



Štúdia hodnotenia potenciálneho vplyvu scenárov na poskytovanie ekosystémových služieb v Poloninách

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Abstrakt

Štúdia sa zameriava na hodnotenie potenciálneho vplyvu rôznych scenárov hospodárenia v lesoch Polonín na poskytovanie lesných ekosystémových služieb (FES). Analyzuje súčasný stav a budúci vývoj kľúčových FES, najmä produkcie dreva, ukladania uhlíka, biodiverzity a rekreácie, v kontexte platnej lesníckej legislatívy a participatívneho plánovania hospodárenia v lesoch. Na hodnotenie FES bola využitá metodika vyvinutá v rámci projektu FESWEB (APVV-21-0290). Jadrom štúdie je porovnanie referenčného scenára „business-as-usual“ s environmentálne orientovaným scenárom, pričom sa hodnotia relatívne zmeny v poskytovaní jednotlivých služieb. Výsledky poukazujú na rozdielne kompromisy medzi jednotlivými scenármi a zdôrazňujú význam integrovaného prístupu k lesnému hospodárstvu. Záver prináša odporúčania pre budúce rozhodovanie a využitie výsledkov pri plánovaní udržateľného hospodárenia v regióne Polonín.

Štúdia je spracovaná v anglickom jazyku a slúži ako výstup (D 2.2.2) projektu Interreg Central Europe *HealthyForestRegions*.

Acronyms

ES - ecosystem services

FES - forest ecosystem services

FML - Forest management plan

NP - national park

SFM - sustainable forest management

SQ - Status quo

WTP - willingness to pay

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Introduction

Forests are among the most important ecosystems in Central Europe and provide not only wood and raw materials, but also important ecological, social and cultural services. In the three pilot regions in Austria, Slovenia and Slovakia, forests play a central role in shaping the natural landscape, biodiversity and human well-being in the region. Their management therefore requires a balance between economic use and ecological conservation.

In this framework, the joint assessment of forest development scenarios investigates how alternative management strategies compared to the status quo influence the provisions of ecosystem services (ES) such as timber production, carbon sequestration, biodiversity, and recreation.

During a regional workshop in the National Park Poloniny together with local stakeholders, three management scenarios were developed reflecting social, economic and environmental dimensions of sustainable forest management (SFM). The reference scenario served as the first scenario, which is based on management practices governed by the currently valid Forest Management Plan (FMP). It represents a baseline focused on multifunctional forest management that accounts for both social and economic considerations, while their impacts remain relatively balanced across the assessed ES.

In the contrast, the environmental scenario, which was selected as the second approach, reflects a more conservation-oriented management. It promotes close to natural tree species composition, raising average age of forest stands, a higher proportion of deadwood and an expansion of areas with significantly reduced harvesting interventions. This scenario focuses on increased timber stock, enhanced biodiversity and carbon storage, and improved recreational opportunities.

Assessment of key ES under these scenarios was conducted based on a set of selected forest indicators, which encompass various dimensions (conditions, environment, management, and infrastructure). Indicators consist of several components and were derived from technical units and physical quantities. They represent the state of the forest, management and infrastructure. The data were sourced from the information system of forest management, Forest Management Record, Basic Data Base for Geographic Information System, OpenStreet Map, and comprehensive information and monitoring system. Economic evaluation of selected ES was based on socio-economic information including market prices, regional statistics, willingness-to-pay studies and stakeholder assessments. This methodologies formed the basis for comparing the environmental, economic and social trade-offs between different forest management scenarios and for deriving conclusions on sustainable forest development in HFR Poloniny.

The results show that forests must be evaluated beyond the timber yield. A comprehensive perspective that includes ecological, social and economic dimensions shows that close-to-nature management can lead to more resilient forests, improve the attractiveness of the region and bring significant benefits for climate protection, tourism and the well-being of the population.

Scenario development and description

Management scenarios were developed during a regional workshop involving experts from various fields. The goal was to create alternative forest management scenarios that consider different aspects of sustainable forest management (SFM), ensuring a balance between ecological, economic, and social factors. The workshop report, including scenario development, is a part of D 2.2.1.

A key aspect of this process was the identification of ten relevant forest environment attributes/indicators, manageable through measures, that would help assess and compare different scenarios. Participants were divided into three groups representing social, environmental, and economic dimension of SFM to define target values for the identified indicators under each scenario, reflecting different management priorities.

A key challenge in the discussion was balancing the often-divergent priorities of stakeholders. While the economic group emphasized sustainable logging practices to ensure economic viability, the environmental group focused on biodiversity conservation and minimizing disturbances. Meanwhile, the social group considered the needs of local communities, recreational use, and the broader societal benefits of ES.

The results of the workshop are summarized in the Table 1, highlighting potential trade-offs and benefits of each scenario.

Table 1 Alternative forest management scenarios

Indicator	Social scenario	Environmental scenario	Economic scenario
Annual wood production (m ³)	+5%	Divide the HFR into NP and non-NP areas, reduce logging in the NP area, with a view to 75% of the area being without intervention. Outside the NP area use the increment height.	Available increment in managed forests and special purpose forests. Subtract increment SQ
Annual fuelwood production (m ³)	Maintain SQ	Assuming an increase in residents and recreationists in the region, the increase in the need for firewood may increase by as much as 100%.	Rise, difficult to determine share just by grades in FMP , often price decides energy security
Number of tree species (pcs)	+1 (Oak)	To get closer to the natural tree composition (number of trees) - in some places an increase is possible. In some places a decrease is necessary (pure beech forests). We cannot define the number of species.	SQ, maybe introduced (especially Douglas) due to safety
Degree of naturalness of the tree composition	-1	1-2 Approach the composition of natural forests.	Maintain SQ
Trees damage (%)	Maintain SQ	We cannot define the % of damaged trees. Anthropogenic damage should be minimized and natural damage - abiotic, biotic - should be allowed. Damaged trees create a natural habitat for some other species.	Maintain SQ
Average age of stands (year)	+20 years	Increase the average age, to approach the average age on reserves, approx. 90 years.	Maintain SQ
Percentage of dead wood (%)	maintain, in the vicinity of watercourses reduce (water buffer) by 4%	The share can be increased up to 20%.	Maintain SQ
Number of layers (pcs)	Maintain SQ	1-3, according to natural processes (an average of 2 is about OK).	Maintain SQ
Percentage of trees of interest to bees, birds, etc. (%)	Maintain SQ	We cannot judge that; it may stay.	Maintain SQ
Logging intensity (%)	Maintain SQ	Reduce visibility of interventions to 0%, move logging away from tourist infrastructure, or minimize and disperse interventions.	Maintain SQ

The management measures proposed for scenario development were selected to align the indicators with stakeholder preferences. The reference scenario served as the first scenario, based on the valid FMP conditions, as the changes in the social and economic scenario did not significantly deviate from this baseline. The environmental scenario was selected as the second scenario.

General strategies for forest management according to forest law and biodiversity strategy

The HFR is located on the territory of the Poloniny National Park and overlaps with other territories of the national and European system of protected areas. The total area of the HFR Poloniny is approximately 459.2 km², of which about 70% is covered by forest.

Professional level of forest management is ensured by the Authorized Forest Manager who is a licensed individual guaranteeing expert treatment of forest property for the forest owner in accordance with the law. Forest management plans (FMP) which are elaborated for forest management units for the period of 10 years include current requirements for nature protection and the maintenance or improvement of forest habitats. In HFR Poloniny, forests are managed according to 4 FMPs, their overview is given in the Table 2. In HFR Poloniny, part of the forests on state lands are managed by the Poloniny NP administration, forests on private lands are mainly managed by private companies. Supervision of forest management is carried out by state authorities on the basis of the Act on Forests, the Act on Nature and Landscape Protection, and the FMP. NGOs or the public can also control forest management and give input to state authorities during the preparation of FMP.

Table 2 Overview of the currently valid FMPs in HFR Poloniny

Management Unit	FMP	Validity of FMP	Area of forest stands (m ²)	Number of forest stands
Forests Zboj	LA170, 2024	2024-2033	61,635,411	763
Forests Ulič, Topľa	LA171, 2024	2024-2033	96,233,489	1,747
Forests Starina	SL248, 2020	2020-2029	165,191,051	2,669
Non-state forests Ubl'a	SL249, 2020	2020-2029	377,874	5
Total			323,437,825	5,184

Nature protection is also ensured by the state through state bodies and professional organizations, which include the State Nature Conservancy of the Slovak Republic and the Poloniny National Park administration.

Landscape systems of ecological stability are developed at the regional and local level. These include a proposal for a network of biotopes, biocorridors, gene pool sites, a proposal for mitigating/removing the identified negative phenomena in the country. The Regional Landscape System of Ecological Stability of the Snina District (2019) is approved in the relevant HFR.

At the level of the protection area, the Care Program of the Poloniny National Park and its buffer zone for the years 2023-2032, and the Project for the Conservation of the Poloniny National Park and its buffer zone are drawn up. These include the protection of the national park, the protection of the UNESCO site, the NATURA 2000 network, and the Eastern Carpathians biosphere reserve.

Presentation of the participatory process of forest management planning

The duty of elaboration of FMP, list of its mandatory components and exact descriptions of steps and terms/dates applied at FMP elaboration process are stated in the Act on Forests no. 326/2005 of the Coll. Elaboration of FMPs is administered and organized by the forestry state administration authorities.

The FMP is a state tool for ensuring sustainable forest management. It is usually prepared for a period of 10 years. The costs of the mandatory components of the FMP are usually covered by the state, while the costs of the optional components are covered by the applicant.

The process of FMP preparation is within the competence of the state forestry administration body. The state forestry administration body shall notify the owners, administrators and forest managers no later than 24 months before the expiration of the FMP that it will procure the elaboration of a new FMP. The notification shall also be sent to the affected state administrative bodies and the nature conservation organization.

The person preparing the FMP (authorized person) shall prepare a report on the management to date and on determining the principles for preparing the FMP for the relevant forest unit.

The state forestry administration body shall immediately notify the administrator of the information system, the affected state administration bodies, legal entities and public whose rights may be affected by the preparation of the FMP that they may inspect the management report and at the same time invite them to submit comments (as a rule within 15 days of delivery of the notice). Comments and requests that have not been submitted within the specified period shall not be taken into account.

A protocol shall be drawn up on the results of the discussion of the management report and comments and requests, which shall contain instructions for the preparation of the FMP and the deadline for submitting the proposal.

The draft FMP is approved by the state forestry administration body by decision, after the administrator of the forest management information system has issued a confirmation of its correctness and after the binding statement of the state administration bodies concerned, by which they check the fulfillment of the comments and requirements applied in the process.

