OTKA záró 2015-09-01 - 2021-02-28

1. To determine the critical wind velocity on the typical soils of the southern Great Hungarian Plain

We focused on analysing the typical soils and variations of soils in those regions of the southern Great Hungarian Plain which are most affected by aridification (Backa loess plain, Dorozsma-Majsai sand plain) and in the Lower-Tisza Region in the first phase of the research preiod.

In the first stage of the research, we chose sample parcels (38 parcels) in the microregions of the Backa loess plain, the Dorozsma-Majsai sand plain, and the Lower Tisza Region. The designation of the sample parcels is based on soil diversity with a special emphasis on the mechanical composition, structure, and humus content of the soils. We carry out wind tunnel experiments on the soils of the sample parcels in order to determine the critical wind velocity of the soils which have different structure and other physical properties. In addition, we also aim at identifying relationships between the studied basic soil parameters and critical wind velocity values.

We carried out an in situ wind tunnel experiment on sand and chernozem soils in the region of Szatymaz-Szeged on 4-6 July, 2016. We aimed at quantifying the extent of soil loss caused by different wind events on samples with original structures as well as quantifying the changes in structural characteristics, humus and nutrient contents. The topsoil of the sample parcels was patterned before and after the wind events of our wind tunnel experiments in order to monitor wind-erosion-induced structural changes. Wind velocity measurement was continuous during the experiments.

We used two types of trapping systems during the in situ wind tunnel experiments: MWAC trapping systems, and the prototype of an active, wet trapping system (WAST) of our own development, which was further developed even during the days of the measurement. We used BWS-60 type soil scales to measure the amount of soil transported during the different wind events, and to test the efficiency of the developed trapping systems (WAST). The scales were placed under the wind path (Fig.1.).

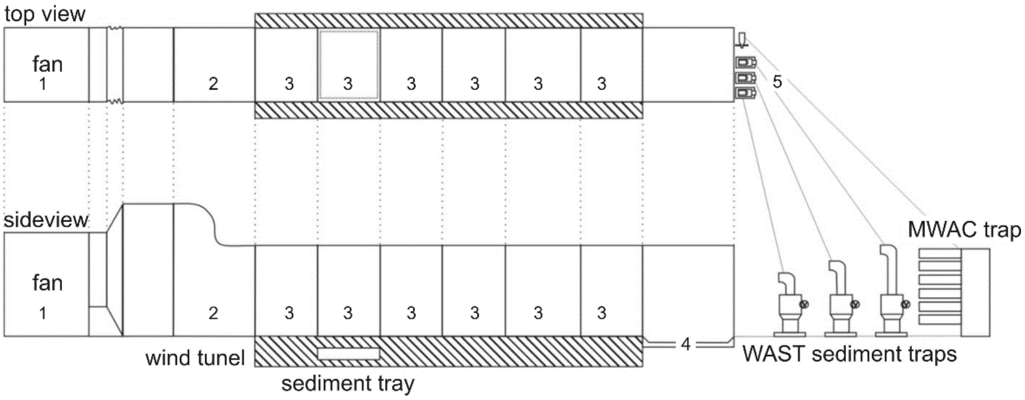

Fig. 1. Plan view and side view of the wind tunnel (Elements: 1) fan, 2) laminator, 3) wind tunnel pieces, 4) sediment tray, 5) outlet opening of the wind tunnel complete with the trapping devices)

The physical diversity of soils is a determining property in terms of agronomic structure and starting speed. Soil samples were classified into four groups according to physical variety: sand (n = 7), sandy loam (n = 11), loam (n = 5), clay loam (n = 8) and clay (n = 1). The effect of physical soil type on starting speed is shown in Figure 2. The figure shows that as the Yarn test by Arany increases, the starting velocity of the soils increases. There is an exponential correlation between the value of yarn test by Arany and the starting velocity with a deterministic coefficient (R2) of 0.4313.

