

Research of Wind Erosion Intensity in the Region of Subotica-Horgos Sands¹

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Abstract: Wind is an important erosional process in the areas of steppe-savanna climate in Europe as typified by the Vojvodina plain in Yugoslavia. Cultivated and forested plots on the Subotica-Horgos Sands were used to study aeolian erosion processes. Wind erosion on the cultivated plot was 3-29 times greater than that occurring on a plot planted to forest trees. That erosion results in important losses of humus and nutrients. A practical equation estimating wind erosion from wind parameters is presented.³

Deflation processes in the zone of steppe-savanna climate in Europe are represented in the large plain of Vojvodina, which is a cornfield and a region of particular importance to Yugoslavia. The use of contemporary agricultural engineering, the inappropriate organization of the territory, destruction of protective green cover, and other unfavorable effects lead to the initiation and development of deflation processes of different intensities. This aspect of soil destruction affects, first of all, agriculture, water resources management, traffic, infrastructure, environment, etc. The region of Vojvodina is characterized by heterogeneous soil types, ranging from sands, black soil, chernozem, and smonitza to gleyed soil which, in given climate conditions, are differently threatened by the process of wind erosion. In this paper we shall point out the research on wind erosion (started in 1980) on the soils of light mechanical composition (potentially the most threatened soils), on the Subotica-Horgos Sands.

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The Subotica-Horgos Sands are situated in the North-Northwest part of Vojvodina plain between the Danube and Tisa rivers. The average length of the Sands is 48 km and the average diameter is 5-11 km. The Sands cover an area about of 240 km². The Vojvodina plain is a well-known orchard-grape vine country, with more than 33 percent under vineyards and orchards, about 20 percent forests and woodlands, and over 34 percent under grassland. It is characterized by mildly undulating dune relief of northwest-southeast direction, as well as by a high level of underground waters, 2 - 8 m. As these Sands are in the zone of arid climate, at the boundary of steppe-savanna and slight woodland character, under the influence of pedogenetic factors, there can be distinguished different types of sand: grey-yellow, brown, black, black loamy, and saline sands with different production capacities.

METHOD OF RESEARCH

A comparative method of stationary observation by wind-gage stations has been applied on specially selected erosion plots, of which one, used for agricultural production, has not been protected ("U"), while the other ("P") has been protected with forest plantings, figure 1.

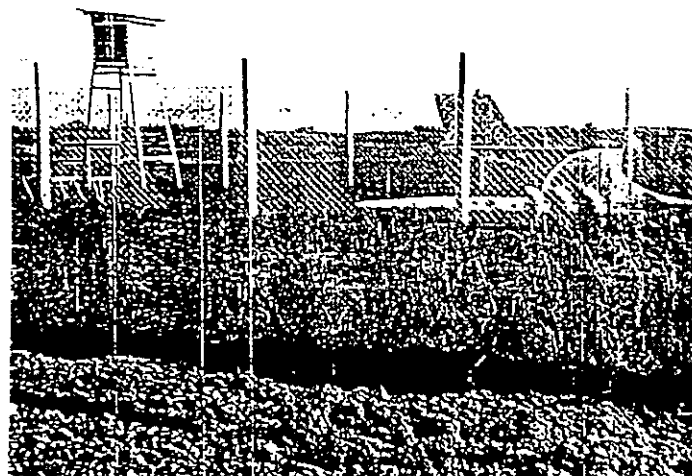


Figure 1--Experimental wind-gage station records deflation processes.

Table 1. Average monthly and annual deposition quantities (E_n kg m^{-1}) Loc. "U" and loc. "P"

E_n	Months												E_n
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	
Loc."U" (kg m^{-1})	0.272	0.765	0.504	0.693	0.306	0.350	0.507	0.106	0.136	0.116	0.040	0.062	3.857
Loc."P" (kg m^{-1})	0.017	0.026	0.028	0.047	0.053	0.038	0.040	0.039	0.025	0.019	0.014	0.010	0.356
Relation U/P	16	29	18	15	6	9	13	3	5	6	3	6	11

Table 2. Average monthly velocities (m s^{-1}) at 0.05 m above ground frequencies (pct) and storm winds (12.3 m s^{-1}) NW and N directions.

