Ranking the Key Forest Habitats in Ecosystem Function Provision: Case Study from Morava River Basin

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Abstract: Floodplain forests are considered important forest ecosystems, and providers of ecosystem functions and services. The subject of this research was to assess the level of provision of five selected ecosystem functions (climate regulation and regulation of short water cycle, biomass production, oxygen production, and carbon sequestration) and biodiversity by relevant groups of forest habitats, and their mutual comparison. Assessment of ecosystem functions was performed in biophysical units based on published data, our own research, and expert knowledge. The results showed the high importance of floodplain forests. In the majority of the services that were studied, this habitat reached high values and, in comparison with the other habitats, took one of the leading positions. When comparing the ranking in the provision of individual ecosystem functions per unit area, the best-assessed habitat in all assessed functions was floodplain and wetland forests, followed by ravine forests and beech forests, but the analysis of the rate of ecosystem function provision, related to the total area of interest, showed a different order of values. Understanding the context of the individual ecosystem functions of natural ecosystems and those close to nature, in comparison with anthropogenically altered ecosystems is a suggested route for ecologically and economically balanced landscape decision-making, which may increase the efficiency of nature and landscape protection.

Keywords: biodiversity valuation; biomass; ecosystem functions; carbon sequestration; floodplain forest; local level

1. Introduction

Energy moves life [1]. An ecosystem is a functional system of living and non-living components of the environment, which are interconnected by the flow of energy, exchange of substances, and the transmission of information, and which interact and develop in a certain space and time [2]. Ecosystems live from gradients, and form more and more dissipated structures, which can be indicated by the concentration of gradients or the degree of structural or functional heterogeneity. The quantities that integrate and characterize the information included in a complex data set, i.e., those which represent highly complex conditions in a very condensed form, can generally be used as indicators for ecosystem valuation [3]. If we succeed in characterizing the complexity of the ecosystem using a limited number of functions, we could use it for ecosystem service valuation [4].

For these purposes, selected groups of characteristics are usually evaluated, such as physical characteristics, e.g., hydrology, morphology; substrate chemical characteristics,
e.g., temperature, alkalinity, hardness, pH, conductivity, nutrient concentration; and biotic characteristics, e.g., coastal and wetland vegetation, algae, wood debris, invertebrates, fish, birds [5]. Nakamura [6] proposed an index of river floodplain ecosystem services (ES) that reflects the hydrological, geochemical, ecological, and socio-economic functions relevant to the study of floodplain services. The index is a weighted average of the values of defined indicators; the weights are determined according to the management of the floodplain. In the detailed method used to evaluate revitalization measures in watercourse floodplains [7], physical characteristics are divided into geomorphology (meander geometry, bank erosion rate, the ratio between rapids and still water, and depth-to-width ratio) and hydrology (sedimentation, particle size, groundwater flow and exchange processes, the amount of runoff (annual, seasonal, and episodic), retention time, sediment flows, flow rate, and water depth). Another criterion is water quality, which corresponds to chemical characteristics (e.g., acidity/alkalinity, dissolved toxins, dissolved salts, conductivity, dissolved oxygen, P and N concentrations, sediment being settled/turbidity, water temperature), and biotic characteristics that are evaluated more comprehensively and in greater detail (e.g., biotic interactions, coarse wood debris, fish life stages, vegetation cover, the presence of species sensitive to pollution, algal production, macrophytes, bacteria/fungi, invertebrates, fish, species richness and diversity, trophic diversity) [8]. One of the important indicators in the assessment of wetlands is the total nitrogen content in the soil [9].

Ecosystem functions (EF) are attributes related to the performance of an ecosystem that are the consequence of one or multiple ecosystem processes [10]. Ecosystem functions that directly or indirectly benefit humans are perceived as a precondition for final ecosystem service provision [11–14]. Haines-Young and Potschin [15] suggested a framework involving the ecosystem cascade model, which describes the relationship of ecosystem structure and processes, functions, services, and benefits that humans finally use. They recommend determining the percentage of provision of ecosystem functions and the ecosystem services possibly derived from them, in comparison with the ideal state of an undisturbed habitat [15]. A comprehensive critical overview of methods for evaluating wetland functions has been provided by the study [16].

The aim of our paper is to present a method for the valuation of selected ecosystem functions (Table 1), demonstrated on the quantification of ecosystem functions in the floodplain. The method is based on the understanding of the principal meaning of biomass production and evapotranspiration. Evapotranspiration (ET) is the process of converting solar energy into the heat of water [17]. This process is very dynamic; it depends mainly on the amount of available energy (sunlight) on the ratio of living and non-living surfaces, on the species composition, the condition of a particular stand of trees, and on the amount of water available. Evapotranspiration cools the surface from which the water evaporates, and energy is transferred in the form of latent (hidden) heat to places where water vapour condenses and releases latent heat. Evapotranspiration therefore balances temperatures between places, and over time.

