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Assessing the Provision of Ecosystem Services Using Forest Site Classification as a Basis for the Forest Bioeconomy in the Czech Republic

Kateřina Holušová and Otakar Holuša *

Department of Environmental Science and Natural Resources, Faculty of Regional Development and International Studies, Mendel University in Brno, Tř. Generála Píky 7, 613 00 Brno, Czech Republic; holusova.katerina@seznam.cz

* Correspondence: holusao@email.cz

Abstract

The ecosystem services (ESs) of forests are the benefits that people derive from forest ecosystems. Their precise recognition is important for differentiating and determining the optimal principles of multifunctional forest management. The aim of this study is to identify some important ESs based on a site classification system at the lowest level—i.e., forest stands, at the forest owner level—as a tool for differentiated management. ESs were assessed within the Czech Republic and are expressed in units in accordance with the very sophisticated Forest Site Classification System. (1) Biomass production: The vertical differentiation of ecological conditions given by vegetation tiers, which reflect the influence of altitude, exposure, and climate, provides a basic overview of biomass production; the highest value is in the fourth vegetation tier, i.e., the *Fageta abietis* community. Forest stands are able to reach a stock of up to 900–1200 $m^3 \cdot ha^{-1}$. The lowest production is found in the eighth vegetation tier, i.e., the *Piceeta* community, with a wood volume of 150–280 $m^3 \cdot ha^{-1}$. (2) Soil conservation function: Geological bedrock, soil characteristics, and the geomorphological shape of the terrain determine which habitats serve a soil conservation function according to forest type sets. (3) The hydricity of the site, depending on the soil type, determines the hydric-water protection function of forest stands. Currently, protective forests occupy 53,629 ha in the Czech Republic; however, two subcategories of protective forests—exceptionally unfavorable locations and natural alpine spruce communities below the forest line—potentially account for 87,578 ha and 15,277 ha, respectively. Forests with an increased soil protection function—a subcategory of special-purpose forests—occupy 133,699 ha. The potential area of soil protection forests could be up to 188,997 ha. Water resource protection zones of the first degree—another subcategory of special-purpose forests—occupy 8092 ha, and there is potentially 289,973 ha of forests serving a water protection function (specifically, a water management function) in the Czech Republic. A separate subcategory of water protection with a bank protection function accounts for 80,529 ha. A completely new approach is presented for practical use by forest owners: based on the characteristics of the habitat, they can obtain information about the fulfillment of the habitat's ecosystem services and, thus, have basic information for the determination of forest categories and the principles of differentiated management.

Keywords: SITE classification system; FOREST categories; ecosystem services; wood production; edaphic-soil protection service; hydric-water management service; Czech Republic

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1. Introduction

Each forest ecosystem fulfills a range of functions [1,2], which are determined by the influence of energy and material flows in each forest ecosystem. Historically, the primary purpose of forest management was biomass production. Through gradual research and the acquisition of knowledge, other functions of forests were identified which, at the beginning of the 21st century, resulted in the definition of ecosystem services [3]. Ecosystem services have been the focus of much research, especially in the last two decades (see, e.g., [4–9]).

Forest ecosystem services are divided based on the CICES classification [7] into three groups: (i) provisioning services, (ii) regulating services, and (iii) cultural services. Several classification systems have added (iv) supporting services [4]. However, many authors deal with the classification of ecosystem services [7,10–15]. In the Czech Republic, for example, methodological aspects of ecosystem service valuation have been proposed at the national level [16].

There has been an effort to establish a framework of policy instruments to express ecosystem services in terms of money for payment schemes, especially on the European continent [17–20].

The concept of the bioeconomy represents an approach to sustainable development that connects environmental and economic objectives. One of its pillars is based on the use of renewable natural resources, including forest-based products. The findings have the potential to support more effective decision-making under increasing uncertainty and contribute to shaping economic policies oriented toward long-term sustainability. A habitat analysis can play a fundamental role for this [21]. These models allow for the assessment of investment impacts and specific risks for the performance of forestry and wood-processing enterprises, especially at a time when we are trying to find the funds for ecosystem service schemes at national and international levels [20–22]. Integrating regional forest productivity maps with supplemental data to optimize forest management priority [23] can help decision-makers to establish a practical forest policy framework.

The currently valid Act 289/1995 Coll. (Forest Act and on Amendments to Certain Acts) [24] covers the same three categories as the previous Act; however, in addition, it clearly defines which habitats are protective forests and describes their subcategories in the Czech Republic.

The site classification system was defined in 1971 [25,26] and is gradually being introduced into forest management plans [27,28] because of its definition of basic economic units—management units. However, its importance is significantly enhanced by the introduction of Regional Forest Development Plans (Decree 298/2018 Coll. Decree on the preparation of regional forest development plans and on the definition of management sets) [29], which represent the basic tool for framework planning in forests. The main purpose is to determine the functions and functional potential of forest stands. Toward the end of the 20th century, there was a clear connection between site classification—management units and forest functions—and management style.

The functions of forests and the subsequent provision of the expected ecosystem services are determined by natural conditions and the state of forest stands (current tree composition or its structure: age, height, development, position, etc.). This clearly sets limitations on the use of forest ecosystems for the provision of ecosystem services. The potential for the provision (or provision) of ecosystem services is therefore clearly based on natural conditions [30]. For the classification of natural conditions, we clearly use the site classification system. However, this system entails being able to evaluate both the trophicity and hydricity of the habitat and other characteristics of the forest eco-system. The classification of current and potential vegetation plays a crucial role in the approach. The site classification presented here works with potential vegetation—see [26]. It is true that each forest ecosystem provides ecosystem services with different intensities. It is possible to regulate forestry management according to the prevailing function of a forest and the expected provision of ecosystem services [31]. The principle of multifunctional management should be supported, with the aim of identifying the most optimal management measures and sustainability.

For assessing the provision of ecosystem services using forest site classification as a basis for the forest bioeconomy, we set the following research questions. The study area includes the entire territory of the Czech Republic (which are average conditions in Central Europe).

Research question I: How is site classification able to reflect the provision of ecosystem services that are directly linked to site characteristics (i.e., conditions that cannot be influenced by humans)?

Research question II: How are forests classified in the territory of the Czech Republic from the perspective of "habitat" ecosystem services and their reflection in the fulfillment of forest functions and current management (understood as categories or subcategories of forests)?

2. Materials and Methods

2.1. Study Area—Czech Republic

The Czech Republic (CZ) is a country in the middle of the European continent. It has an area of 78,866 km^2 and a mean altitude of 430 m. From a biogeographical point of view, the area is partly located in the *Carpathicum* region, and the greater part falls within the *Hercynicum* region [32]. According to [33], the forest cover of the territory is around 34%, which represents 2,681,764 ha. The forest cover of the territory is increasing every year. Coniferous trees (67.7%) currently dominate the territory, followed by deciduous trees (30.1%), and the rest (2.2%) comprises clearings created by the disintegration of spruce stands. These clearings are now being actively afforested. Within the current species composition of forests in the Czech Republic, the most represented tree species are Norway spruce (*Picea abies*/L./H. Karst.) at 46%, Scots pine (*Pinus sylvestris* L.) at 16%, European larch (*Larix decidua* Mill.) at 4%, Sessile oak (*Quercus petraea*/Matt./Liebl.), Pedunculate oak (*Quercus robur* L.) at 8%, European beech (*Fagus sylvatica* L.) at 10%, and birches (*Betula pendula* Roth, *Betula pubescens* Ehrh.) at 3%. Within the potential species composition (that which would occur here without human intervention; reconstructed species composition based on the results of forest habitat classification), the most represented tree species are European beech at ±40%, Silver fir (*Abies alba* Mill.) at ±20%, Norway spruce at ±11%, and Oaks at ±20%.

The most widespread soil types are cambisols, podzols in mountainous areas, rankers on scree slopes, brown earths and luvisols with loess overlays in lowlands, and alluvium fluvisols in rivers; other soil types are less common. The total and average stocks of wood in the territory of the state reach 686 million m^3 and 263 m^3·ha^{-1} (calculated with clearing areas), respectively. The average rotation period is 115 years, and the average timber cutting increase is 4.9 m^3 per ha (without bark). In 2023, extraction was 18.5 million m^3, and forest renewal reached 44,788 ha [33].

2.2. Forest Site Classification System in the Czech Republic and Its Use in Forest Management Practices

2.2.1. Definition of System and Its Framework and Units

In the Czech Republic, the Forest Site Classification System is used for 100% of the forest land area (defined as land designated for forest functions, according to Act No. 289/1995 Coll., on Forests, as amended, § 2 a).

Forest site classification can be considered a basic discipline of forest management, which deals with the classification of permanent ecological conditions of habitats. In particular, it is used to divide forests into segments with similar growth conditions, evaluate these ecological conditions, and draw conclusions for appropriate forest management. For this purpose, the Forest Site Classification System is used as a tool [34], which applies the following units: i. (forest) vegetation tiers (taking into account the gradient of the vertical zonality of vegetation); ii. edaphic categories (taking into account the gradient of trophicity and hydricity of the habitat); iii. forest site complexes (i.e., basic application units of this system; for zonal habitats, they are defined by a combination of the vegetation tier and edaphic categories); and iv. forest site types (basic mapping units). The system is based on the description of potential (i.e., natural) vegetation, but it classifies all forest ecosystems in the Czech Republic, which means that a significant feature of this system is the classification of the naturalness of forest ecosystems and the assessment of the degree of naturalness within units [35].

The aim of forest site classification is to derive growth conditions based on the identified causal relationships between vegetation and the main physical–geographical, geological–pedological, and climatic elements. Forest site classification thus serves as a basis for determining management measures in forests and setting operational and production objectives in forest management plans and outlines. Its importance has increased under new political–economic–environmental conditions (after 1989), and it has also been used to evaluate the functions of forest ecosystems [36], value forests [37], or create management plans for specially protected areas [26,38,39].

As a tool for classifying permanent ecological conditions, the Forest Site Classification System describes ecosystems with respect to potential vegetation and is used to create management units according to Decree No. 298/2018 Coll. [29]. A schematic representation of the units of the Forest Site Classification System is shown in the Tabular Overview "Overview of forest types and forest type sets in the Czech Republic" [40].

The basic unit of this system is the forest site type, which was defined by Zlatník [41] as a set of forest biogeocenoses that are developmentally related to each other; namely, a set that includes all biogeocenoses and stages of biogeocenoses that can form (possibly also under human influence) in places with certain ecological conditions and that formed there in the past under the then-current climate.

The application unit of this system is the forest site complex. This unit connects forest types according to ecological relationships. Forest site complexes are created by a combination of superstructure units—the vegetation tier and edaphic categories. Forest site complexes represent certain natural sets of forest geobiocenoses and are related to them in terms of the natural composition of tree species or changed geobiocenoses in commercial forests.

The ecological superstructure unit of geobiocenological units related to the climate applicable to landscape segments is, according to [42], the vegetation tier (altitudinal vegetation zone).

Vegetation tiers are defined according to the ecological manifestation of the species combination in segments of the leading hydric–pedological series, where the difference in the influence of climate on the composition of woody and understory synusia is least disturbed by local water shortages or, conversely, by local water not from atmospheric sources.