Parameters	Months												Average
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	
Velocity (m s^{-1})	8.10	8.49	8.13	6.24	7.89	9.36	7.11	8.61	6.97	9.59	7.45	7.05	7.92
	4.32	-	9.01	4.90	7.13	5.53	5.89	9.67	-	7.73	8.12	4.38	6.67
Frequency (pct)	23.42	11.88	7.21	6.23	5.76	9.32	17.25	2.25	4.04	1.96	1.84	8.84	8.33
	4.65	-	16.85	32.51	0.77	11.40	6.24	1.20	-	5.77	10.44	10.17	10.00
Force (K)	3.08	2.48	3.00	2.82	3.51	4.16	2.75	4.26	3.50	4.75	3.71	2.83	3.33
	8.47	3.13	3.04	3.38	5.44	3.59	4.15	5.23	1.00	4.25	3.81	2.92	3.85

Experimental stations record: quantity of aeolian deposition, wind frequency and velocity, air and soil temperatures, air and soil humidity, etc. Field data are analyzed in order to qualify and quantify the deflation process, as well as to define the conditions of climate and residual soil in which they occur.

RESULTS OF RESEARCH

The analysis of the data obtained at experimental stations "U" and "P" has proved significant differences in the distribution and intensity of deflatory processes, as well as in the parameters of climate and residual soil which affect them.

The data on the annual intensity of wind erosion, with 2.127-5.490 t km^{-1} per year, emphasize that unprotected areas (loc. "U") of the researched region are threatened by erosion, whereas the protected areas (loc. "P") are subjected to deflation processes of about 11 times lower intensity, ranging from 0.247 to 0.444 t km^{-1} per year, average 0.356 t km^{-1} per year (table 1). According to the data in table 1, maximum values of wind erosion intensity occur in the first half of the year between January and July, amounting to about 80 percent total annual quantity of aeolian deposition, whereas the remaining 12 percent are deposited between August and December.

Therefore in the unprotected areas of the Subotica-Horgos Sands, deflation processes oscillate within categories II and III, starting from medium intensity

erosion (2.0 - 5.0 t km^{-1} per year) to intensive erosion (5.0 - 7.0 t km^{-1} per year). In the protected areas of the Sands, deflation processes are reduced to the level of normal erosion (category I of erosion processes) with the intensity lower than 0.5 t km^{-1} per year.

The degree of hazard (comparison of protected and unprotected areas of the Sands) is included in the expression $B = I_{ee}P/I_{ee}S$, and ranges between 11 for annual and 171 for diurnal intensities of wind erosion. This points out the significant differences in the degree of hazard of the compared lands, which is conditioned by the buffering effect of protective plantings on the deflatory processes in the protected erosion plots.

The establishment of "erosion active" winds has been performed by the criterion of critical (initial) velocities ($V_s \geq V_{kr}$). Accordingly, the initial velocity necessary to move the mixture of D. Tavankut sands $D_s = 0.18$ mm, is about 3.0 m s^{-1} at the height of 0.05 m above ground. This denotes stormy winds (>12.3 m s^{-1}) as erosion active winds.

In the researched region of the Pannonian Plain, by the "Modified Method of Instrumental Analysis", the following dominant winds have been distinguished: NW (14) and N (16) with the degree of dominance ranging up to 10 times. Average monthly velocities (at 0.05 m) and wind frequencies are presented in Table 2.

Stormy winds in the Subotica-Horgos Sands occur 48.96 percent in the period

Table 3. Average monthly air temperatures (°C), precipitation (mm), relative air humidity (pct), and total soil moisture, loc. "U" and "P"

Climatic Factors	Loc.	Months												Annual	VP*	NVP**
		Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec			
Air Temp. °C	"U"	-0.87	-0.54	6.07	10.01	15.58	17.63	20.16	19.81	16.64	10.88	3.91	0.41	9.98	16.64	3.25
	"P"	-1.52	-0.49	5.86	10.70	15.00	18.04	19.53	18.91	16.02	10.58	3.07	-0.04	9.64	16.64	2.91
Precip. (mm)	"U"	28.78	21.48	35.42	32.16	54.92	90.30	35.22	30.74	43.18	39.84	40.20	47.36	499.60	286.52	213.08
	"P"	31.36	22.88	37.48	34.38	57.44	88.76	39.66	25.70	46.24	44.26	41.62	49.26	519.04	292.18	226.86
Relative Humidity of Air (pct)	"U"	81.45	78.24	68.92	64.19	65.40	66.77	67.49	67.89	71.88	72.76	77.59	83.01	72.13	67.27	77.00
	"P"	88.66	81.06	72.57	68.31	67.32	70.44	69.34	72.27	75.70	77.73	82.96	86.54	75.91	70.56	81.25
Total Soil Moisture (pct)	"U"	3.82	6.52	2.68	3.36	3.32	2.30	2.42	2.56	2.68	3.96	4.96	7.04	3.80	2.80	4.80
	"P"	15.78	21.02	12.60	9.56	6.70	6.42	5.70	4.96	7.56	10.88	11.42	17.80	10.87	6.80	14.90

* VP denotes Vegetational Period

** NVP denotes Non-Vegetational Period

between 10 a.m. and 3 p.m. As per their duration, category II winds (60 - 360 min.) occur most frequently in March and October. In addition, it has been observed that erosionally active air currents of NW direction (14) are more favorable (warmer and drier air) to the development of deflation, than the winds of N (16) direction.

