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Provision of Ecosystem Services in Riparian Hemiboreal Forest Fixed-Width Buffers

Mārcis Saklaurs [1], Zane Lībiete [1], Jānis Donis [1], Māra Kitenberga [1], Didzis Elferts [1,2], Edgards Jūrmalis [1] and Āris Jansons [1,*]

[1] Latvian State Forest Research Institute "Silava", 111 Rigas Str., LV-2169 Salaspils, Latvia; marcis.saklaurs@silava.lv (M.S.); zane.libiete@silava.lv (Z.L.); janis.donis@silava.lv (J.D.); mara.kitenberga@gmail.com (M.K.); didzis.elferts@lu.lv (D.E.); edgars.jurmalis@silava.lv (E.J.)
[2] Faculty of Biology, University of Latvia, Jelgavas Street 1, LV–1004 Rīga, Latvia
* Correspondence: aris.jansons@silava.lv

Abstract: The importance of riparian forest protection is widely acknowledged. However, scientific discussions are still ongoing as to the most suitable and effective protection activities for these forests. The quality of the provision of different ecosystem services in protected riparian forest buffers could provide an insight into the impact of protection regulations. Cultural ecosystem services in riparian forests have an important social-ecological context, especially with the growing interest in recreation activities in forests. The aim of our study was to compare provision of different ecosystem services in riparian forest buffers located both adjacent to (0–50 m) and distant from (51–200 m) the stream. In our study, four small-to-medium-sized rivers in Latvia were used. In total, six different indicators of ecosystem services were estimated, based on data from the National Forest Inventory and the European Soil Data Centre. Bayesian ordinal regression was employed to assess the differences between the two buffer strips. Our results showed that the majority of assessed ecosystem service indicators (Recreation potential of the forest ecosystem, Visual quality of the forest landscape, Potential for the presence of medicinal plants and Potential for the presence of nectar plants) were of higher quality in the adjacent (0–50 m) buffer. Only one indicator (Flora with phytoremediation potential) had significantly higher values in the distant buffer strips (estimate 0.24, CI: [0.11, 0.38]). The observed distribution of quality classes showed that, only for the indicator Potential of medicinal plants, the highest quality class was the most common (>60%), for other indicators dominated average quality class estimations. The obtained results suggested that the current protection status that riparian forest buffers have facilitated maintain the provision of several cultural and regulation & maintenance ecosystem services.

Keywords: riparian forests; ecosystem services; hemiboreal forests

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1. Introduction

Ecosystems provide essential material and non-material goods and services to society. The concept of ecosystem services (ES) has grown out of the need to have a standardized system to account for the diverse multifunctionality of ecosystems, and where possible, to estimate their economic value. The European Union Forest Strategy for 2030 commits to securing the multifunctionality of European forests [1]. Some of the most important ES provided by forest ecosystems include recreation, biodiversity, air quality, carbon storage, water availability, and erosion protection [2]. In the current ecosystem service framework (CICES), three main sections are distinguished: provisioning, regulation & maintenance, and cultural ES. Cultural ecosystem services (CES) refer to the non-material benefits of ecosystem goods and services in relation to people's quality of life [3]. Over the last few years, there has been a considerable growth in research studies describing

CES in different ecosystems, highlighting the relevance of such knowledge in a socio-ecological context.

Riparian forests, which are transition zones between aquatic and terrestrial ecosystems, have been described as multifunctional ES hotspots [4]. These areas have a crucial role in maintaining water quality, regulating flood risks, recycling nutrient and organic matter, and erosion control [5–7]. This is also confirmed by a recent study, which highlighted that the erosion rate is particularly higher in the riparian forest ecosystems of environmental important areas [8]. Additionally, the erosion process in these areas may have profound effects on the landscape. Studies have shown that in riparian forests the provision of regulating ES is higher than in other forest ecosystems [4]. Besides their ecological importance, riparian forests are highly attractive areas for recreation and tourism [9]. People have become more interested of late in outdoor activities in forests, especially during the COVID-19 pandemic, when other socializing activities were less available [10]. Studies show that people clearly prefer a diversity of forest structural elements over dense, monospecific stands [11]. Stakeholder and society perception of nature or landscape has a strong influence on management and restoration project outcomes [12]. Studies show that by combining ecological knowledge with a socio-cultural understanding, restoration projects in riparian areas have a significantly higher potential for a successful outcome [13]. Although management actions in riparian areas must be primarily based on ecology, additional information about CES in these areas could provide valuable insights for trade-offs or synergetic links across a range of ecosystem services.