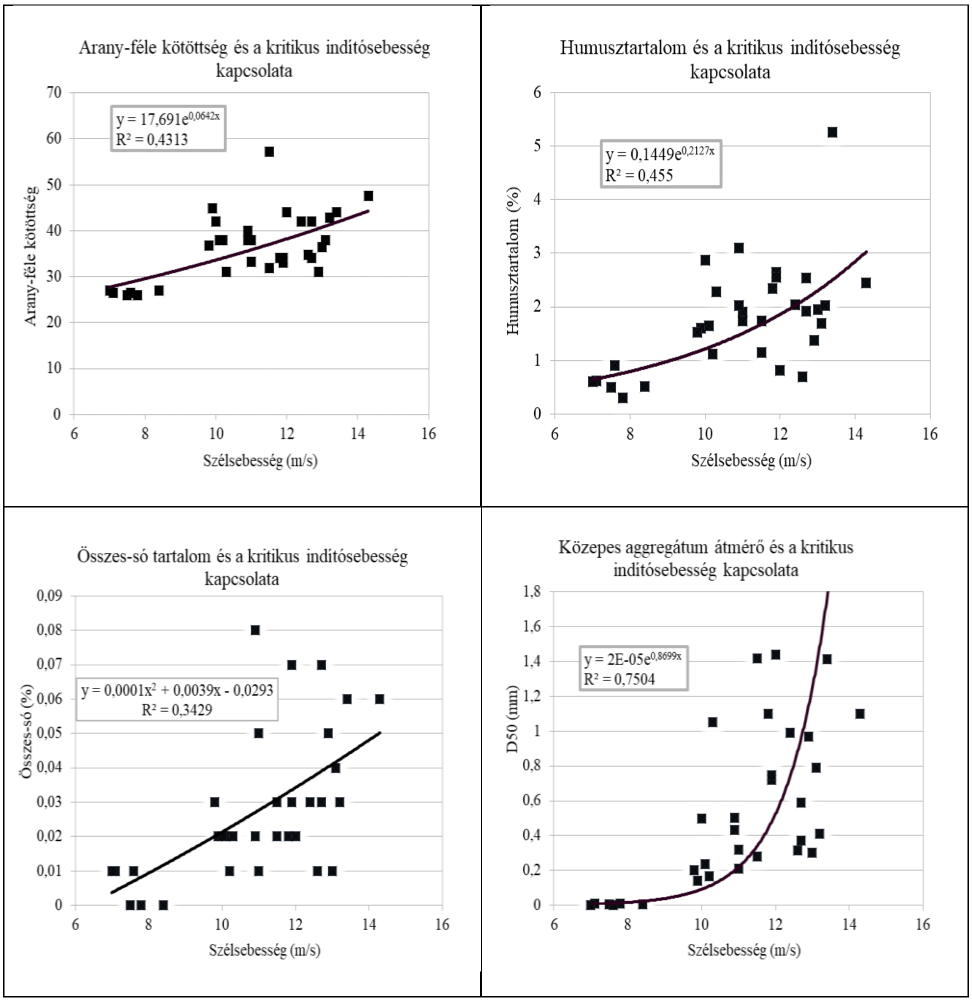

Fig 2.: The physical diversity of the soil, the humus and total salt content,and the effect of medium aggregate diameter is critical starting speed

Another important element in the formation of the agronomic structure of soils is the humus content of the soils. The humus content of the examined soil samples remains, with a few exceptions, below 3%, and in general it can be said that the humus content of sandy soils is the lowest, while the humus content of sandy loam - clay physical chernozem is the highest. The relationship between the humus content and the starting speed is shown in Figure 2, based on which the value of the starting speed increases exponentially with the humus content of the soils (R2 = 0.455).

Examining the agronomic structure of the soil samples, we determined the effect of the ratio of the three agronomic fractions (lump (> 10mm), crumb (0.25–10 mm) and dust (<0.25

mm)) and the critical starting speed on each other. A positive correlation was found for the lump and crumb fraction, while a negative correlation was found for the dust fraction in relation to the critical starting speed. Of the three fractions, the ratio of the powder fraction (Pearson correlation, r = 0.871; 0.01 at the significance level) moved most along with the critical start rate. The same value for the crumb and lump fractions: r = 0.779 and r = 0.656 was also at the 0.01 significance level. Another important feature of the agronomic structure is the medium aggregate diameter (D50). An exponential relationship was found between the mean aggregate diameter and the critical start velocity (Fig. 2, R2 = 0.7504).

Due to the limitations of ex-situ wind tunnel studies, the critical launch speed values mentioned so far have only been determined by measuring a relatively small soil surface. To determine a more accurate critical start rate value, we used the results of our in-situ experimental series conducted in 2013 (FARSANG et al. 2013a, 2013b; FARSANG et al 2011; FARSANG et al 2017). Comparing the in-situ and ex-situ measurements, it can be concluded that the critical start-up speed values measured under in-situ conditions are 72.5% of the values measured under ex-situ conditions. This value was determined from the average of 14 in-situ field measurements on sand and clay physical species and 9 on-site ex-situ studies on the same physical species. The difference was considered as the difference of the ex-situ - in-situ measurement method, therefore the results of the ex-situ measurements for all 5 physical species were corrected by this percentage value (Table 1). As mentioned earlier, the difference can be caused by disturbance and different blowing surfaces.

The corrected critical starting speed values (KorrUt10m) calculated for a height of 10 m are shown in Table 1.