A vegetation tier represents a biocenological (geobiocenological) structural unit that reflects the influence of macro- and mesoclimates on the composition of chthonophytic synusia of biocenoses (geobiocenoses), which is determined by this composition. Vegetation tiers are determined by the differentiation of species, which are primarily arboreal or shrubby determinants of the synusia at the main level of original forest and shrub biocenoses and chthonophytes in general, reacting decisively to the length of the growing season and to negative climate phenomena.

Vegetation tiers can be determined primarily by the representation and ecological manifestation of tree species. Ten vegetation tiers are distinguished. The main species in vegetation gradation in the Central Europe are Sessile oak (*Quercus petraea*), Pedunculate oak (*Quercus robur*), European beech (*Fagus sylvatica*), Silver fir (*Abies alba*), Norway spruce (*Picea abies*), and mountain pine (*Pinus mugo* Turra). The individual vegetation tiers were named based on species with a dominant or significant influence on the formation of the community.

The structural characteristics, or determining features, of individual vegetation tiers have not yet been defined, cf. [42,43]. The first comprehensive characteristics of vegetation tiers, especially with structure-determining features, were published recently [44–46]. However, these characteristics are described for northeastern Moravia and Silesia—the third and fourth vegetation stages [44], the fifth and sixth vegetation stages [45], and the seventh and eighth vegetation stages [46].

The normal sequence of vegetation tiers is understood to be the sequence of vegetation tiers that formed under the influence of the macroclimate with increasing altitude from lowlands to mountains in a gradually increasing area, where exposure and inverse mesoclimate are not applied. The hilly and mountainous character of natural forest areas imparts a fragmented character to vegetation tiers, necessitating the construction of the Forest Site Classification System.

Different conditions of the ecotope are reflected in the nutrient content and soil reaction, leading to the formation of trophic series and trophic intermediate series [43,47,48]. In the Forest Site Classification System [25], ecological series are defined on the basis of permanent soil conditions, which form a broader framework for edaphic categories. An ecological series is a superstructure unit that is differentiated using the trophic and hydric factors of the site. Edaphic categories are based on the specific properties of the soil environment and are determined by the prevailing soil type. An edaphic category is also a superstructure unit that differentiates forest geobiocenoses on the basis of physical and chemical soil and terrain properties. The main criteria are the pedogenetic process, soil type, and skeletal content. Edaphic categories are grouped into ecological series.

The Latin and English equivalents were first named in the study [49], although not described. These basic units are then renamed and standardized in detail by law.

The ecological series *Trophicum* includes normal average soil conditions. This series comprises the basic edaphic category B—*eutrophica* (nutrient-rich)—and the following secondary categories: F—*lapidosa mesotrophica* (fresh stony); C—*subxerothermica* (drying); W—*calcaria* (limestone); and H—*illimerosa trophica* (clay). It also contains the transitional edaphic category S—*mesotrophica* (medium-rich). The ecological series *Acidophilum* includes habitats on poor soils that genetically developed but with impaired humification. It is represented by edaphic categories K—*acidophila* (acidic) on clay soils; I—*illimerosa acidophila* (acidic loamy) on skeletal soils; N—*lapidosa acidophila* (acidic stony); and M—*oligotrophica* (poor).

The ecological series *Acerosa* is humus-enriched and is found in habitats that have very favorable humification. It includes the edaphic categories J—*saxatilis acerosa* (enriched skeletal); A—*acerosa lapidosa* (enriched stony); and D—*deluvia* (enriched clay). The ecological series, being acidic, nutritious, and enriched with humus, forms the basis of the system and represents zonal communities; namely, communities related to the climate on developed soils: true climax communities. The ecological series *Extrema* is associated with extreme habitats in exposed positions, habitats with unfavorable soil conditions, or habitats where climatic conditions lead to the stunting and natural loosening of forest stands. It includes the basic edaphic category Z—*humilia* (dwarf)—and two secondary edaphic categories: Y—*saxatilis* (skeletal), and X—*xerothermica* (xerothermic). Habitats influenced by flowing water are associated with the ecological series *Fraxinosa* (i.e., water-rich), which represents communities on the alluvial plains of streams and rivers, which are more or less regularly flooded and have high groundwater levels. This series includes the basic edaphic category L—*alluvial* (alluvial); the secondary edaphic category U—*validosa* (valley); and the transitional edaphic category V—*humida* (humid). The ecological series *Variohumia* (gleyed—strongly fluctuating water tables) is characterized by the alternating wetting and drying of the soil and includes the basic edaphic category P—*variohumida acidophila* (gleyed acidic); edaphic category Q—*variohumida oligotrophica* (gleyed poor); and edaphic category O—*variohumida mesotrophica* (gleyed medium-rich). The ecological series *Paludosa* (waterlogged) includes habitats permanently under the influence of groundwater; it is represented by the basic edaphic series G—*paludosa mesotrophica* (waterlogged medium-rich), and the edaphic series T—*paludosa acidophila* (waterlogged poor). Transitional and upland peat soils with a peat layer of at least 0.5 m are included in the ecological series *Turfosa* (peaty) with a single edaphic category: R—*turfosa* (peaty). The general and basic characteristics of ecological series and edaphic categories are described in [27,48]. The arrangement of ecological series and edaphic categories is shown in the "Overview of forest sites and Complex of forest sites in the Czech Republic" [40].

2.2.2. Definition of Forest Categories

Act No. 289/1995 [24] establishes three categories of forests for their management in the Czech Republic on the basis of their predominant functions:

a. Protective forests;
b. Special-purpose forests;
c. Economic forests.

The category of protective forests is further divided into the following groups:

1. Forests in extremely unfavorable sites (scrubs, rocky seas, steep slopes, rapids, unstabilized alluvium and sand, peat bogs, embankments, landfills, etc.);
2. Forests of natural high-mountain spruce communities below the tree line, protecting lower-lying forests and forests on exposed ridges;
3. Forests in the dwarf pine and alpine vegetation tiers.

These forests are not considered within separate subcategories; they are only used when determining management units—target management sets.

The category of special-purpose forests represents forests that have other specific functions that are superior to the bioproduction function and require regulated management. This category is further divided into subcategories [24]:

1. Forests in sanitary protection zones for water resources of the first degree;
2. Forests in protective zones of sources of natural medicinal and table mineral waters;
3. Forests in the territories of national parks and national nature reserves.

These subcategories are always included in the category of special-purpose forests.

The following forests can also be included in the category of special-purpose forests:

4. Forests in the first zones of protected landscape areas and forests in nature reserves, national natural monuments, and natural monuments;
5. Spa forests;
6. Suburban and other forests with an increased recreational function;
7. Forests used for forestry research and forestry education;
8. Forests with increased soil protection, water protection, climate, or landscape-forming functions;
9. Forests necessary for the preservation of biological diversity;

10. Forests in recognized game reserves and separate pheasant farms;
11. Forests, in which another important public interest necessitates a different method of management.

Economic forests are forests that are not classified as protective forests or special-purpose forests.

The category of special-purpose forests includes protected areas in the sense of nature conservation. The category of protective forests therefore includes forests that are protected to preserve their functions, which they ensure. For example, protection against soil erosion. But in the sense of Czech law, this does not mean that they cannot fulfill a bioproduction function. The system functions in such a way that there is a possibility of overlapping the fulfillment of forest functions in the sense of ensuring polyfunctionality.

2.2.3. Management Units

For management purposes, the Forest Site Classification System units are too detailed; therefore, in accordance with certain rules, the application units (i.e., forest site complexes) are combined into management units (i.e., target management sets). Then, according to the representation of the dominant tree species, target management sets are further divided into forest stand management sets [29]:

- Target management sets are the basic units of forestry management and are based on the basic characteristics of permanent ecological conditions and the fulfillment of forest functions, combining the basic forest site classification application units according to the vegetation tier and ecological series or edaphic category. The definition of current management sets is based on several factors: the functional focus of the forest based on public interests, determined through forest categorization; the framework definition of target management sets, based on the forestry site classification (classification of natural conditions), i.e., through forest types and forest site complexes; and the condition of forest stands, defined by specific stand types.
- Forest stand management sets are the basic units of forestry management and are based on target management units and the characteristics of forest stands with regard to the species composition.

2.3. Source and Evaluation of Data

2.3.1. Source Data and Processing of Maps

The provision of forest ecosystem services was assessed using national data for the Czech Republic; the data were sourced from the Forest Management Institute of the Czech Republic (hereinafter FMI) and reflect information up to the date 31 December 2023. The data include the total map layer of forest site complexes in ESRI shapefile format, EPGS 5514; the territorial extent of the entire Czech Republic (excluding areas that are managed by the Ministry of Defense and subject to a special regime); and the areas of forests in individual categories and subcategories (from anonymized data in forest management plans and outlines of all forest owners in the Czech Republic and from documents on decisions of State Forest Administration) in ESRI shapefile format, EPGS 5514 with attributes of subcategories, as well as summary outputs in m^2 in table format in xlsx files. These data were provided in accordance with a data provision agreement. In addition, freely accessible data from the results of the third cycle of the National Forest Inventory in the Czech Republic (2016–2020) were prepared according to the Decree of the Government of the Czech Republic No. 247/2009 Coll. announcing the implementation of a forest inventory (available at https://nli.gov.cz/portfolio/nil/, accessed on 22 July 2025).

Results displayed using maps were further processed on the binding initial map basis for the creation of forestry maps, which is the state map of the Czech Republic at a scale of 1:5000. For the creation of forestry maps, especially maps working from the forest site classification system, they were taken from the materials of the FMI (see above): map of vegetation tiers, map of target management sets, and map of edaphic categories and ecological series.

Within the framework of the unification of graphic objects and their cartographic presentation, the inventory and standardization of the elements of the Forest Management Information Standard for Forest Management Planning and the processing of Regional Forest Development Plans was used, and regularly updated. Specifically, schemes, templates, and coding were used [50].

The resulting maps processed based on the schematic procedure shown in Figure 1 were processed using the ESRI 2020 ArcGIS ArcMap 10.8 software.

A series of collected data on the growing stock for specific forest stand types with a combination of site indices (forest site complexes) was used on the base of several of our own studies [44–46]. The following scale (derived by interpolation) of distribution of the range of growing stock in cubic meters per hectare for individual vegetation tiers was designated:

- Very low with growing stock from 50 to 200 $m^3 \cdot ha^{-1}$ for the nineth and eight vegetation tiers;
- Low with growing stock from 201 to 400 $m^3 \cdot ha^{-1}$ for the first and seventh vegetation tiers;
- Mean with growing stock from 401 to 600 $m^3 \cdot ha^{-1}$ for the second vegetation tiers;
- High with growing stock from 601 to 800 (900) $m^3 \cdot ha^{-1}$ for the third and sixth vegetation tiers (also for the floodplain habitats);
- Very high with growing stock from 801 to 1200+ $m^3 \cdot ha^{-1}$ for the fourth and fifth vegetation tiers.

These data of growing stock are valid for forest stands that can be characterized in mature phase with an average age of 90 to 130 years, and are also valid for individual forest site complexes, but are different for individual vegetation tiers.

2.3.2. Methodology of Quantitative Evaluation of Ecosystem Services of Forest Ecosystem

Figure 1 presents a diagram showing the following ecosystem levels used to quantify the selected ecosystem services:

A. Ecotope level—that is, the site's geological, geomorphological, and soil conditions; conditions that cannot be influenced by human activity or management. A detailed description of site classification, including the forest categories used for this research, is provided in Section 2.2.
B. Forest stand level—the conditions driven by the tree species composition of the forest stand;depends on the style of forestry management.
C. Level of public interest—other societal requirements to fulfill specific functions for the public.