If the submitted draft contains shortcomings that prevent its approval, it is returned to the drafter of the FMP for further elaboration, after the fulfillment of which the FMP can be submitted for approval. The decision on the approval of the FMP is made no later than one year from the commencement of the procedure; the Ministry of Agriculture and Rural Development may extend this period in justified cases.

The participants in the procedure and the persons involved are only served with a notification of the approval of the FMP. An appeal against the decision on the approval of the FMP does not have a suspensive effect; a party to the proceedings may only lodge an appeal in respect of the part concerning it.

The participants in the procedure for the approval of the FMP are the owners, administrators and forest managers in the forest unit for which the FMP is being prepared.

Other participants in the proceedings are the affected state authorities, the administrator of the forest management information system, the affected nature conservation organizations, and other organizations or the public that could be affected by the preparation of the FMP. The public is usually represented by NGOs. This creates an opportunity for the public to articulate their demands and requirements regarding the provision of FES (Adjustment of the plan for the needs of recreation, biodiversity protection, etc.)

The participants in the proceedings mainly comment on the method of forest management, the level of timber extraction in forest stands, the construction of forest roads, the inclusion of forest stands in protected areas and levels of protection, or the non-intervention regime.

The FMP must take into account the requirements of the nature conservation authority, otherwise it cannot be approved or may be subject to an Environmental Impact Assessment.

Similarly, in D.2.2.1, the stakeholders divided into three groups were invited to express their perspectives on desired changes in specific indicators related to nature conservation and forest management. This approach was intended to capture a broad range of viewpoints and to ensure that diverse interests and priorities related to management practices were adequately reflected in the indicator selection process.

Connection of forest management to FES

HFR Poloniny is located in the north-eastern corner of Slovakia and lies within the Poloniny National Park located in the Bukovské vrchy mountain range in the Eastern Carpathians. It covers a protected area of 298 km², with an additional buffer zone of 110 km². Some areas of the National Park form part of the UNESCO World Heritage site, “Ancient and Primeval Beech Forests of the Carpathians and Other Regions of Europe”. The park is also part of the East Carpathians Biosphere Reserve (UNESCO), the world’s first trilateral biosphere reserve, spanning Slovakia, Poland, and Ukraine, making it a globally significant natural treasure.

Forest ecosystems in HFR Poloniny, especially beech and fir-beech forests, are the dominant natural feature, covering more than 70% of the area. This region holds the highest concentration of natural and pristine forests, as well as primeval forest communities in Slovakia. Poloniny National Park is renowned for its exceptional biological diversity, hosting numerous protected species as well as rare and endangered plant and animal species.

Forests in NP Poloniny are divided into three main categories according to their prevailing function: production forests (64.6%), protective forest (7.4%) and 28% special purpose forests (with a special, differentiated management regime). Despite the overall high share of production forests, their share has been decreasing slightly since 2014. Since 2024 all forests in the territory of the National Park are managed by the NP administration and the main purpose is nature conservation. The NP is currently undergoing a zonation process that establishes three distinct protection levels within the park, as well as a protective zone.

Forest management in HFR Poloniny ensures a resilient and multifunctional forest landscape that safeguards biodiversity, enhances carbon storage, and supports sustainable wood production for balanced regional development.

This vision expresses the ambition to transform forest management in *HFR Poloniny* into a holistic, ecosystem-based approach. It aims to conserve natural heritage while supporting climate change mitigation, economic well-being, and community resilience aligning with all three dimensions of sustainable forest management: social, ecological, and economic.

Methodology for evaluation of FES

Forest ecosystem services in HFR Poloniny were assessed through a set of selected forest indicators, which encompass various dimensions (conditions, environment, management, infrastructure). Indicators consist of several components and are derived from technical units and physical quantities. They represent the state of the forest, management and infrastructure. An overview of the measurable forest indicators that were used to express the potential of supply of individual FES is provided in the next chapter.

The relative value of the indicators reflects the potential FES supply in each forest stand, rated on a scale from 0 to 1. The result is a determination of the potential FES supply into five distinct levels. Each level represents, on a relative scale, how a specific FES is potentially supplied within a given forest stand in the HFR Poloniny. The levels of FES supply are detailed in the table 3.

Table 3 Levels of potential FES supply in HFR Poloniny

*	Almost negligible potential supply - characterised as zero or close to zero
**	Low or poor potential supply - characterised as below average
***	Good potential supply - characterised as average or medium supply
****	Almost ideal potential supply - characterised as above average
*****	Ideal potential supply - maximum or almost maximum supply

FES wood production and carbon storage were calculated in absolute values as well.

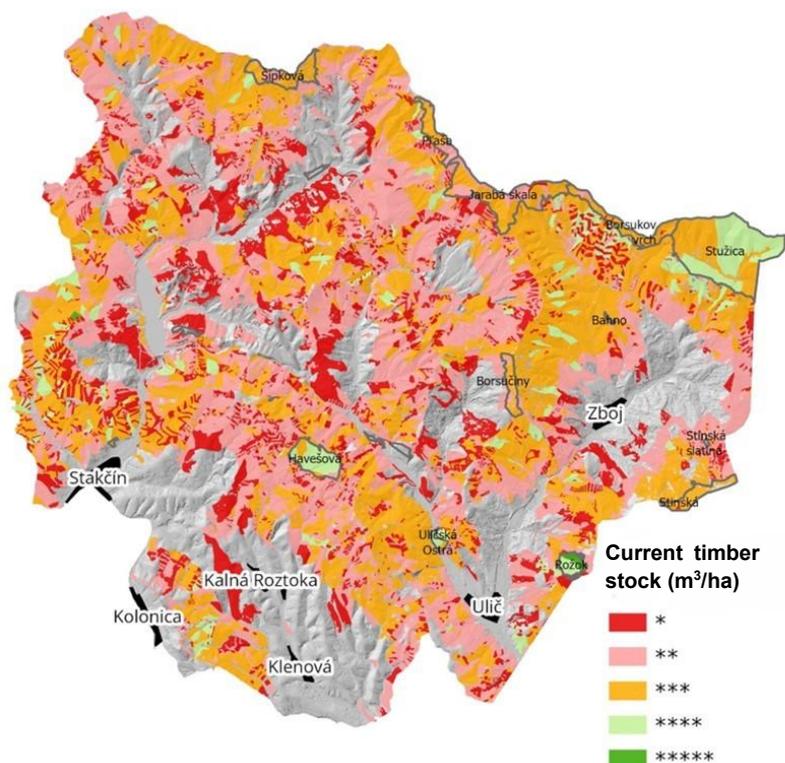
Calculations were made following established/published methodologies (e.g. Klein, Schulz, 2011; Thorsen et al. 2014; Getzner et al. 2020, Maes.J. et al. 2020) and utilizing spatial, database and geospatial data sourced from the information system of forest management, Forest Management Record, Basic Data Base for Geographic Information System, OpenStreet Map, and comprehensive information and monitoring system.

Current status of FES in HFR Poloniny

Wood production

FES wood production represents the relative level to which a forest stand fulfils the forest production function - the production of wood (under bark).

The assessment of FES - wood production was conducted using the indicator of current timber stock in the forest stand (under bark), as recorded in FMP and updated based on annual increment and timber felling (data from the Forest Management Record). The results (Map 1) indicate that the potential supply of this FES provided by the majority of forest stands is low, and in several cases almost negligible.



Map 1 Current status of FES - current timber stock in HFR Poloniny

The relative value of potential FES supply was estimated at 0.36, indicating a low level of service supply (see the table below).

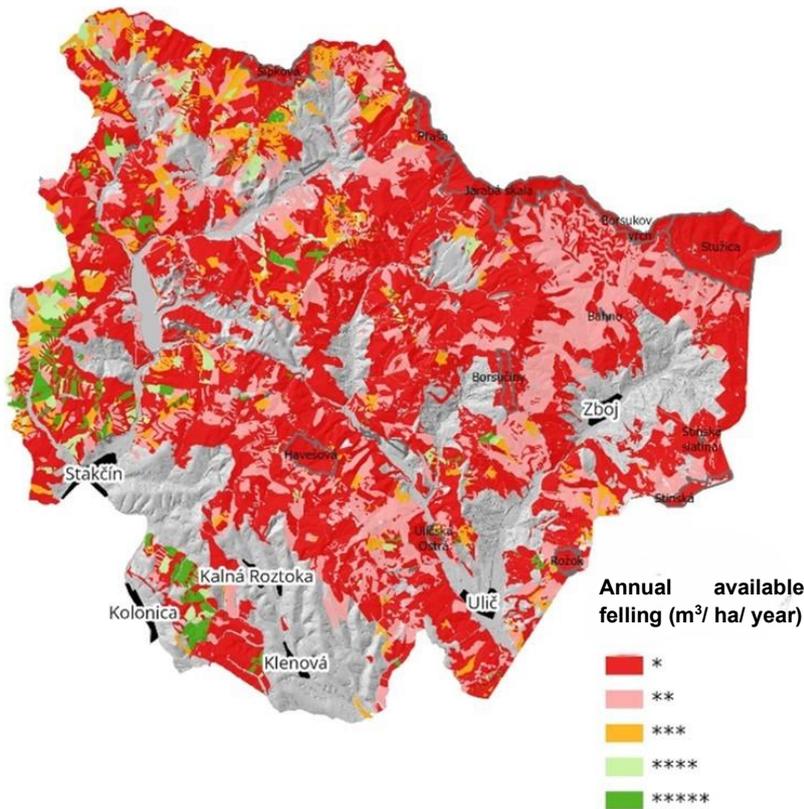
Table 4 Absolute and relative values of FES - current timber stock

Absolute values of FES	
Total timber stock	8,883,460 m ³
Average timber stock	226 m ³ /ha
Relative value of potential FES supply	0.36 - ** low potential supply

Within the wood production annual available felling was assessed as well. Annual available felling represents the potential volume of timber felling (in m³.ha⁻¹) that can be carried out in a forest stand until the end of FMP validity, in accordance with the prescribed volume of timber felling in the forest stand.

For this assessment, data on the prescribed volume of planned felling in the forest stand (based on FMP) was used, updated with the data on timber felling (from Forest Management Record).

As shown in Map 2 and based on the calculated relative value of FES supply (0.19), it can be concluded that this FES is provided in HFR Poloniny at almost negligible to poor level. This is because the FMP has been in effect in these stands for several years, during which timber felling could have been carried out, reducing the timber available for harvesting. Generally low supply of this FES also reflects the management priorities within the National Park (NP), where non-production functions are given priority.