Our study is based on the hypothesis that elucidating the connection between energy-material flows and hydride cycles in the functioning of natural ecosystems and those close to nature, in comparison with anthropogenically transformed ecosystems is a fundamental route to ecologically and economically balanced landscape decision-making, increasing the efficiency of nature and landscape protection [18], and promoting the principles of sustainability in social and economic life. The evaluation of ecosystem functions is presented in this article by means of a case study of the Morava river basin in the Czech Republic [19].

2. Materials and Methods

2.1. Study Area

For the quantification of ecosystem functions of the floodplain forests in the context of all forest types, the study area of the Morava river basin, covering more than a third of the Czech Republic, and having the largest proportion of floodplain forests of all river basins was selected. The Morava river basin is situated in the eastern part of the Czech Republic.
The Morava river basin is a 2nd order river basin, and is a part of the Danube river basin. In the north, it borders the Odra river basin, in the west the Elbe river basin, and in the east the Váh river basin. In the south, it borders the river basins of the smaller left-hand tributaries of the Danube. The highest point of the basin is peak Praděd in the Jeseníky Mountains, with an altitude of 1491 m a. s. l. The average altitude of the basin is 395 m a. s. l. The fluvial system of Morava is very cohesive, as the Morava river basin is similar to the Moravia region borders [19].

**Figure 1.** Localization of the study area.

The Morava river originates in the Kralicky Sneznik Mountains, near the state border between the Czech Republic and Poland. The length of the Morava river, from its source to the confluence with the Dyje River at the border of the Czech Republic, is about 270 km [20]. The Morava River feeds the Danube river in Slovakia by an average flow of 120 m³ × s⁻¹. The drainage area of the Morava river is 21,132 km². The watershed line running along Moravia’s border from west to north and east is part of the European Watershed.

Geologically, the study area covers a transitive area between the Bohemian Massif and the Carpathians (from west to southeast), and between the Danube basin and the North European Plain. Its core geomorphological features are three wide valleys, namely the Dyje-Svratka Valley, the Upper Morava Valley, and the Lower Morava Valley. The first two form the westernmost part of the Outer Subcarpathia, the last is the northernmost part of the Vienna Basin. The valleys surround the low range of the Central Moravian Carpathians [21].

The floodplain of the river has an area of 635.7 km², the elevation ranges from 151 to 900 m a. s. l. The floodplain of the river represents the conditions of preserved floodplain forest complexes in Central Europe [22]. The current land cover of the basin consists of artificial surfaces (1428 km²), agricultural areas (12,566 km²), forest, and semi-natural areas (7022 km²), wetlands (5 km²), and water bodies (111 km²) according to the Corine Land Cover 2018 dataset. Forest habitats have an area 3702 km² (Table 2). In the past, land use in the study area was severely altered by human activity; the most frequent changes were the grazing of arable land and the growth of discontinuous suburban development [23]. Currently, the main environmental driver of land-use changes in the Morava river floodplain are the changes in distribution and pattern of precipitation, causing...
an increase of both dry periods and very heavy rains, resulting in a higher frequency and severity of flood episodes. Based on model outputs, this trend is expected to increase in the future [24].

The definition of natural forests, as well as the classification of forest habitats, is taken from the Natura 2000 ecological network (Council Directive 92/43/EEC). The forests that are part of Natura 2000 network are referred to as natural forests, i.e., natural habitats. Forest habitats are integrated into groups of habitats defined in the Habitat Catalogue of the Czech Republic [25]. All forest natural habitats (including their codes) according to the terminology of the European Natura System, belonging to individual forest habitat groups, are listed in Table 2. All other forests that are not part of the Natura 2000 Network, because their structure, species composition or diversity has been anthropogenically altered, are referred to as unnatural forests. In the Czech Republic, the most common unnatural forest is Norway spruce plantation, often planted in climatically or habitually unsuitable conditions.

2.2. Quantification of Ecosystem Functions

This study evaluates five ecosystem functions (climate regulation and regulation of the short water cycle, biomass production, oxygen production, and carbon sequestration) and a biodiversity value (Table 1). Assessment of ecosystem functions (EF) was performed in biophysical units on the basis of published data, our own research, and expert knowledge.

