RELATIVE HUMIDITY OF THE AIR AND CRITICAL WIND VELOCITY IN RELATION TO EROSION

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ABSTRACT

Wind tunnel research on soils susceptible to wind erosion showed that, under the influence of the relative moisture content of the air, the wind velocity and the time of exposure, sometimes physical changes occur in the soil surface; those changes are evidently the cause of the different levels at which the critical wind velocity manifests itself for the same soil.

Under the influence of the factors mentioned, also quantities of blown sand per unit time may vary.

It is therefore concluded that investigations for the purpose here described should be conducted in tunnels of the closed-circuit type, especially in zones with a humid climate.

Introduction

In research on erodibility of soils and on methods to control (wind) erosion, the wind tunnel is a suitable aid. With this apparatus it is possible to work without interfering factors, as they occur outdoors. It is possible to do research on natural objects as well as artificial ones and on products. The wind velocity can be varied at will.

The required air can be drawn from outdoors or from a more or less closed room. In the latter case one can think of a closed circuit or of a large room or hall in which the tunnel installation is located.

In the cases mentioned, it is clear that the air is from "different origins", possibly with different humidity levels.

In the closed-circuit system, fluctuations in humidity of the air are negligible, partly because variations in temperature are small. When air is being drawn from outdoors, the (relative) humidity may or may not change considerably.

Investigations have shown that the erodibility of a soil -expressed as the critical wind velocity- may vary considerably with changes in relative humidity of the air.

It is therefore concluded that investigations for the purpose here described should be conducted with wind tunnels of the closed-circuit type, especially in zones with a humid climate.

Susceptibility to blowing and composition of the soil

The erodibility of a soil depends on its composition, i.e.

a) the granular composition : the quantities and the sizes of the individual mineral particles,
b) the presence or absence of binding ingredients between the particles.

Binding material can be colloidal organic matter and clay particles (< 0,002 mm).

Artificial binding materials are not considered here.

Characterization of the wind-erodibility of a soil

The susceptibility of a soil to wind erosion can be characterized by the critical wind velocity and the quantity of eroded soil material per unit time, the latter of course with wind velocities which are higher than the critical value.

Each of these parameters separately constitutes a soil characteristic; both parameters in combination, however, give a better evaluation of the soil.

Critical wind velocity

At the critical wind velocity a soil surface begins to blow and continues to do so. The magnitude of this characteristic may vary -also for the same soil- depending on the nature of the soil surface (parameter of soil roughness), as a consequence of different forms of tillage or the weather, and the moisture content of the air which is in contact with the soil.

The critical wind velocity sometimes constitutes a rather sharply defined "point", sometimes a range of velocities.

The humidity of the air and the moisture content of air-dry soil

The moisture content of an air-dry soil (surface) is a more or less variable factor, depending on the composition of the soil and the moisture content of the air, which is in contact with it.

To come to a moisture equilibrium between a practically air-dry soil and (almost) still air is, generally speaking, a slow process (diffusion). If, however, the air movement is more rapid (a higher wind velocity), the moisture supply or removal is accelerated. In general it may be said that when the soil is more humid than the air, the rate of drying of the soil depends on the difference in moisture level between soil and air and on the velocity of the air current with which moisture is removed from the soil surface.

The air can also be more moist than the soil. In case the air is not moving, the exchange of moisture takes place by diffusion. If the air is moving (wind) the soil surface is, as it were, bombarded with moist particles; in this way it is even possible that the moisture percentage of the upper layer of the soil becomes higher than that of the air. The time of exposure is a very important factor in these processes.

The magnitude of the critical wind velocity for a soil changes with the moisture level in the soil surface.

Research has shown to what extent changes in the critical wind velocity sometimes occur in a single soil, as affected by the various humidity levels of the air; it is assumed that the moisture is present as invisible vapour. Wetting of the soil surface by movement of water from a wetter soil layer below or by rain is not considered here.

The soil

The soil used in the trials was a so-called wind blown cover sand, taken from the eastern part of the Dutch province of Noord Brabant; its origin is a reclaimed woodland soil which is very susceptible to blowing. At 10 spots samples were taken to furrow depth (0-20 cm) for research in the wind tunnel.

The particle size distribution of the samples and the percentages of organic matter are shown in table 1.

Almost three quarters of the mineral fraction lies within the range of 75 to 300 μm; this is a grain fraction which can be removed by wind rather easily. The quantities of organic binding materials and mineral particles < 16 μm (so also < 2 μ) are small.

Quantities of the soils studied were sieved to obtain an impression of the extent of aggregation; sieve openings (square) were about 12-13 and about 5-6 mm. Aggregates in excess of 12-13 mm amounted to 2.1 %, and between 5-6 and 12-13 mm to 8.3 %. This indicated once more that there is little binding between the individual sand grains.

