Extent and Severity of Wind Erosion in the Ukraine

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Introduction

The total area of the Ukraine is 603,700 km^2 and its geographic co-ordinates are 22°08′-40°05′ west long. and 44° 22′ - 52° 18′ north lat. The amount of area for farming is 421,000 km^2. The farm land is 30 % of total Forest zone and natural forest is also 30%.The Forest-Steepe zone includes 12% of forest and extensive arable lands. The area of afforestations in the Steepe zone is 3% and the area of arable land reaches 85%. Due to climatic conditions, properties of soils and agricultural systems of agriculture, wind erosion destroys the soils over an area of 220,000 km^2. Wind erosion has detrimental effects on the economics of agriculture and the environment. During the dust storms, high amounts of radionuclides, heavy metals and residues of pesticides are transferred by the wind and contaminate the agrolandscapes. Soil erosion control systems are carried out on agricultural lands but social-economic changes in agriculture and anthropogenic stress on agrolandscapes require research into all aspects of wind erosion to correct soil conservation systems.

Material and Methods

Meteorological informations about dust storms over a 40 years period including the number, duration and the wind velocity of storms at all meteorological stations of the Ukraine was analyzed using a computer programme and applying statistics (1). 150 soil were researched in laboratory using aerodynamic tunnel to determine magnitude of the wind erosion (2). Structure of soil, stability of structure, humus, silt, clay and calcium carbonate contents were investigated using methods described by Kachinsky and Peterburgsky (5,6). Radiocaesium activity concentrations in soil samples and dust were determined by gamma-ray spectrometer.

Results and Discussion

Analysis of meteorological informations about dust storms during 40 years indicate that wind erosion takes place in all natural zones of the Ukraine.The climatic parameters of wind erosion were determined. The mean number of days with dust storms reaches 3-5 in the Steepe zone and 1 days per year in the Forest zone. The duration of dust storms is 8-17 and 3 hours per year . Wind velocity during dust storms with 10% of probability reaches 21 and 15 $m*s^{-1}$ respectively (Tables 1 and 2).

Chernozemic soils have the most susceptibility to wind erosion and are severely degraded. Of all the soils, solonez were the least degraded by wind erosion. Wind erodibility of reclaimable peat reaches 1.4, soddy podzolic soils 22.0, chestnut soils 0.3,chernozemic soils 8 $t*ha^{-1}$ per hour (Table 3).At the same time, each year soil loss reaches 70 t/ha in the Steepe zone, 6 t/ha in the Forest-Steepe zone and 9 t/ha in the Forest zone.

Table 1. Duration and number of days with dust storms in natural zones of Ukraine, mean per year

Zone	Number of days	Duration of dust storms, h
Forest	1.1	2.7
Forest-Steepe	1.1	2.6
North and Central Steepe	2.9	8.5
South Steepe	5.3	17.5

Table 2. Probability of wind velocity during dust storms in the Ukraine, %

Zone	**Wind velocity, m/s**								
	2-4	5-7	8-10	11-13	14-16	17-19	20-22	23-25	26-28
Forest	13	24	25	14	11	8	5	-	-
Forest-Steepe	15	26	22	15	9	9	4	-	-
North and Central Steepe	8	15	21	12	17	14	10	2	1
South Steepe	6	14	20	14	17	17	9	2	1

Table 3.Modulus (soil erodibility), and soil loss to wind erosion in the Ukraine

Soils names	**Modulus, $t*ha^{-1}*h^{-1}$**	**Mean soil loss, $t*ha^{-1}*yr^{-1}$**
North and Central Steepe zone		
Deep clay chernozem	0.3	2.6
Modal carbonated clay chernozem	8.3	70.5
Modal clay loamy chernozem	2.2	18.7
South Steepe		
Southern clay chernozem	2.3	40.3