Physical soil types	Sand	Sand-loam	Loam	Clay-loam	Clay
Sample number	6,0	11,0	6,0	8,0	1,0
Ut_{10cm}* (m/s)	7,6	11,8	11,0	12,2	11,5
Ut_{10cm}* dispersion	0,5	1,1	1,1	1,6	n.é.
$KorrUt_{10m}$** Mean (m/s)	8,2	12,3	12,5	14,0	12,6
$KorrUt_{10m}$** dispersion	0,7	1,8	2,2	2,6	n.é.
Z_0*** (m)	0,00002	0,00003	0,00004	0,00021	0,00001
Z_0*** dispersion	0,00004	0,00005	0,00006	0,00031	n.é.
* Ut10cm: critical starting speed at a height of 10 cm in ex-situ conditions					
** KorrUt10m: critical starting speed corrected on the basis of in-situ measurements at an altitude of 10 m					
*** Z0: Aerodynamic roughness					
n.é. not applicable					

Table 1: Critical starting speed and aerodynamic roughness of different physical soil types in the Southern Great Plain

2. WAST (Wet Active Sediment Trap) – Description and operation of the developed trapping system

The development of the trapping system had many criteria: the designed trap must be cost-effective, portable, and easily operable in field circumstances too. Industrial filters have been known for a long time, they have a good degree of efficiency even in the case of fine particle fractions, but they do not meet the criteria mentioned above. They are expensive, usually non-portable, or they are expensive to transport. Industrial filters are designed to trap big amounts of dust, and trapped material is not necessarily suitable for further analyses.

Our wind erosion research had further criteria. One of our objectives was to design a trap that is able to sample horizontally flowing soil particles with good efficiency. Another criterion of the trap was to sample the sediment flow at different heights in order to provide better possibilities for the experiment evaluation. A further aim of ours was that this trap would be an isokinetic, active trapping system.

The basic conception was to have the floating material absorbed in a certain medium. We adapted the operation principle of a wet dust-collecting equipment for a trapping device. The principle is that the airflow transporting the sediment is directed toward a wet medium which separates the particles from the airflow, and they are collected in the bottle containing the wet medium. The characteristics of the wet medium were important here. First, it had to be easily separable from the collected material so that the samples could be used in laboratory analysis. Also, the medium was not allowed to affect the sample chemically in order to secure the efficiency of further analyses. Third, the amount of the medium was also an important parameter. The amount of the wet medium should be sufficient for trapping the sampled material, but it should be kept within reasonable limits in order to be separable from the sediment easily, fast, and simply. The chosen medium was distilled water.

The developed trapping system consists of several parts. The first element is a PVC tube serving as an inlet opening, one end of which points toward wind direction. The continuation of the pipe is broken in perpendicular direction to the soil surface, and leads into the interior of the trap. The length of the tube is determined by the height corresponding to sampling (Fig. 3). The trap also consists of a cylindrical trap (PVC); a plastic supporting plate, which has a hole in the middle with the same diameter as the trapping body; a bottle containing the wet medium; an outlet opening (a PVC pipe); and an electric fan. The WAST is an active trapping device. Airflow in the trap is provided by an electric fan.

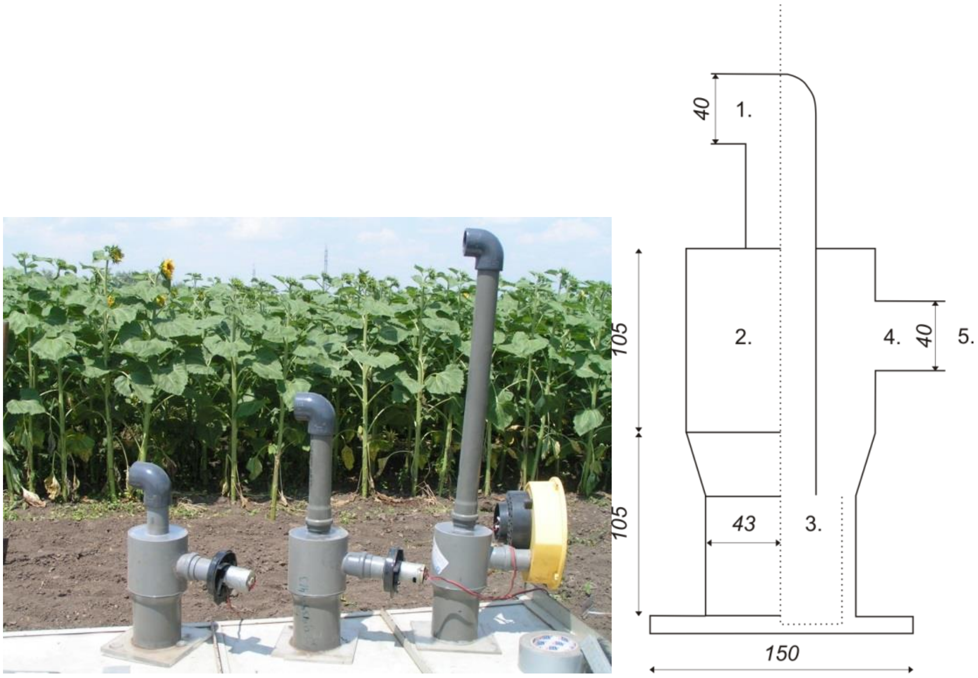

Fig. 3. Three WAST traps with various sampling heights and its parts: 1) inlet opening 2) trapping body 3) sampling bottle 4) outlet opening 5. fan (dimensions are in mm)

