*Research article*

# Relation between the Level of Degradation and the Wind Speed Reduction Efficiency of Tree Windbreaks Systems in Ovche Pole Region, Macedonia

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**Abstract** Ovche Pole is an agricultural region in Macedonia with dry climatic conditions characterized by low precipitation and high ambient temperatures during the growing period as well as prevailing winds that are present considerable time of the year. During the 1950s series of measures have been implemented to improve the agriculture productivity in the region. One of the measures taken was the establishment of tree windbreaks (field shelterbelts) aimed to reduce wind velocity and protect shelter crops. Ever since they become essential elements for the regional landscape, performing many important ecosystem functions. As far as authors' knowledge, so far there are no scientific studies that investigated the performance of the tree windbreaks in Ovche Pole-research area of this study. To fill the gap of scientific data, this study examines the relation between wind reduction efficiency of tree windbreaks with their level of degradation in that area. Optical porosity is used as a proxy for quantitative description of the level of degradation of the structure of the tree windbreaks. To this aim, field measurements for wind velocity and optical porosity (OP) were done on 3 (three) windbreaks sections. Photogrammetry method was used to determent the porosity at each windbreak section. Wind velocity field measurements were done with two handheld cone anemometers The windspeed reduction efficiency was assessed by comparing the windspeed at the windward side with the windspeed at 3 points on the leeward side. The results show that the level of degradation is significantly related with the relative windspeed at distance of 30m and 60m from the tree line at the leeward side.

**Keywords** windbreaks, windspeed reduction efficiency, optical porosity, Ovche Pole region, North Macedonia

## INTRODUCTION

Ovche Pole is an agriculture region in Macedonia with dry climatic condition characterized by low precipitation and high ambient temperatures during the growing period as well as year-round prevailing winds. The region is part to the semi-arid agriculture zone and sub-humid agriculture zone of the country (Aksoy et al., 2020). Northern winds are most dominant, blowing throughout the entire year, with an average frequency of 188% and an average speed of 4.6 m/sec. North-western winds have an average frequency of 127% and an average speed of 3.9 m/sec, blowing throughout the entire year, but mostly in June and August. The third most frequent are the southern winds, with an average frequency of 66% and an average aped of 2.4 m/sec. (Evolving DOO, 2016). During the 1950's series of projects were taken to improve the agriculture productivity in the region. One of the activities was the establishment of tree windbreaks. The tree windbreaks were planted on a surface of 555.66 ha (Forest public enterprise, 2011). The trees rows are 10 m wide row in rectangle grid that formed agriculture parcels that are approximately 1000 m in length and 250 m width. Tree windbreaks are planted in southwest to northeast direction perpendicular to direction of the prevailing northwest winds. Today, much of the initial area is lost and certain areas are degraded because of illegal cutting done by the local population. Depending on the level of degradation, different sections of the tree wind brake systems have different wind speed reduction efficiency. The ability of windbreak to fulfill its wind protection function in landscape is given by its external and internal structure. The external structure is defined by width, height, shape, and orientation. The internal structure is given by the amount and arrangement of branches, leaves, and trees or shrubs trunks (Brandle et al., 2004). The most used descriptor of internal structure for artificial windbreaks has been porosity which is a simple ratio of perforated area to total area (Heisler and Dewalle, 1988). Height of the windbreak and porosity of windbreak are main parameters used to explain the windspeed reduction efficiency (Brandle et al., 2004; Helfer at al., 2009; Středová et al., 2012; Řeháček et al., 2017; Kučera, 2020). The windbreak porosity is classified as real (aerodynamic) and optical.

**Fig. 1 Tree windbreaks in the research area showing its width is 10 m**

*Note: Taken by Onchevski in August 2021*

Aerodynamic porosity is defined as the ratio between the average wind speed measured on the windward side of windbreak and the average speed in open space. Since aerodynamic porosity is difficult to define, the parameter of optical porosity (OP) is mostly used. For the evaluation of windbreak efficiency, optical porosity (OP) is determined by using the photogrammetry method (Kučera, 2020). Although, there is a linear relationship between windbreak efficiency and optical porosity; this connection can be influenced by several external characteristics of tree windbreaks (Wu et al., 2018). Therefore the objective of this study is see the relation between the level of degradation of the tree windbreaks and optical porosity and relate this parameter with the windbreak efficiency to protect the agriculture land from negative effects of prevailing wind.

## METHODLOGY

### Study Area and Measuring of Wind Speed

Windbreak efficiency was analyzed on three windbreaks sections near the village of Erdzelija in the region of Ovche Pole. The agricultural field are located on around 3.5 km from village with latitude 41°51'18.45"N and longitude 22° 0'50.12"E.