All levels will be reflected in the basic forestry management framework, i.e., in the determination of target management and forest stand management sets, which are classified into the relevant forest categories and subcategories. Individual levels will be reflected in the provision of important ecosystem services.

Production functions are expressed in $m^3 \cdot ha^{-1}$ in the case of wood production (results are evaluations of wood production service) and in $kg \cdot ha^{-1}$ for other production functions (production of mushrooms or forest fruits, etc.).

Ecosystem services that are defined by site conditions are expressed in ha of forest stands where these services are fulfilled. Similarly, other services defined by public interest, but also forest categories, subcategories, target management sets, and forest stand management sets, are expressed in ha of forest stands.

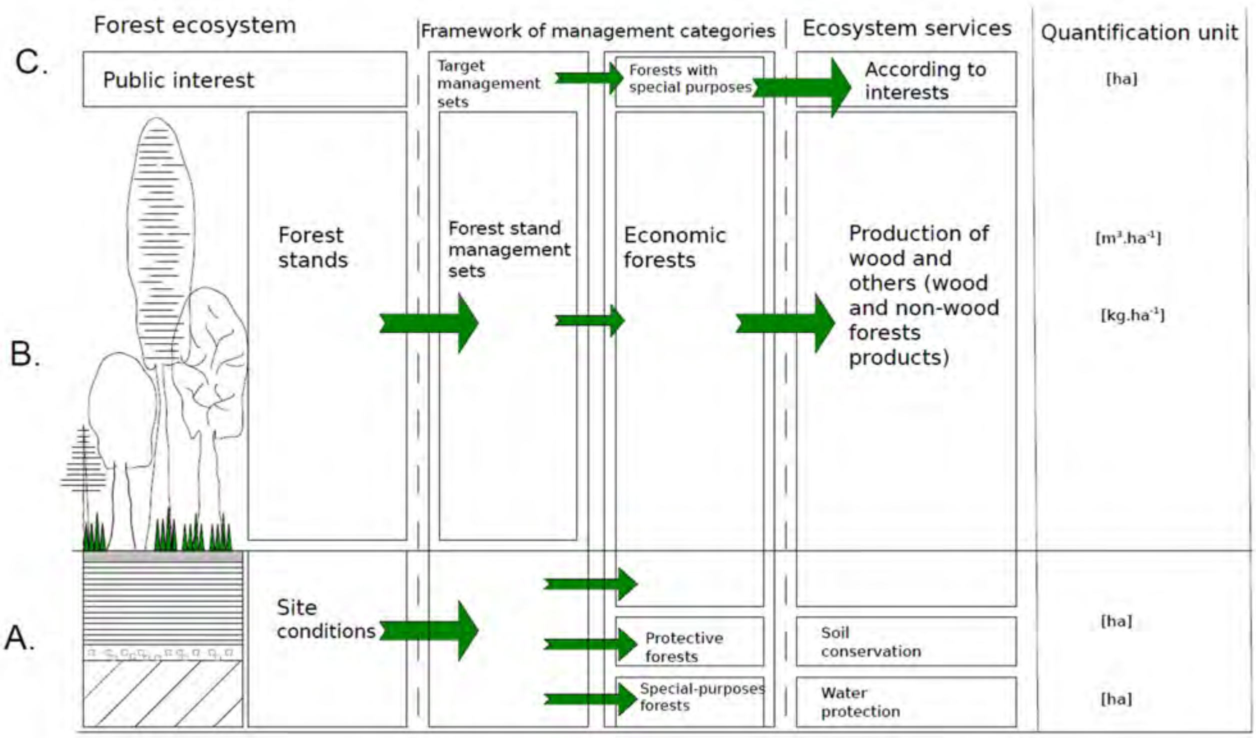


Figure 1. A scheme of the relationship between parts of the forest ecosystem, forest management frameworks, and ecosystem services and their quantification (orig.).

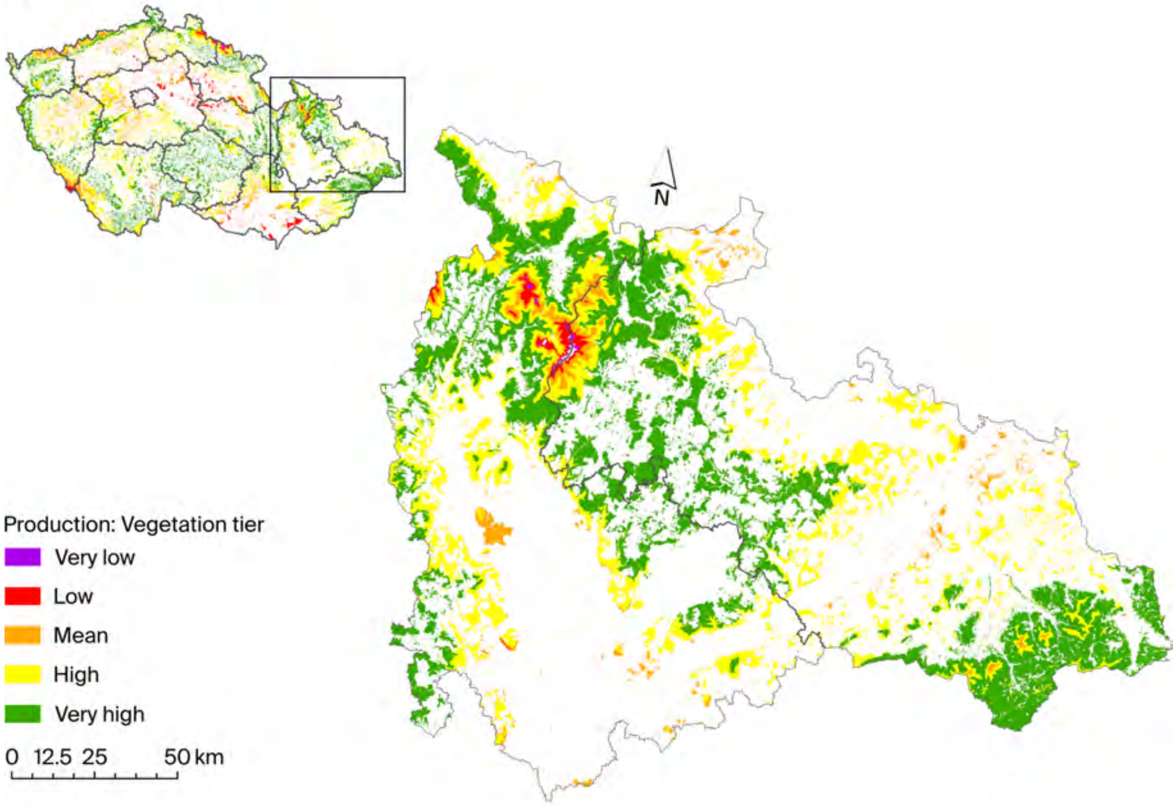
3. Results

3.1. Evaluation of Wood Production Service

The main ecosystem service of forests remains bioproduction, as we value it financially through wood production. When comparing the value of wood production (from the volume of aboveground biomass without branches up to 7 cm in diameter) in forests aged 120–150 years, the highest value is in the fourth vegetation tier, i.e., the *Fageta abietis* community. Forest stands are able to reach a stock of up to 900–1200 $m^3 \cdot ha^{-1}$. On the contrary, the lowest production is found in the eighth vegetation tier, i.e., the *Piceeta* community, with a wood volume of 150–280 $m^3 \cdot ha^{-1}$.

The fourth vegetation tier (*Fageta abietis* communities) represents habitats at altitudes of approximately 380–650 m above sea level, which is a very high part of the Czech Republic (Figure 2). Maximum production is achieved by forest stands with a high degree of naturalness at the age of 120–150 years, with an upper stand height of 40–45 m, in the stratum dominated by *Fagus sylvatica*, with an admixture of *Abies alba*, *Fraxinus excelsior* L., *Acer platanoides* L., *A. pseudoplatanus* L., *Tilia cordata* Mill., and *T. platyphyllos* Scop., with single occurrences of *Ulmus glabra* Huds., *Carpinus betulus* L., and *Quercus robur* [49]. The eighth vegetation tier, i.e., the *Piceeta* community, represents habitats at altitudes of approximately 1200–1420 m above sea level, which are the highest peaks of the highest mountain ranges (Figure 2a). Maximum production is achieved by forest stands with a high degree of naturalness at the age of 120–150 years, with an upper stand height of 20–22 m, in the stratum dominated by *Picea abies*, with an admixture of *Sorbus aucuparia* L.

(a)



(b)

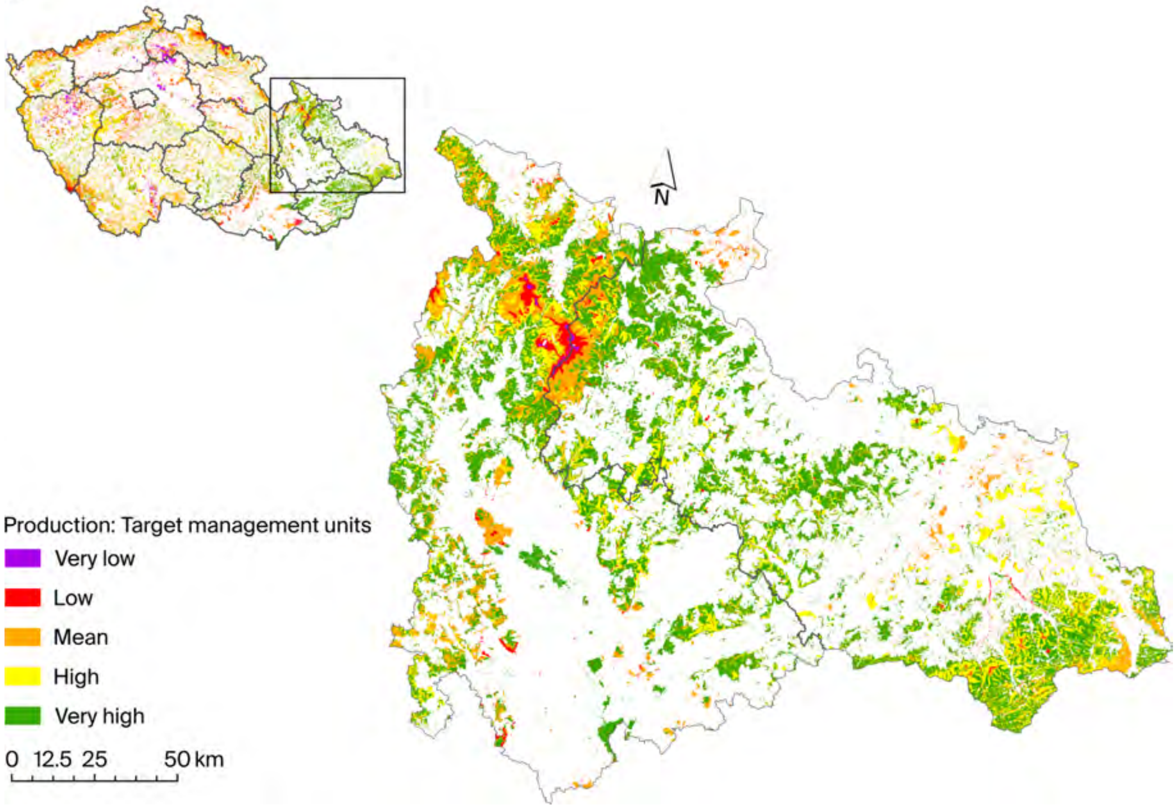


Figure 2. Production levels displayed using vegetation tiers and target management sets: (**a**) vegetation tiers without representation of azonal floodplain habitats; (**b**) target management sets.