The efficiency of the newly developed WAST exceeds the efficiency of the MWAC in each wind blowing experiment, even though the MWAC is considered to have the highest relative efficiency based on international literature data (Sterk 1993, Bakkum 1994, Pollet et al. 1998, Goossens 2000). The MWAC trap's efficiency varied between 3-51% (rounded data), while that of the WAST trap ranged between 13–142%. The efficiency of the WAST trapping device proved to be three times more on average than that of the MWAC trapping device when sampling loamy soils. The median calculated for the efficiency values is 27% for the MWAC, 87% for the WAST. The trapping devices and the tray that served to collect sediments transported by saltation collected the most sediment from the study experiments A3, A4, and A8. We removed the results of the A4 experiment from the efficiency investigations because, during the A4 experiment series, which is characterised by the highest average wind speed (16.7 m/s), the estimated values of soil loss provided by the data of the trapping devices exceeded several times the estimated values of soil loss provided by the data of the platform scales. *Figure 4.* represents how the amount of sediment collected by the traps changes with height. It also shows that the result of this particular experiment is high. It differs significantly from the other experiment results of both types of traps (*Fig. 4*). Three reasons cause the difference: 1) high wind velocity, 2) the topsoil of study parcel A4 had the highest humus content value (2.8%), 3) it was the last wind blowing event of the first study day, and, due to the hot July temperature, soil moisture content decreased to 3.7% by the afternoon (soil moisture content was 5.6% in the morning) when this particular wind blowing event took place.

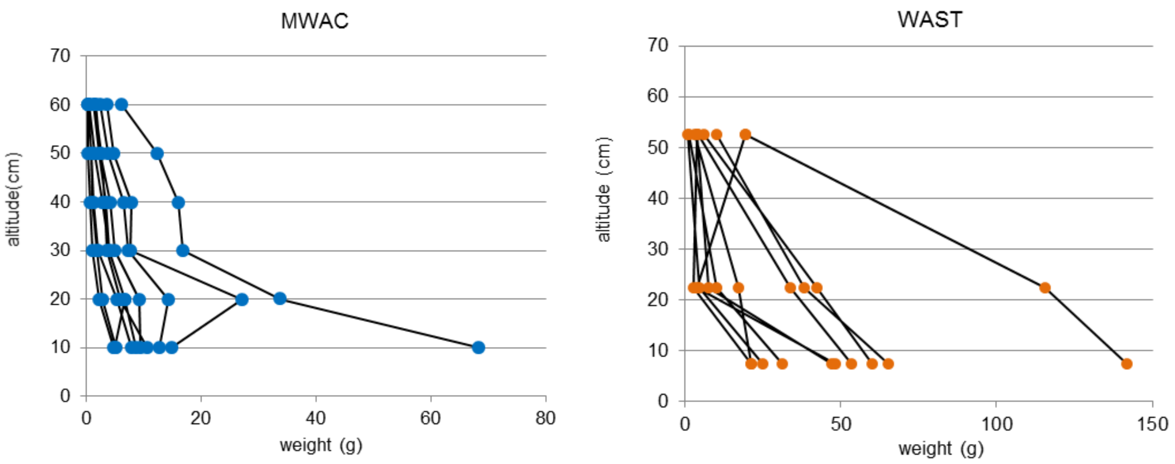

Fig. 4. Changes in the amount of sediment correlating with height as collected by the two traps

Fig. 5 show that when wind speed increases, the amount of trapped sediment material also increases, and the WAST traps react to the rise in wind speed to a greater extent than the MWAC traps. The relationship between the mass of sediment carried by the wind (m) and wind speed (u) is represented by a cubic power function, which is generally the function

$$m = a(u-b)^3,$$

where a 95% confidence level determines the values of a and b. Values of function b represent the average per-minute rates where the particles start moving, in theory. The relationship between the mass of trapped sediment and the cubic function of wind speed is similar to Bagnold's formula (1941) and the modified O'Brien-Rindlaub formula (Dong et al., 2003, O'Brien & Rindlaub 1936). Critical starting velocity values recorded during the ten parallel wind blowing experiments ranged from 6.5 to 9.0 m/s, which were described well by the b value of the modified O'Brien-Rindlaub formula representing the power function set for the mass values of the sediment collected by the WAST.