In the Nordic-Baltic region, the protection given to riparian forests varies, ranging from voluntary commitments in Sweden and Finland to rather strict mandatory regulation in Latvia and Estonia [14]. There is a long history of discussion about the most effective and appropriate regime for protecting riparian forests. A fixed-width buffer zone is easier to implement and supervise from the administration perspective, but it may not always serve to ensure the highest total value of the ecosystem services in riparian forests [15]. Studies show that variable-width buffer zones could be a more cost-effective option, one which does not compromise on water quality but at the same time can maximize ES [6,16–18], especially for small-to-medium-sized streams [15].

Due to their protection status and variable water level, riparian forests are not attractive areas for commercial forestry. Yet such areas contain the potential to provision of non-wood forest products (NWFPs). In Northern European forests, wild berries and mushrooms are the most widely collected NWFPs for household consumption and/or the retail market [19]. In Latvia, a common activity with a long history of accumulated knowledge is the collection of wild plants with medicinal properties for use in traditional medicine and as an ingredient in certain drugs [20,21]. The study of the potential use of wild plants in treating different diseases highly popular in Latvia [22,23], as well as in other European countries [24,25]. Hence, information on the prevalence of such plants in different ecosystems is highly relevant.

Beekeeping is another common and traditional activity in Baltic countries [26–28], and relies on the nectar from wild plants. Although the majority of wild nectar plants grow in fields and meadows, specific types of honey are produced that rely on plants from forest ecosystems, for example, common heather (*Calluna vulgaris*) [29], as well as several other ericaceous plants [30]. Information on the nectar plants growing in forests could be used as an indicator of the potential food sources for pollinators, whose presence is crucial for the development of many wild plants and also of plants in agroecosystems. Traditionally, pollination potential has been assessed by measuring pollinator abundance and diversity [4,31]. More recently, however, vegetation-based indicators have been developed to help to assess pollination potential based on the abundance of Flora [32].

In this study, we aim to compare the provision of different ecosystem services in the riparian forest buffer strips located adjacent to the stream (0–50 m), or with a distance of 51–200 m from the stream bank. Considering the rather strict and long-standing (since 1997) protection status of the adjacent buffer strips (0–50 m), we hypothesized that the

CES values would be lower, because increasing stand age increases mortality and hence the amount of deadwood [33], which is perceived negatively by society [34]. We also hypothesized that regulation and maintenance and provisioning ES would have higher values in the adjacent zone than in the distant buffer due to the absence of soil disturbance [35]. Additionally, the higher availability of sunlight in the understory close to the river could help vascular plants to develop better. Information about the provision of ES in buffer areas of riparian forests could help to develop protection zone regulations with an increased concern for socio-economic factors.

2. Materials and Methods

The study was conducted in the country of Latvia (55°40′–58°05′ N, 20°58′–28°14′ E), which is in the hemiboreal forest zone [36]. For this study, we aimed to select streams with a length of up to 100 km (small to medium-size), which flow through a forested area at least 4 km in length, and where the forest is at least 300 m wide on both sides of the river. We also aimed to select rivers with different mean slopes (m/km), covering both potamal (slow) and ritral (fast) types of river, according to the Latvian regulations of river typology. We selected four rivers that met the criteria mentioned above and had available forest inventory data (Figure 1). Two of the rivers (Svētaine, Vitrupe) are potamal-type, and two (Korģe, Līgatne) are ritral-type rivers. The ritral rivers had sediments composed of boulder, pebble, gravel, and sand, while the potamal-type rivers had more sand, mud, and clay in their sediments. The catchment areas for the ritral rivers ranged from 89 to 113 km^2, and their length from 14 to 31 km. For the potamal rivers, the catchment areas ranged from 43 to 193 km^2, and their length from 18 to 49 km. According to Latvian legislation, all the selected rivers have 50 m wide buffer strips where clear-cutting is forbidden [37].