Table 1. Classification of evaluated ecosystem functions and services.

| Ecosystem Functions | Categories of Ecosystem Services | ES According to TEEB, 2020 (Group) | ES According to CICES (Group—CICES v.5.1., 2020, Classes—CICES v.4.3., 2013) |
|---------------------|----------------------------------|------------------------------------|--------------------------------------------------------------------------------|
| CARBO               | Carbon sequestration             | Regulating                         | Food/Carbon sequestration and storage                                      | Global climate regulation by reduction of greenhouse gas concentrations |
| PROD                | Production function              | Provisioning                        | Food/Carbon sequestration and storage                                      | Cultivated terrestrial plants for nutrition, materials and energy       |
| OXY                 | O₂ production                    | Regulating                          | Local climate and air quality                                               | Ventilation and transpiration                                          |
| CLIM                | Climate regulation               | Regulating                          | Local climate and air quality                                               | Micro and regional climate regulation                                  |
| SWC                 | Regulation of short water cycle  | Regulating                          | Local climate and air quality                                               | Micro and regional climate regulation                                  |

Explanations: ES—Ecosystem services; TEEB—The Economics of Ecosystems and Biodiversity; CICES—The Common International Classification of Ecosystem Services.

To determine the biodiversity value (BDV), we applied the Habitat Valuation Method. Every habitat type was evaluated by an interdisciplinary team of ecologists, economists, and other specialists operating in various scientific fields. A six-point scale (1–6) was applied, diversified by eight ecological characteristics. The biodiversity value is expressed as the value of a single point at one square metre [26]. A higher value of points represents a higher degree of biodiversity [27]. A complete list of point values of particular habitats can be found in [26] at the following address: http://fzp.ujep.cz/projekty/bvm/bvm.pdf.

The methodological approach of the Energy Water Vegetation Method (EWVM) was used for ecosystem functions. This method captures the actual significance of a natural environment in its full variety, and the maximum utilization of the incoming solar energy. This method was developed in 2007–2009 [17], and follows Ripl’s Energy Transport Reaction (ETR) model [28,29], and reveals the fundamental benefits provided by nature and autotrophic ecosystems in the form of ecosystem services for society. The method shows increasing losses of solar energy caused by anthropogenic changes to the cultural landscape, based on systemic evaluation of the four supporting and regulating functions. All four functions correlate in a mutual synergy. Individual habitats are characterized by an average
annual value over a longer period, expressed per m². The key input for the calculation of selected ecosystem functions is the value of net annual production of above-ground and underground biomass (in kg of biomass × m⁻²) for specific types of habitats.

Climate regulation (CLIM) classifies the vegetation according to the annual evaporation. A high annual sum of evaporation is considered positive; a high share of solar radiation is reflected in water evaporation and in temperature balancing [30,31]. This is expressed in l × m⁻² × year⁻¹ units.

Regulation of short water cycle (SWC) represents the quantity of water which is returned back to the landscape in the form of fog, dew, and minor precipitations [32]. It is expressed in l × m⁻² × year⁻¹ units.

Biomass production (PROD) represents the quantity of plant biomass production in dry matter. The quantity of nutrients retained depends on the amount of biomass produced, whereby the accumulation of organic substances in the soils with a high level of ground water prevails over decomposition [17]. It is expressed in kg × m⁻² × year⁻¹.

Oxygen production (OXY) represents the amount of oxygen calculated from the biomass production according to the photosynthesis equation, and follows the stoichiometric ratio (O₂ production = biomass production × 1.0666) [17]. It is expressed in kg × m⁻² × year⁻¹.

The values that were applied are based on research in the literature and a number of experimental measurements in research projects in the Czech Republic, published in the period 2003 to 2011 and continuously updated [17]. The individual values that were acquired have been continually refined since then. We used the latest published version (2018) as our basis [33]. Carbon sequestration is expressed as the existing carbon reserve in three carbon reservoirs (above-ground and below-ground biomass, and dead organic matter) [34]. Values for the individual carbon reservoirs of particular natural and anthropogenically affected habitats were derived from the literature, and based on our measurements [35,36].

2.3. Data Processing

All analyses were carried out in the GIS environment, particularly in the ArcGIS Pro 2.6 program. All the input data were supplied in the vector format (Esri geodatabase/shapefile format), and in the national projection (epsg: 5514).

The boundaries of the Morava river basin were obtained from official data from the hydro-ecological information system guaranteed by the Research Institute of Water Management T.G. Masaryk. A layer of habitat mapping produced by the Nature Conservation Agency of the Czech Republic was used for the classification and evaluation of individual habitats. These data were created in the years 2000–2004, and are regularly updated as part of the construction and management of the European Natura2000 network. The data are in the scale of 1:10,000, and the classification of habitats was made according to the Habitat Catalogue of the Czech Republic [25]. The usability of this data for habitat assessment is given by [37].

In our analysis, we worked with habitats representing forests and shrubs (but they also included herb floors). Individual habitats were aggregated into habitat groups according to the Habitat Catalogue of the Czech Republic [25]. A representation of the evaluated habitat groups is given in Table 2.

