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PRESENT STATE OF PROTECTIVE FOREST BELTS (PFBS) AND THEIR POTENTIAL FOR ENHANCING EUROVELO CYCLING ROUTES IN VOJVODINA

POSTOJEĆE STANJE ŠUMSKIH ZAŠTITNIH POJASEVA I NJIHOV POTENCIJAL ZA UNAPREĐENJE EUROVELO BICIKLISTIČKIH RUTA U VOJVODINI

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ABSTRACT

Vojvodina is characterized by low forest cover, intensive agricultural production, and extensive areas exposed to wind erosion. Protective Forest Belts (PFBs) are a multifunctional nature-based solution that can contribute to soil protection, microclimate regulation, biodiversity conservation, and landscape enhancement. This study assessed the current spatial distribution of PFBs and their potential for improving cycling conditions along EuroVelo Routes 6, 11, and 13 in Vojvodina. Spatial datasets on PFBs and EuroVelo routes were processed in a GIS environment. Euclidean distance analysis and zonal statistics were applied to determine the proximity of each route to existing PFBs. The results revealed a highly uneven distribution of PFBs, with the highest concentration in the northwestern part of Vojvodina and extensive areas with limited or no PFBs coverage in the central and southern parts of the province. All three EuroVelo routes contained sections directly adjacent to PFBs. The lowest mean distance from existing PFBs was recorded for EuroVelo Route 11 (8.942 m), followed by Route 13 (9.076 m), whereas the greatest mean distance was observed for Route 6 (12.458 m). The establishment of new PFBs along priority sections of the EuroVelo network could reduce cyclists' exposure to wind and direct solar radiation while improving landscape attractiveness and ecological connectivity. Integrating PFBs into future afforestation, green infrastructure, and cycling development strategies could therefore support sustainable tourism and provide broader environmental benefits in Vojvodina.

Keywords: Windbreaks, shelterbelts, ecosystem services, recreation, cycling, EuroVelo

APSTRAKT

Vojvodinu karakterišu niska šumovitost, intenzivna poljoprivredna proizvodnja i velike površine izložene eolskoj eroziji. Šumski zaštitni pojasevi (ŠZP) predstavljaju

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multifunkcionalno rešenje zasnovano na prirodi koje može značajno doprineti zaštiti zemljišta, regulisanju mikroklime, očuvanju biodiverziteta i unapređenju pejzažnih vrednosti. Cilj ovog istraživanja je da se procene postojeća prostorna rasprostranjenost ŠZP i njihov potencijal za unapređenje uslova za biciklizam duž EuroVelo ruta 6, 11 i 13 na području Vojvodine. Prostorni podaci o ŠZP i EuroVelo rutama obrađeni su u GIS okruženju. Analiza Euklidskog rastojanja i zonska statistika primenjene su radi utvrđivanja udaljenosti pojedinačnih ruta od postojećih ŠZP. Rezultati su pokazali izrazito neravnomernu prostornu raspodelu ŠZP, sa najvećom koncentracijom u severozapadnom delu Vojvodine, dok su u centralnim i južnim delovima zastupljene velike površine sa malom zastupljenošću ili potpunim odsustvom ŠZP. Na sve tri analizirane EuroVelo rute identifikovane su deonice koje se nalaze neposredno uz postojeće ŠZP. Najmanja prosečna udaljenost od postojećih ŠZP utvrđena je za EuroVelo rutu 11 (8.942 m), zatim za rutu 13 (9.076 m), dok je najveća prosečna udaljenost zabeležena za rutu 6 (12.458 m). Uspostavljanje novih ŠZP duž prioritetnih deonica EuroVelo mreže moglo bi doprineti smanjenju izloženosti biciklista vetru i direktnom sunčevom zračenju, uz istovremeno povećanje atraktivnosti pejzaža i unapređenje ekološke povezanosti. Integrisanje ŠZP u buduće strategije pošumljavanja, razvoja zelene infrastrukture i biciklističke mreže moglo bi doprineti razvoju održivog turizma, uz ostvarivanje širih ekoloških koristi na području Vojvodine.

Ključne reči: vetrozaštitni pojasevi, poljezaštitni pojasevi, usluge ekosistema, rekreacija, biciklizam, EuroVelo

INTRODUCTION

The presence of green spaces in the surrounding environment can have a positive impact on various components of the ecosystem and human well-being (Tzoulas et al., 2007). These benefits include improved air quality, reduced air temperature, lower stress levels, and enhanced public health. In this way, vegetation indirectly creates favorable conditions for a wide range of outdoor recreational and sports activities, such as running, cycling, and team sports. Therefore, the strategic conservation of existing green spaces and the establishment of new ones are essential for enhancing their recreational function and encouraging their active use by the people.