By comparing the individual vegetation tiers, they can be semi-quantitatively classified according to their production (Figure 2a).

A more precise estimation of production is obtained by dividing vegetation tiers according to the trophicity and economic properties of the forest stands to generate target management sets (TMSs). The framework of the vegetation tier is then differentiated in more detail according to the trophicity and hydricity of the habitat (Figure 2b). The highest production is achieved by TMS in the fourth vegetation tier, i.e., TMS 45 (management of nutrient-rich habitats at medium altitudes), but also by azonal meadow habitats classified as TMS 19 (management of floodplain habitats) (Figure 2b), which are located in the first or second vegetation tier at an altitude of 155–300 m above sea level. Due to their specific conditions—a fluvisol soil type with plenty of water and therefore favorable humification, with wood production reaching 920–1050 $m^3 \cdot ha^{-1}$—these habitats are composed of *Quercus robur*, *Juglans nigra* L., *Fraxinus excelsior*, and *Acer campestre* L.

Vegetation tiers are ideal for determining the framework of the bioproduction function and, in practice, for the optimal selection of trees in commercial stands.

3.2. Non-Production Ecosystem Services Based on Habitat Conditions

3.2.1. Edaphic/Soil Protection Function and Ecosystem Service

The edaphic/soil protection function is defined as the ability of forest ecosystems to modify soil properties, influence pedogenetic processes, protect the soil surface and upper horizons from erosive mechanical processes, and eliminate physical and chemical changes. The most important function is the protection of the soil surface and upper horizons from erosion; namely, the removal of fine soil and thus the destruction of the soil profile itself.

Within the framework of the site classification, two groups, distinguished according to edaphic categories, are threatened by soil erosion due to the occurrence of ranker, ranker cambisol, ranker podzisol, or rendzina, pararendzina, or lithsol soil types:

a. Sites where the soil has high skeletal content, often on sloping slopes and ridges: edaphic categories A—*acerosa lapidosa*; F—*lapidosa mesotrophica*; and N—*lapidosa acidophila* (Figure 3a,b, Table 1);
b. Sites that are characterized by their high "extremity"—rocks, boulder scree, exposed peaks, extremely dry limestone outcrops, or dry loess (xerothermic): edaphic categories X—*xerothermica*; Z—*humilis*; Y—*saxatilis*; and J—*saxatilis acerosa* (Figure 4a,b, Table 1).

The group of habitats classified into edaphic category A—*acerosa lapidosa*—occupies 46,923 ha in the Czech Republic, with the most abundant sites being those with code 3A in the third vegetation tier at 13,930 ha and code 4A in the fourth vegetation tier at 13,263 ha (Table 1). The group of habitats classified into edaphic category F—*lapidosa mesotrophica*—occupies 52,980 ha in the Czech Republic, with the most abundant sites being those with code 3F in the third vegetation tier at 8113 ha and code 4F in the fourth vegetation tier at 14,592 ha (Table 1). The group of habitats classified into edaphic category N—*lapidosa acidophila*—occupies 89,095 ha in the Czech Republic, with the most represented sites being 5N sites in the fifth vegetation tier at 23,774 ha and 6N sites in the sixth vegetation tier at 23,982 ha (Table 1). In total, this group of habitats, with a significant soil protection function, occupies 188,997 ha. With regard to their forest categories, most of these habitats are classified as economic forests—farms on exposed habitats; however, regarding the fulfillment of the soil protection function and, therefore, the ecosystem service of soil protection, the habitats can be classified into the subcategory of soil protection forests under the category of special-purpose forests.

Table 1. An overview of sites with the ecosystem service of soil protection and their areas in the Czech Republic.

Edaphic Category *	Site Classification (Code/Name) *	Area in the Czech Republic (ha)	Forest Category	Forest Subcategory **
A—*acerosa lapidosa*	1A—*Aceri-Carpineto-Quercetum lapidosum*	778	Management or special-purpose	Soil protection
	2A—*Aceri-Fageto-Quercetum lapidosum*	6061		
	3A—*Tilii-Querceto-Fagetum acerosum lapidosum*	13,930		
	4A—*Tilieto-Fagetum acerosum lapidosum*	13,263		
	5A—*Acereto-Fagetum lapidosum*	9337		
	6A—*Aceri-Piceeto-Fagetum lapidosum*	3431		
	7A—*Aceri-Fageto-Piceetum lapidosum*	121		
F—*lapidosa mesotrophica*	1F—*Carpineto-Quercetum lapidosum acidophilum*	91	Management or special-purpose	Soil protection
	2F—*Fageto-Quercetum lapidosum acidophilum*	503		
	3F—*Querceto-Fagetum lapidosum mesotrophicum*	8113		
	4F—*Fagetum lapidosum mesotrophicum*	14,592		
	5F—*Abieto-Fagetum lapidosum mesotrophicum*	22,595		
	6F—*Piceeto-Fagetum lapidosum mesotrophicum*	5934		
	7F—*Fageto-Piceetum lapidosum mesotrophicum*	917		
	8F—*Piceetum lapidosum mesotrophicum*	235	Protective	Sites of natural high-mountain spruce forests
N—*lapidosa acidophila*	0N—*Piceeto-Pinetum (lapidosum acidophilum)*	1499	Management special-purpose	- Soil protection
	1N—*(Carpineto)-Quercetum lapidosum acidophilum*	254	Management or special-purpose	Soil protection
	2N—*Fageto-Quercetum lapidosum acidophilum*	2149		
	3N—*Querceto-Fagetum lapidosum acidophilum*	10,794		
	4N—*Fagetum lapidosum acidophilum*	15,572		
	5N—*Abieto-Fagetum lapidosum acidophilum*	23,774		
	6N—*Piceeto-Fagetum lapidosum acidophilum*	23,982		
	7N—*Fageto-Piceetum lapidosum acidophilum*	8280		
	8N—*Piceetum lapidosum acidophilum*	2791	Protective	Sites of natural high-mountain spruce forests

Table 1. *Cont.*

Edaphic Category *	Site Classification (Code/Name) *	Area in the Czech Republic (ha)	Forest Category	Forest Subcategory **
X—*xerothermica*	0X—*Pinetum xerothermicum*	166	Protective	Extremely unfavorable sites
	1X—*Corneto-Quercetum xerothermicum*	2526		
	2X—*Corneto-Fagi-Quercetum xerothermicum*	331		
	3X—*Corneto-Fagetum xerothermicum*	310		
	4X—*Fagetum xerothermicum*	186		
Z—*humilis*	0Z—*Pinetum relictum*	6080		
	1Z—*Quercetum humile*	5696		
	2Z—*Fageto-Quercetum humile*	2568		
	3Z—*Querceto-Fagetum humile*	1325		
	4Z—*Fagetum humile*	675		
	5Z—*Abieto-Fagetum humile*	1445		
	6Z—*Piceeto-Fagetum humile*	1489		
	7Z—*Fageto-Piceetum humile*	1798		
	8Z—*Sorbeto-Piceetum humile*	7110		Sites of natural high-mountain spruce forests
	9Z—*Pinetum mughi*	3296		Sites in the dwarf pine and alpine vegetation tier
	10Z—*Arctoalpinum*	340		
Y—*saxatilis*	0Y—*Pinetum saxatile*	1565	Protective	Extremely unfavorable sites
	2Y—*Fageto-Quercetum saxatile*	437		
	3Y—*Querceto-Fagetum saxatile*	3335		
	4Y—*Fagetum saxatile*	3524		
	5Y—*Abieto-Fagetum saxatile*	6146		
	6Y—*Piceeto-Fagetum saxatile*	6491		
	7Y—*Fageto-Piceetum saxatile*	1504		
	8Y—*Piceetum saxatile*	596		Sites of natural high-mountain spruce forests
J—*saxatilis acerosa*	(1)J—*Carpineto-Aceretum saxatile*	2114		Extremely unfavorable sites
	(3)J—*Tilieto-Aceretum saxatile*	8443		
	(5)J—*Ulmi-Fraxineto-Aceretum saxatile*	3636		
	(6)J—*Ulmi-Piceeto-Aceretum saxatile*	89		

* Latin name according to [49]. ** In the case of protective forests, inclusion in the target management set is understood as a subcategory.

The second group of habitats is represented by the edaphic categories X—*xerothermica*; Z—*humilis*; Y—*saxatilis*; and J—*saxatilis acerosa*. This group represents habitats in exposed areas or otherwise extreme habitats (rock outcrops, boulder scree, exposed peaks) and is distinguished from the previous group by the habitats' marked extremity, which is due to not only the accessibility of the terrain but, above all, the impossibility of forestry management. This group often follows the above group of habitats (Figure 4a,b). The group of sites classified into edaphic category X—*xerothermica*—occupies 3520 ha in the Czech Republic, with the most abundant being 1X sites in the first vegetation tier at 2526 ha (Table 1). The group of habitats classified into edaphic category Z—*humilis*—occupies 31,821 ha in the Czech Republic, with the most represented sites being 8Z in the eighth vegetation tier at 7110 ha (Table 1). The group of sites classified into edaphic category Y—*saxatlis*—occupies 23,598 ha in the Czech Republic, with the most represented sites being 5Y in the fifth vegetation tier at 6146 ha and 6Y in the sixth vegetation tier at 6490 ha (Table 1). The group of sites classified into edaphic category J—*saxatlis acerosa*—occupies 14,262 ha in the Czech Republic, with the most represented being (3)J azonal sites at 8442 ha (Table 1). In total, this group of habitats occupies 73,221 ha, with significant functions in protecting the entire ecosystem, but also a very significant soil protection function. Regarding their forest categories, these habitats are already classified as protective forests according to Decree No. 298/2018; therefore, their fulfillment of the soil protection function is taken into account. In practice, this category is not divided into subcategories, but given the different occurrences of these sites, it would be appropriate to distinguish subcategories in a manner similar to the way that target management sets are determined, i.e., the following subcategories: a. extremely unfavorable habitats; b. sites of natural alpine spruce forests; and c. habitats in the dwarf pine and alpine vegetation tier (Table 1).

