

Full Length Research Paper

Turbulent Velocity Fluctuations as Affected by Biotic and Abiotic Windbreaks under Field Conditions

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Windbreaks have been used for centuries to shelter crops from wind damage and to protect soils from wind erosion. This study was performed in 5 steps to evaluate the effects of biotic and abiotic windbreaks on mean horizontal flow and turbulent velocity fluctuations under field conditions. These steps included of granulometry analyzing, determination of field threshold velocity of soil erosion, estimation of acceptable wind speed, optimizing windbreak distance and wind speed recording. Two kinds of windbreaks were used in this study, include of biotic windbreak (*Tamarix aphylla*) with 45% density and abiotic windbreak (Mud wall) with 100% density. Results of field experiment showed that optimized distances for abiotic and biotic windbreak are respectively observed at 7.87h and 4.5h after windbreak. Finally mud wall is applicable for high decreasing wind speed at the back of windbreak but its high wind speed fluctuation and high turbulent were limited these windbreak in agro ecosystem. *Tamarix aphylla* with 45% density is applicable for medium decreasing of wind speed and creating low turbulent after windbreak.

Keywords: Mud wall, *Tamarix aphylla*, threshold velocity, windbreak, Wind

INTRODUCTION

Wind erosion is the prevailing factor in desertification in the most arid and semi –arid countries of the world wind flow carries the fertile part of the soil which is nutrient source for plants. Windbreaks have been used for centuries to shelter crops from wind damage and to protect soils from wind erosion. They reduce wind speed and alter the characteristics of airflow around them, inducing changes in the surrounding atmospheric, plant, and soil environments (Cleugh, 1998). The interaction between the windbreak and the airflow is complicated by the turbulent

characteristics of the wind and by the complex behavior caused by natural obstacles. Although much effort has gone into the measurement and characterization of wind flow in the lee of wind barriers and isolated obstacles at a range of scales, relatively little attention has been given to the direct interaction of the air with the individual plants that can be characterized by a drag coefficient. Our understanding of wind interaction with three-dimensional, porous obstacles, however, such as tree windbreaks and isolated trees and shrubs, is much less complete (Heisler and DeWalle, 1988). The consequence of this lack of knowledge results in the use of surrogate data in models. For example, Raupach (1992) and Raupach, et al. (1993), by necessity, use drag coefficients of solid roughness

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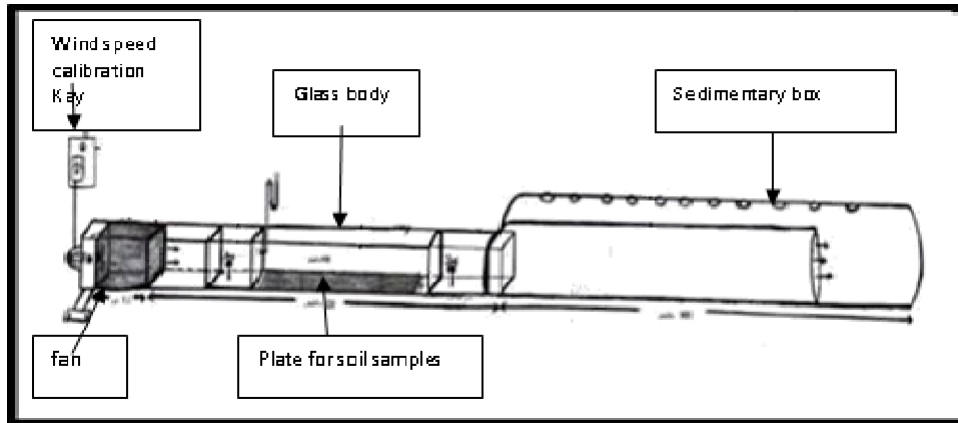


Figure 1. Wind erosion meter (wind tunnel-Field Model W.E Meter), Iran (Ekhtesasi, 1993)

elements reported by Taylor (1988) to represent natural, porous vegetation. Furthermore, the very causes of wind-speed reduction, pressure perturbation related to width and structure, permeability and drag force, are largely unknown for three-dimensional, porous obstacles (Wang and Takle, 1996).