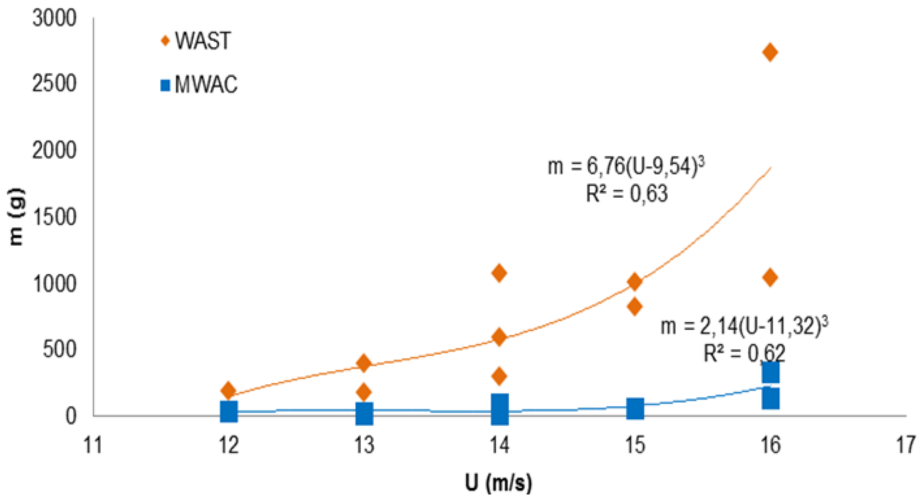

Fig. 5. The mass - wind velocity diagrams of the MWAC and the WAST traps

When height increases, the WAST device traps decreasing amounts of sediment, as described in literature concerning the vertical profile of trapped sediment (Bouza et al. 2011), when height increases, there is an exponential decrease (the fitting of the exponential function varied between r^2: 0.7–0.9) (Fig. 5).

We started patenting the WAST trap in 2014. The process ended on January 21, 2020. Patent Application No. 9530/19. (see detailed data among puplications).

3. The annual wind erosion vulnerability of the soils of Csongrad County

The study site of our research is located in the surroundings of Szeged. The diverse soil types of the Southern Great Plain provide a great opportunity to study wind erosion sensitivity. The main reason for selecting the nearly forty study sites was the possibility to collect representative samples of the diverse soils in the area. A 12 m long, 0.7 m wide and 0.75 m high wind tunnel was used for the experiment series. During wind tunnel experiments, a 40x50 cm (0.2 m2) and 5 cm deep sample holder was placed in the wind tunnel, and the soil samples collected in the study sites were put there. In order to determine the critical launching speed of soils, we measured wind speed 10 cm above the surface.

Weather data were obtained by processing the SYNOP telegrams from 2000 to 2019 of the Szeged Meteorological Station (WMO index: 12982). In our study, we followed the same procedure as in the case of the WEQ model, and we selected wind erosion-critical periods from the weather data. For this reason, we only processed data of March and April, as the soils of the arable lands of our study sites are the most vulnerable (i.e. they have the weakest protection) in this period.

By analyzing the weather and wind erosion data together, we estimated the annual wind erosion vulnerability of the soils around Szeged. In order to determine aerodynamic roughness, wind velocity profiles were measured for all soil types by measuring wind velocity values at 4 heights (5; 10; 15; 20 centimeters) above the soil surface. The higher the aerodynamic roughness of a certain soil surface is, the more it brakes and slows the speed of the wind moving above it. The aerodynamic roughness was calculated from the logarithmic curve of the obtained wind profile using a regression equation (ZHANG et al., 2004). Subsequently, based on the agrotopographic database, we selected those wind erosion events which were characterized by speeds greater than the critical launching speed for each physical type. Finally, by using data obtained from SYNOP telegrams, we determined the wind erosion events. A wind erosion event is a period of time that begins when the average hourly wind speed (10-minute average speed measured at the height of 10 meters) of the SYNOP telegrams exceeds the critical soil surface launching speed, and it lasts until wind speeds are above the average value. Wind erosion exposure was characterized by the number and length of wind erosion events.

3.1. Critical launching speed and aerodynamic roughness of soil surfaces

The value of aerodynamic roughness determined for the samples is in the same order of magnitude as the results of Zhang et al. (2004) and our previous field research results (FARSANG et al., 2013a, 2013b). With the increase of critical launching speed and soil texture values (Arany yarn test), aerodynamic roughness also increases, the relationship between aerodynamic roughness and critical launching speed is similar to that of mentioned in academic literature. (FRYREAR, SKIDMORE, 1985). Critical launching speed values increase with the values of the Arany yarn test (texture), Tatárvári and Négyesi also pointed out the similar relationship between the two values (2013).

In order to determine wind erosion exposure, we first determined how long soil surfaces are exposed to wind erosion and how many times a wind erosion event occurs. After that, areas affected by wind erosion were located.

By analyzing the temporal values of wind erosion exposure, it can be stated that the number of wind erosion events and hours on sandy soils is one order of magnitude higher than on sandy loam, loam or clay loam soils. These values are related to the increase of critical launching speed values of soils, which is consistent with our previous field measurements and academic literature data. (LÓKI, 2001). The average annual number of wind erosion events over the 20 years studied is more than 16, and the average length of one such event is 3 hours. The same values for sandy loam, loam and clay loam soils are 2 events and 1.4 hours/year respectively, and 0.4 and 1 hour/year respectively. Based on these results, it can be stated that in the case of clay loam soils a significant wind erosion event can be expected only every 3 years.