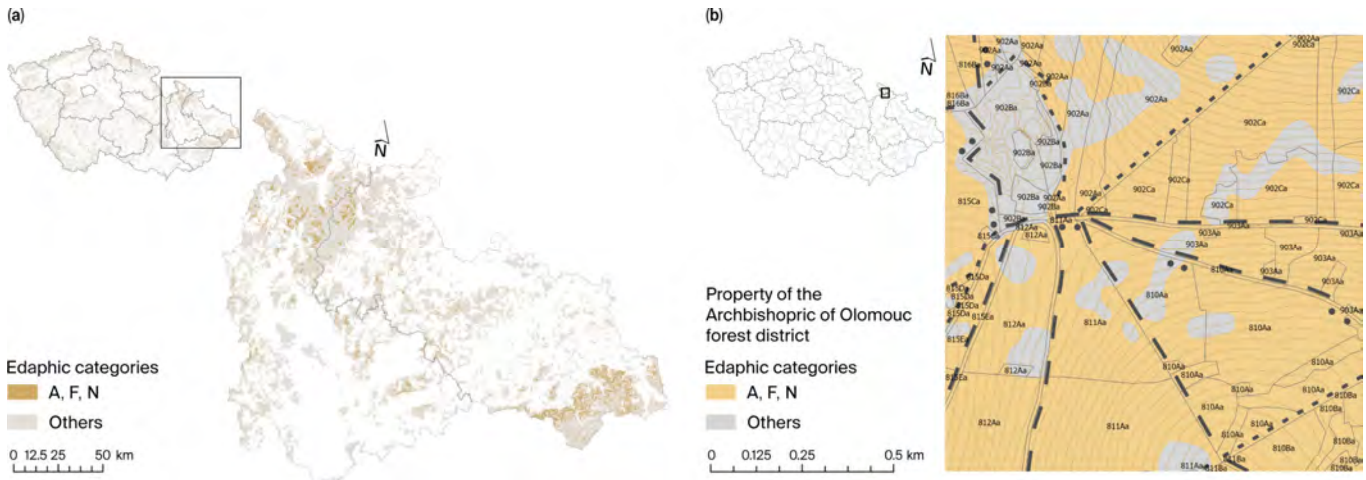


Figure 3. Representation of the potential of soil conservation forests in the Czech Republic for edaphic categories A—*acerosa*; F—*lapidosum mesotrophica*; and N—*lapidosum acidophila*: (**a**) representation of the occurrence of edaphic categories in the Olomoucký and Moravskoslezský regions in the Czech Republic; (**b**) the property of the Archbishopric of Olomouc with details of the division of the forest (spatial units).

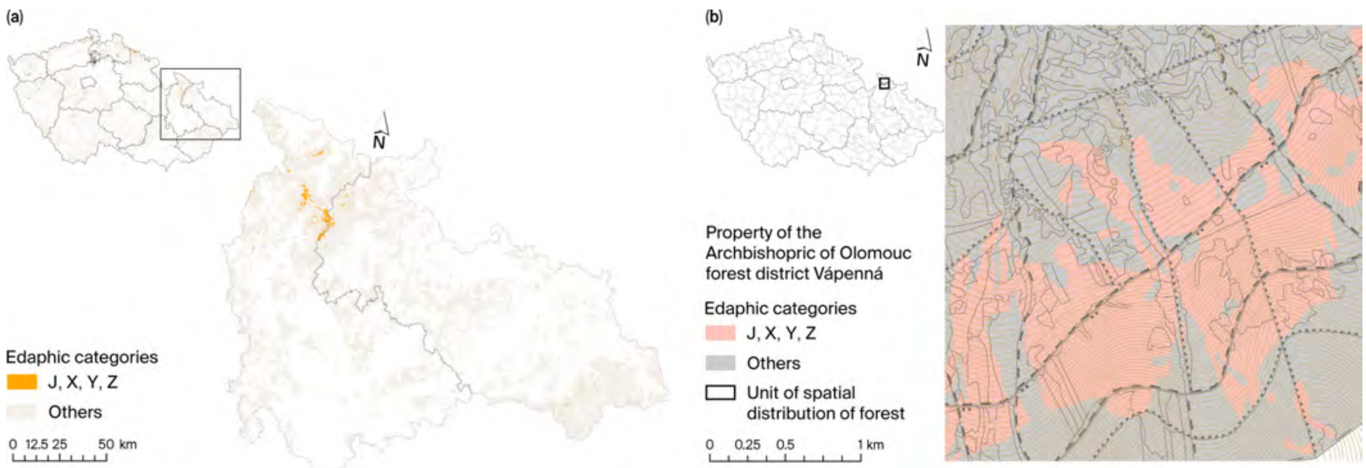


Figure 4. Representation of the potential of soil conservation forests in the Czech Republic for edaphic categories J—*saxatilis acerosa*; X—*xerophytica*; Y—*saxatilis*; and Z—*humilis*: (**a**) representation of the occurrence of edaphic categories in the Olomoucký and Moravskoslezský regions in the Czech Republic; (**b**) the property of the Archbishopric of Olomouc with details of the division of the forest (spatial units).

Within the Czech Republic, both subgroups are more concentrated at higher altitudes (Figures 3a and 4a) in the peak parts of extensive ridges with long slopes. These habitats can form continuous areas (Figure 3b) and occupy as much as 100% of the area of individual forest stands. The habitats of the second subgroup then occupy parts of ravines, extreme slopes with rock outcrops, or the peak parts of peaks and ridges (Figure 4b). They are classified as protective forests when the area is higher than 50% of the area of the given forest stand.

3.2.2. Function and Ecosystem Service of Hydric-Water Management

The hydric-water management function is the ability of a forest ecosystem to shape and modify the water balance and water regime through hydric effects. However, this service can be more specifically described as water protection, since these habitats preserve and protect the hydrological regime of the habitat or landscape segments. Specifically, the habitats can be used as water sources. Habitats in alluvia that line watercourses also serve a bank protection function, which manifests primarily during higher water levels or floods.

In fact, these are forest stands where the hydricity of the habitat is higher; that is, these sites are influenced by both stagnant and flowing water. Within the site classification, two groups influenced by water can be distinguished according to their edaphic categories:

a. Sites with stagnant water, where the soil is permanently waterlogged with a gley or peaty pedogenetic process: edaphic categories G—*paludosa mesotrophica*; T—*paludosa oligotrophica*; and R—*turfosa*. Otherwise, the soil is alternately waterlogged during the growing season with signs of gleying: edaphic categories O—*variohumida mesotrophica*; P—*variohumida acidophila*; Q—*variohumida oligotrophica*; or V—*humida* (Figure 5a,b, Table 2). These are plateaus, terrain depressions on plateaus, or subslope deluvia, often along the alluvia of streams or rivers with the occurrence of gley or histosol soil types. For semihydromorphic types, the soil types are planosols, luvisols, or gleyed.
b. Sites with flowing water, where flowing water is present in the alluvia of rivers, streams, creeks, or narrow creek beds: edaphic categories L—*alluvialis*; U—*validosa* (Figure 6a,b, Table 3). The soil types are fluvisol, gley fluvial, and cambisol gleyed.

Sites that are important sources of water are waterlogged edaphic category G—*paludosa mesotrophica*—occupying 58,801 ha in the Czech Republic, with the most abundant being 5G sites in the fifth vegetation tier at 7249 ha and 4G sites in the fourth vegetation tier at 5653 ha (Table 2); waterlogged poor edaphic category T—*paludosa oligotrophica*, occupying 6452 ha in the Czech Republic, with the most abundant being (1)T sites, occupying 1289 ha (Table 2); and edaphic category R—*turfosa*—occupying 30,729 ha in the Czech Republic, with the most abundant being (8)R sites at 6123 ha (Table 2). Semihydromorphic sites, where the soil is alternately waterlogged and significantly influenced by water during only a certain period of the growing season and shows signs of gleying, are edaphic categories O—*variohumida mesotrophica*; P—*variohumida acidophila*; and Q—*variohumida oligotrophica*. Sites of edaphic category O—*variohumida mesotrophica*—occupy 160,359 ha in the Czech Republic, with the most abundant being 4O sites at 41,811 ha and 5O sites at 36,400 ha; edaphic category P—*variohumida acidophila*—occupying 145,835 ha within the Czech Republic, with the most abundant being 4P sites at 50,337 ha and 5P sites at 30,846 ha; and edaphic category Q—*variohumida oligotrophica*—covering a total of 24,934 ha, with the most abundant being 4O sites at 41,811 and 5O at 36,400 ha. Separately, this group also includes habitats of forest springs and narrow forest streams, or wet deluvia—edaphic category V—*humida*—which occupies 82,022 ha in the territory of the Czech Republic, with the most represented being 5V sites at 25,432 ha in the fifth vegetation tier and 6V sites at 23,622 ha in the sixth vegetation tier (Table 2). In total, this group of sites occupies 289,973 ha in the territory of the Czech Republic.

Table 2. An overview of sites with the ecosystem service of water protection with a water source function with their areas in the Czech Republic.

Edaphic Category *	Site Classification (Code/Name) *	Area in the Czech Republic (ha)	Forest Category	Forest Subcategory
G—*paludosa mesotrophica*	0G—*Piceeto-Pinetum paludosum mesotrophicum*	7282	Management or special-purpose	Water protection: water source
	(1)G—*Saliceto-Alnetum paludosum mesotrophicum*	4734		
	2G—*Quercetum abietinum paludosum mesotrophicum*	766		
	3G—*Abieto-Quercetum piceosum paludosum mesotrophicum*	1365		
	4G—*Querceto-Abietum piceosum paludosum mesotrophicum*	5653		
	5G—*Abietum quercino-piceosum paludosum mesotrophicum*	7249		
	6G—*Piceeto-Abietum paludosum mesotrophicum*	13,316		
	7G—*Abieto-Piceetum paludosum mesotrophicum*	13,283		
	8G—*Piceetum paludosum mesotrophicum*	5155	Protective Or special-purpose	Extremely unfavorable sites or sites of natural high-mountain spruce forests Water protection: water source
T—*paludosa oligotrophica*	0T—*Betuleto-Pinetum (paludosum oligotrophicum)*	1132	Management or special-purpose	Water protection: water source
	(1)T—*Betuleto-Alnetum (paludosum oligotrophicum)*	1290		
	2T—*Quercetum abieti paludosum oligotrophicum*	203		
	3T—*Abieto-Quercetum paludosum oligotrophicum*	214		
	4T—*Querceto-Abietum piceosum paludosum oligotrophicum*	249		
	5T—*Abietum quercino-piceosum paludosum oligotrophicum*	749		
	6T—*Piceeto-Abietum paludosum oligotrophicum*	294		
	7T—*Abieto-Piceetum paludosum oligotrophicum*	1052		
	8T—*Piceetum paludosum oligotrophicum (humilis)*	1270	Protective	Extremely unfavorable sites or sites of natural high-mountain spruce forests
R—*turfosa*	0R—*Pinetum turfosum*	5716	Protective	Extremely unfavorable sites
	(1)R—*Alnetum turfosum*	168	Management or special-purpose	Water protection: water source
	(3)R—*Piceetum relictum turfosum acidophilum*	1936		
	(4)R—*Piceetum relictum turfosum mesotrophicum*	2266		
	(5)R—*Pineto-Piceetum turfosum acidophilum*	712		
	(6)R—*Piceetum turfosum mesotrophicum*	2444		
	(7)R—*Piceetum turfosum acidophilum*	7336		
	8R—*Piceetum turfosum montanum*	6123	Protective	Sites in the dwarf pine and alpine vegetation tier
	9R—*Pinetum mughi turfosum*	4028		
O—*variohumida mesotrophica*	0O—*Pinetum quercino-abietinum variohumidum mesotrophicum*	365	Management or special-purpose	Water protection: water source
	1O—*Tilieto-Quercetum variohumidum mesotrophicum*	19,068		
	2O—*Abieto-Quercetum fagi variohumidum mesotrophicum*	9278		
	3O—*Abieti-Querceto-Fagetum variohumidum mesotrophicum*	36,360		
	4O—*Querceto-Abietum variohumidum mesotrophicum*	41,811		
	5O—*Fageto-Abietum variohumidum mesotrophicum*	36,400		
	6O—*Piceeto-Abietum variohumidum mesotrophicum*	11,820		
	7O—*Abieto-Piceetum variohumidum mesotrophicum*	5135		
	8O—*Piceetum variohumidum mesotrophicum*	92	Protective	Extremely unfavorable sites or sites of natural high-mountain spruce forests

