead, a flexible and adaptable strategy that considers both environmental and economic factors, along with the needs of local communities and tourists, is crucial. Achieving a sustainable solution for the VT trail requires a tailored approach that balances the interests of various stakeholders while ensuring the long-term well-being of the forest ecosystem.

Replicating this study across all remaining VT trail regions is essential. Within the Romanian regulatory context, the analysis demonstrated the value of FMPs as a rich data source. FMPs can be used to assess the supply of recreational opportunities and inform simple, decision-oriented opportunity cost analyses. This allows for valuation of the trade-offs between land sparing and land sharing management options. Additionally, research from the perspective of demand is necessary, specifically to understand the attractivity of the trail for visitors, the average duration of visits, the recreational users' satisfaction (or dissatisfaction) with the current forest management practices and, their willingness to pay for improved recreational facilities. This comprehensive approach will lead to the development of a sound decision support system for managing forests with high socio-cultural importance.

Authors' Contributions

Conceptualisation: CT, LN and LB; Data curation: CT and LN; Formal analysis: CT; Funding acquisition: LN; Investigation: CT, LN and LB; Methodology: CT and LN; Project administration: CT, LN and LB; Resources: CT, LN and LB; Software: CT; Supervision: LN and LB; Validation: CT, LN and LB; Visualisation: CT; Writing-original draft: CT; Writing-review and editing: CT, LN and LB. All authors read and approved the final manuscript.

Ethical approval (for researches involving animals or humans)

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Conflict of Interests

The authors declare that there are no conflicts of interest related to this article.