Map 2 Current status of FES - annual available felling in HFR Poloniny

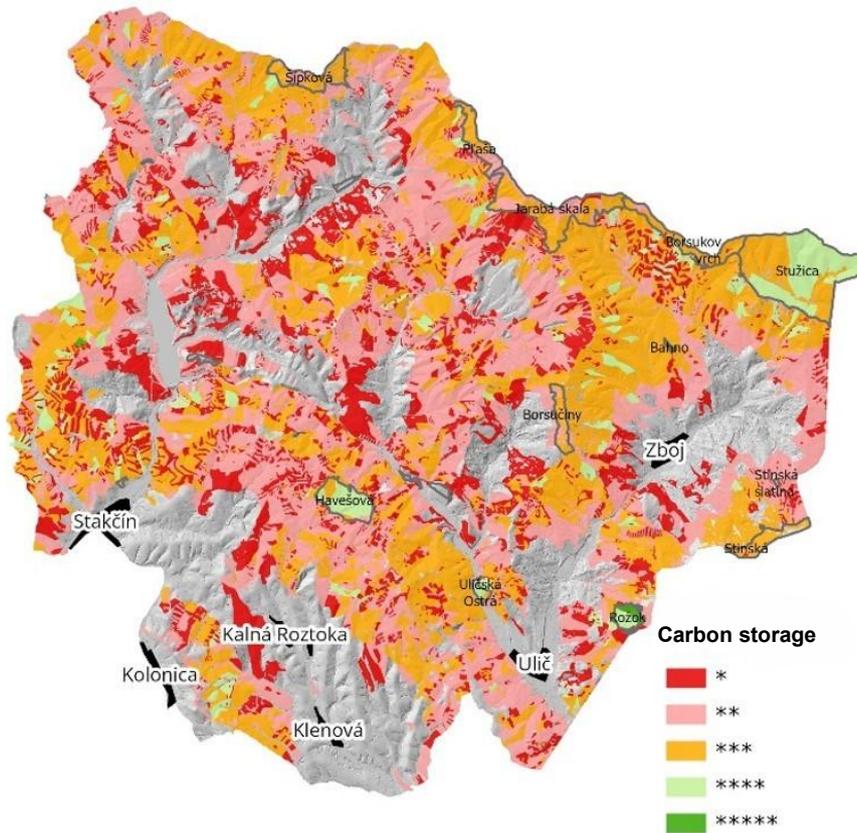
Table 5 Absolute and relative values of FES - annual available felling

Absolute values of FES	
Annual timber volume available for harvesting	129,377 m ³
Relative value of potential FES supply	0.19 - * almost negligible potential supply

Carbon storage

The assessment of carbon storage was conducted using the indicator of the current timber stock in the forest stand. The volume of the carbon potentially stored in the forest stand was calculated following a methodology that takes into account the current timber stock, the wood density of individual tree species and the carbon mass coefficient (t/m³).

As shown in Map 3, the potential supply of this FES closely mirrors those of wood production, ranging from almost negligible level to good level. This reflects the fact that the carbon storage is closely linked to the current timber stock.



Map 3 Current status of FES - carbon storage in HFR Poloniny

Table 6 Absolute and relative values of FES - carbon storage

Absolute values of FES	
Carbon stock	2,860,555 t
Relative value of potential FES fulfilment	0.36 - ** low potential supply

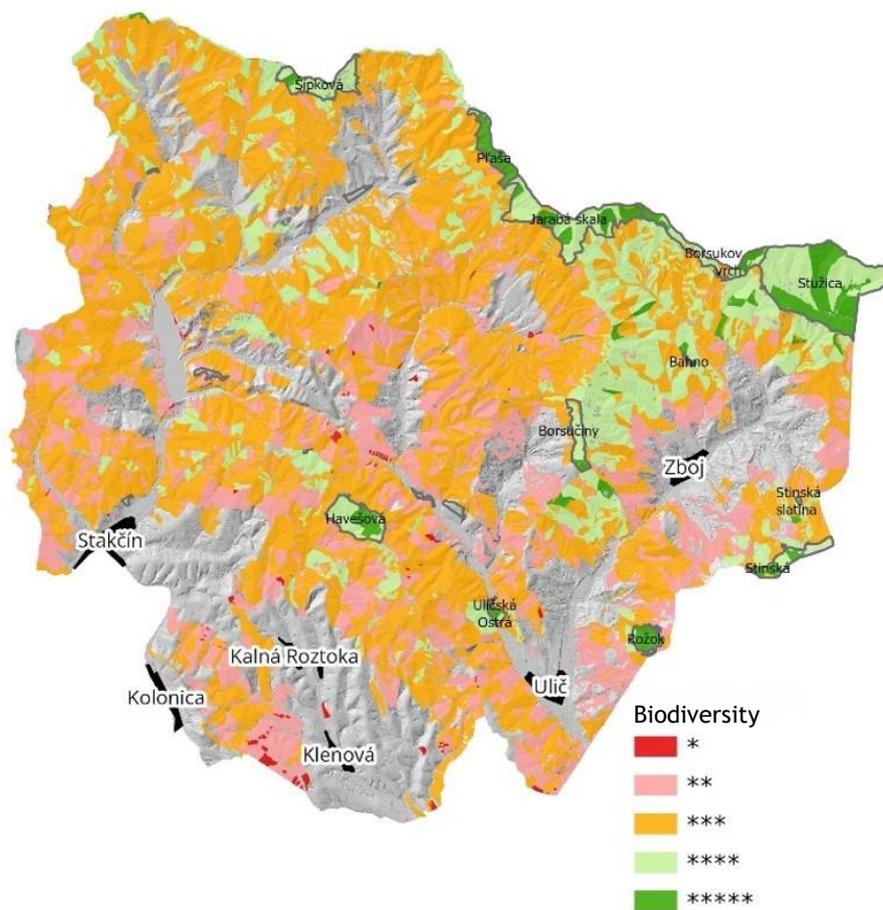
Biodiversity

FES - Biodiversity reflects the level of biodiversity supply in forest stands. The following indicators were used to assess the potential supply of this FES:

- Tree species composition
- Naturalness of forest stands
- Forests health/tree species damage
- Distribution of forest types
- Estimated volume of dead wood
- Thickness of trees
- Protected areas
- Support of biodiversity (biodiversity support score derived from level of nature protection; management method; occurrence of harvesting, afforestation; age structure and method of forest regeneration)

As shown in Map 4, the potential supply of FES - biodiversity in HFR Poloniny ranges mostly from poor to good. However, in the eastern part and along the ridges, there are more continuous areas of forest stands demonstrating almost ideal level of FES supply. The forest stands within the National Park also have an ideal supply of FES - biodiversity, indicating the relatively favourable conditions of these forest stands.

Based on the relative value of biodiversity (0.49), the potential supply of FES can be assessed as good.



Map 4 Current status of FES - Biodiversity in HFR Poloniny
Table 7 Absolute and relative values of FES - biodiversity

Absolute values of FES	
Biodiversity	n.a.
Relative value of potential FES fulfilment	0.49 - *** good potential supply

Recreation

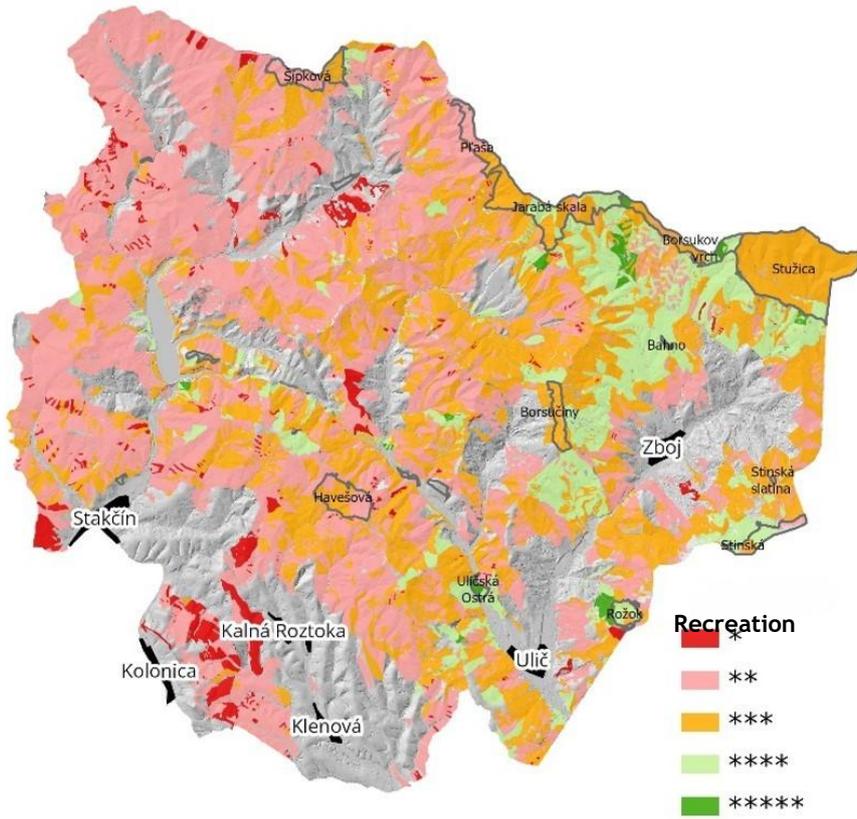
FES - recreation was assessed using following indicators described in the table below.

Table 8 Measurable indicators for FES - Recreation

Dimension	Attribute	Indicator and its description
Environment	Location	Reachability - minimum distance from settlements
		Passability - presence of hiking trails and cycle paths
		Movement across the location - terrain type
	Visibility	From the stand to landscape - average height of layers
		Inside the stand - vertical diversity (number of layers), forest shape

Forest	Appearance	Perception of aesthetic beauty and majesty/grandeur - variety and seasonal variability, aesthetics of tree species composition, stand class
		Perception of freedom, wildness and roughness - naturalness of tree species composition, dead wood, dimensional variability (calculation based on three thickness, stand class and age), diversity of tree species composition
		Perception of antiquity and eternity - age of the forest stand, time of logging completion, rotation and regeneration period, average lifespan of tree species
		Perception of peace, silence and fragrance - fragrant honey bearing trees
Management		Perception of care for the forest and the environment - degree of support for recreational services through management (incidence of afforestation, and method of restoration)
		Extend of interventions - intensity of timber harvesting, biodiversity support score (derived from level of nature protection; management method; occurrence of harvesting, afforestation; age structure and method of forest regeneration)
		Management and its targets - score of support for recreation and aesthetics of the forest through management (incidence of afforestation and method of restoration, zonation/level of nature protection)
Infrastructure and support of physical interactions		Support of interactions, tourism, stay, game management a fulfilment of other cultural services - presence of recreational infrastructure

As shown in Map 5 and based on the calculated relative value (0.42), the potential supply of FES - recreation can be assessed as good. Better assessment of recreation is observed in the eastern part of HFR (within the NP territory). Conversely, poorer supply of this FES is achieved especially in the western part of HFR.