TABLE 1 : Particle size distribution and organic matter content.

	Soil % of weight (oven-dry)			Percent by weight of the mineral fraction										
	organ. mat.	partic. <16 µm	sand >16 µm	16-50 µm	50-75 µm	75-105 µm	105-150 µm	150-210 µm	210-300 µm	300-420 µm	420-600 µm	600-850 µm	850-1200 µm	1200-1700 µm
	2.5	4.1	93.4	9.2	9.5	15.3	20.5	23.5	11.7	2.2	0.8	0.4	0.3	
	2.5	4.5	93.0	8.8	9.4	29.0	5.3	24.2	12.5	2.4	0.8	0.4	0.2	
	3.2	4.9	91.9	9.6	9.6	19.0	14.9	21.2	12.6	2.6	1.0	0.8	0.5	0.1
	3.0	4.8	92.2	9.0	9.4	25.7	7.8	22.0	13.1	2.8	1.1	0.7	0.5	0.1
	2.5	4.3	93.2	8.6	9.8	22.1	13.0	22.7	12.1	2.4	1.0	0.6	0.4	
	2.5	4.8	92.7	7.9	9.2	31.4	4.7	25.1	11.4	2.1	0.7	0.4	0.2	0.1
	2.8	4.7	92.5	9.2	9.6	22.2	10.5	23.1	12.8	2.7	1.2	0.8	0.4	
	2.5	4.4	93.1	8.9	9.3	15.5	18.1	24.9	12.0	2.6	0.9	0.5	0.4	
	2.9	4.4	92.7	9.2	9.0	14.1	20.0	22.5	12.7	2.8	1.1	0.8	0.5	
	2.9	4.4	92.7	9.0	9.0	21.6	12.4	22.8	12.3	2.8	1.2	0.9	0.6	0.1
averages	2.7	4.6	92.7	8.9	9.4	21.6	12.7	23.3	12.3	2.5	1.0	0.6	0.4	

ca. 70%

Table 1 : Particle size distribution and organic matter content.

In a field moist condition -that is about 10 % moisture- the soils were put on trays (each 35 x 122 cm^2, 7 trays per treatment) and dried there until air-dry.

In air-dry condition the soils were exposed in the wind tunnel to increasing wind velocities beginning at 7.0 m/s, with increments to 8.0, 8.6, 9.6, 10.4, 11.1, 12.2, 12.9, 13.5, 14.1 and 15.0 m/s (calculated to the standard height of 10 m). Each wind velocity was maintained for 40 minutes. The air in the tunnel was sucked in from outside the building. The series of trays were weighed after every 40 minutes of exposure. The critical wind velocities and the relative moisture contents of the air during the trials in the tunnel were determined.

Results

From the many wind tunnel trials conducted, the results of three were selected (Figure 1 a, b and c) to show to what extent the critical wind velocity and the quantities of eroded soil are effected by the relative moisture content of the air. The moisture percentages varied not only between trials, but also during one single trial.

The upper graph in the figure shows the course of the humidity of the air during each of the three trials. On the wind velocity axis is indicated (.) which wind velocities were employed successively in the tunnel (see "The soil"). The three lower graphs refer to the changes in weight of three of the seven trays with soil per treatment, referring to the three trials a, b and c.

Trial a

The relative humidity of the air during this trial was high and stayed so during the whole experiment (90-95 %). From the changes in weight of the soil it is evident that, in spite of the increasing wind velocities, the soil surface continues to take up moisture from the air stream, as much as about 30 g per tray; this corresponds to about 750 liters of water per ha, in a thin surface layer. This experiment resulted in a critical wind velocity of about $12\frac{1}{2}$ m/s, as indicated by the strong decrease in weight.

Trial c

At the beginning of the trial the relative moisture percentage of the air was rather low, about 50 %; there was a slight erosion at the soil surface which remained constant at the successively increased wind velocities (7.0 and 8.0 m/s). When the wind velocity was increased to 8.6 m/s, the critical phase for this surface was ob-