The expert’s point values for individual habitats [points × m⁻²] were transferred to habitat groups by means of the weighted average method. The current areas of individual habitat groups were calculated in the GIS in square metres (this corresponds to the accuracy of the input data), and subsequently converted to square kilometres.

3. Results

In the study area, eleven habitat groups occur; eight natural habitats and three unnaturally affected habitats. Within the river basin, the evaluated habitats cover various areas, which have
a significant impact on the absolute values of the level of ecosystem function provision (Table 2).

Table 2. Representation of evaluated habitats in the Morava river basin.

| Habitat Group                  | Area (km²) | Percentage | Natura 2000 Habitat Code | Habitat Type                                                                 |
|-------------------------------|------------|------------|--------------------------|------------------------------------------------------------------------------|
| Floodplain and wetland forests| 292.84     | 9.59       | 91E0                     | Alder carrs                                                                   |
|                               |            |            | 91E0                     | Montane grey alder galleries                                                |
|                               |            |            | 91E0                     | Ash-alder alluvial forests                                                   |
|                               |            |            | 91E0                     | Hardwood forests of lowland rivers                                           |
|                               |            |            | 91E0                     | Willow-poplar forests of lowland rivers                                      |
|                               |            |            | 91E0                     | Hercynian oak-hornbeam forests                                               |
|                               |            |            | 91E0                     | Polonian oak-hornbeam forests                                                |
|                               |            |            | 91E0                     | Pannonian-Carpathian oak-hornbeam forests                                   |
|                               |            |            | 91E0                     | West Carpathian oak-hornbeam forests                                         |
|                               |            |            | 91E0                     | Galio-Carpinetum oak-hornbeam forests                                        |
|                               |            |            | 91E0                     | Pannonian thermophilous oak forests on loess                                |
|                               |            |            | 91E0                     | Central European basophilous thermophilous oak forests                      |
|                               |            |            | 91E0                     | Acidophilius thermophilous oak forests with Genista pilosa                   |
|                               |            |            | 91E0                     | Acidophilius thermophilous oak forests without Genista pilosa               |
|                               |            |            | 91E0                     | Dry acidophilous oak forests                                                 |
|                               |            |            | 91E0                     | Wet acidophilous oak forests                                                 |
|                               |            |            | 9110                     | Subcontinental pine-oak forests                                             |
|                               |            |            | 9110                     | Acidophilius oak forests on sand                                            |
|                               |            |            | 9110                     | Herb-rich beech forests                                                     |
|                               |            |            | 9110                     | Montane sycamore-beech forests                                               |
|                               |            |            | 9110                     | Limestone beech forests                                                     |
|                               |            |            | 9110                     | Acidophilius beech forests                                                  |
|                               |            |            | 91T0                     | Boreo-continental pine forests with lichens on sand                         |
|                               |            |            | 91T0                     | Boreo-continental pine forests, other stands                                |
|                               |            |            | 91T0                     | Peri-Alpidic serpentine pine forests                                         |
|                               |            |            | 91T0                     | Montane Calamagrostisspruce forests                                          |
|                               |            |            | 91T0                     | Bog spruce forests                                                          |
|                               |            |            | 91T0                     | Waterlogged spruce forests                                                  |
|                               |            |            | 91T0                     | Montane Athyriumspruce forests                                               |
|                               |            |            | 91T0                     | Birch mire forests                                                          |
|                               |            |            | 91T0                     | Pine mire forests with Vaccinium                                            |
|                               |            |            | 4060                     | Subalpine Vaccinium vegetation                                               |
|                               |            |            | 4060                     | Willow carrs                                                                |
|                               |            |            | 3240                     | Willow scrub of loamy and sandy river banks                                 |
|                               |            |            | 3240                     | Tall mesic and xeric scrub                                                  |
|                               |            |            | 40A0                     | Low xeric scrub, primary vegetation on rock outcrops with Cotoneaster spp.  |
|                               |            |            | 40A0                     | Low xeric scrub, secondary vegetation with Prunus tenella                    |
|                               |            |            | 40A0                     | Low xeric scrub, other stands                                               |
|                               |            |            | 40A0                     | Scrub with ruderal or alien species                                          |
|                               |            |            | 40A0                     | Forest plantations of coniferous trees                                       |
|                               |            |            | 40A0                     | Forest plantations of deciduous trees                                       |
| Oak and oak-hornbeam forests  | 824.14     | 26.98      |                          |                                                                              |
| Ravine forests                | 25.56      | 0.84       | 9180                     | Ravine forests                                                              |
| Beech forests                 | 775.26     | 25.38      | 9130                     | Herb-rich beech forests                                                     |
|                               |            |            | 9140                     | Montane sycamore-beech forests                                               |
|                               |            |            | 9150                     | Limestone beech forests                                                     |
|                               |            |            | 9110                     | Acidophilius beech forests                                                  |
|                               |            |            | 91T0                     | Boreo-continental pine forests with lichens on sand                         |
|                               |            |            | 91T0                     | Boreo-continental pine forests, other stands                                |
|                               |            |            | 91T0                     | Peri-Alpidic serpentine pine forests                                         |
| Dry pine forests              | 5.49       | 0.18       |                          |                                                                              |
| Spruce forests                | 42.84      | 1.40       | 9410                     | Montane Calamagrostisspruce forests                                          |
| Peat forests                  | 0.09       | 0.01       | 91D0                     | Bog spruce forests                                                          |
| Natural shrubs                | 33.27      | 1.09       |                          |                                                                              |
| Unnatural shrubs              | 1.18       | 0.04       |                          |                                                                              |
| Unnatural coniferous forests  | 1012.62    | 33.15      |                          |                                                                              |
| Unnatural deciduous forests   | 40.98      | 1.34       |                          |                                                                              |
| Total                         | 3054.27    | 100        |                          |                                                                              |