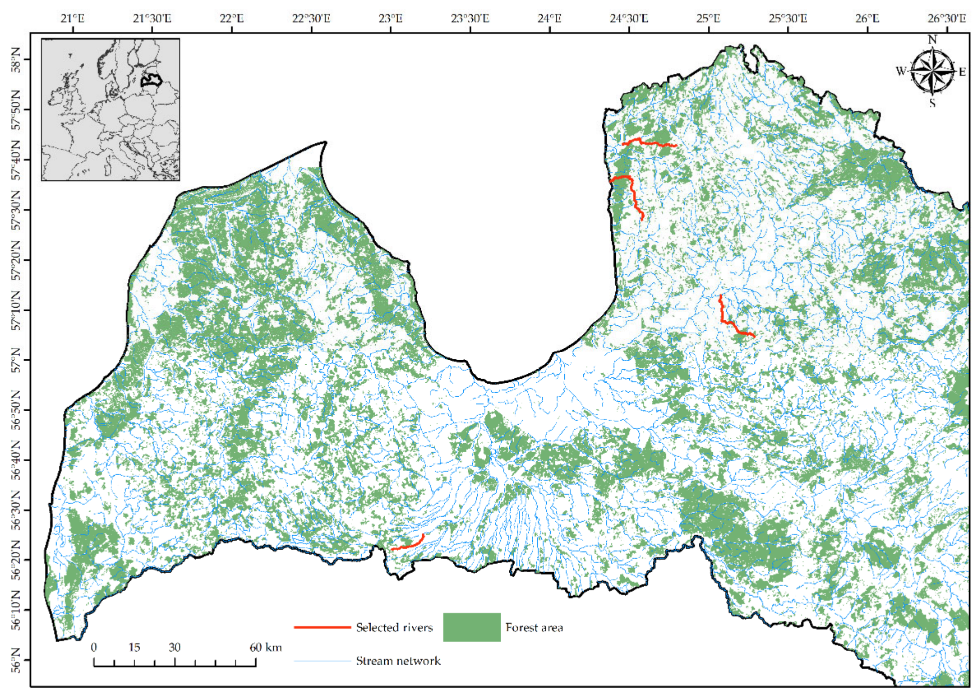

Figure 1. Location of the selected four small-to-medium-sized rivers in Latvia. The blue color shows all stream networks, the green color all forested areas.

Information about forest site type, dominant tree species, stand age, and undergrowth was obtained from the National Forest Inventory database. All forests located within 200 m distance on either side of the rivers were selected for the analysis. Using

ArcGIS tools, two types of buffer strips were distinguished, those adjacent to the river banks (0–50 m), and those distant (51–200 m) from the river banks. Adjacent buffer strips are characteristic of riparian forest zones under protection without management activities in Latvia. Distant buffer strips (51–200 m) characterize managed forests without restrictions. In our study, the forest site types are classified according to the eastern Baltic phytocoenological system [38]. For both buffers, the most common forest site type was fertile *Oxalidosa*, comprising from 34 to 55% of the forested areas analyzed. Only in Svētaine river drained forest stands (*Mercurialiosa* mel.) comprised a rather large part (~30%) of both buffers (Table 1). In the more distant buffers strips, the proportion of younger stands was higher than in the adjacent buffer strips (Figure 2). The most common dominant tree species in both buffer strips were grey alder (*Alnus incana*), silver birch (*Betula pendula*), and Norway spruce (*Picea abies*). For both buffer strips, we used the CICES V5.1 classification system to identify indicators that can be attributed to the ecosystem services set out below [39] (Table 2).