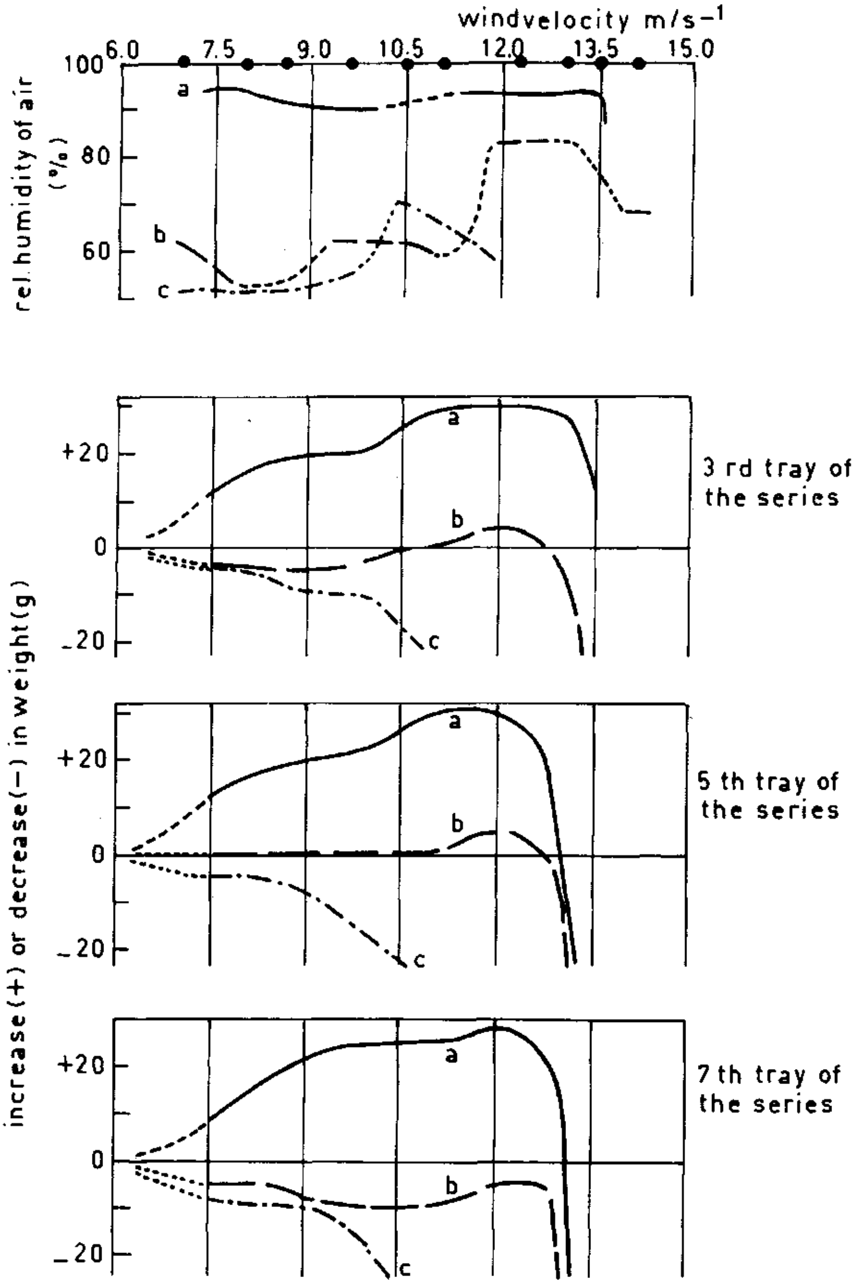

Figure 1 : Relation between relative moisture content of the air, wind velocity and increase (+) or decrease (-) in weight of the soil.

a, b and c : three trials
wind velocities calculated for 10 m height.

viously reached under the given conditions.

When the wind velocity was increased further, the erosion continued, although in the meantime the relative moisture content of the air began to rise.

The critical velocity, although less sharply indicated, was $8\frac{1}{2}$ - 9 m/s.

Trial b

At the beginning of this trial the relative moisture content of the air was a little higher than in trial c, resulting in somewhat less erosion at the soil surface. Although the relative moisture content of the air immediately began to decrease a little over 50 %, no increase in erosion resulted at the subsequent wind velocities (7.0 and 8.0 m/s).

At a wind velocity of 8.6 m/s the situation began to become critical on the 7th tray. In the meantime the relative humidity of the air had increased to about 60 %, causing an increase in weight of the soil by adsorption of moisture from the air. When subsequently the relative humidity rose to more than 80 %, and the wind velocity was increased further, the critical velocity was reached at about $12\frac{1}{2}$ - 13 m/s.

Figure 2 summerizes the results of all wind tunnel trials with the same soil, the critical wind velocities, and the relative humidities at which the critical values were reached.

The solid line shows that, between 50 - 55 and about 75 % relative humidity, the critical wind velocities varied between about $7\frac{1}{2}$ - 8 and $12\frac{1}{2}$ - 13 m/s. Above 75 and below about 50 % relative humidity the critical wind velocities hardly change.

The scatter in the graph cannot be satisfactorily explained at the moment. It is possible caused by the heterogeneity of the soil and the changing relative humidities during the trials in the wind tunnel.