The largest area, covering 33.15% of the area of the territory that was examined, is taken up by the unnatural coniferous forests habitat. The second-largest area, with approximately
27% of the territory, is covered by the oak forests and oak-hornbeam forests habitat, and the third largest (25.4% of the territory) by the beech forests habitat. The floodplain and wetland forest habitats cover approximately 10% of the territory that was examined. Other habitats cover areas between 0.01% and 1.40%, with the smallest habitats being unnatural shrubs and bog woodlands (0.04 and 0.01% of the territory).

3.1. Average Values of Provided Ecosystem Functions

The summary of the determined average values of ecosystem functions is shown in Table 3.

| Habitat Group                  | CLIM $\times 1 \text{ m}^2 \times \text{ Year}^{-1}$ | SWC $\times 1 \text{ m}^2 \times \text{ Year}^{-1}$ | PROD $\times 1 \text{ kg} \times \text{ m}^2 \times \text{ Year}^{-1}$ | OXY $\times 1 \text{ kg} \times \text{ m}^2 \times \text{ Year}^{-1}$ | CARBO $\times 1 \text{Tons} \times \text{ ha}^{-1}$ | BDV $\times 1 \text{ Points} \times \text{ m}^2$ |
|-------------------------------|--------------------------------------------------|--------------------------------------------------|--------------------------------------------------|--------------------------------------------------|------------------------------------|----------------------------------|
| Floodplain and wetland forests| 650                                              | 300                                              | 2.03                                             | 2.17                                             | 127.35                             | 53.46                            |
| Oak and oak-hornbeam forests  | 450                                              | 225                                              | 1.76                                             | 1.87                                             | 127.35                             | 53.55                            |
| Ravine forests                | 500                                              | 250                                              | 1.79                                             | 1.91                                             | 127.35                             | 42.00                            |
| Beech forests                 | 500                                              | 250                                              | 1.79                                             | 1.91                                             | 127.35                             | 43.5                             |
| Spruce forests                | 400                                              | 200                                              | 1.56                                             | 1.66                                             | 143.55                             | 36.84                            |
| Peat forests                  | 400                                              | 200                                              | 0.98                                             | 1.05                                             | 129.01                             | 56.00                            |
| Natural shrubs                | 350                                              | 150                                              | 1.07                                             | 1.14                                             | 18.67                              | 33.44                            |
| Unnatural shrubs              | 300                                              | 125                                              | 1.06                                             | 1.13                                             | 15.09                              | 21.6                             |
| Unnatural coniferous forests  | 398                                              | 172                                              | 1.55                                             | 1.65                                             | 141.00                             | 19.86                            |
| Unnatural deciduous forests   | 396                                              | 142                                              | 1.54                                             | 1.64                                             | 126.97                             | 19.72                            |

Explanations: CLIM—Climate regulation; SWC—Regulation of short water cycle; PROD—Biomass production; OXY—Oxygen production; CARBO—Carbon sequestration; BDV—Biodiversity value.

The floodplain and wetland forest habitats reached the highest expert values for the ecosystem functions of climate regulation, regulation of small water cycle, dry matter production, and oxygen production (Table 3). When assessing biodiversity, it had the third highest point value, only the habitats peat forests and oak and oak-hornbeam forests had a higher value. Comparing the average of all expert values describing the studied ecosystem functions, beech forests, ravine forests, and oak and oak-hornbeam forests showed the highest values, followed by spruce forests and peat forests, reaching high values for all EF with the exception of carbon sequestration. On the contrary, the lowest values were to be found for the dry pine tree habitat in the evaluation of climate regulation, regulation of small water cycle, biomass, and oxygen production, with intermediate values in the evaluation of biodiversity. Unnatural coniferous forests and unnatural deciduous forest habitats were evaluated similarly. Somewhat higher values were to be seen for the unnatural shrub and natural shrub habitats.