Besides windbreak height and porosity, the actual form of the wind speed curve depends on other important characteristics of the airflow–windbreak system. These are the approach flow characteristics, such as wind speed, wind direction, turbulence intensity, and atmospheric stability, and external windbreak properties, such as windbreak shape, width, and length (Heisler and Dewalle, 1988). The effects of these factors are important but often contradictory, and they are seldom defined analytically (Cleugh, 1998; McNaughton, 1988; Heisler and Dewalle, 1988).

The evaluation of properties of different windbreaks and its effects on turbulent velocity fluctuations is very important and necessary for designing suitable windbreak for agro-ecosystems in any climatic conditions.

The objectives of this study were to determine: (1): the effects of biotic and abiotic windbreaks on mean horizontal flow and turbulent velocity fluctuations under field conditions, (2) estimation of optimal distance between parallel windbreak to reduce soil erosion in the space between.

METHODS AND MATERIALS

Field study:

The case study was Jiroft catchment which located between 28° 33' N and 28° 45'N latitudes and between 57°43'E and 57° 45'E longitudes in East south of Iran. The climate of this region is sub humid with warm summer and moderate winter (UNESCO, 1979). In the Jiroft station

average temperature is 25°C, and annual rainfall is 150mm which 85% is concentrated in the winter and autumn seasons and 15% in the spring. Average of maximum velocity of dominant wind has been 54 km per hour. The forestry and rangelands covered 320000 and 1467517 hectares respectively.

Step1: Granulometry analyzing

This step was performed in order to estimate threshold velocity of wind erosion. Threshold velocity is defined the minimum velocity which causes to move soil particles. For evaluation this parameter, the soil samples were collected from 0-20cm depth. Soil samples were powdered and categorized them according to ASTM (American Society for Testing and Materials International). GR (Graph software) was used to determine of granulometry index and soil texture.

Step2: Determination of field threshold velocity of soil erosion

Threshold velocity was determined base on Ekhtesasi method (1993) using wind erosion meter (wind tunnel-Field Model W.E Meter), which made in Iran (Ekhtesasi, 1993). As this method described, 7 kilogram of powdered soil, was putted into wind tunnel (figure1) then the minimum speed which able to raise soil particles was recorded as threshold velocity (Ekhtesasi, 1993). Von Karman method (1921) which described follow was used to converting tunnel threshold velocity of soil erosion to field threshold velocity of soil erosion.

$$V_{2(\frac{m}{s})} = V_{1(\frac{m}{s})} \times (H_2/H_1)^{0.16} \quad (\text{equation1})$$

Table 1. characteristics of studied windbreaks

windbreak	height of windbreak	density
abiotic wind break (Mud wall)	2 meter	0% porosity
biotic wind break (<i>Tamarix aphylla</i>)	4 meter	55% porosity

Table2. results of step1 to 4

Step1	Step2	Step3	Step4 for abiotic wind break	Step4 for biotic wind break
Soil texture	Threshold velocity of soil erosion	Average of max wind speed	Acceptable ratio of wind speed (%)	Optimizing windbreak distance
Medium sand	7.5 m/s	15m/s	50% of the initial wind speed	8h (16m) / 3h (=12m)

V_1 = tunnel wind speed; V_2 = field wind speed which estimated above 10 meters of ground surface; (H_2 = standard for field wind speed estimation that is 10 m (Ekhtesasi, 1993); H_1 = for wind erosion meter was 0.2 meter (Ekhtesasi, 1993).

Step3: Estimation of acceptable ratio of wind speed

In this step acceptable wind speed ratio was estimated using equation (2). Acceptable ratio of wind speed is defined as ratio of threshold velocity (which estimated in step2) to maximum velocity (which estimated from long term wind data of Jiroft climatology station). Acceptable ratio show how much of wind speed should be decrease which will not cause to soil erosion (Amiri, 2007). This ratio was applied for each windbreak to determine acceptable ratio of wind speed. Base of equation (2) optimized parallel windbreak distance was estimated.

and means the amount of wind speed which
 Acceptable ratio = $(V_e / V_m) \times 100$ (equation2) V_e :
 field threshold velocity of wind erosion soil
 V_m : maximum of wind speed

Step4: Optimizing windbreak distance

This step determines the location of the next rows of the windbreak base on soil texture, threshold velocity of wind erosion soil and acceptable wind speed. The next rows were located in distance from previous windbreak where wind speed increase above acceptable wind speed.