By combining the available soil texture and critical launching speed data in the affected areas, a critical launching speed sensitivity map for each soil surface was prepared for the soils of Csongrád County. The wind erosion event values for Csongrad County complement well the wind erosion risk maps prepared in previous researches (LÓKI, 2001; MEZŐSI et al. , 2015) . Our result maps do not only indicate the degree of wind erosion risk of different soil surfaces, but they also indicate the number of expected annual wind erosion events in each area. In order to determine a more precise area risk, we took into account the land cover of the areas by using the map of Corine Land Cover 50 (CLC50). Based on this, more than half of the area of Csongrád County has a high risk of wind erosion (57.5%) (Fig. 6.). This value can be refined by taking into account wind erosion exposure and other data of areas exposed to wind erosion, which means that on an annual basis 37.5% of the areas are exposed to wind erosion and 20% of the areas is expected to be affected by wind erosion every three years (bartus et al., 2017).

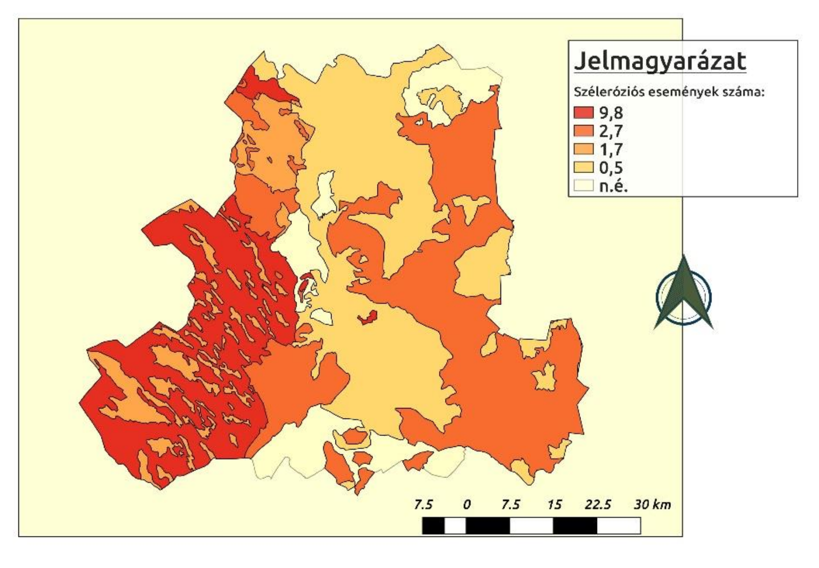

Fig.6. Annual number of wind erosion events in Csongrád county (2000-2016)

4. The potential risks of agricultural dust in urban environments, he displacement of pesticide residues by wind

Due to climate change, intensive soil use, inadequate agricultural cultivation and agrotechnics lead to an increase in soil deflation sensitivity. The problem is not only the physical degradation of the nutrient rich topsoil, but also the removal of toxic elements from the affected areas, bound to the moving soil particles. Deflation can become a major human health problem, especially for the inhabitants of settlements, where arable land of intensive cultivation is dominant. The airborne particles that are released by the wind have a serious impact on human and animal health. Due to their size, they can easily reach the bronchial tube by inhalation, causing serious respiratory diseases. The aim of the research was to evaluate the potential risks of agricultural dusts with using a portable wind tunnel.

The study area is located near Szeged. Chernozem soils are characteristic of the area. The wind tunnel studies were conducted in the sum ing soil particals (sediments) were trapped at various heights (5-10 cm, 20-25 cm and 50-55 cm) and the pesticide concentrates were measured. We examined loam and sandy soil. Before the experiments, a portion of the sample area was treated with chlorpyrifos and pendimethalin. A control area was also selected. In 2017-2019, a total of 42 wind event experiments were conducted by examining the topsoil samples (pH (H2O)), $CaCO_3$, Arany yarn test, OM %, total salt content, humidity and pendimethalin and chlorpyrifos contents in the rolling and suspended soil fractions. Pesticide measurements were performed by GC-MS. After that, the enrichment ratios (ER) of concentrations in the rolling samples were calculated (1). If the values of the enrichment factors are around 1 or less, the test component will not be enriched in the erosion-displaced sediment.

ER = Element concentrationsediment/Element concentraionsoil (1)

The statistical tests were carried out by SPSS software (IBM SPSS Statistics, Version 24). The Kolmogorov-Smirnov test was used to test the normality of all data. Spearman’s coefficient was used for the non-parametric correlation analysis.

In 2017, we performed 13 in-situ wind tunnel experiments. Before the experimental run part of the sampling area were treated with chlorpyrifos. Ten experimental run, were performed on the sprayed area and three on the control area. The chlorpyrifos content of the treated topsoil varied between 0.004 and 0.09 mgkg-1. In the collected rolling soil fraction the concentration of chlorpyrifos varied between 0.014 and 0.096 mgkg-1. The enrichment factors were calculated. These values ranged from 0.61 to 6. The average of the enrichment values of chlorpyrifos were 3.4.