3.2. Quantification of Ecosystem Functions in the Study Area

The subsequent results show the final values of the selected ecosystem functions in terms of absolute values for each type of habitat over the entire study area (Table 4). They also offer a percentage share of each habitat in the quantified value of the selected ecosystem functions within the study area. This data is mutually comparable only within the given ecosystem function. The relative share of a particular habitat type in a particular ecosystem function provision does not reflect the percentage representation of the habitat in the study area.
### Table 4. The degree of provision of ecosystem functions for the entire area of the territory that was monitored in absolute and relative units.

| Habitat Group                          | CLIM $1 \times 10^6$ Year$^{-1}$ | %  | SWC $1 \times 10^6$ Year$^{-1}$ | %  | PROD $kg \times 10^6$ Year$^{-1}$ | %  | OXY $kg \times 10^6$ Year$^{-1}$ | %  | CARBO Tons $\times 10^3$ | %  | BDV Points $\times 10^6$ | %  |
|---------------------------------------|----------------------------------|----|----------------------------------|----|----------------------------------|----|----------------------------------|----|------------------------|----|----------------------|----|
| Floodplain and wetland forests        | 234,275.4                        | 12.16 | 204,990.9                        | 12.71 | 594.5                         | 11.4 | 6354.7                         | 11.43 | 3729.3                | 9.33 | 15,656.9             | 13.21 |
| Oak and oak-hornbeam forests          | 566,039.3                        | 29.37 | 480,910.2                        | 29.81 | 1447.5                        | 27.76 | 15,447.9                        | 27.78 | 10,495.5              | 26.25 | 44,131.9             | 37.23 |
| Ravine forests                        | 17,892.2                         | 0.93  | 15,336.1                         | 0.95  | 45.8                          | 0.88  | 488.2                          | 0.88  | 325.5                 | 0.81  | 1073.5               | 0.91  |
| Beech forests                         | 542,682.7                        | 28.16 | 465,156.6                        | 28.84 | 1387.7                        | 26.61 | 14,807.5                        | 26.63 | 9872.9                | 24.69 | 33,802.5             | 28.51 |
| Dry pine forests                      | 2194.3                           | 0.11  | 1234.3                           | 0.08  | 4.9                           | 0.09  | 52.7                           | 0.09  | 78.7                  | 0.2   | 223.7                | 0.19  |
| Spruce forests                        | 21,910.9                         | 1.14  | 17,545.1                         | 1.09  | 66.8                          | 1.28  | 71.1                           | 1.28  | 614.9                 | 1.54  | 1578.3               | 1.33  |
| Peat forests                          | 75.5                             | 0.01  | 61.4                             | 0.01  | 0.1                           | >0.01 | 0.9                            | >0.01 | 1.2                   | >0.01 | 5.3                  | 0.01  |
| Natural shrubs                        | 17,035.6                         | 0.88  | 10,646.1                         | 0.66  | 35.7                          | 0.68  | 380.4                          | 0.68  | 62.1                  | 0.16  | 1114.9               | 0.94  |
| Unnatural coniferous forests          | 647.1                            | 0.03  | 352.9                            | 0.02  | 1.2                           | 0.02  | 13.2                           | 0.02  | 1.8                   | >0.01 | 39.5                 | 0.03  |
| Unnatural deciduous forests           | 504,286.1                        | 26.16 | 400,745.4                        | 24.84 | 1567.9                        | 30.07 | 16,684.9                       | 30.71 | 142.8                 | 35.71 | 20,110.7             | 16.96 |
| Total                                 | 1,927,365.1                      | 100.00 | 1,613,022.9                      | 100.00 | 5215.2                       | 100.00 | 55,611.9                      | 100.00 | 39,980.8             | 100.00 | 118,545.4           | 100.00 |

The evaluation of the share of individual habitats for the level of providing ecosystem functions of climate regulation and regulation of small water cycle showed that the habitats of oak and oak-hornbeam forests, beech forests, and unnatural coniferous forests contributed the most to the provision of these functions; floodplain and wetland forests accounted for 10% of this. Other habitats, except for the spruce forests habitat, whose share exceeds one percent, did not reach even one percent. The evaluation of the share of individual habitats in the level of providing EF biomass production and oxygen production showed that the non-natural coniferous forests habitat contributed the most, followed by the oak and oak-hornbeam forests, and beech forests habitats. More than 10% was found for the floodplain and wetland forests. The habitats, spruce forests and unnatural deciduous forests showed more than one percent, other habitats show a share below one percent. The calculation of carbon sequestration in the monitored habitats showed the highest values of carbon stock in the habitat, unnatural coniferous forests (around 36%), and a somewhat lower stock in the habitats oak and oak-hornbeam forests, and beech forests (around 25%). The habitats, floodplain and wetland forests accounted for 9% of carbon stocks. Oak and oak-hornbeam forests were habitats with the highest value of biodiversity. Lower relative values were achieved by unnatural coniferous forests and floodplain and wetland forests.