Map 5 Current status of FES - recreation in HFR Poloniny

Economic evaluation of FES

An economic evaluation of the status quo was conducted to estimate the monetary values of those ecosystem services provided by HFR Poloniny that can be quantified in monetary terms. The assessment focuses on the economic benefits derived from wood production, carbon stock and storage, recreational services and hunting tourism. These services represent a significant portion of the provisioning and cultural benefits delivered by forest ecosystems.

Economic Valuation of Wood Production

The economic valuation of wood production was based on the average market prices for timber assortments of different tree species recorded in the region during the year 2023, calculated according to the official pricelists of state enterprise LESY SR (Ponukový cenník, effective from 16 February 2023). Two metrics were assessed:

Current Standing Timber Stock

The total current standing volume of timber in HFR Poloniny is estimated at 8,883,460 cubic meters. Using average market prices differentiated by timber assortments and quality classes, the total economic value of this standing stock amounts to approximately 1,110,933,117 €. This valuation reflects the gross asset value of the forest's timber resources without considering harvesting costs or future discounting.

Annual available felling

The annual volume of timber available for sustainable harvesting is estimated at 129,377 cubic meters. Based on market prices differentiated by timber assortments and quality classes, the estimated market value of this annual harvest is approximately 11,466,308 €. This figure represents the potential yearly revenue that could be realized from timber harvesting under current management and regulatory conditions.

Table 9 Average timber prices by species and quality classes of assortments in the region (2023)

Species	Quality classes of assortments (EUR/m ³)						
	I.	II.	III.A	III.B	III.C	IV.	V.
Pine	154.55	94.55 - 114.55	65.00 - 78.18	57.18 - 73.18	56.18 - 68.18	45.00	41.91
Beech	110.00 - 350.00	90.00 - 140.00	61.00 - 120.91	66.82 - 101.82	81.55 - 87.73	72.27	67.27
Oak	320.00 - 700.00	150.00 - 600.00	97.00 - 400.00	87.56 - 310.00	80.00 - 200.00	85.00	67.27
Fir	165.45	135.45	100.00 - 105.91	80.91 - 95.91	70.00 - 85.00	45.00	41.91
Spruce	171.82	120.00 - 141.82	100.00 - 113.18	88.18 - 103.18	77.27 - 92.27	45.91	41.91

Economic Valuation of Carbon Stock

The total carbon stock contained in above-ground biomass (measured as rough wood under bark) is estimated at 2,860,555 tonnes. For the calculation of carbon storage in forests and wood products, we included data obtained from previous deliverables as well as from the forest inventory database. Using an average CO₂ certificate price of 46.71 EUR/t - based on market trends over the past six years (Table 10). The estimated economic value of the carbon stock is approximately 133,630,827 €.

This valuation highlights the critical role of forest ecosystems in providing natural carbon offset services and underscores the importance of preserving forest cover as part of climate change mitigation efforts.

Table 10: Calculated average prices of CO2 certificates

Year	Average price of CO ₂ certificates (EUR per tonne)
2018	15.44
2019	24.60
2020	24.31
2021	52.89
2022	79.75
2023	83.30

Source: Trading Economics website <https://tradingeconomics.com/commodity/carbon>

Economic Valuation of Recreational Services

Recreational services represent key cultural ES, contributing to the local economy through ecotourism and nature-based outdoor activities. The economic value of recreational service was determined based on an analysis of visitors' attendance /number of overnight stays in the Snina district (five-years average attendance was 5,321 visitors) and data on willingness to pay for forest visit according to a nationwide survey from 2024 (Sarvašová, Kovalčík, 2024).

Based on a questionnaire survey on a sample of 419 respondents, the willingness to pay for a visit to the forest was determined. As shown on Fig. 6, 41.9% of respondents are willing to pay for a visit to the forest to a forestry company or forest owner who takes care of the forest. The average value of payment for visiting the forest is 6.28 €.

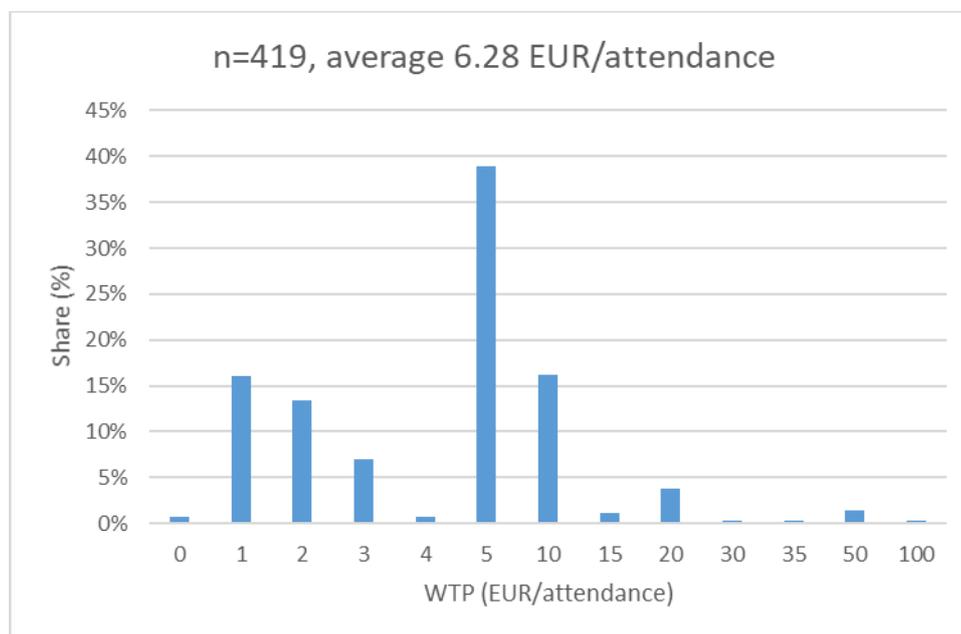


Fig. 1 Distribution of willingness to pay for visiting the forest

With an average number of 15 thousand visits per year (estimation of the National Park), the value of the recreational service was set at 94,200 €/per year.

In addition to the WTP approach, an alternative valuation of recreational services can be derived from official tourism statistics for the Snina district, which also includes the HFR Poloniny. A similar approach was applied by our Austrian partners, ensuring methodological consistency across the project. Table 11 summarizes the development of accommodation revenues, visitor numbers, and municipal accommodation tax revenues between 2019 and 2024. These data illustrate a clear increasing trend of tourism in the region.

Table 11 Tourism statistics for the Snina district (2019-2024)

Year	Accommodation revenues (€)	Number of visitors	Accommodation tax revenues (€)
2019	216,241	4,825	-
2020	248,621	5,527	-
2021	-	-	7,592
2022	326,850	4,952	7,644
2023	534,809	5,979	9,832
2024	672,227	7,473	18,990

Source: Statistical Office of the Slovak Republic, DATAcube

These figures provide an alternative estimate of the economic value of recreational services, demonstrating their contribution to the local economy through direct tourism expenditures and fiscal revenues.

Economic Valuation of Hunting Tourism

Economic evaluation of recreation includes also valuation of hunting tourism, encompassing both trophy hunting and the harvesting of game meat, that generates additional economic benefits for the local economy, especially in rural and forested areas. HFR Poloniny comprises 15 hunting grounds, where red deer, roe deer, and wild boar are the primary game species.

To estimate the economic value of trophy hunting, annual culling data from 2021 to 2023 for roe deer, red deer and wild boar were analysed, and the price list of state enterprise LESY SR was used. The approximate economic values were estimated assuming that all animal removals were conducted under trophy hunting.

The estimated economic contribution (calculated according to the pricelist of state enterprise Lesy SR) from trophy hunting in HFR Poloniny is 292,727 €.

Table 12 Economic values of trophy hunting

	Category		Number	EUR/pcs	EUR
Roe deer	young		7	40	280
	female		14	40	560
	male	spike	16	80	1,280
		I	16	220	3,520
		II	37	387	14,319
		III	8	1,508	12,064

Daily fee			98	75	7,350	
Total					39,373	
Red deer	young		53	105	5,565	
	female		75	105	7,875	
	male	spike		10	157	1,570
		I		10	400	4,000
		II		28	1,059	29,652
		III		22	2,861	62,942
		IV		17	5,385	91,545
Daily fee			215	75	16,125	
Total					219,274	
Wild boar	young		15	80	1,200	
	yearlings		37	180	6,660	
	female		6	375	2,250	
	male		15	1233	18,495	
Daily fee			73	75	5,475	
Total					34,080	
TOTAL (all species)					292,727	

The valuation of consumable game meat derived from regulated hunting activities is approximately 46,059 EUR representing a modest but notable provisioning benefit.

Table 13 Economic values of game meat

	Category		Number	Average weight	EUR/kg	EUR	
Roe deer	young		7	8	3.7	207.2	
	female		14	12	3.7	621.6	
	male	spike		16	10	3.7	592
		I		16	15	3.7	888
		II		37	15	3.7	2,053.5
		III		8	15	3.7	444
Total						4,806.3	

Red deer	young		53	30	2.2	3,498	
	female		75	55	2.2	9,075	
	male	spike		10	50	2.2	1,100
		I		10	70	2.2	1,540
		II		28	120	2	6,720
		III		22	150	2	6,600
		IV		17	180	2	6,120
Total						34,653	
Wild boar	young		15	20	1.5	450	
	yearlings		37	50	1.5	2,775	
	female		6	75	1.5	675	
	male		15	120	1.5	2,700	
Total						6,600	
TOTAL (all species)						46,059	

The table below provides an overview of economic values of all ecosystem services in HFR Poloniny that can be expressed in monetary terms.