Step5: Wind breaks wind recording

Two kinds of windbreaks were used in this study, include of biotic windbreak (*Tamarix aphylla*) and abiotic windbreak (Mud wall)(table1). Wind velocity was recorded in front of windbreaks at -20, -1, 1, 2,3,4,6,8,10,11,12,16 and 18 times distances of its height and 1 meter above ground level. Wind speed was recorded in 3 replications using Digital Anemometer (General DAF. 2005. MDL).

RESULTS

Results of step1 -4 are presented in table2. Base on Ekhtesasi method(1993) the threshold wind velocity in the wind tunnel was recorded 4m/s. This velocity was converted to field velocity using Von Karman method (1921).

$$4\text{m/s} \times (10/ 0.2)^{0.16} = 7.5\text{m/s} = 27\text{km/h}$$

So according to average of maximum wind speed which recorded in meteorological data (54km/h) the acceptable ratio of wind speed was calculated as follow:

$$V_e/V_m = (27^{km/h} / 54^{km/h}) \times 100 = 50 \text{ percentage of maximum wind speed}(V_m).$$

Mudwall windbreak distance was optimized according to acceptable wind speed (50% of the initial wind speed) and the field experimental result which presented in table2. Wind speed decreasing in the distance of 6h and 8h was respectively 15.27% and 77.2% of initial wind speed. Using interpolation 50% wind speed decreasing of initial wind speed will occur in 6.87h (which approximately equal to7h). According to table3 the distance of 1h back of windbreak,

Table 3. means and standard deviation of wind speed due to distance from wind break

distance from wind break	Tamarix aphylla	Mud wall
-20	100±2.64	100±2.7
-1	77.56± 2.55	48.9±2.8
1	41±3.51	13.7±4.24
2	43±3.1	8.65±4.26
4	71.6±2.02	38.9±3.88
6	79.2±3.1	15.3±3.81
8	86.21±3.2	77.2±4.03
10	88.8±4.03	50±2.41
12	94.86±4.02	59±2.40
14	100.9±5.02	75±2.85
16	103.46±3.01	86.98±4.03



Figure 2. View of Mud wall wind break which used in this study as an abiotic windbreak

the wind speed was lower than estimated threshold (50% of the initial wind speed) so this was added to 7.87h (1h+6.87h) for estimating the location of next windbreak(Figure 2).

So in order to control of soil erosion or decreasing wind speed under estimated threshold the next windbreak should be set in distance of 7.87h from previous windbreak. Turbulent velocity fluctuations of abiotic windbreak (mud wall) with density of 100% compressed was shown in figure4 (table 3).

Tamarix aphylla was studied as biotic windbreak in this research. Windbreak distance was optimized according to estimated acceptable wind speed (50% of the initial wind speed) and the field experimental result which presented in table4. Wind speed decreasing in the distance of 2h and 4h was respectively 43% and 71.6% of initial wind speed. Using interpolation 50% wind speed decreasing of initial wind speed was estimated in 3.5h. According to table4, at

the distance of 1h back of windbreak, the wind speed was lower than estimated threshold (50% of the initial wind speed) so this was added to 4.5h (1h+3.5h) for estimating the location of next windbreak.

So in order to decreasing wind speed under estimated threshold the next windbreak should be set in distance of 4.5h from previous windbreak. Turbulent velocity fluctuations of biotic windbreak (Tamarix aphylla) with density of 45.5 uncompressed was shown in figure 5 (table 3).

DISCUSSION

This study was performed to improving agro ecosystems under arid climatic conditions. Windbreak could improve crop yields, soil stabilization, and evaporation but these



Figure 3. View of *Tamarix aphylla* wind break which used in this study as a biotic windbreak

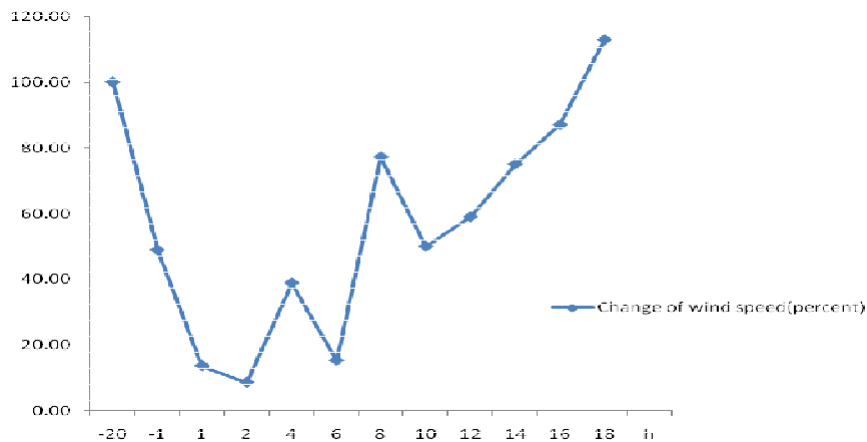


Figure 4. wind speed fluctuations around windbreak zone of Mud wall.