#### 3.3. Order of Providing Ecosystem Functions of Forest Habitats in the Morava River Basin

When comparing the ranking in the provision of individual EFs per unit area (Table 5), the habitat with highest values in all assessed functions was floodplain and wetland forests, followed by ravine forests and beech forests.
Table 5. Ranking of forest habitats, by importance in ecosystem function provision related to area unit.

| Rank | Habitat Group               | CLIM | SWC | PROD | OXY | CARBO | BDV | ø   |
|------|----------------------------|------|-----|------|-----|-------|-----|-----|
| 1    | Floodplain and wetland forests | 1    | 1   | 1    | 1   | 5     | 3   | 2.00|
| 2    | Ravine forests              | 2    | 2   | 2    | 2   | 7     | 5   | 3.33|
| 3    | Beech forests               | 3    | 3   | 3    | 3   | 8     | 3   | 3.83|
| 4    | Oak and oak-hornbeam forests| 4    | 4   | 4    | 4   | 6     | 2   | 4.00|
| 5    | Spruce forests              | 5    | 5   | 5    | 5   | 2     | 7   | 4.83|
| 6    | Peat forests                | 6    | 6   | 10   | 10  | 4     | 1   | 6.17|
| 7    | Unnatural coniferous forests| 7    | 7   | 6    | 6   | 3     | 10  | 6.50|
| 8    | Dry pine trees              | 10   | 10  | 11   | 11  | 1     | 6   | 8.17|
| 9    | Unnatural deciduous forests | 8    | 8   | 7    | 7   | 9     | 11  | 8.33|
| 10   | Natural shrubs              | 9    | 9   | 8    | 8   | 10    | 9   | 8.83|
| 11   | Unnatural shrubs            | 11   | 11  | 9    | 9   | 10    | 9   | 9.83|

However, the analysis of the rate of EF provision, related to the total area of interest, showed a different order of values. None of the habitats was the best in terms of meeting all evaluated EFs (Table 6). According to the presented results, the strongest ecosystem function providers are oak and oak-hornbeam forests, followed by beech forests and unnatural coniferous forests. The oak and oak-hornbeam forests were the best-rated habitats in provision of climate regulation, regulation of small water cycle, and in the value of biodiversity, and the second best in provision of the rest of the evaluated EFs. The second ranked provider of EFs was the habitat, unnatural coniferous forests, which ranked first in the value of biomass, oxygen production, and carbon sequestration, and third in the provision of climate regulation, regulation of small water cycle, and in the assessment of biodiversity. The beech forests ranked second in providing EF climate regulation, small water cycle regulation, and biodiversity assessment, and third in EF biomass production, oxygen production, and carbon sequestration. The floodplain and wetland forests habitat ranked fourth in all evaluations, and the spruce forests habitat had the fifth (the average) ranking in all evaluated functions. Unnatural shrubs and peat forests were worst rated habitats.

Table 6. Ranking of forest habitats, by importance in ecosystem function provision, considering their total area.

| Habitat Group                        | CLIM | SWC | PROD | OXY | CARBO | BDV |
|--------------------------------------|------|-----|------|-----|-------|-----|
| Floodplain and wetland forests       | 4    | 4   | 4    | 4   | 4     | 4   |
| Oak and oak-hornbeam forests         | 1    | 1   | 2    | 2   | 2     | 1   |
| Ravine forests                       | 7    | 7   | 7    | 7   | 7     | 7   |
| Beech forests                        | 2    | 2   | 3    | 3   | 3     | 2   |
| Dry pine forests                     | 9    | 9   | 9    | 9   | 8     | 9   |
| Spruce forests                       | 5    | 5   | 5    | 5   | 5     | 5   |
| Peat forests                         | 11   | 11  | 11   | 11  | 11    | 11  |
| Natural shrubs                       | 8    | 8   | 8    | 8   | 9     | 6   |
| Unnatural shrubs                     | 10   | 10  | 10   | 10  | 10    | 10  |
| Unnatural coniferous forests         | 3    | 3   | 1    | 1   | 1     | 3   |
| Unnatural deciduous forests          | 6    | 6   | 6    | 6   | 6     | 8   |

4. Discussion

The study of individual ecosystem functions (EF) and services (ES) and their interrelationships has recently become more frequent [38,39]. Rodriguez et al. [40] reported that carbon stored in aboveground biomass was positively correlated with both water supply and water regulation. Flood prevention has been shown to be positively correlated with biodiversity protection [41,42] and carbon stock [43], although correlation values were generally low. For the needs of landscape planning, studies dealing with spatial contexts are beneficial [44,45]. A number of studies have pointed to the great importance of biodiversity for ES provision. For example, Onaindia et al. [46] described the spatial
congruence of biodiversity, carbon sequestration, and water flow regulation, with the preservation of biodiversity, ensuring the provision of regulatory services by maintaining native forest ecosystems. The synergy between biodiversity and carbon sequestration has been confirmed in many other studies [47–49], to the extent that some areas with high biodiversity could be protected by carbon-based protection strategies [50]. Today, studies focusing on the multifunctional expression of EF and ES [45], or comparing ecosystem services provision at a detailed level of resolution [51], are in high demand.