Table 1. The most common forest site types (%) in adjacent (0–50 m) and distant (51–200 m) riparian forest buffer strips for each river. The forest types are based on eastern Baltic phytocoenological classification (in Latin).

River	Buffer	The most common forest site types (% of area)
Korģe	Adjacent	*Oxalidosa* 50%; *Hylocomniosa* 15%; *Myrtilloso-polytrichosa* 13%
	Distant	*Oxalidosa* 37%; *Myrtilloso-polytrichosa* 16%; *Hylocomniosa* 15%
Līgatne	Adjacent	*Oxalidosa* 55%; *Hylocomniosa* 33%
	Distant	*Oxalidosa* 46%; *Hylocomniosa* 37%
Svētaine	Adjacent	*Oxalidosa* 48%; *Mercurialiosa* mel. 33%
	Distant	*Oxalidosa* 47%; *Mercurialiosa* mel. 32%
Vitrupe	Adjacent	*Oxalidosa* 37%; *Hylocomniosa* 16%; *Aegopodiosa* 16%
	Distant	*Oxalidosa* 34%; *Aegopodiosa* 18%; *Hylocomniosa* 14%

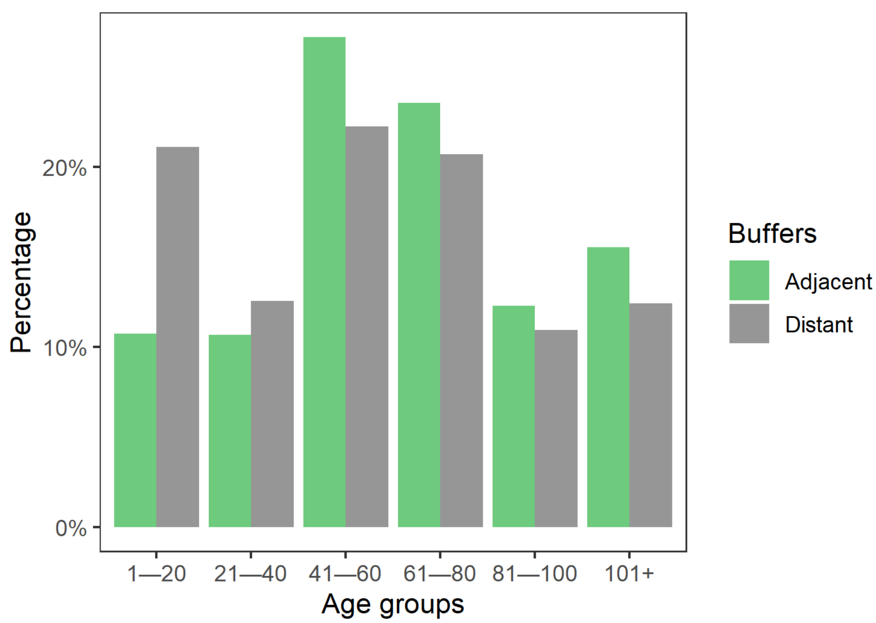

Figure 2. The division proportion (%) of stands by age group in adjacent (0–50 m) and distant (51–200 m) buffer strips in riparian forests.

Erosion risks were calculated using the Revised Universal Soil Loss Equation (RUSLE) model with ArcGIS software. Input data for soil erodibility, the cover-management factor, and rainfall erosivity (R factor) were obtained from the European Soil Data Centre (ESDAC) [40]. The selected spatial and temporal resolutions for the layers of the dynamic factor were compromised as there were no alternatives for locally sourced data without enlarging the scope and complexity of this study. Topography data to calculate the slope length factor (LS) (derived from LIDAR) for the areas of Latvia were obtained from the University of Latvia, Faculty of Geography and Earth Sciences.

Table 2. Ecosystem services and indicators estimated.

