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Impact of Short Rotation Coppice Windbreak Systems on Soil Wind Erosion: A Case Study

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Summary
Soil quality plays a crucial role in maintaining sustainable agriculture and stable food production. Earlier studies indicate that Short Rotation Coppice (SRC) may contribute to soil improvement, especially in the rehabilitation of degraded farmland due to wind erosion. This research aimed to assess the effects of introducing SRC on agricultural soils, focusing on minimizing wind erosion. Wind erosion was evaluated by measuring airborne soil particles and recording wind speed and direction. The findings revealed statistically significant differences in wind erosion, which was markedly reduced within the alley cropping system compared to the open field. The study concludes that alley cropping systems with SRC play an important role in protecting soil from wind erosion, although long-term research is necessary to determine their full impact on soil quality.

Keywords: agroforestry, black locust, poplar, willow

Introduction

Soil is a non-renewable natural resource that is subject to degradation processes such as soil erosion and loss of organic matter (Martinović, 1997). In addition to natural and climatic factors, human activity has significantly contributed to soil degradation through irresponsible use and nutrient depletion. In the past, practices such as growing multiple crops together (intercropping) helped maintain soil health. However, during the 20th century, agricultural modernization and the development of mineral fertilizers led to intensive agriculture becoming dominant, replacing traditional intercropping systems.

Intensive agriculture, based mainly on mineral fertilization, frequent machinery passes and without green manure, increases the risk of wind erosion. Wind erosion removes the most fertile topsoil layer, reduces productivity, contributes to desertification, damages soil structure and water retention, worsens air quality, harms infrastructure, reduces crop growth, and causes economic losses (Jug et al., 2022).

Intercropping (growing two or more crops simultaneously on the same land) is now recognized as a method for protecting natural resources (Špoljar, 2019). It improves nutrient and light use efficiency, increases resistance to abiotic stress, enhances soil fertility, improves yield quality, and increases production stability. One of such intercropped systems is the agroforestry practice of alley cropping, where crops are grown within the tree alleys. Alley cropping integrates trees and shrubs with crops, combining forestry and agriculture. In such a system trees have protective functions, such as windbreaks against erosion, while also providing additional income (timber, firewood, fruit) (Tsonkova et al. 2012; Žalac et al. 2022).

The most common silvoarable agroforestry practice of windbreaks is established with fast-growing short-rotation tree species, such as black locust, willow, and poplar. These species grow quickly and can also be used for biomass energy production. Short-rotation coppice (SRC)

significantly benefits the environment by increasing biodiversity and providing habitats for many plant and animal species (Stolarski et al., 2014; Dimitriou & Rutz, 2015). In Croatia, the cultivation of short-rotation woody crops is regulated by the Act on Short-Rotation Woody Crops (NN 15/18, 111/18) and the Ordinance on the List of Plant Species for Establishing Short-Rotation Woody Crops and the Conditions for Their Cultivation (NN 16/19). Although this legal framework represents a positive step toward soil conservation and potential recovery of degraded land, it does not explicitly mention terms such as "agroforestry" or "alley cropping." While establishing agroforestry and alley cropping systems is possible, the absence of these terms in legislation, insufficient ministerial support, and limited farmer education restrict the wider adoption of these practices in Croatian agriculture. Research shows that introducing trees into agricultural land improves soil quality, although measurable changes often become visible only after 10–20 years (Ivezić et al., 2022). One of the most important effects is the reduction of soil erosion. Since soil erosion reduces fertility and nutrient availability, understanding how short-rotation tree species can reduce erosion is crucial for developing sustainable agricultural practices. This research aims to determine the impact of establishied short-rotation coppice on agricultural land to reduce the wind erosion.

Material and Methods

Experimental site

The experiment with short-rotation crops (SRC) was set up on 2021 at the experimental site of the Faculty of Agrobiotechnical Sciences Osijek. The selected species were black locust, willow, and poplar. The trees were planted in four strips, each 8 meters wide, with each strip consisting of six rows of trees (spacing between tree rows within a strip was 1–2 m). The distance between two tree strips (crop alley between strips) was 24 meters wide to allow undisturbed passage of agricultural machinery (Figure 1). The length of each strip was 150 m, while individual species occupied 50 m sections. In 2024, experiment was conducted observing the wind erosion within the crop alleys when trees were between 5 and 8 meters tall (depending on the species). Figure 1 shows a satellite image of the experiment, with orange-marked locations representing the sites where airborne particles were collected to determine wind erosion intensity. On the western side of the experimental field, there is a canal excavated in the mid-20th century. During excavation, the removed soil was piled along the canal edge, causing soil degradation extending from the canal inward, particularly affecting the first strip and the first inter-row area.