The presented results provide a set of expert values of EF provision, expressed per unit area, and subsequently projected onto the Morava river basin, to describe the current state of EF provision in an area of interest. Expert values can be used in a wide range of studies in much wider geographical regions, throughout the Czech Republic, and with some modifications, throughout Central Europe. The expert values for the individual functions are not final, and generally valid. To compile them, the authors tried to find all known information (from experiments or the literature) for the given habitats. In addition, only values from the same geographical region were used. Under this condition, the authors tried to avoid the results of studies which combined data from experiments from a wide region (worldwide), regardless of the geographical (climatic, hydrological) specifics of the regions in which the experiments were performed. In addition, it is a synthesis of results from a long-term study, where the current level of implementation may be lower due to the manifestations of climate change. All values used represent optimal values, i.e., the values that habitats reach in their maturity under usual environmental conditions, and where all their internal ecosystem processes work. However, the real situation in the landscape is different, and the real values are usually lower. This is due to the different age, developmental stage, and health status of individual segments of habitats. For the time being, this method cannot take such variability into account.

In last decades remote sensing techniques have been introduced into ecosystem studies to detect selected properties that can modify the rate of EF performance of vegetation (health status, developmental phase). With the use of several vegetation indices and multispectral images, it is already possible to determine areas with a relative deterioration in the health status of individual segments in space, and subsequently reduce the proportional values of the function. The fact that all analysed services are evaluated as dependent on plant production, i.e., the amount and condition of biomass produced, also speaks for this direction of expansion. This is also a key feature for the necessary remote sensing methods (spectral analyses and vegetation indices) [52,53]. Algorithms for determining vegetation indices, which can be used to assess the health of vegetation, are well known today, and are optimized for different types of multispectral data (Landsat, Sentinel . . . ) [54–57]. The task of further research is to derive a relationship that defines the relationship between the (decreasing) value of the vegetation index, indicating the health status/fitness of the habitat, and the value determining the rate of reduction of production capacity (climate regulation, regulation of short water cycle) of the affected habitat. In the case of the application of the method to a specific area (in this case the Morava river basin), the current acreage of individual habitats plays a very important role. In this paper, the current occurrence of individual habitats was mapped at a scale of 1:10,000 to capture both habitat variability, and their exact spatial geometry and distribution [58,59]. If the research question is defined in the form of, what is the total value of the performance of the function in the area of interest, it is necessary to reflect the acreage in the calculation [60]. For interpretation, however, it is necessary to have this information (representation of individual habitats in the area) always available.

If the user is interested in the mutual comparison of habitats according to the degree of provision, then it is appropriate to use values related to the defined area. A debatable point in the mutual comparison is the question of assigning weights to individual functions. This step, depending on the range of weights, would significantly affect the resulting habitat classification. In the presented article, the authors proceed from the thesis that all analyzed functions are equivalent for landscape development and securing ecosystem
functioning. For application in another study, it would be easy to add scales, and thus prefer one of the functions. Weights could be obtained by a questionnaire survey among relevant stakeholders, or from the defined objectives of the planned landscaping measures, which should be aimed at correcting/supporting a function.

5. Conclusions

The aim of this paper was to contribute to a better understanding of the significance of floodplain forests within the scope of the landscape. The subject of the research was to assess the level of provision of five selected ecosystem functions and biodiversity by significant groups of forest habitats and their mutual comparison. The results showed the high importance of floodplain forests as ecosystem function providers. In the majority of the functions that were monitored, namely in climate regulation, regulation of short water cycle, biomass production, and oxygen production, this habitat reached high values and, in comparison with the other habitats, took the leading position.

The results presented here must be viewed in a comprehensive manner. Although unnatural coniferous forests have high values of biomass production and carbon sequestration, this positive feature is decreased through low biodiversity. Although they have values of ecosystem function provision that are only a little lower, floodplain forests resulted in better overall assessment as they also reach high values in the biodiversity valuation. For the design of regional management, leading to sustainable land use, it is necessary to evaluate several functions at the same time and to prefer, in adjustments made to the landscape, those groups of habitats which show high values for all the indices that are monitored.

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