	Ecosystem Service	CICES 5.1 Class Code	Indicator	Grade
1	Cultural (biotic): Ecological and geographical qualities of the forest stand which attract people	3.1.1.1	Recreation potential of the forest ecosystem	0–100
2	Cultural (biotic): Visual features (aesthetics) of the forest stand which attract people	3.1.1.2	Visual aesthetic quality of the forest landscape	1–5
3	Cultural (biotic): Characteristics of the forest stand which help to withstand recreational pressure	3.1.1.1	Potential to withstand recreational pressure	1–7
4	Regulation & Maintenance (biotic): Filtration/sequestration/storage/accumulation by micro-organisms, algae, plants, and animals (Phytoremediation)	2.1.1.2	Flora with phytoremediation potential	1–5
5	Provision (biotic): Wild plants used for nutrition	1.1.5.1	Potential for the presence of nectar plants	1–5
6	Provision (biotic): Fibers and other materials from wild plants available for direct use or processing	1.1.5.2	Potential for the presence medicinal plants	1–5

The recreation potential of the forest ecosystem was calculated according to the formula developed by Repshas [41], with modifications implemented by Donis [42]:

$$VR = (Vs \times Kw \times Ks \times Va) \times Kp \times Kd,$$

where Vs is the value of the recreation suitability of a forest type according to the dominant tree species; Kw, the coefficient of proximity to a body of water (km); Ks, the coefficient of proximity to urban areas (km); Va, additional points if the forest stand is adjacent to large areas of housing estates, a nature reserve, or a camping site; Kp, the coefficient of environmental contamination; and Kd, the coefficient of the amount of deadwood.

The visual aesthetic quality of the forest landscape was estimated using a regression model [42] [29] based on a semantic differential survey (with photo-questionnaire) of different forest sceneries:

$$V = a0 + aD + aB + aL + aC,$$

where V is the value of Visual aesthetic quality of the forest landscape; a0, +4.80; D, the dominant tree species; B, the age group; L, the landscape type; C, the amount of deadwood amount; and coefficients a, the coefficient values from the regression model.

The potential for withstanding recreational pressure was assessed according to the formula developed by Emsis [43] and modified by Donis [42], where the following factors are used: forest site type, stand age, dominant tree species, and topography (Description S1).

The indicators: Potential for the presence of medicinal plants, Potential for the presence of nectar plants and plants with phytoremediation potential were calculated according to the procedure below (Figure 3) [44]. Each plant having the specific property concerned was assigned a value from 1 to 3, depending on how common it was in the particular forest site type. The indicator value is the sum of all the potential plants with the specific property in the particular forest site type.

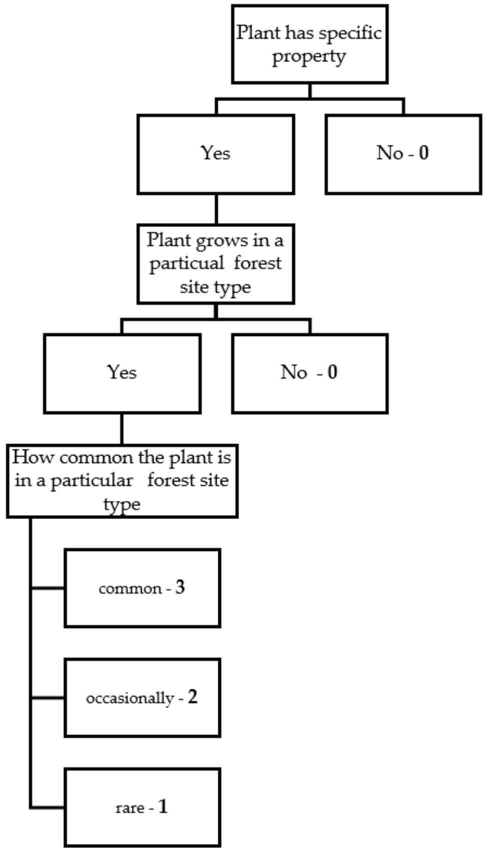

Figure 3. Formula for estimating the indicator of potential plant presence.