The degree of nonuniformness of air currents expressed through the factors of force (K) and frequency (percent) ranges between 1.0 and 9.6. These values for NW (14) and N (16) winds oscillate much less, averaging 3.33 and 3.86 (table 2) which is very significant for the evaluation of the aggressiveness of air currents.

The analysis of data (table 3) of the hydrometric regime of the researched erosion plots points to the significantly more humid regime on the protected erosion plot, which decreases the development of deflatory processes.

The analysis of aeolian deposit (E_n) and residual soil (O_z) resulted in several indicators of conditions in which deflation processes occur. The following are the most important ones:

Particle-size composition of the researched sands indicates a very "erodible soil". The content of erodible particles smaller than 1 mm (to the depth of 0.05 m) amounts to more than 99 percent, and the condition of erodibility is 40 percent of these particles.

Sand moisture (rough dispersion) is a very significant factor in the group of soil physical properties which condition the "pseudo cohesion" reducing the

development of the deflation process. The content of total sand moisture (to the depth of 0.05 m) on the unprotected area ranges between 2.3 percent and 7.0 percent, and on the protected area it is 4.9 percent to 21 percent (table 3). The relation of moisture (W_z) and apparent cohesion (c) is defined by the function:

$$c = -0.23 + 0.16 \times W_z + 0.07 \times W_z^2 - 4.74 \times 10^{-3} \times W_z^3 + 8.58 \times 10^{-5} \times W_z^4,$$

and it has been established for $W_z = 1 - 21$ percent, with the corresponding values of cohesion of up to $c = 6.79 \text{ kN} \times \text{m}^{-2}$. On this occasion it has been observed that deflation processes occur at the soil moisture below 7 percent, which corresponds to cohesion below $c = 3.0 \text{ kN} \times \text{m}^{-2}$.

The analysis of the relation of chemical characteristics of the aeolian deposition (E_n) and the residual soil (O_z) points to the very significant indication of soil fertilization loss affected by deflation processes. It is denoted by the "deflation coefficient" presented in table 4.

Table 4. The degree of the damaging effect of deflation process expressed as deflation coefficient $\mu = E_n \times O_z^{-1}$

Number	Nutrients	$\mu = E_n \times O_z^{-1}$
1	Humus	5.7 - 16.2
2	CaCO ₃	1.1 - 1.3
3	Total Nitrogen	3.2 - 14.0
4	Readily Available P	15.5 - 20.3
5	Readily Available K	6.4 - 14.3

By the research of correlation between aggressive factors of climate, resistances of soil particles, and the quantity of aeolian deposition in the conditions of the Pannonian Plain, the basic equation of wind erosion has been developed:

$$E_n = A \times e^{(B \times Q_v)} \times T \quad (\text{kg m}^{-1})$$

where:

- E_n - Quantity of aeolian deposition in kg m^{-1} ;
- A and B - coefficients of regression;
- e - base of natural logarithms;
- Q_v - air flow in seconds through the observed cross section in $\text{m}^3 \text{s}^{-1}$;
- T - duration of each aggressive wind in s.

The formula is practical, as it is incomparably easier (with the aid of analytical evaluations and graphs of input parameters) to evaluate the erosion process, which otherwise calls for a rather complicated procedure of measurements.

CONCLUSIONS

By the analysis of data presented in the paper, it can be concluded as follows:

- In steppe-savanna conditions of the Pannonian Plain deflation processes represent a significant factor of soil destruction. They are factors which have adverse effects on the quality of the environment and, in general, on human activities in the region.

- Light soils (sands) of the Subotica-Horgos Sands are very erodible (containing

more than 90 percent particles smaller than 1 mm) and they can be classified as category III wind erosion hazard (Chepil and Woodruff 1954) - soils not resistant to wind erosion, or as (III), category of intensive erosion (Letic, Lj. 1989) with 5.0 - 7.0 t km^{-1} per year of deflation.

- Deflation processes occur in the periods winter - spring (Jan - Apr) and summer (June - July) and they are caused by aggressive winds NW (14) and N (16), velocity above 3.0 m s^{-1} (at 0.05 m above ground).

- The researched soils are subject to the accelerated nutrient loss resulting in fertility loss.

- These researches have a practical value, as they widen and supplement the knowledge of the measures of struggle against the phenomena of deflation, i.e. the establishment of shelterbelt plantings (and other measures) in this part of the Pannonian Plain.

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