Table 14 Overview of economic values of ecosystem services in HFR Poloniny

Ecosystem service		Economic valuation (€)
Wood production	Current Timber stock	1,110,933,117
	Annual available felling	11,466,308
Carbon	Carbon storage	133,630,827
Hunting tourism	Trophy hunting	292,727
	Game meat	46,059
Recreation	WTP	94,200
	Accommodation revenue 6-year average	340,916

SCENARIO EVALUATION

1. Scenario 1: Reference scenario - Business-as-usual

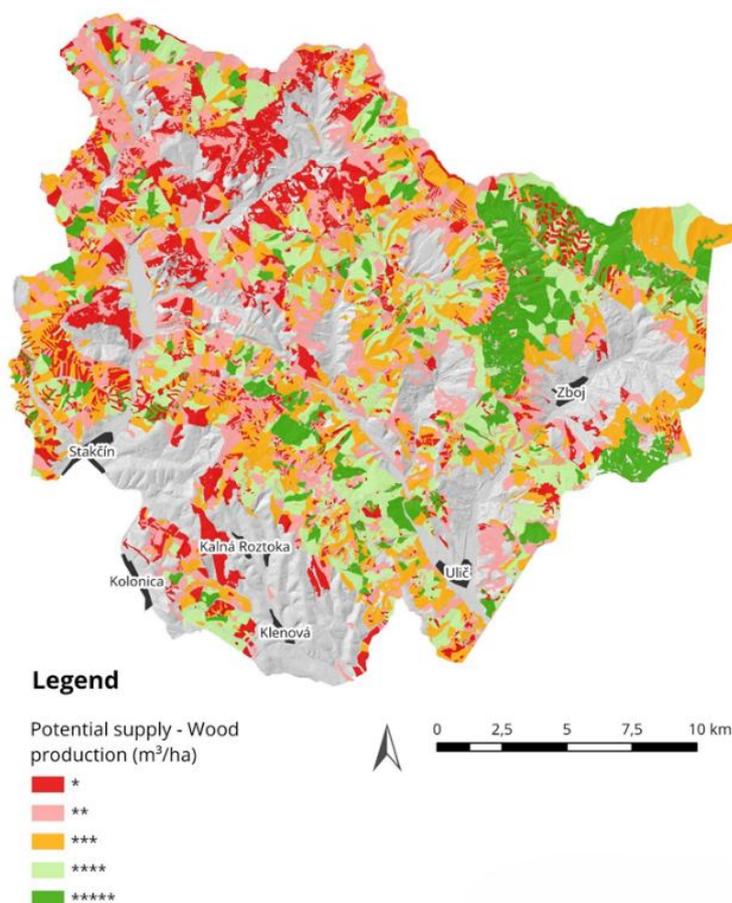
In the reference scenario, five FES in HFR Poloniny were assessed using specific indicators outlined in previous chapters. The assessment was conducted under business-as-usual conditions, i.e. meaning that the management practices were maintained following currently valid FMP.

1.1. Relative evaluation of FES for business-as-usual scenario

Wood production

The assessment of FES - wood production was conducted according to the conditions of reference scenario as follows: the starting point is the current timber stock in the forest stand (under bark) as recorded in FMP, updated by annual increment and timber felling as prescribed in FMP.

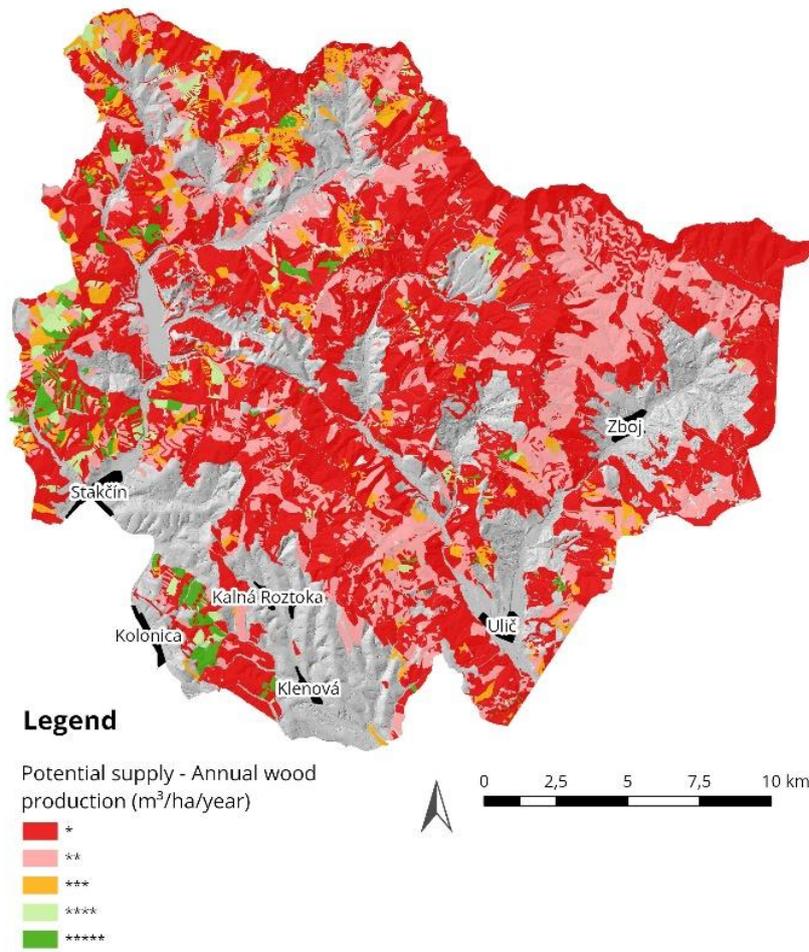
The results (Map 6) indicate that in the case of reference scenario, most forest stands in the north-western part of HFR fulfil this FES very poorly to well. In contrast, the relative supply of wood production expressed by the current timber stock is higher in the rest of the area, where the potential FES supply in most forest stands ranges from well to excellent.



Map 6 Potential supply of FES - current timber stock in HFR Poloniny according to reference scenario

In addition to assessment of the current timber stock, the annual available felling was evaluated as well. For this assessment, conducted under the reference scenario, data on the prescribed volume of planned felling in the forest stand (as outlined in FMP) was utilised, and further updated with the data on timber harvesting (based of Forest Management Record).

As shown in the Map 7, the results indicate that the relative supply of this FES is rated as almost negligible to poor in the majority of forest stands within HFR Poloniny. The overall poor supply of this service is due to the nature of management in the national park, where functions other than wood production predominate.

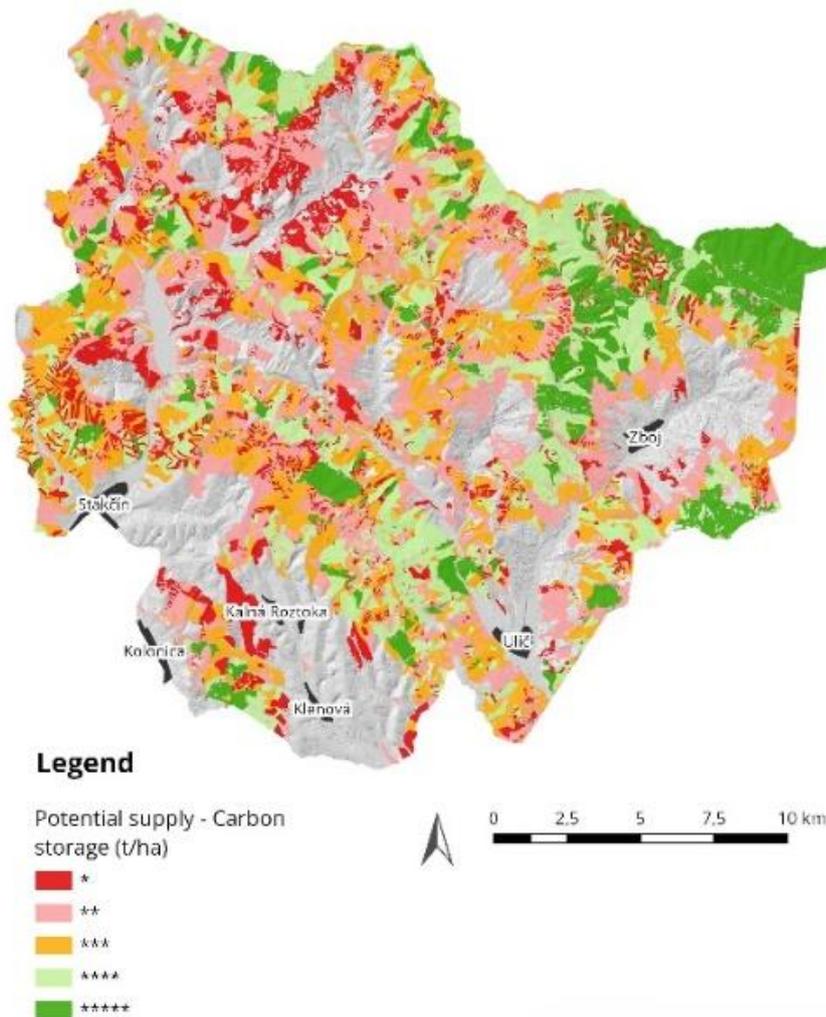


Map 7. Potential supply of FES - annual available felling in HFR Poloniny according to reference scenario

Carbon storage

The assessment of carbon storage under the reference scenario is based on the current timber stock (under bark) using data from FMP. In addition to the current timber stock, the assessment also incorporates the wood density of individual tree species and the carbon mass coefficient (t/m³).

As illustrated in Map 8, the potential supply of carbon storage ranges from very poor to good, similarly as in the case of wood production since the assessment of the carbon storage is derived from the current timber stock.