Data Analysis

The indicator values are expressed as grades from 1 to 5 or from 1 to 7 (ordinal data). Hence, we employed a Bayesian ordinal (binary) regression (BOR) to assess the effect of strip buffers on the indicators. The indicators are categorical data. We set the family function of the model to "cumulative" and used the logit link function. Ordinal regression was used as the five of the indicators (Table 2) where on the ordinal scale. For the recreation potential (expressed as a grade from 0 to 100), a Bayesian zero-one beta regression (BZOBR) was used as the response variable could be attributed to proportion scale with the 0 and 100 values present. Rivers and forest compartment IDs were used as nested random factors in all the models, as there were multiple observations for each compartment. General form for the BOR model was: response variable (indicator expressed as factor variable with 5 of 7 levels) = buffer strip (factor with two levels) + (1 | River ID/Forest compartment ID). All calculations were completed using R 4.1.1 [45] library brms [46]. For each of the four chains, the number of iterations was 2000. Rhat values were used to assess the convergence of the model (all values were 1.00). The number of observations across all models was 3,965. The significance of the difference between the strip buffers was assessed using Bayesian credible intervals (CI) of 95% for the precision of the estimate.

3. Results

Using BOR analysis, we aimed to assess the effects of buffers on the values of the indicators. The indicators—Recreation potential (estimate −0.12, CI: [−0.18, −0.06]); Visual (aesthetic) quality of the forest landscape (estimate −0.22, CI: [−0.35, −0.09]); Potential for the presence of medicinal plants (estimate −0.37, CI: [−0.54, −0.20]); and Potential for the presence of nectar plants (estimate -0.23, CI: [−0.39, −0.07])—had significantly higher values in the adjacent than in the distant buffer strips. Only for the indicator Flora with phytoremediation potential were the values in the distant buffer strips significantly higher than those in the adjacent buffers (estimate 0.24, CI: [0.11, 0.38]). For the indicator, Potential to withstand recreational pressure, no significant differences were found between the buffers.

For the indicator Potential of medicinal plants, the highest quality class (5) was the most common (>60%) for both buffers (Figure 4A). Similarly, for the indicator Potential of medicinal plants, most common (>70%) was the second highest quality class (4) (Figure 4C). For the rest of the ES indicators, the observed distribution of quality classes was less distinct. The average quality classes (3, 4) were the most common (~20~50%) for the indicators Flora with phytoremediation potential and Visual aesthetic quality (Figure 4B,E).