Figure 1. Experimental design – orange dots indicate the location of collecting wind erosion residue. Yellow rectangles show the location of meto stations

Wind

The wind direction and speed were measured using anemometers (Davis Vantage Pro2) installed as part of weather stations. One weather station was placed in an open area to record meteorological data outside the alley cropping system, while the second station was located within the system in the first inter-row between two tree strips. The aim was to determine the impact of short-rotation crops on wind direction, wind speed, and wind run (distance travelled by wind). Wind speed was measured in meters per second (m/s), and wind direction was recorded relative to cardinal directions.

Erosion

Soil wind erosion was measured using the "dust catcher" method, where devices were installed in the field to capture airborne soil particles. Although commercial measuring stations are available, improvised devices made from plastic bottles were used in this experiment. Each station had openings facing all cardinal directions (north, south, west, east) to determine the dominant direction of erosion. All stations were placed and measured at heights of 15 cm while four stations were also measured at 50 cm. Erosion was monitored from February 26, to April 9, 2024, the period without any vegetation. Measuring stations were installed at seven locations: two in the control area (away from the short-rotation crops) and the others within the intercropping system (Figure 1). After removing the measuring stations from the field, the collected material was rinsed with water and transferred into Petri dishes. The dishes were then placed in a drying oven to allow the remaining water used during rinsing and sample transfer to evaporate. After drying, the dry mass of the material collected by each station was measured with a precise digital scale.

Results and Discussion

Soil erosion is considered the leading soil degradation process in Europe. According to Kohnke (1972), surface soil layers contain higher concentrations of calcium, phosphorus, and other materials. Since erosion primarily removes the topsoil layer, it leads to nutrient depletion. Plants grown on eroded soils are not necessarily lower-yielding, but they may contain fewer minerals and higher levels of nitrogen and carbohydrates, which can negatively affect human health.

The results of the experiment provided insight into the effect of SRC on wind direction, speed, wind run, and transport of soil particles. Based on the obtained data, it is possible to assess whether SRC significantly influenced soil changes and in what way.

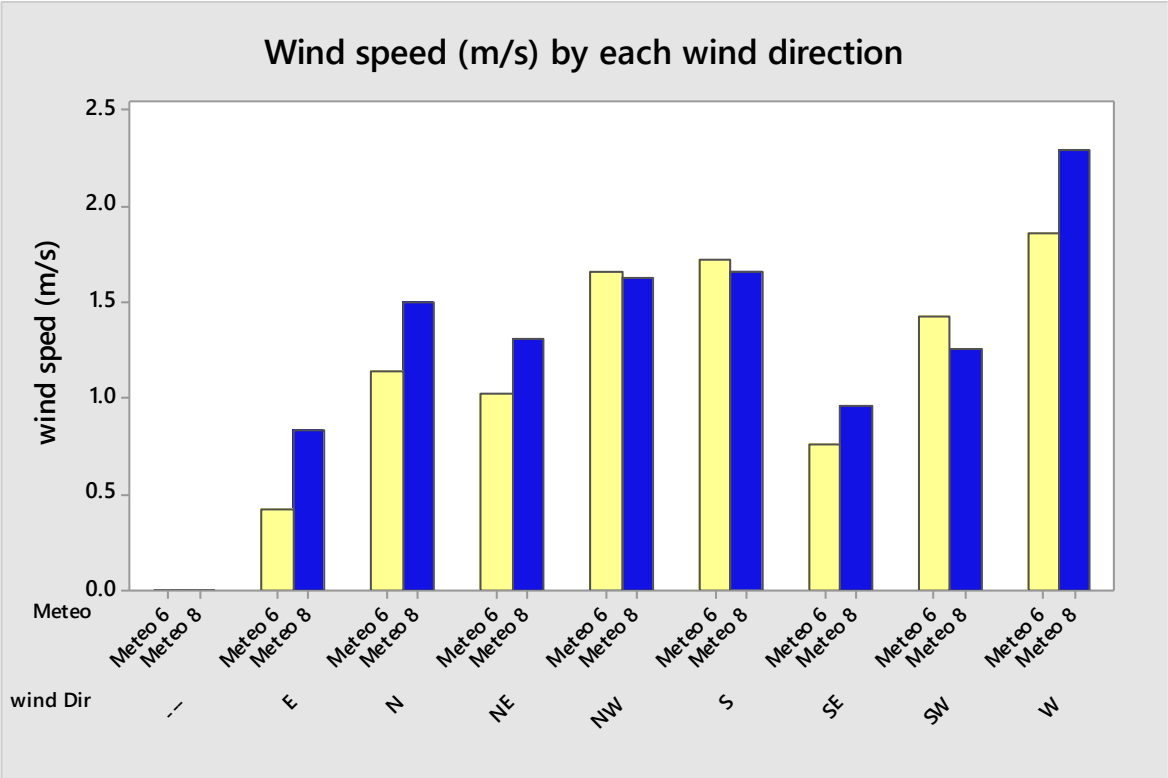
Analysis of variance of the data collected during March from the weather stations (one located in the open field and the other within the intercropping system) showed that wind speed outside the intercropping system was statistically significantly higher than inside (Table 1). Descriptive statistics indicate that the wind most frequently blew from the east, while the strongest winds came from the west.