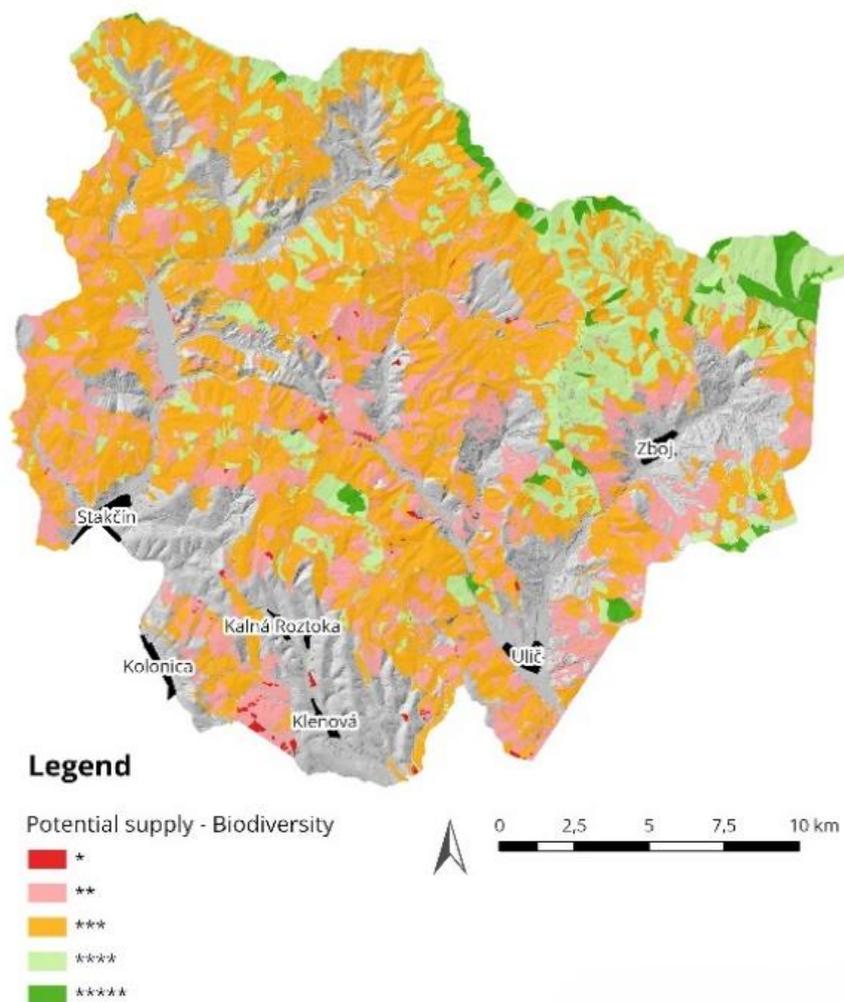


Map 8 Potential supply of FES - Carbon storage in HFR Poloniny according to reference scenario

Biodiversity

Within the reference scenario, the same indicators (as in the case of assessment of the current status of FES) were used to assess the potential supply of FES - Biodiversity. The most important indicator is support of biodiversity describing the nature of forest management, occurrence of harvesting, afforestation; age structure and method of forest regeneration following the currently valid FMP.

As shown on Map 9, the relative supply of FES - biodiversity in HFR Poloniny under the reference scenario is mostly good. In the eastern part of HFR (within the National Park), there are also forest stands that demonstrate very good and excellent level of FES supply, which indicates the relatively favourable conditions of these stands.



Map 9 Potential supply of FES - Biodiversity in HFR Poloniny according to reference scenario

Recreation

To assess the FES recreation, all indicators (as mentioned within the current status of FES) were used. Under the conditions of the reference scenario, indicators related to management were changed (Table 15).

Table 15 Changed indicators for assessment of FES - Recreation in the reference scenario

Dimension	Indicator and its description
Management	Perception of care for the forest and the environment - degree of support for recreational services through management
	Extend of interventions -intensity of timber harvesting, biodiversity support score
	Management and its targets - score of support for recreation and aesthetics of the forest through management

The potential supply of FES - recreation is assessed as good to almost ideal (Map 10), particularly on the territory of the National Park. In contrast, throughout the remaining areas, the relative supply of this FES is assessed as almost negligible to low level in most forest stands.

Map 10 Potential supply of FES - Recreation in HFR Poloniny according to reference scenario

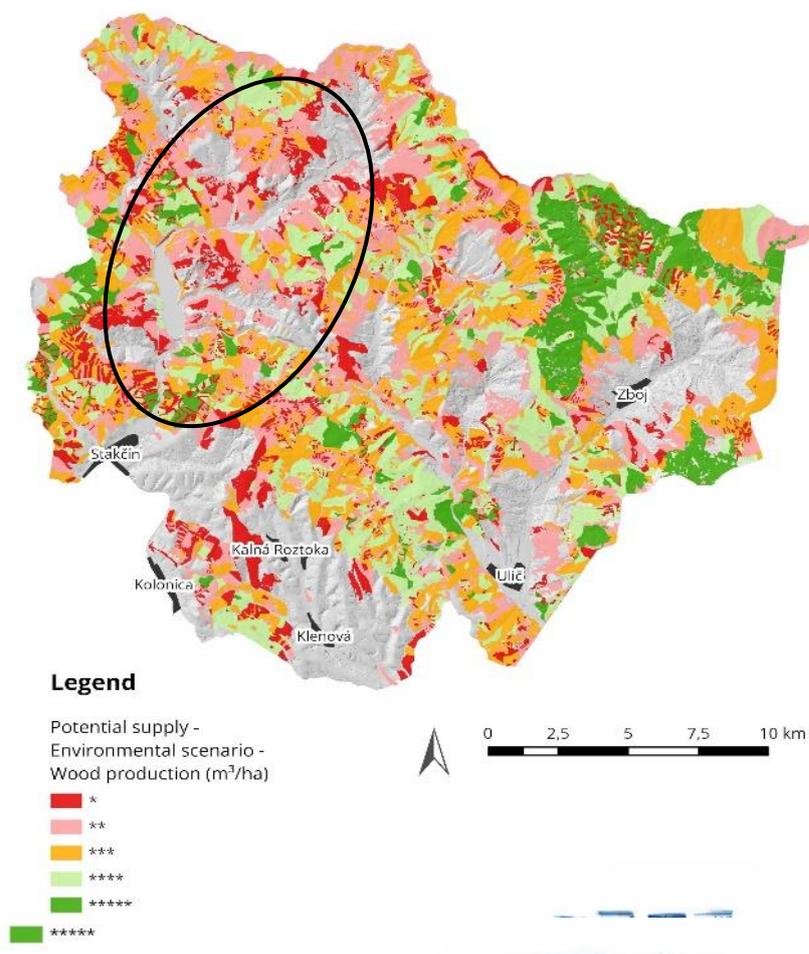
2. Scenario 2: Environmental scenario

The previous Deliverable 2.1.3 focused on the environmental scenario, which was designated as scenario 2. Under scenario 2, individual FES in HFR Poloniny were assessed using indicators tailored to reflect the specific conditions of the environmental scenario (as detailed in Table 1).

Wood production

In the case of the environmental scenario, the potential supply of FES - current timber stock was influenced by changes in forest management conditions. These changes involve dividing HFR Poloniny into two areas: the National Park area and the area outside the National Park. Within the National Park, timber felling is significantly reduced, with 75% of the area intended as area without interventions. In the remaining area of the NP and all areas outside the NP, forest management is carried out following the FMP. Regarding the species composition, the environmental scenario assumes an approach to get closer to the natural tree species composition.

The assessment of potential FES supply was based on the current timber stock in the forest stand (under bark) as recorded in FMP, updated with annual increment and timber harvesting (based on Forest Management Records). The prescribed volume of timber felling (set in FMP) was not considered for this assessment.



Map 11 Potential supply of FES - current timber stock in HFR Poloniny according to environmental scenario

The map 11 illustrates the changes in potential supply of FES - current timber stock, that have occurred as a result of the environmental scenario compared to the reference scenario. More significant improvements in the potential supply of FES are observed mainly in the forest stands located in the western part of HFR Poloniny.

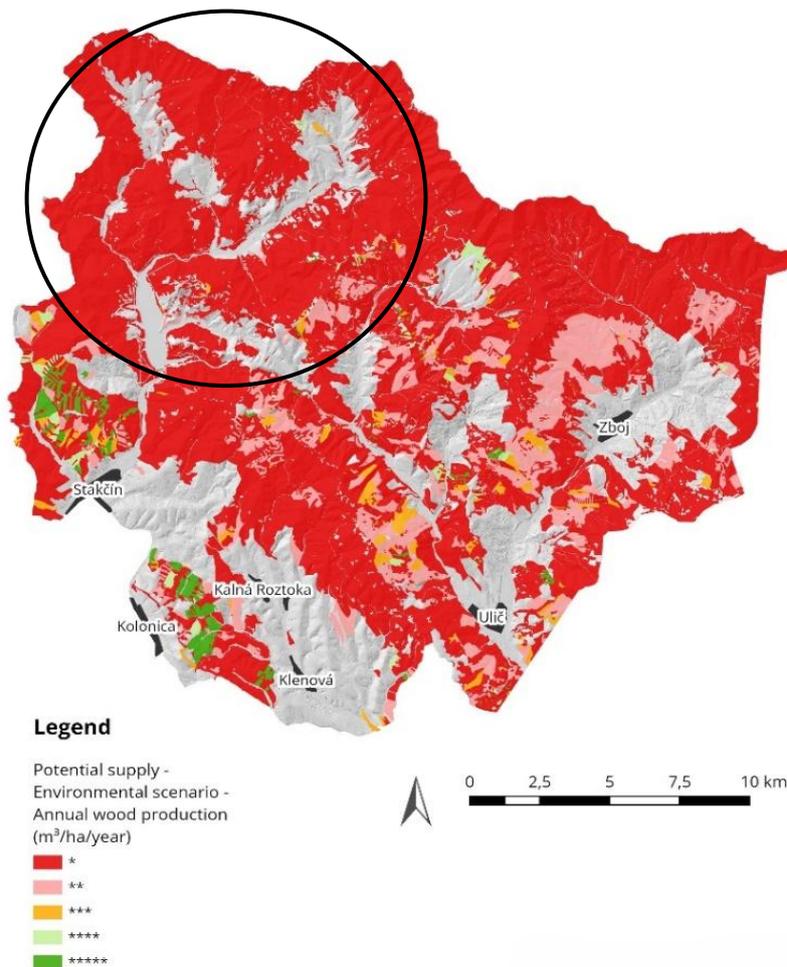


Fig. 2 Display of changes by percentage change in area in relative assessment of FES -current timber stock

The change in management conditions under the environmental scenario led to a deterioration of potential supply of the current timber stock across 10% of the HFR area, while approx. 12% of the area experienced an improvement in potential FES supply when compared to the reference scenario.

As already mentioned in the reference scenario, the annual available felling is determined based on the prescribed volume of planned felling in the forest stand (as specified in FMP) and updated with the data on timber felling data from Forest Management Record. However, under the environmental scenario, 75% of the NP area is designated as no intervention area, meaning that the prescription of timber harvesting is equal to zero. Consequently, the annual available felling for this area is set to zero. The rest of the area of the National Park as well as areas outside the National Park is managed according to FMP, similar to the reference scenario.

The impact of the environmental scenario conditions on the potential supply of FES - annual available felling is illustrated in Map 12. As depicted, the supply of this FES is reduced across almost the entire HFR Poloniny, but especially in the north-western part of the area in comparison with the reference scenario.