It is clear that other conditions of wind-velocity, time of exposure and relative humidity, may lead to other results. However, the effect of the moisture content of the air upon the result of the trials will remain.

In conclusion it may be stated that there is a strong interaction between the magnitude of the critical wind velocity on the one hand and the condition of the soil as well as the relative humidity of the air stream on the other.

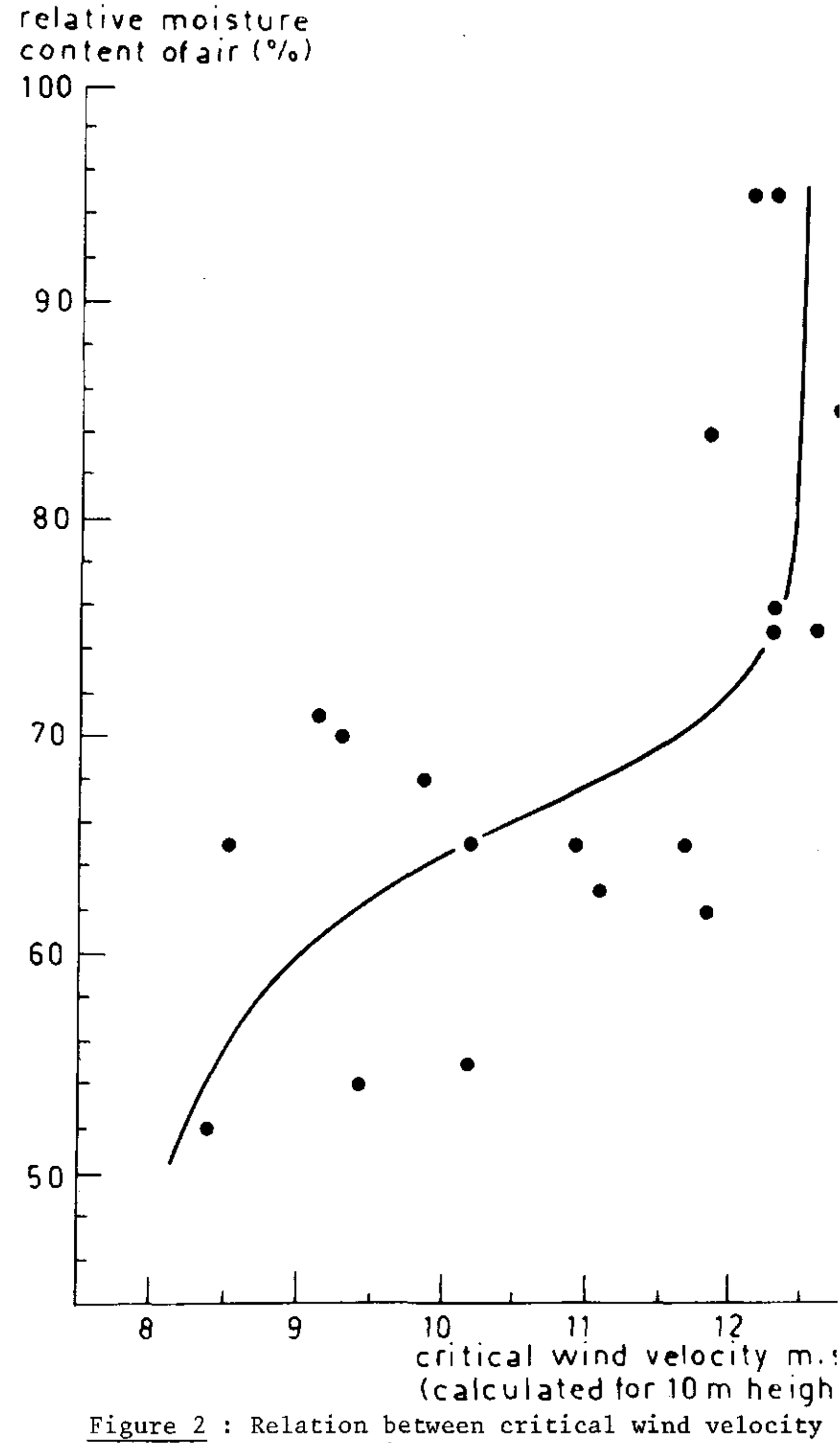

Figure 2 : Relation between critical wind velocity
and relative moisture content of air.

When recommendations for field conditions have to be made, the aspects described should be known. Soil and weather conditions at which the lowest critical wind velocity can occur should be reckoned with.

To avoid the difficulties in wind tunnel research described here, especially in humid climates, wind tunnels with closed circuits, placed in a building, should preferably be used.