Table 2. *Cont.*

Edaphic Category *	Site Classification (Code/Name) *	Area in the Czech Republic (ha)	Forest Category	Forest Subcategory
P—*variohumida acidophila*	0P—*Pinetum quercino-abietinum variohumidum acidophilum*	5653	Management or special-purpose	Water protection: water source
	1P—*Betuleto-Quercetum variohumidum acidophilum*	5111		
	2P—*Quercetum abietinum variohumidum acidophilum*	6708		
	3P—*Abieto-Quercetum variohumidum acidophilum*	17,142		
	4P—*Querceto-Abietum variohumidum acidophilum*	50,337		
	5P—*Abietum piceosum variohumidum acidophilum*	30,846		
	6P—*Piceeto-Abietum variohumidum acidophilum*	23,745		
	7P—*Abieto-Piceetum variohumidum acidophilum*	5238		
	8P—*Piceetum variohumidum acidophilum*	1054	Protective	Extremely unfavorable sites or sites of natural high-mountain spruce forests
Q—*variohumida oligotrophica*	0Q—*Pinetum quercino-abietinum variohumidum oligotrophicum*	4639	Management or special-purpose	Water protection: water source
	1Q—*Betuleto-Quercetum variohumidum oligotrophicum*	2752		
	2Q—*Quercetum abietinum variohumidum oligotrophicum*	4455		
	3Q—*Abieto-Quercetum variohumidum oligotrophicum*	1676		
	4Q—*Querceto-Abietum variohumidum oligotrophicum*	5535		
	5Q—*Abietum piceosum variohumidum oligotrophicum*	2442		
	6Q—*Piceeto-Abietum variohumidum oligotrophicum*	862		
	7Q—*Abieto-Piceetum variohumidum oligotrophicum*	665		
	8Q—*Piceetum variohumidum oligotrophicum*	1909	Protective	Extremely unfavorable sites or sites of natural high-mountain spruce forests
V—*humida*	1V—*Carpineto-Quercetum fraxinosum humidum*	3584	Management or special-purpose	Water protection: water source
	2V—*Fageto-Quercetum fraxinosum humidum*	1603		
	3V—*Querceto-Fagetum fraxinosum humidum*	10,308		
	4V—*Fagetum fraxinosum humidum*	12,905		
	5V—*Abieto-Fagetum fraxinosum humidum*	25,432		
	6V—*Piceeto-Fagetum fraxinosum humidum*	23,622		
	7V—*Fageto-Piceetum acerosum humidum*	3577		
	8V—*Acereto-Piceetum humidum*	990	Protective	Extremely unfavorable sites or sites of natural high-mountain spruce forests

* Latin name according to [49].

In some parts of the Czech Republic, where there are larger plateaus and water accumulates in the soil profile, these sites are very common, and in some areas, they are very significant and even dominant (Figure 6b).

In most cases, these sites are classified as economic forests. Given that these glial or glial-covered sites clearly have an impact on the water cycle (i.e., the fulfillment of the water protection function), when obtaining water, the function can also be described as a water source, since some sites are used as sources of drinking water. Some sites are used as sources of drinking water, in which case the stands surrounding this source are classified as special-purpose forests, specifically in the subcategory of water resource protection zones of the first degree. However, due to the significance of the water source function, most of these sites could be classified as special-purpose forests in the subcategory of water resource protection zones of the first degree with the fulfillment of the water source function (Table 2).

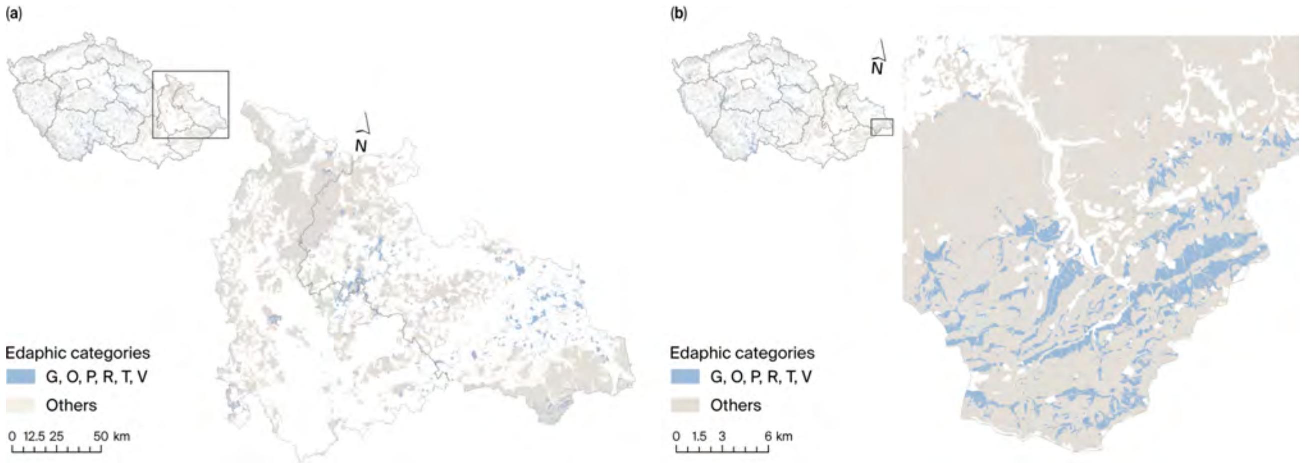


Figure 5. Illustration of the potential of water protection forests with a water source function in the Czech Republic: edaphic categories G—*paludosa mesotrophica*; T—*paludosa oligotrophica*; R—*turfosa*; O—*variohumida mesotrophica*; P—*variohumida acidophila*; and V—*humida*: (**a**) illustration of the distribution of edaphic categories in the Olomoucký and Moravskoslezský regions in the Czech Republic; (**b**) detail in Moravskoslezské Beskydy Mts.

Table 3. Overview of sites of water protection forests with a bank protection function with their area in the Czech Republic.

Edaphic Category *	Site Classification (Code/Name) *	Area in the Czech Republic (ha)	Forest Category	Forest Subcategory
L—*alluvialis*	(1)L—*Ulmeto-Quercetum alluviale*	36,181	Management or special-purpose	Water protection: water source + bank protection
	(2)L—*Fraxineto-Quercetum alluviale*	5297		
	(3)L—*Fraxineto-Alnetum alluviale*	14,980		
	(4)L—*Fraxineto-Alnetum alluviale aceri*	430		
	(5)L—*Fraxineto-Alnetum montanum*	4738		
	(6)L—*Alnetum incanae*	337	Protective	Extremely unfavorable sites
U—*vallidosa*	(3)U—*Acereto-Fraxinetum vallidosum*	12,248	Management or special-purpose	Water protection: water source + bank protection
	(5)U—*Fraxineto-Aceretum vallidosum*	6319		

* Latin name according to [49].

Sites with flowing water, where flowing water is present in the alluvia of rivers and streams (edaphic category L—*alluvialis*) occupy 61,963.17 ha in the Czech Republic, with the largest share, 36,181 ha, belonging to azonal habitats (1)L, which are wide alluvial areas in large rivers in the lowlands. Habitats of narrow stream gullies in edaphic category U—*vallidosa*—occupy an area of 18,566 ha in the Czech Republic; the dominant habitat is (3)U, with a total area of 12,248 ha (Table 3). Regarding forest categories, these habitats are already classified as economic forests according to Decree No. 298/2018 (Table 3). In total, these habitats occupy 80,529 ha in the Czech Republic. Given that these alluvial habitats also have an impact on the water cycle (i.e., the fulfillment of the water protection function), when obtaining water, they can also be described as serving a water source function. In addition, parts of forest stands that are directly adjacent to the bed of a stream or river serve a bank protection function.

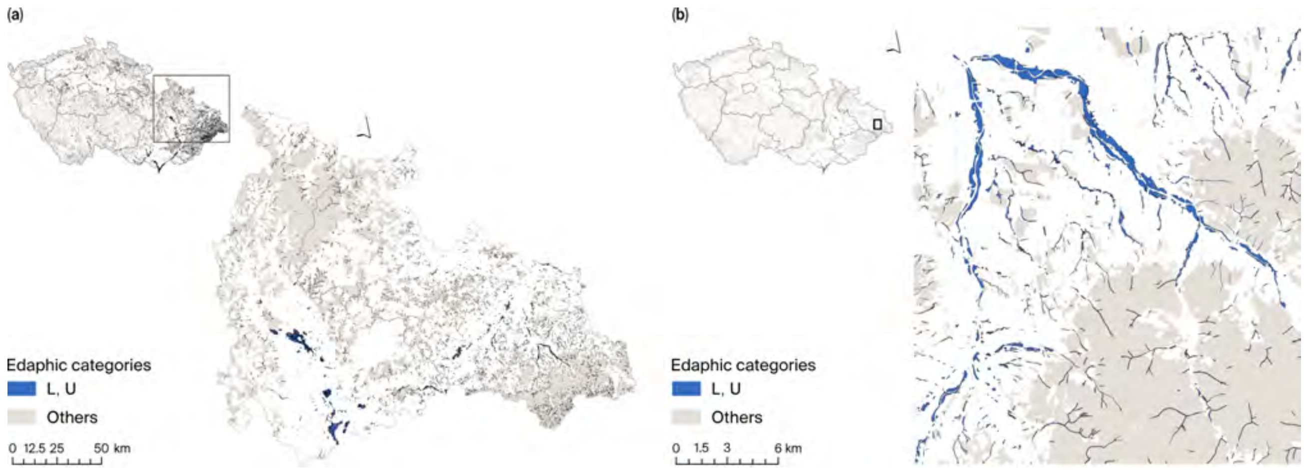


Figure 6. Illustration of the potential of water protection forests with a shore protection function in the Czech Republic: sites of edaphic category L—*alluvialis*; U—*vallidosa*: (**a**) illustration of the distribution of edaphic categories in the Olomoucký and Moravskoslezský regions in the Czech Republic; (**b**) details of Moravskoslezské Beskydy Mts. and hills.

Regarding forest categories, these habitats are already mostly classified as economic forests according to Decree No. 298/2018; only (6)L sites are classified as protective forests, due to their occurrence around streams high in the mountains. If these habitats fulfill their water source or bank protection function, they can be classified as special-purpose forests in the water protection subcategory (Table 3).

The occurrence of these habitats is tied to the alluvia of streams and rivers (Figure 6a,b), and in some regions of the Republic, they are the dominant habitat type.

3.3. Forest Categories and Subcategories in the Czech Republic

Currently, forest stands in the Czech Republic are classified into three forest categories (Table 4): economic forests are dominant, occupying 74% of forest land; protective forests occupy 2% of forest land; and special-purpose forests occupy 24% of forest land.

Table 4. Representation of forest categories in the Czech Republic (as of 31 December 2023).