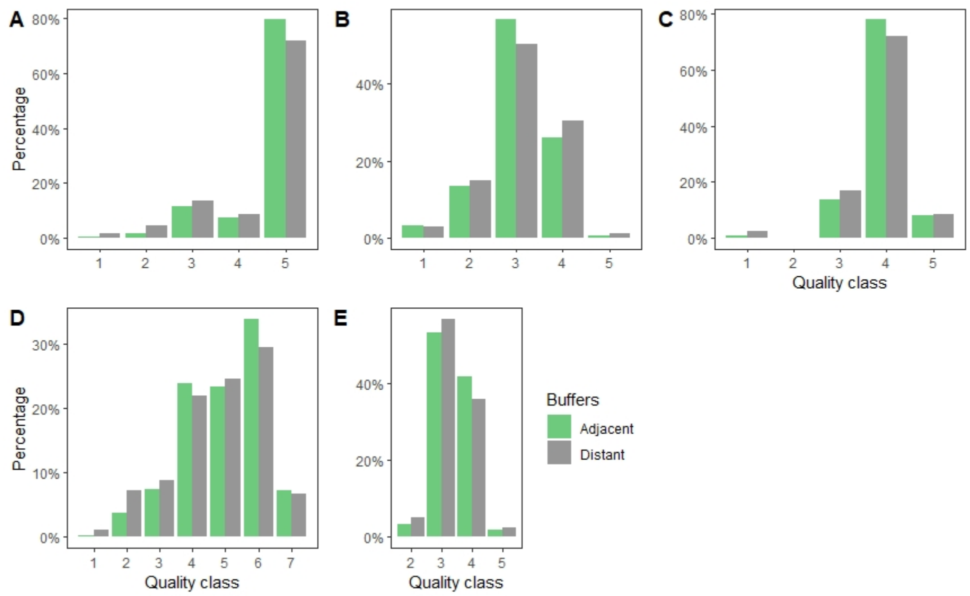

Figure 4. Percentage (%) of forest stands in adjacent (0–50 m) and distant (51–200 m) riparian buffers strips by indicator quality class. (**A**) is the indicator Potential for the presence of medicinal plants; (**B**) the indicator Flora with phytoremediation potential; (**C**) the indicator Potential for the presence of nectar plants; (**D**) the indicator Potential to withstand recreational pressure; and (**E**) the indicator Visual aesthetic quality of the forest landscape.

The results of the RUSLE analysis indicated that the buffer zones of the streams studied have rather high values of erosion protection, indicating low amounts of erosion of soil material on the banks and in the immediate surrounding buffer zone (Table 3). The Korģe and Līgatne rivers showed relatively lower values for the erosion indicator. Overall, no observable issues of critical or highly insufficient erosion protection were detected in this analysis.

Table 3. Values of erosion protection for each river, according to USLE analysis.

River	Percentages (%) of Quality Classes				
	5	**4**	**3**	**2**	**1**
Korģe	90.6	5.9	2.6	0.9	-
Līgatne	95.7	3.4	0.6	0.1	0.1
Svētaine	63	28.7	5.6	2.7	-
Vitrupe	83.5	11.9	3.5	1	-

4. Discussion

The observed significant differences in the provision of ecosystem services have most likely been influenced by the contrast in protection regulations between the adjacent and the distant buffer strips. In Latvia since 1997, forest management has been strictly limited in the first 50 m from the stream banks for small-to-medium-sized rivers [37]. This probably explains the higher proportion of older stands in adjacent buffer strips (Figure 2). Our first hypothesis can be rejected, as the results showed that the indicators Visual aesthetic quality and Recreation potential had significantly higher values in the adjacent buffer strips. The proportions of forest site types were quite similar between the two buffer zones (Table 1). It is likely that the different proportion of older stands caused the differences in the results, as in both the formulas for indicators, higher stand age has a higher coefficient. The assumptions behind our calculations here are in line with other observations, where forest stands with increasing size and age of trees, as well as stands in late successional development stages, are preferred by the public [47].

In an earlier study, where deadwood carbon pools for small-to-medium-sized streams in Latvia were estimated, the amount of deadwood found in the two buffer zones was rather similar (6.8 and 7.0 Mg C ha^{-1}) [48]. Deadwood has a negative effect in calculations of the Recreation potential of the forest ecosystem indicator [42]. The results of other studies show that the public has a negative perception and low tolerance of deadwood, but that this can be improved when targeted information about its ecological importance is provided [22,32]. It has been suggested that deadwood could be removed from forested areas primarily intended for recreational purposes [34]. Due to their close proximity to surface water, riparian forests have a higher potential for recreation activities than other forested areas [49]. The estimates of the Visual aesthetic of the forest landscape indicator for both buffers showed the highest proportion of riparian forest stands in the average quality class (Figure 4E). To enhance forest visits to riparian forest areas, certain silvicultural management activities could be implemented to improve their visual aesthetics. The indicator for Potential to withstand recreational pressure, however, showed quite a high figure for quality class in both buffer strips (Figure 4D), which suggests that the riparian forests could sustainably bear a certain level of recreation activity and tourism. In the calculations for the Potential to withstand recreational pressure indicator, the most significant variables are forest site type, stand age, and dominant tree species [42]. The forest site types with the highest withstanding potential, according to the methodology, were also those most common in the riparian forests (*Oxalidosa*, *Hylocomniosa*, *Mercurialiosa* mel.) (Table 1).