The Protective Forest Belts PFBs are multifunctional landscape elements that provide a wide range of ecosystem services (Xie et al., 2018). Their primary function is the protection of soil against wind erosion; however, they also improve local microclimatic conditions by regulating air temperature and evapotranspiration (Baumgertel et al., 2026). In addition, they contribute significantly to climate change mitigation by sequestering and storing atmospheric carbon dioxide in both biomass and soil (Lukić et al., 2018, Belanović Simić et al., 2024). Beyond these ecological functions, PFBs also have an important recreational value, providing attractive spaces for recreation (Smith et al., 2021). Since PFBs are commonly established along roads, they can represent an important natural element for improving conditions for cycling and other sports and recreational activities. By reducing wind speed, moderating temperature extremes, and creating a more comfortable microclimate, they enhance both the comfort and safety of cyclists. Examples of such practices can be found across various parts of Europe (Figure 1).

Vojvodina is characterized by a very low forest cover and intensive agricultural production, making it highly vulnerable to wind erosion processes both under current conditions and in the context of future climate change (Baumgertel et al., 2019, Baumgertel et al., 2022). Three EuroVelo cycling routes pass through its territory, offering considerable potential for the

development of sustainable tourism and outdoor recreation. The aim of this study is to identify areas suitable for the potential establishment of new PFBs based on the analysis of their existing spatial distribution and distance from the EuroVelo routes. The results may provide valuable support for decision-makers in planning and implementing future PFBs, with the objectives of improving cycling conditions, protecting soil resources, and enhancing green infrastructure.



Figure 1. Examples of cycling routes in Germany, France, and Italy (sources: https://www.cyclomundo.com/cycling-tours/beaujolais-cycling-6-days-102.html, https://graveloo.com/, https://www.bikemap.net/en/l/2921044/

Slika 1. Primeri biciklističkih ruta u Nemačkoj, Francuskoj i Italiji (izvori: https://www.cyclomundo.com/cycling-tours/beaujolais-cycling-6-days-102.html, https://graveloo.com/, https://www.bikemap.net/en/l/2921044/)

MATERIAL AND METHOD

General Characteristics of the Study Area

Vojvodina is an autonomous province located in the northernmost part of the Republic of Serbia and represents an important economic region (Figure 2). The landscape is dominated by intensive agricultural production, while woody vegetation (forests) is largely absent. Vojvodina plays a key role in Serbia's transport infrastructure, as three Pan-European transport corridors pass through its territory. Three EuroVelo cycling routes (6, 11, and 13) also traverse the province (Figure 4).



Figure 2. Research area
Slika 2. Istraživano područje

To create a raster representing the distance from PFBs, the Euclidean Distance tool was applied (Figure 3), with a spatial resolution of 500 × 500 m (pixel). Using the Zonal Statistics tool, the minimum, maximum and mean values of the Euclidean distance raster were calculated for each EuroVelo route. The mean distance was calculated by averaging the Euclidean distance values of all raster cells corresponding to each EuroVelo route. All spatial analyses were performed using ArcMap (Esri, Redlands, CA, USA) in the WGS 1984 UTM Zone 34N coordinate system.

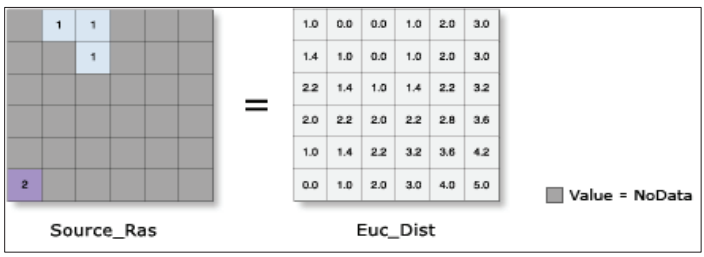

Figure 3. The Euclidian distance workflow
(source: https://desktop.arcgis.com/en/arcmap/latest/tools/spatial-analyst-toolbox/euclidean-distance.htm)

Slika 3. Postupak analize Euklidskog rastojanja
(izvor: https://desktop.arcgis.com/en/arcmap/latest/tools/spatial-analyst-toolbox/euclidean-distance.htm)

In this study, spatial data of the EuroVelo cycling route network and the spatial distribution of PFBs in Vojvodina were used. All datasets used in this study are freely accessible. The EuroVelo route data were obtained from the official EuroVelo database, while the PFBs data

included belts identified and inventoried within the framework of the international AGFORWEB project, implemented from 2022 to 2024. Information on the datasets used in this research, including the data type and source, is presented in Table 1.