Table 1. Wind speed and captured soil particles

	Wind speed		Airborne particles (15 cm)		Airborne particles (50 cm)		Airborne particles (Total)	
	n	m/s	n	g	n	g	n	g
Open field	259	0.0160^{A}	8	0.027^{A}	8	0.004^{A}	16	0.015^{A}
Within the alley	271	0.0046^{B}	20	0.005^{B}	8	0.002^{A}	28	0.005^{B}

Data analysis shows that wind coming from the east was 50% weaker within the alley cropping system, while winds from the west, north, northeast, and southeast were about 20% weaker compared to wind strength in the open field (Graph 1). Statistical analysis also showed similar

results when observing wind run (the distance traveled by wind – not shown here). The distance traveled by wind was reduced by about 20% compared to conditions without protection or barriers. In other words, establishing alley cropping systems or windbreak strips reduces the distance over which wind has an impact. Thus, intercropping with woody species plays an important role in wind protection (Jug et al., 2022), which is confirmed by the results of this study.



Graph 1. Wind speed and direction (Meteo 6 - inside the alley, Meteo 8 – open field)

The erosion results (Table 1) show that the mass of airborne particles was statistically significantly lower within the alley cropping system—three times lower—than in open areas. Based on these results, it can be concluded that SRC intercropping has a important wind-protective role. For a more detailed analysis, the data were categorized according to measurement height, which shows that more statistically significant differences were recorded at 15 cm height compared to 50 cm, although at 50 cm the mass of airborne particles within the intercropping system was nearly half that measured in the open field (Table 1). In addition to measuring particle mass at different heights, analysis was also conducted according to cardinal directions (not shown here). The largest amount of airborne particles was collected from the west. This amount was so significant that the mass of particles collected from the east was ten times lower than that from the west. These results align with wind speed data (Graph 1), which showed that the strongest winds statistically came from the west, explaining the higher particle mass from that direction.

Even when data were divided according to wind direction, the mass of collected particles within the intercropping system remained significantly lower compared to the open field. Regardless of measurement station location, the highest amount of airborne particles was collected from the west, and the lowest from the east.

Conclusion

This research confirmed the influence of short-rotation crops (SRC) on soil quality in agroecosystems. SRC stood out particularly as windbreak strips, effectively reducing soil erosion. This is crucial for preserving soil fertility and ensuring the long-term sustainability of agricultural land. The results suggest that the use of SRC can reduce the negative effects of soil erosion and improve soil fertility, creating new opportunities for integrating these practices into conventional agriculture. In addition to existing research, further studies should examine the impact of SRC on soil moisture and long-term crop yields to determine whether intercropping with SRC is more productive than sole cropping. The implementation of SRC species such as black locust, willow, and poplar has proven to be an effective wind protection strategy, improving soil quality and preserving natural resources. This research lays the foundation for further studies and broader application of SRC, aiming to increase the resilience of agricultural systems to degradation processes and to create sustainable agroecosystems.

Although further investigation and more detailed analysis of the obtained results are needed, this study confirms a positive—or at least neutral—impact of SRC on soil. However, it unequivocally confirms their important role in protecting soil from erosion.

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