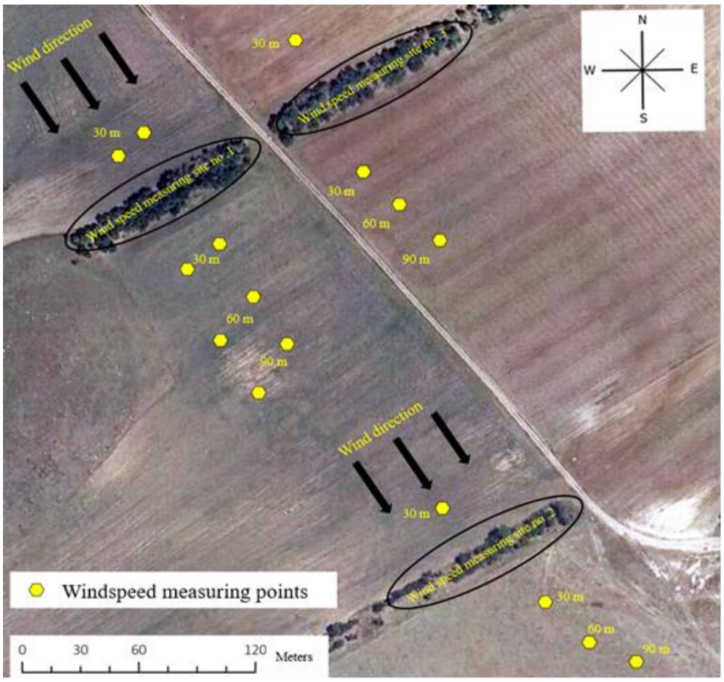


**Fig. 2 Satellite photo showing research sites and windspeed measuring points**

Averagely the tree windbreak sections are 6 m high and 10 m wide, however the level of degradation was different. To analyze the windspeed reduction efficiency, between 18 and 26 August 2021 at each tree windbreak section wind speed was measured on one point at the windward side and at tree points on the leeward side. Windward measuring point was set 30 m from the tree line and the leeward measuring points were set on 30 m, 60 m, and 90 m from the tree line. Windspeed was measured with two handheld cup anemometer type (Sato Tech AM-4257SD) fixed 1m above the ground, measurements were taken every 5 seconds. On the windward side windspeed was measured continuously for 6 hours during, however on the leeward side the first two hours was used for windspeed measuring at the first point (30 m distance), second two hours for measuring at the second point (60 m distance) and the last 2 hours for measuring at the third point (90 m distance).

**Fig. 3 Setting up wind speed measuring equipment**

*Top left corner showing the cup anemometer type used for recording the windspeed*
*Note: Taken by Onchevski in August 2021*

### Optical Porosity- Level of Degradation of Tree Windbreaks

In addition to the windspeed measurements, the optical porosity was analyzed for each windbreak section. Optical porosity of windbreak was described by terrestrial photogrammetry method as the value of the optical porosity from the photo documentation of the windbreak at the time of field measurement. Each section was photographed with iPad Pro 12MP, $f/1.8$ aperture camera from the leeward side of the windbreaks at a 30 m distance from the windbreak on 1.5 m ground. Photogrammetric analysis was done using GIMP (version 2.10.28), AutoCAD and Excel software. At first, all photos were scaled in AutoCAD and then graphically processed to black and with binary image, where vegetation was highlighted and assigned in black against the background assigned in white. Histogram tool was used to calculate the exact number of black (= vegetation) and white(= background) pixels. The value of optical porosity was calculated as distribution of the white (background) pixels expressed as percent value. The higher the value of OP, the lower the vegetation distribution and windbreak effectiveness to reduce windspeed.

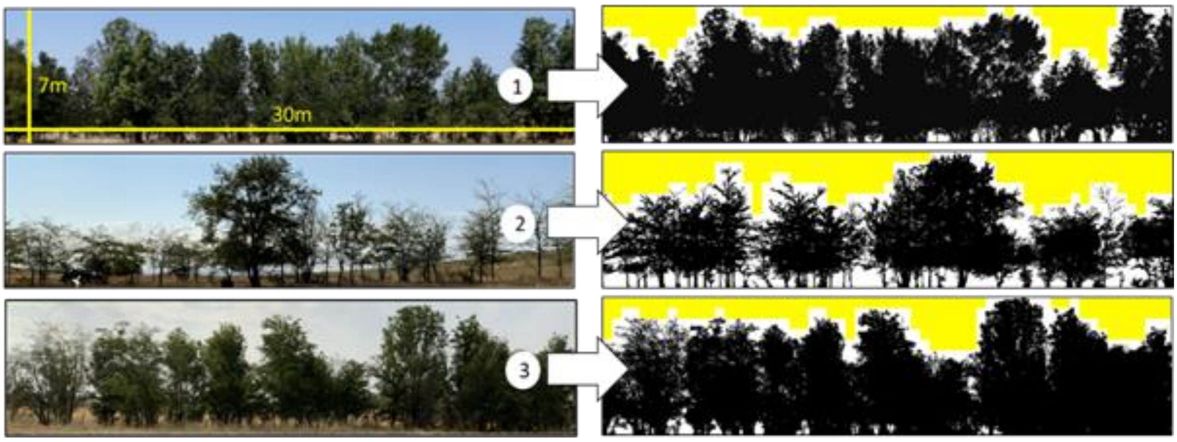


**Fig. 4 Photos indicating tree windbreak measuring sites before and after pixel processing**
*Measuring site no.1 on the top, measuring site no.2 in the middle, and measuring site no.3 in the bottom*

## RESULTS

### Optical Porosity

Analysis showed that site number 2 has the OP value of 35.8% which is highest, while site number 3 has lowest OP value of 16.57 %. Site number 1 has OP of 18.23%, value that is close to value of site number 3. The results of optical porosity (OP) analysis are presented in Table 1.