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Appendix A

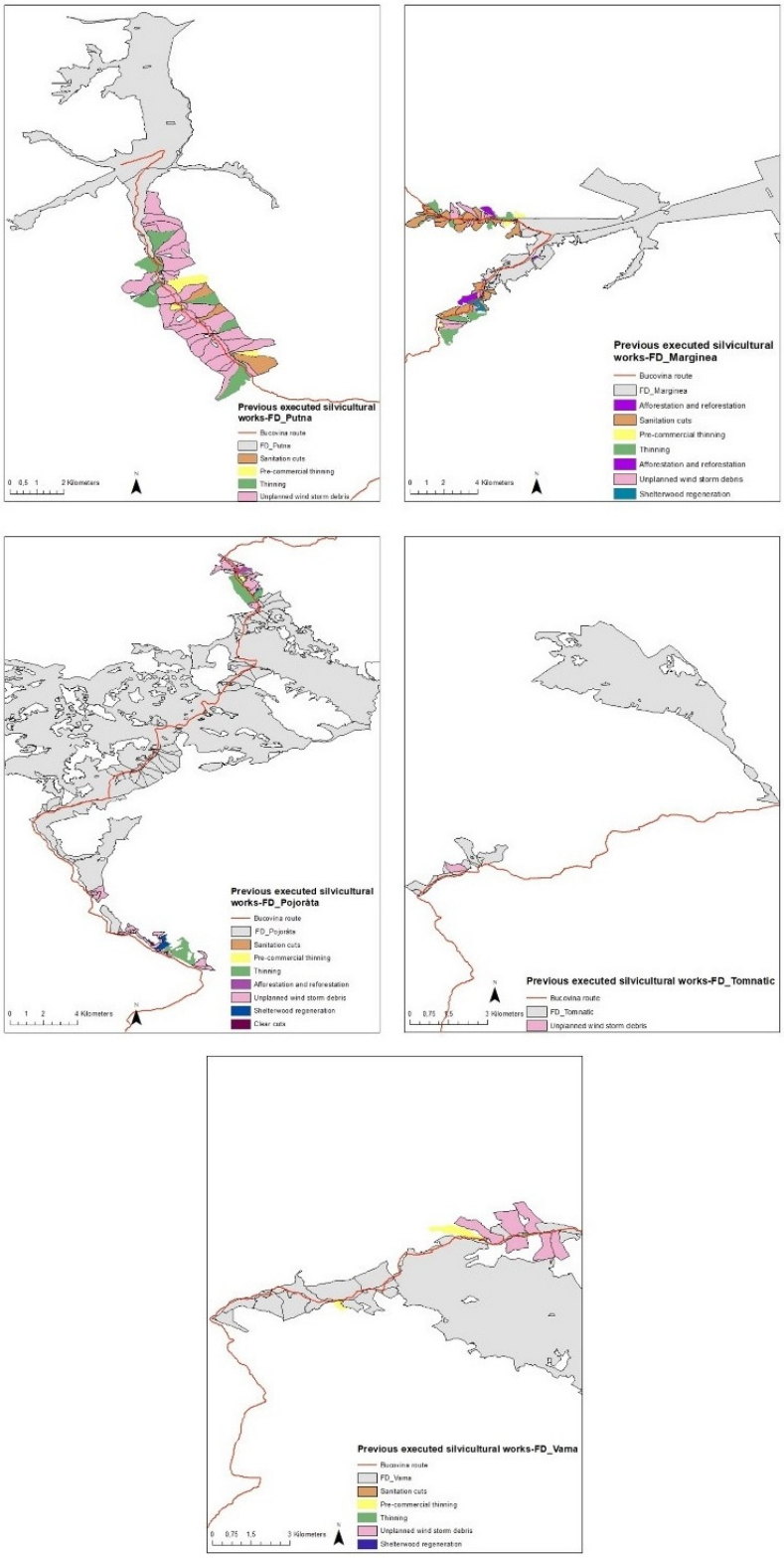

Figure A1. Previous executed silvicultural works

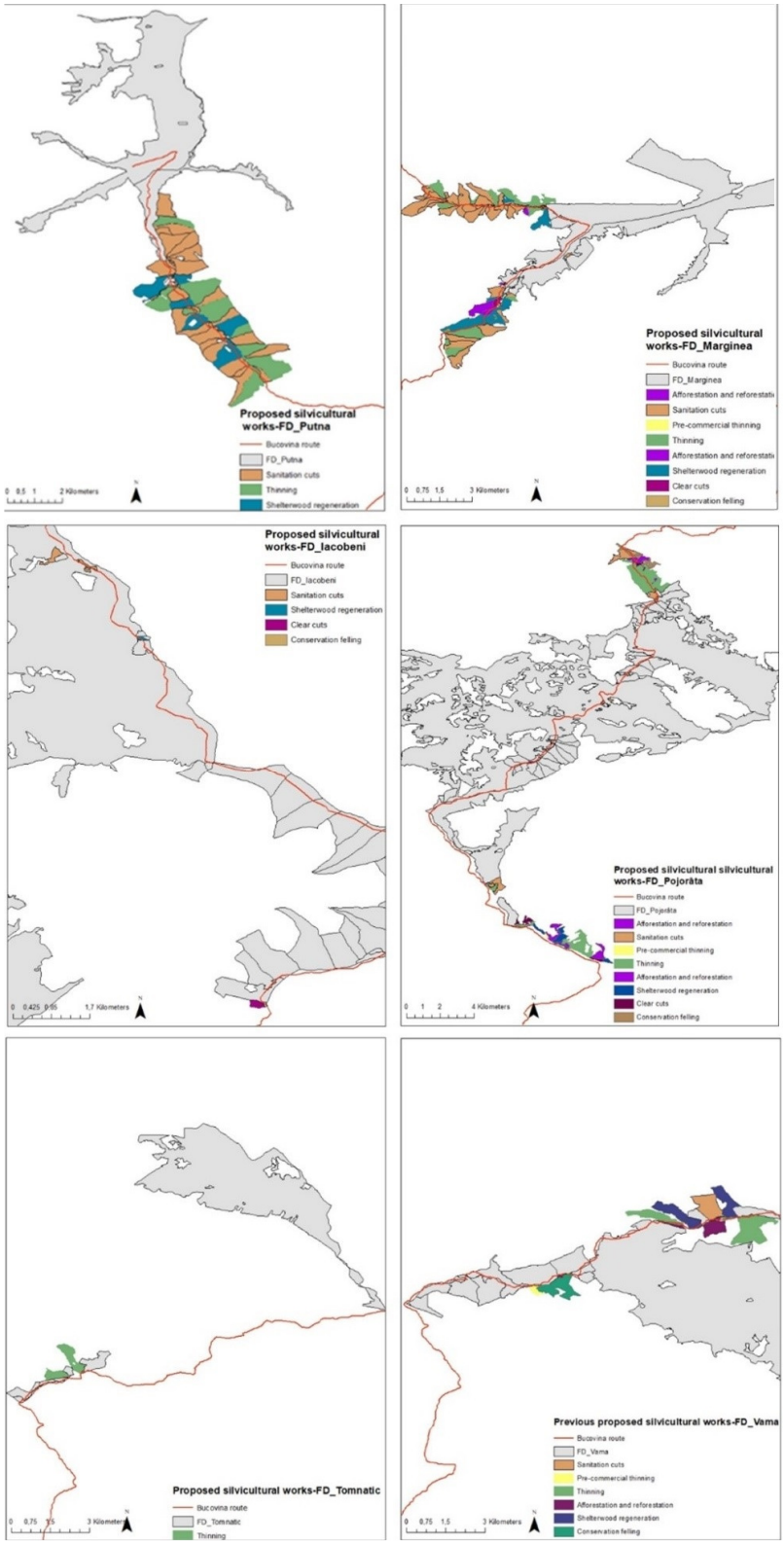

Figure A2. Silvicultural interventions proposed in stands along the VT trail