Map 12 Potential supply of FES - annual available felling for harvesting in HFR Poloniny according to environmental scenario

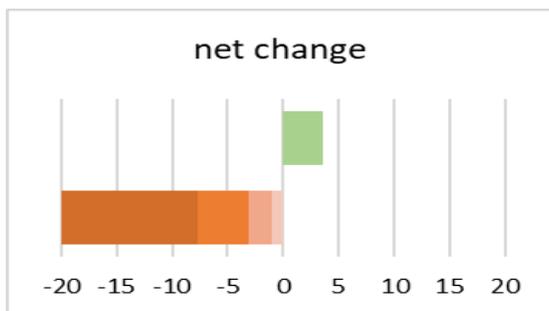


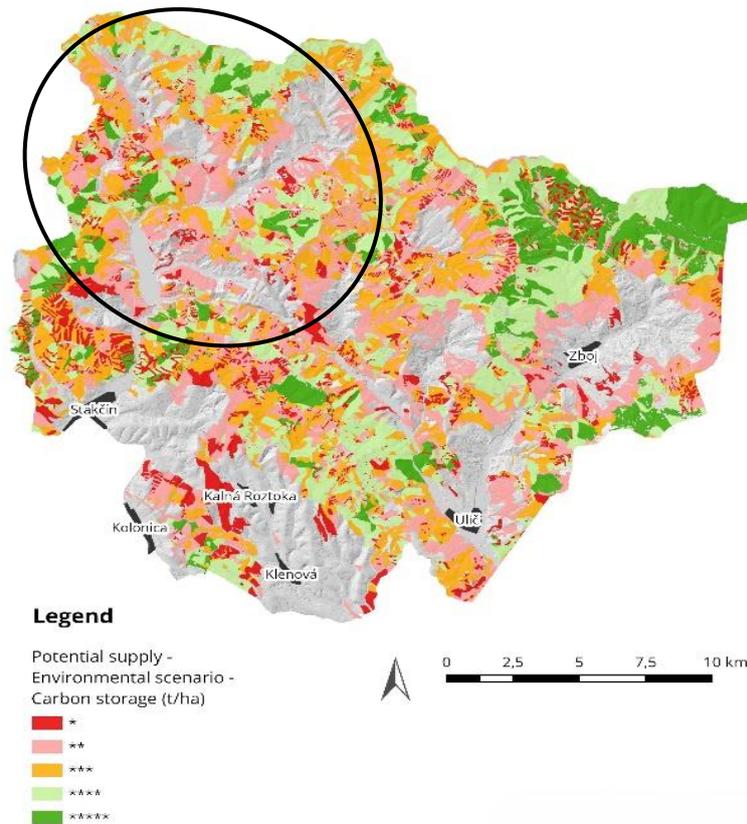
Fig. 3 Display of changes by percentage change in area in relative assessment FES -annual available felling

The change in management conditions under the environmental scenario resulted in a deterioration of potential supply of the annual available felling across 21% of the HFR Poloniny. In contrast, only on 3.6 % of the area experienced an improvement in the potential supply of this FES when compared to the reference scenario.

Carbon storage

As previously mentioned, the current timber stock serves as the basis for carbon storage assessment. Under the environmental scenario, this assessment is primarily influenced by the division of HFR Poloniny, with 75% of the NP area designated as no intervention area, where the prescribed felling is zero. The remaining area is managed in accordance with the FMP.

The revised management conditions introduced in the environmental scenario have led to enhanced potential supply of FES - carbon storage in the HFR Poloniny, with the most notable improvements occurring in the north-western part of the territory.



Map 13 Potential supply of FES - carbon storage in HFR Poloniny according to environmental scenario

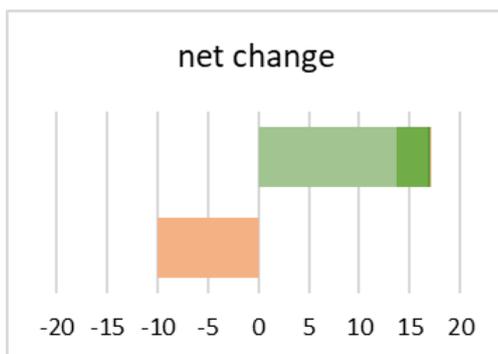


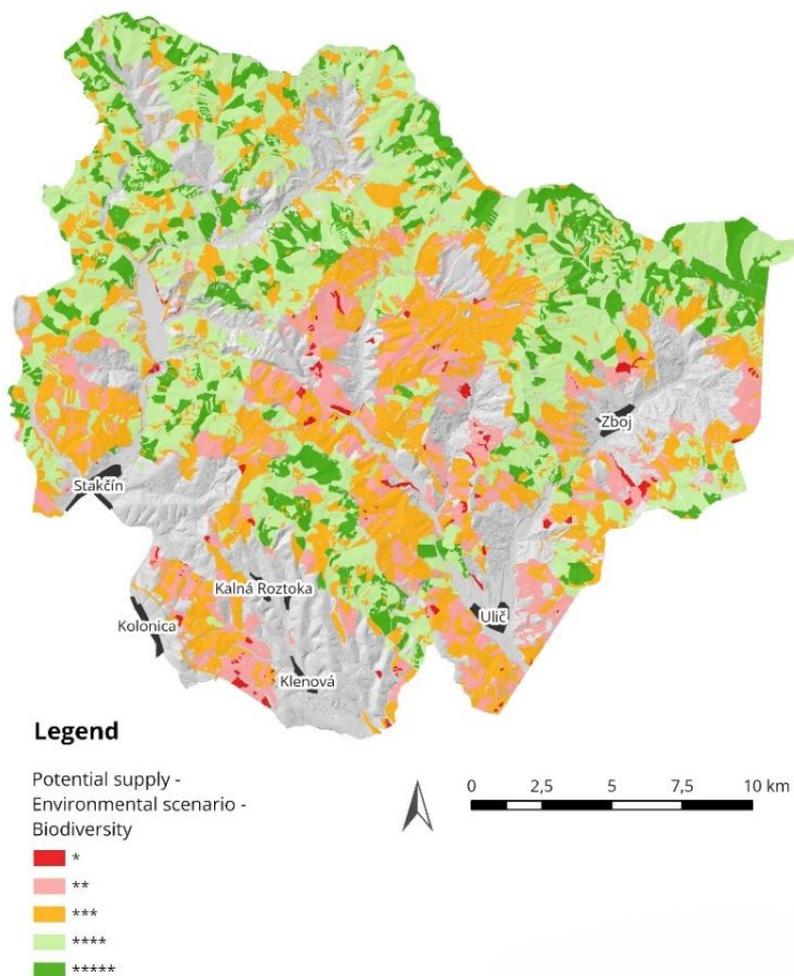
Fig. 4 Display of changes by percentage change in area in relative assessment of FES - carbon storage

The change in management conditions under the environmental scenario led to a decrease in the potential supply of the carbon storage across 10 % of HFR Poloniny. Conversely, approx. 16% of the area showed an improvement in the potential supply of this FES compared to the reference scenario.

Biodiversity

All indicators were used to assess the potential supply of FES - Biodiversity, however the greatest impact under the environmental scenario had naturalness and autochthony of forest stands, volume of dead wood - natural mortality, support of biodiversity (nature of management), and protected areas (level of nature protection).

As shown in Map 14, the potential supply of FES - biodiversity is significantly enhanced across the entire HFR Poloniny under the environmental scenario.



Map 14 Potential supply of FES - biodiversity in HFR Poloniny according to environmental scenario

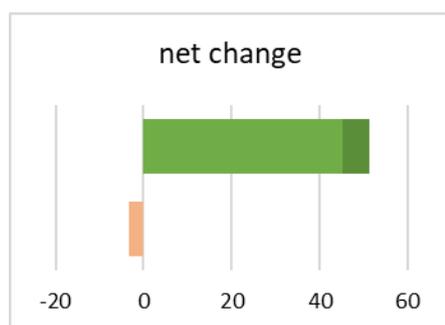


Fig. 5 Display of changes by percentage change in area in relative FES - biodiversity assessment

The change in management conditions under the environmental scenario led to a deterioration of potential supply of the biodiversity in only 3.4 % of HFR Poloniny. In contrast, approx. 51 % of the area experienced an improvement in the potential FES supply compared to the reference scenario.

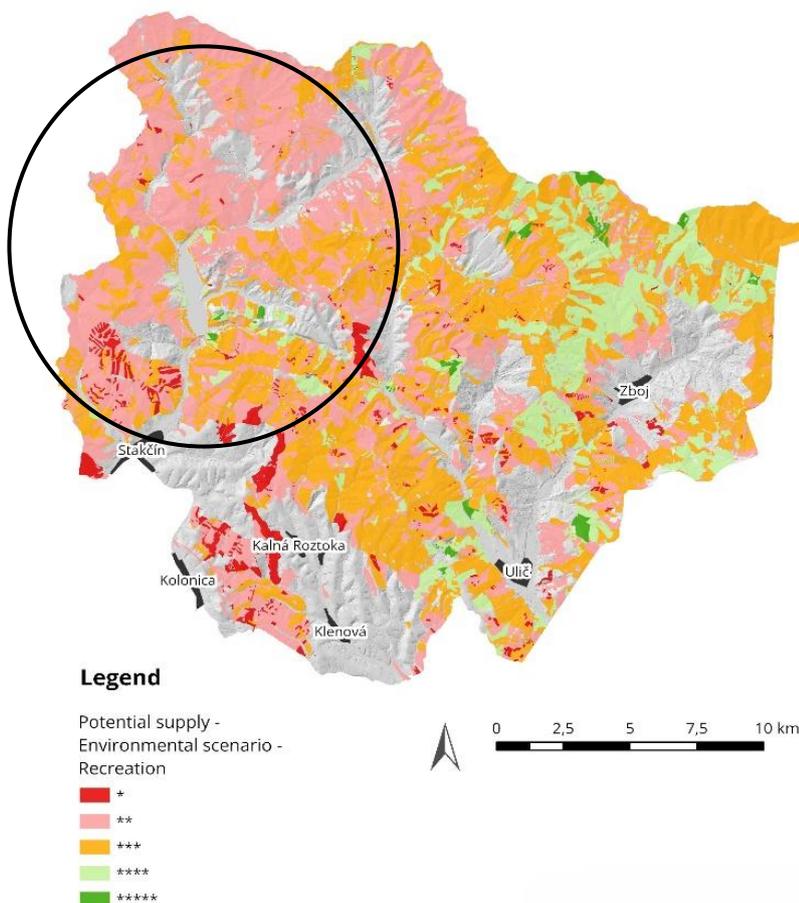
Recreation

The assessment of the potential supply of FES - Recreation under the environmental scenario was most influenced by the indicators listed in the table below.