Table 1. Description of the input datasets
Tabela 1. Opis ulaznih podataka

Data	Type	Source
EuroVello routes database	Shapefile	https://en.eurovelo.com/news/2022-07-25_you-can-now-download-eurovelo-routes-and-stages-as-gpx-tracks
PFBs database		https://agforweb.org/wp-content/uploads/2024/10/AGFORWEB_DigitalDatabase2.xlsx

RESULTS

According to the digital database of the AGFORWEB project, there are 283 PFBs in Vojvodina (Figure 4), with a total length of 332 km. The highest concentration of PFBs is found in the northwestern part of Vojvodina, particularly within the territory of the City of Sombor, where 73 PFBs have been recorded, with a total length of 110.95 km. All three EuroVelo routes crossing Vojvodina—EuroVelo 6, EuroVelo 11, and EuroVelo 13—enter the territory of Serbia through the northern border of Vojvodina and continue southeast toward Romania (Figure 4).

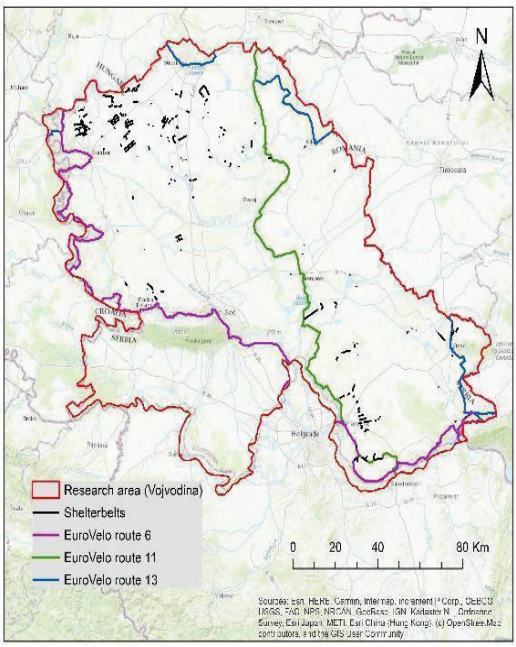

Figure 4. Map of the EuroVelo routes and PFBs in the Vojvodina
Slika 4. Karta EuroVelo ruta i šumskih zaštitnih pojaseva u Vojvodini

The results of the distance analysis between raster pixels and PFBs across the entire territory of Vojvodina are presented in Figure 5. The map clearly shows that extensive areas of Vojvodina are located at considerable distances from PFBs, with these areas being most prevalent in the southern part of the study area.

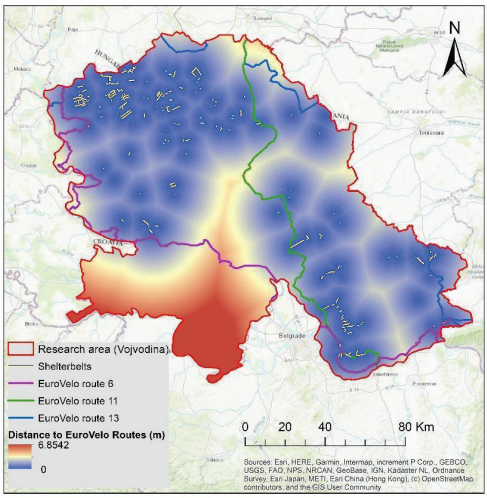

Figure 5. Euclidean distance raster showing the distance of each pixel from the nearest PFB

Slika 5. Raster koji prikazuje udaljenost svakog piksela od najbližeg ŠZP

When considering the individual EuroVelo routes and their proximity to PFBs, the results are presented in Table 2. All EuroVelo routes include sections where PFBs are located directly adjacent to the route (minimum distance - MIN = 0 m). The greatest mean distance between the routes and PFBs was recorded for EuroVelo Route 6, amounting to around 12 km, followed by EuroVelo Route 13 and 11 with around 9 km.. The relatively high standard deviation (around 9 km) observed for Route 6 reflects a heterogeneous spatial distribution of PFBs, with alternating sections characterized by very high and very low proximity (Figure 5). Conversely, the lower standard deviation of Route 13 (around 5 km) suggests a more even distribution of PFBs relative to the cycling route.