effects related to kinds of windbreaks and its planning over the agro-landscapes.

Windbreaks are barriers used to reduce and redirect wind. They usually consist of trees and shrubs, but may also be perennial or annual crops and grasses fences, or other materials. The reduction in wind speed behind a windbreak modifies the environmental conditions or microclimate in the sheltered zone. Mud wall as abiotic windbreaks with 100% density cause to create high turbulent in the back of the windbreak. This turbulent cause to increase the soil erosion. So we don't suggest this kind of wind break for sensitive soil in arid conditions.

In this study *Tamarix* was used as a biotic wind break. The results showed that wind speed fluctuation of biotic windbreak was lower and fewer than abiotic windbreak.

Decreasing of wind speed fluctuation can increase stability of agro ecosystems (Puri et al, 2004).

Heisler and Dewalle (1988) report that studies of shelterbelts field that medium-porous barrier are the most effective in reducing the mean, near-ground wind speeds for the longest distances. The rate of wind speed recovery is faster in the near lee (between 0h and 10h), and slower afterwards, hence low porosity windbreaks are slightly less effective than medium porosity windbreaks(Wang and Takle, 1996).

According to figure1 wind speed at 2h back of Mud wall windbreak was decreased fewer than 9 percent of its initial speed. So high density of windbreak created a zone at the back of windbreak which has a very low wind speed. Other researches suggested this zone created at 2 to 10h back of

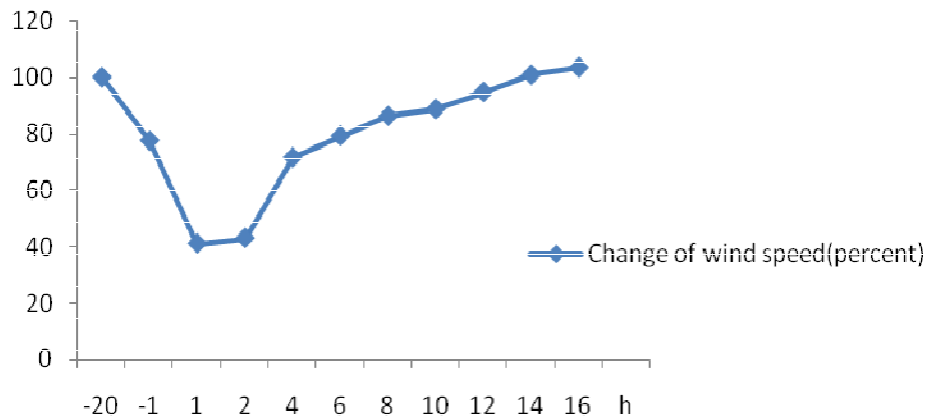


Figure 5. wind speed fluctuations around windbreak zone of *Tamarix aphylla*.

windbreak (Guanming and Wenhu, 2003; Vigiak, et al., 2003; Cornelis, et al., 1997).

A maximum wind speed reduction for biotic wind break was observed at 1h back of windbreak. The wind speed increasing after the minimum point has interesting pattern. This pattern shows the gradually change in wind speed and low fluctuations in contrast to solid windbreak. These findings are in qualitative agreement with simulations using the numerical model of Wilson (1985), Banzhaf et al., (1992) and Olga (2003). Wilson (1987) reported differences in wind reduction and turbulence behind the two fences are fairly slight. Mean wind speed is reduced somewhat more effectively (an additional 10 to 15%) near ground in the near lee ($x/H = 7$) of the fence which is dense at the ground, with no apparent penalty in the turbulent field but with reduced effectiveness at larger distances relative to the uniform fence.