In 2018, we performed 15 wind tunnel experiments. Before the experimental run part of the sampling area were treated with chlorpyrifos and pendimethalin. Nine experimental run were performed on the sprayed area and six on the control area. The chlorpyrifos content of the treated topsoil varied between 0.01 and 0.1 mgkg-1. In the collected rolling soil fraction the concentration of chlorpyrifos value ranged from 0.05 to 0.3 mgkg-1. The enrichment factors were calculated. These values ranged from 0.6 to 7. The mean value of the enrichment were 2.9. The pendimethalin concentration of the treated topsoil varied between 0.01 and 0.8 mgkg-1. In the collected rolling soil fraction the concentration of pendimethalin varied between 0.07 and 2.1 mgkg-1. The enrichment factors were calculated. These values ranged from 0.7 to 52,5.

The average of the enrichment values of pendimethalin were 13.7. The results of the measurements showed that the ER of pendimethalin is much higher in the rolled fraction than ER of chlorpyrifos.

In the summer of 2019, we performed 14 ex-situ wind tunnel experiments on loam texture soil and 4 on sandy texture soil. We put on the ground a plastic sheet and an approximately 5 cm thin layer of the soil was spread on it. The soil was then sprayed with the prepared solution: pendimethalin solution was prepared by diluting Sharpen 330 EC herbicide that contains 330 g/l pendimethalin in water, chlorpyrifos solution was prepared by diluting Alligator™ insecticide that contains 480 g/l chlorpyrifos in water. The prepared soil was measured in a wind tunnel. Each deflation experiments were carried with a duration of 10 minutes and approximately 12 ms-1 wind speed on the loam soil and 6 ms-1 on the sandy soil. Samples were taken from the topsoil (0-5 cm) before and after the wind event at three different places in the wind tunnel. After each run the rolling soil samples (sediments) were collected at the end of the wind tunnel using a clean brush and the suspended particles were collected by WAST (Wet Active Sediment Trap). Trap inlets are 5 10 cm, 20 25 cm, 50 55 cm high. WAST samples were stored refrigerated in a borosilicate sample holder until laboratory measurement.

The chlorpyrifos content of the treated loam texture soil varied between 2.03 and 23.03 mgkg-1. In the collected rolling soil fraction the concentration of chlorpyrifos value ranged from 10.58 to 104.90 mgkg-1. The enrichment factors were calculated. These values ranged from 0.88 to 20.85. The mean value of the enrichment factores were 4.98. The chlorpyrifos content of the treated sandy texture soil varied between 7.05 and 13.93 mgkg-1. In the collected rolling soil fraction the concentration of chlorpyrifos value ranged from 15.01 to 19.09 mgkg-1. The values of enrichment factors ranged from 1.37 to 2.36. The mean value of the enrichment factores were 1.95. In the case of chlorpyrifos-treated soil, the enrichment factor did not reach 1 in any of the suspended fraction (Fig 7.).

The pendimethalin concentration of the treated loam texture topsoil varied between 1.30 and 33.75 mgkg-1. In the collected rolling soil fraction the concentration of pendimethalin varied between 13.60 and 358.60 mgkg-1. In the rolling particals the results of enrichment factors ranged from 1.51 to 42.74. The average of the enrichment values of pendimethalin were 9.01 in the samples of the rolling fractions. The avarage of the enrichment factor was greater than 1 at 5-10 cm too. In the case of sandy texture soil, the enrichment factor was as follows: in the rolling particals the mean values were 2.05 (Fig. 8.). The results of the measurements showed that the ER of pendimethalin is much higher in the rolled fraction than ER of chlorpyrifos.

All statistical analyses were performed in SPSS 22. The Kolmogorov-Smirnov test was used to test the normality of all data. Because none of our data is normally distributed Spearman’s correlation was computed to assess the relationship between pesticides contents. The statistical tests revealed a strong significant relationship between the pesticide’s enrichment factors and the pesticides concentration of the topsoil and between pendimethalin ER chlorpyrifos ER as well (p<0,01).