Forest Category	Area in the Czech Republic (ha)	%
Economic forests	1,937,320	74
Protective forests	53,629	2
Special-purpose forests	625,898	24
Total	2,616,847	100

The classification into individual categories is based on three basic criteria (Table 5):

1. Site conditions according to the site classification;
2. The state of forest cover, defined by tree species composition and stand structure;
3. Other public interests (hunting, national defense, spas, etc.).

Site conditions clearly determine the classification of sites into the protective forest category and its subcategories, and then into the subcategories of special-purpose forests—forests in zones of protection of water resources of the first degree and forests with an increased soil protection function. They may partially determine their classification into the subcategory of protection zones of medicinal and mineral water sources if chemical analyses of the water source are performed.

Table 5. Subcategories of special-purpose forest and protective forest categories in the Czech Republic and their relationship to site conditions (as of 31 December 2023). Where "+" means yes (positive relationship) and "-" means no (negative relationship).

Category	Subcategory	Ecosystem Services According to Site Characteristics	Ecosystem Services According to Structure of Forest Stand	Ecosystem Services According to Public Interest
Protective forests	Forests in extremely unfavorable sites	+	-	-
	Forests of natural high-mountain spruce communities below the tree line	+	-	-
	Forests in dwarf pine and alpine vegetation tiers	+	-	-
Special-purpose forests	Forests in sanitary protection zones for water resources of the 1st degree	+	-	+
	Forests in protective zones of sources of natural medicinal and table mineral waters	-	-	+
	Forests in the territories of national parks and national nature reserves	-	+	+
	Forests in the first zones of protected landscape areas and forests in nature reserves, national natural monuments, and natural monuments	-	+	+
	Spa forests	-	-	+
	Suburban and other forests with an increased recreational function	-	-	+
	Forests used for forestry research and forestry education	-	-	+
	Forests with an increased soil protection function	+	-	-
	Forests necessary for the preservation of biological diversity	-	+	-
	Forests recognized as game reserves and in separate pheasant farms	-	-	+
	Forests used for other important public interests	-	-	+

Currently, protective forests occupy 53,629 ha in the Czech Republic, but the potential area is larger (Table 6). Extremely unfavorable sites are estimated to occupy 87,578 ha, and 44,708 ha is accounted for here; i.e., the potential area in this subcategory is much larger. Similarly, the subcategory of natural high-mountain spruce communities below the tree line is estimated at 8467 ha, while the area of suitable sites could reach 15,277 ha; similarly, the forest subcategory of dwarf pine and alpine vegetation tiers is estimated to occupy 454 ha, but this could potentially reach 4693 ha and be included in the subcategory. The difference in these values probably lies in the division of the forest and the inclusion of entire stands; if only part of the forest stand falls into the protective forest category, the given subcategory is then not considered.

Table 6. Representation of subcategories of special-purpose forests and the category of protective forests in the Czech Republic (as of 31 December 2023).

Category	Subcategory	Area in the Czech Republic (ha)	%
Protective forests	Forests in extremely unfavorable sites	44,708	1.7
	Forests of natural high-mountain spruce communities below the tree line	8467	0.3
	Forests in dwarf pine and alpine vegetation tiers	454	0.0
Special-purpose forests	Forests located in 1st-degree sanitary protection zones for water resources	8092	0.3
	Forests in protective zones of sources of natural medicinal and table mineral waters	76,515	2.9
	Forests in the territories of national parks and national nature reserves	110,506	4.2
	Forests in the first zones of protected landscape areas and forests in nature reserves, national natural monuments, and natural monuments	62,058	2.4
	Spa forests	1757	0.1
	Suburban and other forests with an increased recreational function	33,924	1.3
	Forests used for forestry research and forestry education	18,942	0.7
	Forests with an increased soil protection function	133,699	5.1
	Forests necessary for the preservation of biological diversity	74,094	2.8
	Forests recognized as game reserves and in separate pheasant farms	30,301	1.2
	Forests used for other important public interests	76,011	2.9

Among the subcategories of special-purpose forests (Table 6), which are determined by natural conditions, i.e., the nature of the habitat, water resource protection zones of the first degree occupy 8092 ha, and forests with an increased soil protection function occupy 133,699 ha. The potential area of soil protection forests is higher, potentially reaching 188,997 ha. Within the framework of water protection forests, the water protection function and water resource function should be considered separately, and these habitats occupy up to 289,973 ha in the Czech Republic. In addition, with a separate subcategory of water protection with a bank protection function, these habitats occupy up to 80,529 ha in the Czech Republic. To date, forests classified as water resource protection zones of the first degree occupy only 8092 ha.

Within the Czech Republic, soil protection forests are concentrated in mountainous areas, but only some parts of steeper slopes or peaks are included here (Figure 7). Protective forests are located at the highest points of mountain massifs or locally in unfavorable locations at lower altitudes (Figure 8).

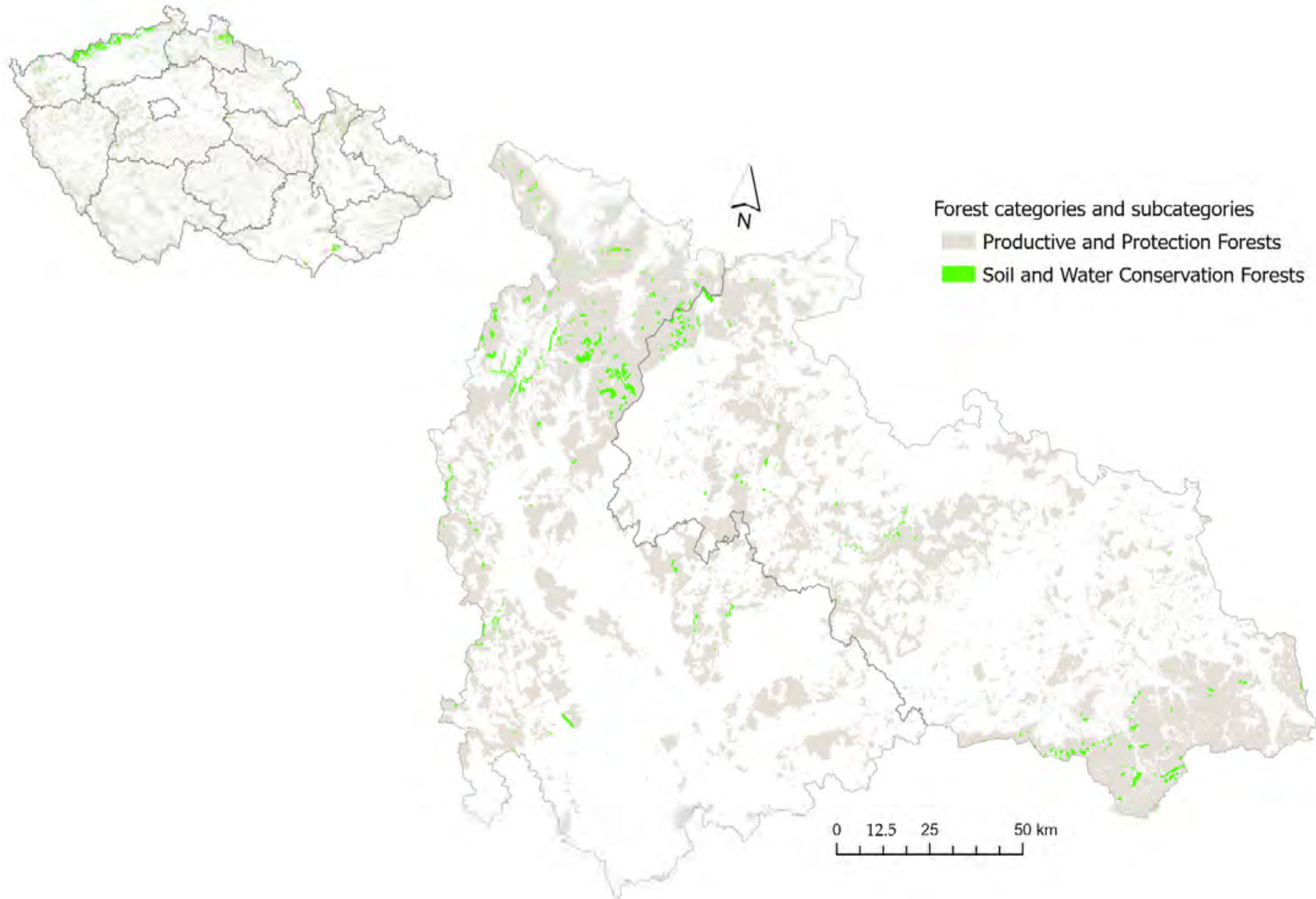


Figure 7. Illustration of current forest categories in the Czech Republic: special-purpose forests—soil protection forests.

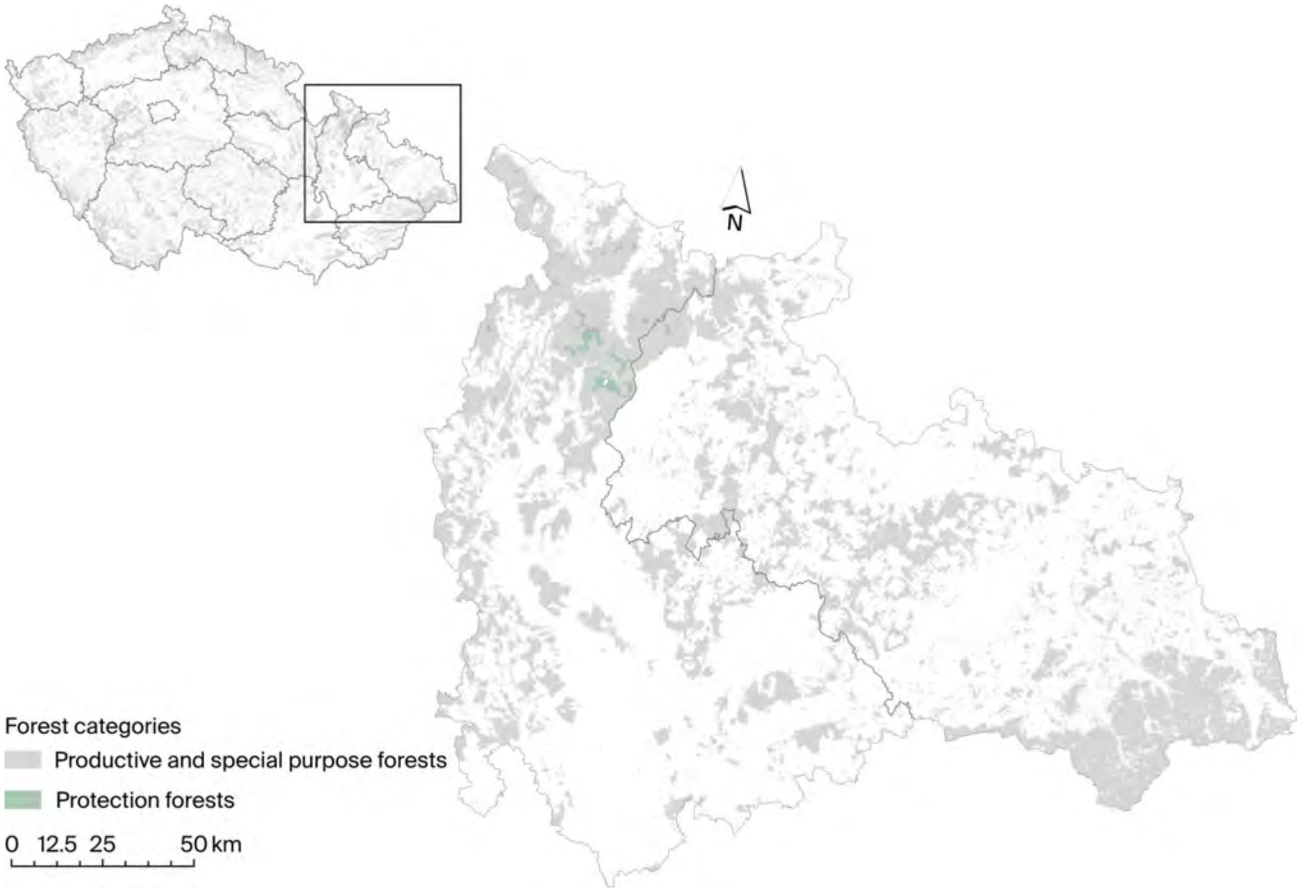


Figure 8. Illustration of current forest categories in the Czech Republic: protective forests.