Table 2. Distance statistics (m) between the EuroVelo routes and PFBs.

Tabela 2. Udaljenost (m) između EuroVelo ruta i šumskih zaštitnih pojaseva

EuroVelo route	Min (m)	Max (m)	Mean ± St.dev (m)
6	0	35.693	12.458 ± 9.125
11	0	26.767	8.942 ± 6.736
13	0	24.000	9.076 ± 5.441

DISCUSION

Forest cover in Vojvodina is considerably lower than the European average of 39% (Eurostat, 2021). As Vojvodina is predominantly an intensively cultivated agricultural region, the integration of tree components into the landscape through agroforestry practices represents an effective land management approach (Mbow et al., 2014). Within agroforestry systems, PFBs represent one of the established agroforestry practices (Baumhardt & Blanco-Canqui, 2013).

The PFBs can provide benefits that extend beyond their traditional role in controlling wind erosion. The results of this study indicate that only a limited number of PFBs are currently located adjacent to the EuroVelo routes in Vojvodina (Table 2). The establishment of PFBs on both sides of the cycling routes (Figure 6) could substantially improve riding conditions. By reducing wind speed and limiting cyclists' exposure to direct solar radiation, such belts could enhance thermal comfort and contribute to a safer, more pleasant, and overall more enjoyable cycling experience (Lusk et al., 2020).



Figure 6. Principle of the protective forest belt's effect on driving conditions (Source: Kalozi, 2022).

Slika 6. Princip delovanja šumskog zaštitnog pojasa na uslove vožnje (izvor: Kalozi, 2022)

Suitable locations for establishing PFBs were identified in the central part of the study area. In this area, PFBs are absent not only along EuroVelo Route 6 but also throughout the surrounding agricultural landscape (Figure 5). Establishing PFBs in these areas could improve cycling conditions while simultaneously increasing the visual attractiveness of the landscape. This is consistent with the EuroVelo Route Development Guide (Bodor et al., 2011), which emphasizes that cycling routes should pass through visually appealing landscapes and points of interest, including protected natural areas, cultural heritage sites, and other attractions, in order to enhance the overall cycling tourism experience.

This approach is consistent with the broader development of cycling infrastructure in Vojvodina. Bogdanović et al. (2016), in their study of the regional cycling route in Srem and

its connection with EuroVelo Route 6, emphasized the importance of existing infrastructure and identifying suitable locations for rest areas and supporting services. In this context, PFBs established along cycling routes and around associated rest areas could provide additional environmental and landscape benefits.

Moreover, PFBs could serve as ecological corridors, a function also recognized within the Draft Regional Spatial Plan of the Autonomous Province of Vojvodina (2022). This potential is particularly relevant in the context of the EuroVelo network, as previous research has proposed the development of greenways along EuroVelo Route 6 as a means of connecting the natural heritage and protected areas of Vojvodina (Kalozi, 2022). Therefore, integrating PFBs into the EuroVelo network could contribute not only to improving cycling conditions but also to strengthening ecological connectivity among protected and other ecologically important areas along the routes, thereby supporting the wider regional ecological network. The areas proposed for the potential establishment of new PFBs were identified based on spatial analysis; however, the selection of specific locations would require further site-specific assessment of the environmental, spatial, and other relevant conditions for their establishment.

Consequently, decision-makers at national, provincial, and local levels should consider the strategic establishment of PFBs along EuroVelo routes as part of future afforestation and green infrastructure development programs. Such an approach would contribute not only to improving cycling conditions but also to achieving broader sustainability objectives related to climate adaptation, biodiversity conservation, ecosystem restoration, and the promotion of active and healthy lifestyles.

CONCLUSION

This study showed that PFBs are unevenly distributed across Vojvodina and that large sections of the EuroVelo network are located far from existing belts. EuroVelo Route 6 had the greatest mean distance from PFBs. Priority for the establishment of new PFBs should be given to central parts of the study area, where they are absent both along the routes and in the surrounding agricultural landscape. Their establishment could improve cycling conditions by reducing wind exposure and providing shade, while also enhancing landscape quality, ecological connectivity, and protection against wind erosion. PFBs should therefore be integrated into future afforestation, green infrastructure, and cycling development plans in Vojvodina.

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