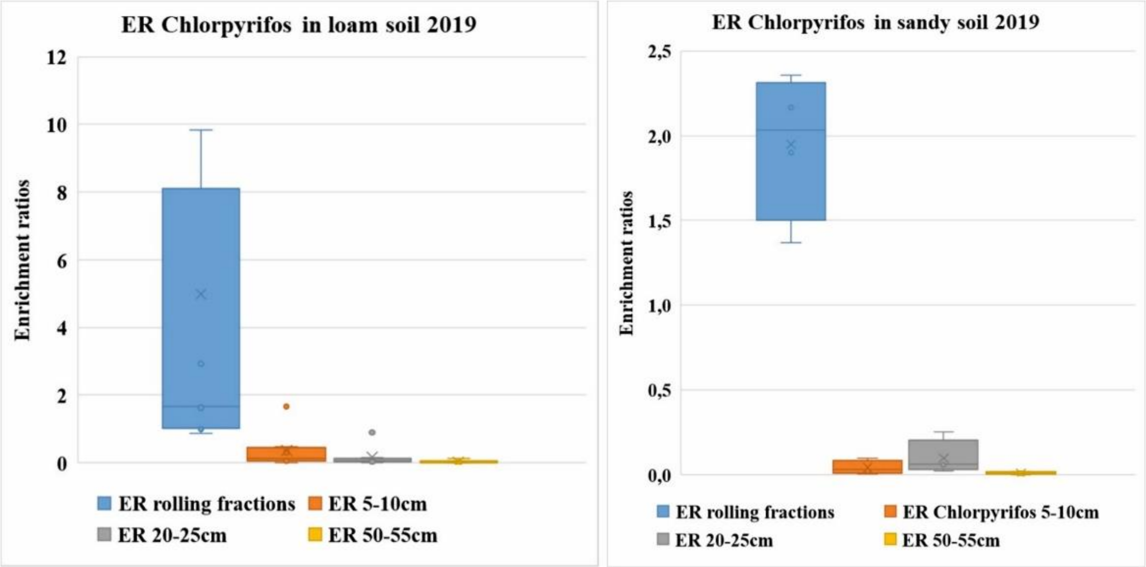

Fig. 7. Enrichment of chlorpyrifos in texture of loam and sandy soil

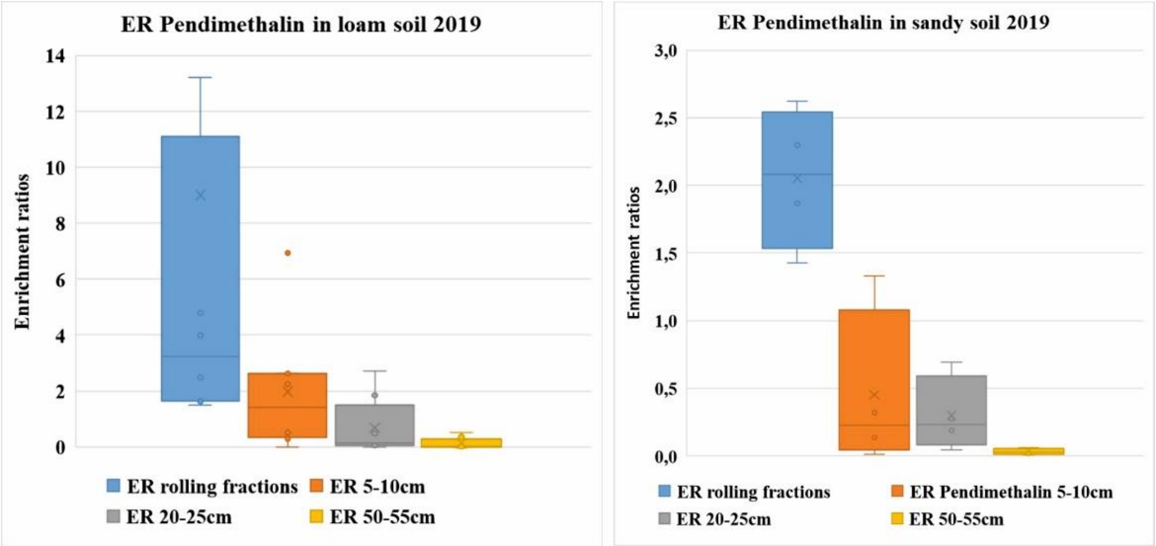

Fig. 8. Enrichment of pendimethalin in texture of loam and sandy soil

5. Conclusions

Due to climate change, the extent of the risk of soil deflation in Hungary will increase in the coming decades. In the course of our research, we sought an answer to the question of how basic soil properties affect the critical starting speed and how much deflation is currently threatened by the soils of the Southern Great Plain, how much nutrients and pesticides leave the areas.

We have developed and patened a new sediment trap (WAST), which is suitable for wind erosion field measurements and can efficiently pattern the movement of finer-textured loam soils in addition to sand. The developed trap is an active horizontal trap; it samples at different heights; it is an isokinetic, wet trap with good efficiency at any standard particle size ranges.

By combining the available soil texture and critical launching speed data in the affected areas, a critical launching speed sensitivity map for each soil surface was prepared for the soils of Csongrád County. Our result maps do not only indicate the degree of wind erosion risk of different soil surfaces, but they also indicate the number of expected annual wind erosion events in each area. Based on this, more than half of the area of Csongrád County has a high risk of wind erosion (57.5%).

During our research, wind tunnel measurements were performed on Chernozem and Arenosol soils in Southern Great Plain of Hungary to investigate the pesticide contents of wind-eroded sediment. The measurements showed that the enrichment of chlorpyrifos and pendimethalin could be detected in the rolling fraction. As shown by our study, airborne particulates can be contaminated with chlorpyrifos and pendimethalin too.

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