Table 16 Indicators with the greatest impact on FES - Recreation in the environmental scenario

Dimension	Attribute	Indicator and its description
Forest	Appearance	Perception of freedom, wildness and roughness - <u>naturalness of tree species composition</u> , dead wood and downed dead trees,
		Perception of antiquity and eternity - age of the forest stand, <u>regeneration period</u>
Management		Perception of care for the forest and the environment - degree of support for recreational services through management
		Extend of interventions - <u>intensity of timber harvesting, biodiversity support score</u>
		Management and its targets - <u>score of support for recreation and aesthetics of the forest through management</u>

As shown in Map 15, the potential supply of FES - recreation shows only a slight improvement under the environmental scenario, with the most notable enhancements occurring in forest stands located in the western part of HFR Poloniny (outside the boundaries of the National Park).



Map 15 Potential supply of FES - recreation in HFR Poloniny according to environmental scenario

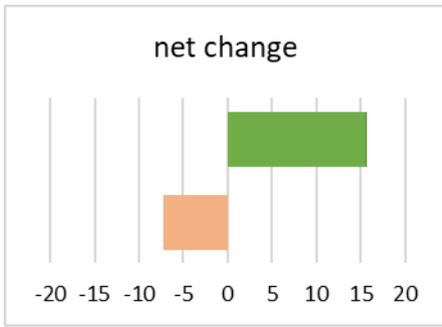


Fig. 6 Display of changes by percentage change in area in relative FES -recreation assessment

The change in management conditions under the environmental scenario resulted in a decline of the potential supply of FES - recreation in only 7.2 % of the HFR Poloniny, while approx. 15.6 % of the area showed an improvement in the supply of this FES compared to the reference scenario.

3. Comparison of FES between the scenarios

As outlined in the initial section of this document, three management scenarios were developed during a regional workshop, reflecting social, economic, and environmental dimension of SFM. Within the project an integrative perspective on sustainable development is adopted, recognizing that economic activities function within broader social systems, which themselves exist within an overarching ecological context—thus, these dimensions are considered as nested rather than separate. Accordingly, in the previous Deliverable 2.1.3, particular emphasis was placed on the environmental scenario.

The radar chart illustrates the average impact of three different management scenarios (social, environmental, and economic) on the supply of five selected FES in HFR Poloniny. It visualizes how different management priorities can shift the balance among particular FES. Each scenario demonstrates a trade-off: maximizing benefits in one area often leads to reductions in others. Social and economic scenarios show relatively balance impact across most FES, without strongly favouring or disadvantaging any particular FES. However, environmental scenario strongly favours biodiversity, recreation and carbon storage. On the other hand, this scenario shows negative impacts on available felling and wood production, which is expected for environmental scenario prioritizing non- production services.

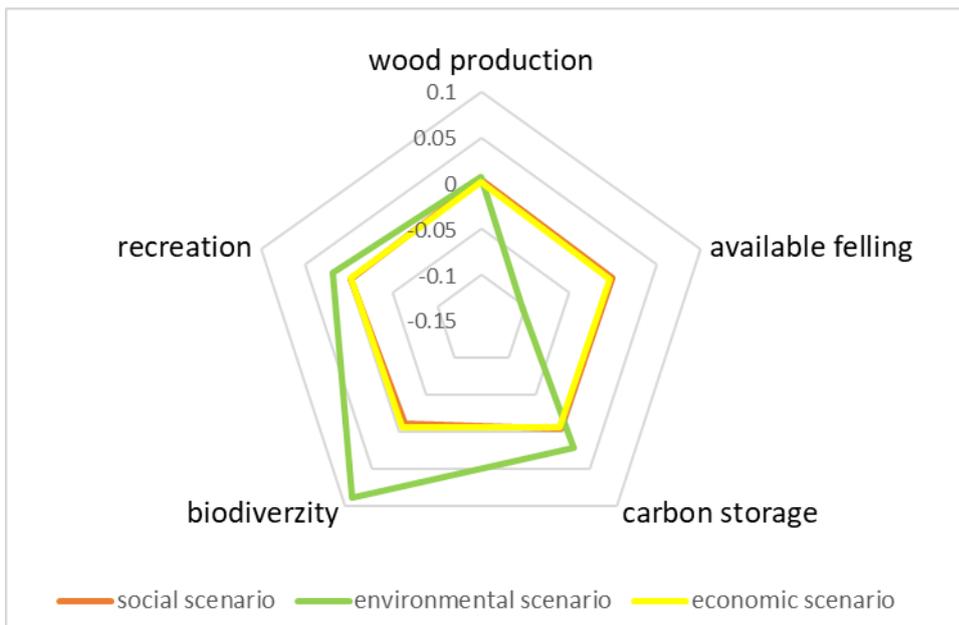


Fig. 7 Average impact of scenarios on the supply of FES in HFR Poloniny

To assess the potential trade-offs between different management approaches, a comparative economic valuation was conducted for two scenarios:

- Reference Scenario - based on management practices following currently valid FMP, which is focused on multifunctional forest management taking into account social and economic scenarios,
- Environmental Scenario - reflecting a more conservation-oriented management approach with reduced harvesting intensity and increase timber stock.

The assessment focused on wood production and carbon storage that could be monetary evaluated.

Wood Production

In the Reference Scenario, the total standing timber stock is estimated at 7,400,332 m³, corresponding to an economic value of 691,263,449 €. The volume of wood available for sustainable harvesting amounts to 117,878 m³ annually, representing a potential market value of 11,466,308 € per year.

In the Environmental Scenario, the timber stock increases to 8,125,493 m³, with a corresponding value of 758,787,184 €. However, the annual available felling is significantly reduced to 56,398 m³, with an estimated market value of 5,487,799 €. This reflects a clear trade-off: conservation-oriented management increases the long-term stock value of timber resources while reducing short-term annual revenues from harvesting.

Carbon storage

The carbon valuation was conducted analogously, based on above-ground biomass converted into carbon storage and monetized using the 6-year average CO₂ certificate price of 46.71 EUR/t.

- In the Reference Scenario, the total carbon storage amounts to 2,378,200 tonnes, with an economic value of approximately 111,085,720 €.
- In the Environmental Scenario, the carbon storage is estimated at 2,613,587 tonnes, corresponding to an economic value of 122,081,122 €.

Table 17 Comparison of economic values of selected ES between reference and environmental scenario

FES	Reference Scenario		Environmental Scenario	
	m ³ / tC	Value (€)	m ³ / tC	Value (€)
Timber stock	7,400,332	691,263,449 €	8,125,493	758,787,184 €
Annual available felling	117,878	11,466,308 €	56,398	5,487,799 €
Carbon storage	2,387,200	111,085,720 €	2,613,587	122,081,122 €

4. Recommendations and future use

The results of the analysis indicate that the environmental scenario exerts the most significant influence on the provision of FES in HFR Poloniny. Building on this finding, it is essential to translate scenario outcomes into concrete forest management recommendations. These measures not only support the project's objectives but also provide a foundation for future decision-making processes at regional and national levels.

Recommended Management Measures

To operationalize the environmental scenario, the following management measures are proposed:

- Significant reduction of timber felling within the National Park, ensuring that approximately 75% of the area remains without interventions.
- Application of forest management in line with Forest Management Plans (FMPs) outside the National Park, thereby balancing conservation and sustainable use.
- Relocation and minimisation of visible interventions, ensuring that logging activities are carried out away from tourist infrastructure. Any necessary interventions should be minimal, dispersed, and designed to reduce visibility to 0%.
- Adjustment of tree species composition to move closer to natural conditions. In some areas, this may involve increasing species diversity, whereas in pure beech forests, reducing the number of tree species may be more appropriate.
- Minimisation of anthropogenic damage, while allowing natural disturbances (abiotic or biotic) to occur. Such disturbances play a vital role in habitat creation, as damaged trees support diverse species.
- Increase in deadwood volume to approximately 20% of total stand volume, enhancing biodiversity and ecological stability.
- Raising the average age of forest stands to around 90 years, in alignment with natural reserves in the region.
- Promotion of multilayered forest structures, with stand layers ranging from one to three, to reflect natural processes.
- Preservation of trees valuable for biodiversity, particularly those that serve bees, birds, and other wildlife species.

Proposed Regional Activities

To ensure successful implementation and continuity, several activities are recommended at the regional level:

- Establish capacity-building and training programs for foresters, rangers, and local stakeholders on ecosystem-based management approaches.
- Strengthen awareness-raising and communication activities targeting local communities, visitors, and decision-makers, highlighting the benefits of reduced interventions and biodiversity-friendly practices.
- Support research and monitoring initiatives to track changes in biodiversity, forest structure, and ecosystem services provision under the environmental scenario.
- Foster sustainable tourism initiatives, where biodiversity-friendly forestry and enhanced landscape quality contribute to local economic opportunities.

Methodological Considerations

The used methodology for assessing FES is still under development. Nevertheless, its application and testing within this project represented an important step in validating its relevance for future wider implementation. The experience gained provides a solid basis for further refinement of the approach and

its broader use in evaluating FES in protected and managed forest landscapes. This creates opportunities to build upon the project results in future research, monitoring, and policy development.

Broader Implications and Future Use Beyond the Project

The recommendations developed within this project are not limited to its timeframe. They can serve as:

- Input for strategic decision-making by regional authorities and national-level policymakers (e.g. ministries).
- Guidelines for long-term forest planning, contributing to biodiversity conservation, climate adaptation, and sustainable rural development.
- Reference for adaptive management approaches, enabling the continuous adjustment of practices in line with ecological monitoring results.
- Inspiration for replication in other protected areas in Slovakia and beyond, showcasing a best-practice example of scenario-based forest management.

An important step forward is to ensure stakeholder involvement in governance processes. Participation in the National Park Committee would allow project representatives and regional actors to contribute actively to decision-making, strengthen cooperation with park authorities, and ensure that environmental scenario recommendations are embedded in official management strategies.

Table 18 Future Use of Project Recommendations

Role / Actor	Responsibilities	Action
National Park administration	Integrate recommendations into planning documents; ensure alignment of management activities with biodiversity conservation goals.	Ongoing monitoring and adaptation.
National-level policymakers (e.g. ministries of environment, agriculture, rural development)	Use recommendations as input for strategic decision-making; align forest, biodiversity, and rural development policies with scenario-based management principles.	Policy adjustments and integration into strategies. Support for funding and legislation.
Forest managers / practitioners	Apply guidelines for adaptive management; adjust practices in line with ecological monitoring; implement biodiversity-friendly measures.	Continuous and regular updates based on monitoring results.
Research and monitoring institutions (e.g. NFC, State nature conservancy)	Provide data for adaptive management; refine and further develop FES assessment methodologies; ensure evidence-based decision support.	Further applications and validation. Continuous refinement and replication.
Enviro NGOs, Forest communicators, other active groups	Use the HFR Poloniny case as inspiration and model; replicate best practices in other areas in Slovakia and internationally.	Knowledge transfer and pilot replications. Scaling up to other landscapes.

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