The high values for the indicators Potential for the presence of medicinal and nectar plants (Figure 4A,C) are likely linked to fertile growing conditions, which are typical of riparian forest stands (Table 1). The most common forest site type, *Oxalidosa*, is characterized by well-drained fertile mineral soils, with abundant understory vegetation. In similar terms, the second most common forest site type, *Hylocomniosa*, is only slightly less fertile, but still with a rich undergrowth plant community [38]. Our second hypothesis was partially vindicated, as in the adjacent buffer zone, the indicators Potential for the presence of medicinal and nectar plants had significantly higher values than in the distant buffers, according to BOR analysis. The observed differences might be linked to the higher proportion of older forest stands in the adjacent buffer strips (Table 1), less soil disturbance due to the protection regime [35], or the more diverse environmental conditions found in a transition zone between water and terrestrial ecosystems. More favorable conditions for the nectar plants could be provided by greater sunlight reaching the understory in forests adjacent to rivers, or by the greater availability of moisture [4]. Work by Agnelstam and Lazdinis (2017) also suggests that the unique ecosystem of riparian forests along a watercourse can be distinguished by a significantly higher presence of tall herbs compared to other parts of the nearby forest [15]. In our study, we did not assess the number of pollinators, but the high abundance of potential for the presence of nectar plants indicates that these can be an additional valuable food source for insects, especially in early spring [3,19].

Only one CES indicator, Flora with phytoremediation potential, showed any significantly higher quality values in the distant than in the adjacent buffer strips (Figure 4B). In general, plants with phytoremediation potential are considerably less widespread than plants with medicinal or nectar potential. In the hemiboreal forests, Norway spruce, Scots pine (*Pinus sylvestris*) and common oak (*Quercus robur*) have phytoremediation potential. [31]. Several plants with phytoremediation potential grow on dry soils (*Festucas* spp., *Calamagrostis epigeios*, *Carex* spp., etc.) [50], which might explain their greater abundance in the distant buffer strips.

The results of erosion data can be further evaluated and analyzed on a specific case-by-case basis, using river profiles derived from terrain data, the surrounding land cover, and the presence of trees or shrubs and their types. The scale of the input data and varying spatial resolutions could be factors behind the uncertainty in the results. As a preliminary method for assessing trends and landscape-level issues of soil erosion on river buffer zones, the current results are good enough [40]. The use of older land cover and weather data was a drawback in this study. In the stream buffer zones, land cover changes were little. Hence, requirement to implement more advanced or newer data sets was not essential. Advanced and ready to use weather data for calculating R factor were not accessible for the scope of this study. The method used in this study can be applied relatively easily across most rivers, where a uniform set of input data curated by the ESDAC is available on at least a regional level, but with their own set of drawbacks concerning spatial (data resolution), temporal (data creation date) limitations. Terrain Model (LIDAR-derived) accuracy and resolution can be critical factors for gaining reliable results. In this study, such a terrain model with locally curated data was used, at least partially offsetting the accuracy issues created by the other factor layers that had lower resolution.

5. Conclusions

The higher figures for several ES indicators (Recreation potential of the forest ecosystem, Visual quality of the forest landscape, Potential for the presence of medicinal plants and Potential for the presence of nectar plants) in the adjacent buffers strips is likely linked to the current protection regime and the diverse ecological conditions that exist there. In both buffers, the high potential of the presence of nectar and medicinal plants shows opportunity to explore riparian forests as a valuable area for ethnomedicine related studies and development of NWFPs-based products. Some management activities could be implemented in order to improve the average estimates of the indicator Visual quality of the forest landscape. This would imply opportunity of development of recreational activities linked to nature tourism as also the estimates of the indicator Potential to withstand recreational pressure were considerably high. Yet any management implications for improving cultural ecosystem services need to be carefully considered so as to avoid any negative ecological effects on water quality and biodiversity.

Supplementary Materials: The following supporting information can be downloaded at www.mdpi.com/article/10.3390/f13060928/s1, Description S1: the formula to estimate the indicator Potential to withstand recreational pressure.

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