Southern carbonated clay chernozem	3.9	68.2
Chestnut clay and loamy soil	0.33	5.8
Solonez	0.04	0.8
Blown sand	366.9	6,422
Forest-Steepe zone		
Gray wooded loamy soil	2.1	5.7
Forest zone		
Soddy podzolic sandy soil	21.8	5.9
Soddy podzolic loamy sand soil	3.5	9.4
Soddy podzolic loamy soil	0.6	1.6
Soddy gley soil	1.2	3.2
Fen peat reclamated soil	1.4	3.8

Research was conducted on the physical and chemical parameters of soils susceptible to wind erosion (Table 4). Clay and microagregates <0.01 mm content are the main soil parameters influence the level of erodibility of soil by wind. Increase of clay and microagregates content leads to decrease of erodibility.

Table 4. Statistical estimation of relations between soil stucture, erodibility and some physical chemistry properties of soils

Function	**Argument**	**Correlation coefficients**
Soil wind erodibility	Clay contents	-0.90
Erosive soil structure contents	Clay contents	-0.79
Erosive soil structure contents	Relation between humus and calcium carbonate content	-0.54
Erosive soil structure contents	Microagregates < 0.01 mm content	-0.80
Stablility of srtucture	Soil detachability	0.68
Stablility of structure	Silt content	0.65
Stablility of structure	Clay content	0.61
Stablility of structure	Relation between humus and calcium carbonate content	-0.78

Using research results, mathematical models describing the relations between soil parameters, soil losses, and classification of soils, were worked out. For soil loss predictions, the mathematical model was developed.

$$\mathbf{E = 0.1\,(U_Z - V_{cr})K_2K_3\ ,\quad t * ha^{-1} * h^{-1}} \qquad \mathbf{(1)}$$

E - soil loss

U_Z - wind velocity at the high z, m/s

V_{cr} - critical wind velocity, m/s; $V_{cr}=3.202+0.025d_e$

$K_2 = 0.22\, d_e^{-3.06}$

$K_3 = [\ln(10/Z_0)]^2\, d_{e_3}^{-0.61}\, [(\ln Z/Z_0)]^{-2}$

d_e - equivalent diameter of soil structures, mm;

$d_e = (d_1P_1+d_2P_2+...d_nP_n)/ (P_1+P_2+...P_n)$

where $P_1,P_2...P_n$ percentage of soil agregates with size of $d_1,d_2...d_n$.

Z_0 - roughness parameter, mm; $Z_0 = 0.03d_e^{1.4}$

Using climatic parameters of dust storms, erodibility of soil and soil losses, the potential wind erosion for all parts of the Ukraine was estimated.

Taking into consideration that damage from wind erosion varies throughout the year, research was also conducted on the seasonal dynamics of dust storms. Depending on climatic zone , the level of soil losses was variable,but the greatest losses were in spring and autumn months.Soil roughness on agricultural fields was used to manage the wind erosion process.

Also, there are many other problems caused by wind erosion which affect the environment. One problems is the prediction of soil losses and the resulting transfer and accumulation of the contaminants in agrolandscapes. The behaviour of contaminants such as radionuclides, heavy metals, remains of fertilizers and pesticides is different in various environments and perhaps depends on the binding of contaminants with soil particles.

Some components of agrolandscape increase generation the dust during wind erosion and the dust then has an influence on neighbouring landscape contaminating the soils, water and other resources. The effects of changes on the agrolandscape should be further researched to understand its effect of wind erosion.

The Ukrainian lands are contaminated by different pollutants.The deposition of contaminants reaches 18 $t*km^{-2}yr^{-1}$.This has resulted in research to determine the effects of wind erosion on the environment.First of all, we have begun to study wind erosion as a factor in radionuclide contamination of the Northern landscapes. The soil erodibility,duration of storms and radionuclide activity concentrations in dust were researched and a mathematical model of radionuclide transfer was developed.

$$Q = E*q*t_n , \quad Bq*ha^{-1} \qquad (2)$$

E - soil erodibility by wind (see model 1)
q - radionuclide activity concentration in dust,Bq / kg (Bq- Becquerel is unit of radioactivity)
t_n - duration of dust storm, h

In this equation Et_n is annual soil loss, t_n is annual duration of dust storms.