4. Discussion

4.1. The Need for Forest Site Classification for Assessing Ecosystem Services

The classification of natural conditions is one of the basic principles on which forestry is based. As applied in our study, this classification provides a basic overview of possibilities and limitations for an essential forest management approach. As described by Konšel [51], we applied all information on specific forest ecosystems (soil characteristics, climate, geology, geomorphology, fauna, flora species occurrence, etc.) and the necessary information on the growth parameters of trees (height, breast-height diameter, the shape of the strain, quality for growing of trees, assortment, etc.).

One of the main methodological approaches to forest ecosystem classification is based on the forest type. This approach exists in several different forms. A forest type is a set of stands that are characterized by the same habitat and biological conditions and, as a result, show the same cultivation, measurement, and technical forestry characteristics. Cajander [52,53] defined the term "forest type" in a broader context. For example, Sukachev [54] identified a forest type with forest plant communities, with a certain plant species as edificators at each level, creating social relationships inside and outside.

For the classification of forest ecosystems, conventional biogeocenological, geobotanical, and cultural approaches are based on the theory of classification of eco-floristic techniques [55] and regional phytocenological knowledge. The division into "eastern" and "western" classification systems reflected trends in environmental sciences at that time and incorporated concepts such as forest type [52,53], phytosociology [55], ecosystem, and polyclimax [56].

We can find a broader use of this system in studies from Central and Eastern Europe [41,44–46,54,57–61]. The results are usually constructed maps of forest types [23]. The biogeocenological approach is mainly used for the classification of forest habitat, which is considered the basic unit of forest site types [57].

Systems using environmental variables with a strong emphasis on vegetation are implemented, e.g., in Germany [62]. Austria employs a similar system that combines characteristics affecting the growth of trees and altitude, thus creating altitudinal levels, for example, European beech, spruce–fir–beech, spruce, etc. [63]. The methodology in Great Britain [64] has been adapted and widely applied in North America [65,66], Finland [67], etc. For example, for the purposes of forest management, the Ecological Site Classification system has been developed and systematically elaborated in Great Britain [68]. This system uses information on the soil, vegetation, climate, woods, etc. In the Slovak Republic, a Forest Site Type Classification was proposed in [41,42,58,69], which has been edited, corrected, and harmonized [70,71]. The principle of forest ecosystem habitat classification used in Slovakia (very similar to that used in the Czech Republic) has been very well described [72]. In the Czech Republic, we apply the generalized idea of "forest type" in the Czech Forest Ecosystem Classification [29,35,61,73]. A detailed comparison can be found, for example, in [61,73].

For a pan-European comparison of forest ecosystems, European forest types were proposed [74], which work more with actual vegetation associated with similar units.

In this sense, the European Habitats Directive [75], which works with habitat types, can also be mentioned. These types express the current vegetation, i.e., a "mere" manifestation of phytocoenosis. These are very broad units that cannot be used for the method of assessment presented here.

Often, systems designed for forest management, particularly in Europe, place a great emphasis on using information on habitat productivity [72,73,76].

The classification of forest ecosystems based on the nature of the habitat and growth parameters for forest management purposes can be specific to each, to some extent, defined area. How it affects the development of historical and political events (i.e., the formation of views and knowledge) depends on the need for classification and, of course, geographic location and associated natural conditions.

In the world today, there are massive databases for vegetation classification. The availability of common standardized geospatial information about the composition, structure, and distribution of forests is essential to supporting environmental measures, sustainable forest management, and forest policy planning [77]. Forest type maps are useful tools to support both cultivation and forest planning options from the local level to the global scale. For this reason, local authorities may develop forest type maps separately, in which case a standardized and harmonized framework is necessary for comparison and aggregation. At the same time, local forest maps may not be directly applicable to the evaluation of pan-European forest resources and classification systems.

4.2. Forest Bioeconomy and Forest Site Classification

Site classification is a tool for the owner or manager of a forest (for forestry management), which provides a basic understanding (description, information) not only about their own biomass production but also about the provision of "site" ecosystem services, which should be respected in one's own management.

Forestry management, as well as forestry itself, is one of the bases of the bioeconomy. In addition to biomass production (production function of forests), forest ecosystems have great potential to ensure the provision of other ecosystem services without endangering the environment. Forests provide a number of socio-economic and environmental services that contribute to supporting biodiversity, mitigating climate change, preventing soil erosion, ensuring water quality, reducing the risk of floods and inundations, providing recreational services, hunting, and a whole range of production and market services.

The forest bioeconomy uses wood-producing and non-wood-producing (e.g., forest fruits and mushrooms) ecosystem services, and products other than wood are obtained from forests or forest biomass. However, other ecosystem services of the forest must also be provided in parallel.

Ecosystem services that can be easily determined based on forest site classification are the most basic, because they are determined by conditions that humans cannot change. By adjusting the tree species composition (i.e., investing in forestry management), the owner or manager of the forest can strengthen the provision of ecosystem services (i.e., their fulfillment or production). This should lead to the expected financial profit for the provision of ecosystem services. However, some ecosystem services are of such a nature that they do not directly yield a financial profit. Therefore, the concept of a payment scheme for ecosystem services has been proposed [20].

For forest owners, incentives are created to ensure that ecosystem services (to internalize positive externalities) are provided by natural systems [78]. The details of the habitat classification, thanks to the determination of vegetation tiers and units of forest type sets, then enable the owner to account for ecosystem services directly in their own management practices. By adjusting the boundaries of the forest management units in detail, the spatial unit can be defined and thus considered when creating the forest management plan, and then providing ecosystem services will be significantly simpler from the point of view of forest management.

Forest economics also addresses the value of the forest itself in terms of market and non-market products and services [79]. In contrast to extractable value, there is non-consumable value. In this spirit, forest functions and ecosystem services take their place here.

Forest economic models are used in economic and financial analyses [80] to evaluate forests as sets compared to other land uses. These models are used not only in the valuation of market and non-market forest products, but also for services to optimize management decisions such as the length of the regeneration period, the washing time, the implementation of cultivation interventions, and harvesting, which can be applied to any stand.

Site characteristics can exclude or determine a specific land use for a given forest land [81]. The ability to classify habitats (production conditions of the natural environment) then elucidates (but also gives) the sets of activities that can be implemented on a given plot of land (site). Economics then provides us with reliable means to determine what is most advantageous in terms of use and what the best management strategies are to achieve the given goals [82].

We also use habitat classifications of forests for forest valuation. For example, it is very easy to process a price map of forest lands. Specific forest subcategories play an important role in this and subsequently also ensure the fulfillment of forest functions, which can then be smoothly linked to the valuation of the ecosystem services of forest lands.

In the case of forest stands, data provided by forest management or forest inventory data are necessary. These bioeconomic data will then allow us to value the forest and subsequently the ecosystem services for the needs of the bioeconomy. This may be the subject of further studies.

Wood production is quantified by the volume of biomass and, therefore, also by financial calculations [83]. European forests and the European forest-based sector play an important role in supplying a growing bioeconomy [84–88].

Wood production also affects the provisioning of other services and biodiversity and represents base information on wood production, which is important for decision-making by forest owners, policy makers, etc. [89–91].

Precise definition and understanding of the performance of ecosystem services are important for determining the optimal parameters of forest management [92,93]. It is therefore appropriate to divide them into services that are provided independently of the management style and those that are influenced by forest management [94].

5. Conclusions

This work presented a completely innovative approach to the assessment of ecosystem services provided by habitats and their properties. However, it is necessary to apply a very detailed site classification system whose units have characteristics with sufficient detail to enable the assessment of the fulfillment of a given ES. The system can also be applied in other areas when needed.

This approach is of great importance for forest owners, who are at the lowest but most important level—i.e., at the level of forest cover—such that they can determine the fulfillment of ESs themselves and thus carry out detailed multifunctional management planning.

In the Czech Republic, the basis for the differentiation of forest management practices is the Forest Site Classification System, which is based on the principle of potential vegetation and whose basic frameworks—vegetation tiers, edaphic categories, and forest complex types—serve to describe permanent ecological conditions.

The classification of forest habitat types expresses the characteristics of potential vegetation, i.e., the type of vegetation that would occur within forest ecosystems if the landscape and ecosystems were not influenced and transformed by human activity.

Each forest ecosystem performs a few services, primarily a bioproduction function. Site classification, thanks to the vegetation tier frameworks, enables the imagining of biomass production. Regarding value, the beech forest zone located 380 to 650 m above sea level and azonal meadow communities at altitudes of 155 to 350 m above sea level are among the most productive in Central Europe.

Ecosystem services are based on site classification, the state of forest cover, and other public interests. With habitat classification, protective forests are categorized into three subcategories: extremely unfavorable habitats, habitats of natural alpine spruce forests below the tree line, and habitats in the spruce and alpine vegetation tiers. These habitats are classified according to Decree No. 298/2018; however, due to the spatial units of forest division, not all areas are classified into this category.

The category of special-purpose forests—in which the fulfillment of another function is superior to the bioproduction function—includes subcategories that are determined by site conditions, but their area is currently smaller than what is possible to include in this subcategory. However, there are no clear criteria for determining some of these subcategories.

Extensive possibilities exist, especially for forests affected by water, which could be included in the subcategory of water protection forests (i.e., forests with potential as a source of drinking water). Detailed research should be carried out precisely to determine their significance in the fulfillment of the water source or bank protection function, which is currently lacking in the forestry of the Czech Republic.

The expression of ecosystem services using site classification is the basis for their subsequent economic quantification and valuation (price valuation), which is required for the forestry bioeconomy. Through such information, the forest owner, as well as state entities and organizations, can then make decisions about forestry policy.

In the future, the consideration of ES fulfillment in the differentiation of forest categories and the determination of management units should be further explored. With the use of remote sensing, the spatial units of forest division could be better determined, which would enable more habitat conditions to be considered, such as geomorphological shapes and extreme soil conditions, in addition to the condition of forest stands. For our own practice, the legislative classification of forest stands into categories and subcategories should be more elaborate. First of all, ES fulfillment is not yet sufficiently supported, especially in hydric-influential habitats, which will be increasingly important in the future for water management in forests and sources of drinking water.

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