**Table 1 Optical porosity of tree windbreak measuring sites**

| Site no. | Black (foreground) pixels | White (background) pixels | Optical porosity |
|---|---|---|---|
| 1 | 4774038 | 1064042 | 18.23% |
| 2 | 3289752 | 1834230 | 35.80% |
| 3 | 4751115 | 943361 | 16.57% |

### Wind Speed Reduction Efficiency

The first wind speed measurements at site no.1 (Fig. 4) showed that this tree windbreak section can significantly reduce the windspeed coming from the windward side. At the leeward side at 30 m distance the there is a reduction of 54%, at 60 m distance there is a reduction of 25% and at 90 m distance reduction of 8%. Expressed as relative windspeed, at 30 m distance the wind velocity is

46% of wind at the windward side, at 60 m the velocity is 75% of the velocity of windward side and at 90 m the wind speed is 92% of the windspeed at the windward side. The second measurements show similar trend in windspeed reduction efficiency. In this time, at 30 m distance the wind velocity is 47% relative to the windward side, at 60 m the velocity is 72% of the velocity of windward side and at 90 m the windspeed reached the same value (100%) as the incoming wind. Table 2 shows the relative windspeed at each site at the different measuring distances.

**Table 2 Windspeed reduction related to different optical porosity and distance to tree line**

| Tree windbreak site no. | Optical porosity background pixels (%) | Relative windspeed (%) | | |
|---|---|---|---|---|
| | | 30 m | 60 m | 90 m |
| 1 (first measuring) | 18.23% | 46% | 75% | 92% |
| 1 (second measuring) | 18.23% | 47% | 72% | 100% |
| 2 | 35.80% | 74% | 95% | 98% |
| 3 | 16.57% | 40% | 78% | 96% |

Correlation results showed that optical porosity and windspeed reduction is significantly correlated for the measuring points at 30 m and 60 m distance from the tree windbreak, however at 90 m distance there was no correlation. For the 30 m distance measuring point the correlation coefficient (r) is high with a value of 0.993 and with a 99% level of significance ($p < 0.01$). For the 60 m measuring point correlation coefficient (r) is 0.95 and the level of significance of 90% ($p < 0.10$). These results confirm other authors' research conclusions that optical porosity is linearly connected with wind speed reduction efficiency and can be reliable measure for evaluation of windbreak efficiency (Brandle et al., 2004; Helfer at al., 2009; Středová et al., 2012; Řeháček et al., 2017; Wu et al., 2018; Kučera, 2020).

**Table 3 Relation between optical porosity and windspeed reduction efficiency**

| Anemometer position (leeward side) 1 m above ground | | | |
|---|---|---|---|
| | 30 m | 60 m | 90 m |
| Measurements | 4 | 4 | 4 |
| Correlation coefficient (r) | 0.993 | 0.950 | 0.292 |
| P-value | 0.007 | 0.05 | 0.708 |
| Level of significance | p < 0.01 | p < 0.10 | n/a |

## CONCLUSION

Research results presented in this chapter shows that tree windbreaks systems in the research area play key role in buffering the negative effect of the prevailing winds. Having in mind that significant windbreak area was lost and existing are under threat of degradation, it is important that existing tree windbreaks systems are protected from degradation, degraded areas should be restored, and new tree windbreaks should be expanded to other areas. Another conclusion coming from the results is that optical porosity (OP) is a reliable measurement that can describe the wind speed reduction efficiency and level of degradation of windbreaks in the research area. This indicate that optical porosity can be used as guidance for maintenance and management of existing tree windbreaks as well as for guidance when establishing new windbreak areas. As recommendation optical porosity of the windbreaks should be maintained between 15-20%. At the degraded windbreak sections with optical porosity higher that 20%, to fill the internal voids and space, interplanting new trees is recommended. New planted trees should be species that can thrive in the local conditions and provide multiple functions such as: nitrogen fixation, fruits, pollen for honey, medicines and other NTFP. Some of the possible tree species are *Elaeagnus angustifolia* (Eng. Russian olive), *Ziziphus jujuba* (Eng. Chinese date), *Quercus* spp. (Eng. Oaks), *Cornus mas* (Eng. Cornelian cherry), *Prunus Amygdalus* (Eng. Almond), *Prunus cerasifera* (Eng. Cherry plum) and others.

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