Wilson (1985) examined the results of several relatively modern windbreak fence experiments and found that in these cases a more dense windbreak yielded not only a greater speed reduction, but also a greater range of shelter. This concurred with the prediction of the numerical model of windbreak flow which was the main subject of Wilson (1985).

The maximum wind speed reductions, which occur close to the slat-fence windbreaks, ranged from 70 percent for the solid windbreak to about 50 percent for the 60-percent porous windbreak. However, average wind speed

reduction over the leeward area was 5 to 10 percent larger for the 40-percent porous windbreak than that for any other windbreak (Heisler et al., 1988).

Finally we concluded that mud wall is applicable for high decreasing wind speed at the back of windbreak but its high wind speed fluctuation and high turbulent were limited these application in agroecosystems which laid in arid or semi arid regions. *Tamarix aphylla* with 45% density is applicable for medium decreasing of wind speed over a larger zone after windbreak. So this biotic windbreak may be more useful for agroecosystems which laid in arid or semi arid regions.

Growing of tree or other biotic windbreaks is interesting property for improving windbreaks, because its annual growth increases the windbreak zones (Bisal, et al., 1964). Other benefits of biotic wind break are their applications to fuel, fruit production, forage and wild shelter in agro landscapes (Wojtkowski, 2003).

REFERENCES

- Amiri I, (2007). Comparative study of wind breaks effects on wind speed changes in Jiroft and Kahnooj region. MSc thesis, University of Zabol, Iran. Pp 100 (in farsi).
- Banzhaf J, Leihner D E , Buerkert A, GSerafini P, (1992). Soil tillage and Windbreak Effects on millet and cowpea :Speed, evaporation, and Wind Erosion.
- Bisal F , Nielsen K F (1964). Soil aggregates do not necessarily break down over winter. Soil Sci. 98(5): 345-346.

- Cornelis WM, Gabriels D, Lauwaerts T, (1997). Simulation of windbreak for wind-erosion Control in a Wind Tunnel.M.Sc .Thesis. University of Ghent, Belgium.96p.
- Ekhtesasi MR (1993). The method for classification and intensity determination of land desertification in Iran. (1993). Natinal Conferences of Desertification and Methods for Combat of Desertification , Vol (1), p 124-125(in farsi).
- H, Carberry PS, ade H (1998). Variations in Wheat Yields Behind Windbreaks in Southern Queensland.4-H-
- Gordon M, Heisle , David R (1988). Dewall published by Elsevier Science BY,
- Guanming lin, Wenhu ye, (2003). wavelet analysis of turbulent signal in the lee of windbreak Australia: SpringerLink, I nc.
- Hagen t J, Skidmore E L, (1971). Turbulent velocity fluctuation sand vertical flow as affected by windbreak porosity. Trans. ASAE 14(4): 634-637.
- Heisler GM, DeWalle DR (1988). International Symposium on windbreak technology, reprinted from Agriculture, Ecosystems and Environment, Elsevier Science Publishers BV, Amsterdam.
- Honda H (1974). Fundamental study on the planting and space effect sin public nuisance prevention in the city: 111. Dust catching ability of plant foliage. Tech. Bul. Fac. Hort. Chiba Univ. 22:81-88.
- J van E , Karschon R, Razumova LA , Robertson GW (1964). Windbreaks and shelterbelts. WMO Tech. Note No. 59, 188 pp.
- JamesR, (2008). Brandle University of Nebraska-Lincoln and Sherman Finch. Soil Conservation Service.
- Jensen M (1954). Shelter effect. Danish Techn, Press, Copenhagen, 266 pp.
- Puri S, Singh S, Khara A (2004). Effect of Windbreak on the Yield of Cotton Crop Semi-arid Regions of aryana. Australia: SpringerLink, I nc.
- Vigiak O, Sterk G, Warren A, Hagen Lg, (2003). Spatial modeling of Wind spead around windbreaks.ctena. v 52(3- 4,1):273-288.
- Von Kármán T (1921) Uber laminare und turbulente Reibung, Z. Angew. Math. Mech., vol.1, 233-252,
- Wang H, Takle ES (1996). On the shelter efficiency of shelterbelts in oblique wind. Agric. and Forest. Meteorol. 81, 95–117.
- Wojtkwski Paul A (2003). Landscape Agroecology. Food Product Press.330p.
- Wright AJ, Brooks SJ (2002). effect of Wind breaks on Potato Production for the Atherton Tablelands of North Queensland.