Using the equation, it was shown that in a contaminated area, wind erosion on soddy podzolic sand soils can generate 27,300,000 $kBq*km^{-2}*yr^{-1}$. Near the a large industrial city, the soil was contaminated by heavy metals. In the southern chernozem area, the level of concentration of Pb reaches 60,Cu and Zn-98-140, Cd-7 $mg*kg^{-1}$. Because of wind erosion, the average soil loss in this area is more than 10 $t*ha^{-1}$. Prognosis shows that every square kilometer generates 1000 t of dust including 200 kg of heavy metals.

Wind erosion will cause contaminated dust to be deposited on another landscapes throughout the year. Wind erosion is a very large scientific and practical problem.Many questions need to be answered by research.. The function of relief as one of main structures of the landscape and ratio between arable land, meadow and forest , including forest shelterbelts , strongly affect wind patterns and affect the processes of wind erosion.It is important to understand effects of these components on the landscape to design predictions for wind erosion control.

From the early 1950's in all the natural zones of the Ukraine, systems of shelterbelts were planted. There are now more than 440,000 ha of shelterbelts on agricultural fields. For the wind erosion control, the systems of shelterbelts were researched and models of systems were suggested (3,4).The main parameter of such system is distance between shelterbelts (L, m):

$$L = f(U, Z_0, H, E) \qquad (3)$$

U - limit of wind velocity to decrease soil loss to a tolerable level, m/s

$$U = \sqrt[a]{E / k}$$

where **a** and **k** are parameters depend on the type of soil

Z_0 - roughness parameter, m

H - the hight of shelterbelts,m

E - erodibility of soil by wind, $t*ha^{-1}*h^{-1}$

For calculations, the model suggested is:

$$L = (3H\, U_0^{2.55}\, Z_0^{0.105} + 28.84\, U^{2.55}\, H^{1.105})(U_0^{2.55}\, Z_0^{0.105})^{-1} \qquad (4)$$

U_0 - wind velocity during dust storms

Expectant of the height of trees in the shelterbelts is 20 m in Forest zone,18 m in Forest-Steepe zone, 16 m in North Steep, 12 m in Central Steepe and 6-8 m in South Steepe zone. The number of rows is 3-5. In Forest zone the main tree species are Pinus sylvestris, Picea excelsia, in Forest-Steepe zone- Betula verrucosa, Carpinus betulus, Quercus pedunculata, Larix europea, in North and Central Steepe - Juglans nigra, Populus balsamifera, Betula verrucosa, in South Steepe zone - Robinia pseudoacacia, Gleditschia triacanthos, Platanus occidentalis.

The systems of forest shelterbelts, grown according to this model, guarantee the decrease of wind velocity to U as well as decrease the soil loss to a tolerable level.For strong wind erosion areas of the Ukraine where soil loss reaches 70 $t*ha^{-1}$ per year, the system of shelterbelts decrease soil loss to 2-3 $t*ha^{-1}$ per year.

It is essential to make information available about the tolerable soil losses to people living on the agrolandscape.A tolerable soil loss of 2-3 $t*ha^{-1}$ per year has been suggested for the main Ukraine soils (3).

The large hilly area of the Ukraine is influenced by water and wind erosions. Joint action of water and wind erosion has not been well researched to erosion control.

Comparision the climate of the past (about 100 years ago) with climate of today shows that the territory of the Ukraine has become arid due to technogenic process. Due to present aridity, wind erosion has become wide-spread in Forest zone. Selective soil blowing has caused degradation of light lands. For this reason, about 10 % of the arable lands have been transformed into untilled lands.Prognosis of the changes in agrolandscapes caused by wind erosion, and determining the adaption of agriculture on these agrolandscapes, are the new problems of researchers.

Acknowledgement

I would like to thank Edward L. Skidmore for the invitation to take part in this International Wind Erosion Symposium and the opportunity to present this paper for publication.

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