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Research
Araştırma

THE SPATIAL VARIATION IN WIND-BLOWN SEDIMENT TRANSPORT IN SMALL SCALES IN KARAPINAR-TURKEY

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Abstract: The wind erosion in Great Konya Basin is one of significant land degradation factors. The rampant grazing and agriculture with no soil conservation measures in Karapınar region accelerated the wind erosion process. This research was conducted in Karapınar region. Two measurement plots were chosen: One of them is located at the agricultural area and the other is located at the protected steppe. 25 MWAC (Modified Wilson and Cooke) traps were placed for every measurement plot of 60 x 60 m^2 area. A full meteorological station was installed to collect climatologic data necessary for modeling the wind erosion. 5 wind events were observed in March 2009. The maximum wind speed was recorded as 17.56 ms^{-1} on the 6th of March 2009. The results showed that while the mass transport amount in the agricultural area was high (maximum amount was 621 Kgm^{-1}), there was no considerable sediment collected/eroded at the plot of the protected steppe. Therefore, analyses for the spatial distribution were restricted to the plot of agricultural area. It is also determined that the most erosive winds come from the S, SSW and SSE. In conclusion, results indicated that the mass flux has a high variation over the measurement plot. This dictated that additional measurements are required to have clear view on the wind erosion distribution in Karapınar region and on the interactions between wind erosion and land use.
Key Words: Wind erosion; Mass transport; Spatial variation

1. INTRODUCTION

Wind erosion is one of the most serious environmental problems in the world (Stroosnijder, 2007). It causes a decrease in ecosystem service to a point at which land yields become deficient to be an essential subsistence (MEA, 2005). The arid, semi-arid and dry sub-humid regions are the most sensitive areas to wind erosion (Stroosnijder, 2007). In arid and semi-arid regions wind erosion is one of the dominant degrading processes (Lal, 1990). Wind erosion occurs when the soil is dry, bare and loose (Sterk and Stein, 1997). It causes the loss of fertile topsoils, and has a negative effect on human health and agricultural production (Sterk et al., 1996). The Great Konya Basin is in the Central Anatolian Plateau at latitude of 37º and between longitudes of 33º and 35º east. The basin covers about 1 million hectares and surrounded by hills and mountains foreclosing considerable drainage out of the basin (Meester, 1971). Several periods of moving sand dunes and serious wind erosion events in the Great Konya Basin at central Anatolia were detected during the Pleistocene and the Holocene (Rognon, 1994). Selected as a research site, Karapınar is located in the Great Konya Basin of south central Anatolia. Threatening the town of Karapınar in 1960s the moving sand dunes closed the Konya - Adana main road several times and caused several tragic accidents on that road (Dogan and Kuzucuoglu, 1993; Gill, 1996). Moreover, the serious wind erosion at that region decreased the productivity of the agricultural lands (Akca, 1998). These hard conditions persuade many families to leave the region looking for better conditions for life (Kuzucuoglu et al., 1998). Since the Turkish government at that time was very aware of the serious problem in Karapınar region, they established the research station in Karapınar in 1962. This step was followed by initiating the land protection project giving successful results in stabilizing moving sand dunes (Akca, 1998). Currently, the land of the project has obviously developed vegetation cover especially when compared to the surrounding area. Resultantly, the wind erosion in research project area is much lower than the total soil loss from grazing and agricultural fields environing it. These productive conditions inside project lands caused less salinity problem deriving to a higher organic matter proved by (Akca, 1998). Indicating that movement of sand dunes has been accelerated recently, in 1998, Kuzucuoglu related these new conditions to the land use out of the protected area. That can be proved easily by noticing the huge erosional contrast between the protected area and the pastures around it (Kuzucuoglu et al., 1998). The objectives of this research are to determine the relation between land use and wind erosion intensity and to analyze the spatial variation of wind – blown sediment transport in small scales in Karapınar region under different types of land use.

2. MATERIAL AND METHODS

2.1. Study area

Located in the Great Konya Basin of south central Anatolia, Karapınar is known for its desertification problems. Dust storms are common phenomenon in this region (Desire Konya, 2008). With an annual precipitation of 275 mm and an average daily temperature of 11.5°C, having total of 2675 km^2, Karapınar has the driest climate in Turkey. About 45 % of the precipitation falls between December and March, and about 72% of the wind erosion events occur between December and May (Kuzucuoglu et al., 1998). The erosive wind comes from the south-southwest and is dominant from January to March with velocities that can exceed 25 m s^{-1} (Desire Konya, 2008). Project to fix and control the moving sand dunes in Karapınar had been initiated in 1960s by Turkish government at that time. Whereas wind erosion inside the project area is at minimal level, lands out project borders are still suffering from wind erosion and sand movements. Especially in the last decades, the region suffers from more intensive wind erosion problem due to reduced rainfall under influence of climate change and the salinization of the soils due to irrigation with ground water.

2.2. Choosing The Measurements Locations

Depending on Land Sat satellite images which were taken on 20th of March 2008, we classified the study area in Konya-Karapınar considering vegetation cover and pattern. In this classification we used the Normalized Difference Vegetation Index (NDVI) (Eq. [1]) to categorize the region into 5 vegetation covers classes. Table 1 shows the 5 main vegetation cover classes with their NDVI values.

$$NDVI = (NIR - red)/(NIR + red)$$

where, NIR = Near Infrared Band value , R = Red Band value, recorded by the satellite sensor.

The land use data for Konya were taken from the agricultural ministry in Turkey. Then the land use of Karapınar region was subtracted and mapped.

2.3. Description of The Measurement Conditions

The measurements were started at the fields of Karapınar Station of the Konya Soil and Water Resources Research Institute. The total area of the project lands is about 88 Km^2. It has been under control by the Turkish government since 1960s because of the serious wind erosion problem in the area. Currently, the land use in these fields includes agriculture (mainly cereals and clover), steppe with a low vegetation cover dispersed, steppe with a low vegetation cover grouped and a small fields with trees named as "forest". Our measurements took place at two locations nearby Latif Cingozu and Ornek Tepe.

2.3.1. Latif Cingozu Location

Measurements were started at fields under cultivation considering them the most sensitive places to wind erosion. Therefore, a representative place of these fields locally called as Latif Cingozu was chosen. Thereupon, we installed our equipments to take detail measurements of wind erosion. The top 5 cm of the soil in the selected area contains a high percentage of sand (around 80 - 90%) (Demiryurek, 2007). This area was planted with Russian olive, Acacia and ash trees last year. However, the trees have no protection effect on the soil surface because they are only about 30 cm in height and there is no any leaf existence at the time of these measurements. At the beginning of measurements, there was a very short and spread grass cover which also has a very limited protective effect on the land surface against the wind erosion process. In fact, the residue of some grasses that can be found on the soil surface played the most important role in protecting the soil surface from the erosive wind. Before wind events, generally the soil surface was dry, however the soil moisture determined by TDR (Time Domain Reflectometer) at 3-4 cm for the same period was about 0.22 - 0.23 %. Moreover, the amount of loose materials determined by soft painting brush on the top-soil was high. On the west border of the measurement location the land use was similar to that inside the plot. In the south border there was a wheat field with almost 20 cm height of the plants at the time of measurements. In all other directions the lands were covered with sparsely distributed vegetation cover. It was clear that the wheat and the partially covered areas were well-protected and had uneasily erodible soil surface. Conclusively, the sediment collected during the wind erosion events came only from the disturbed field [1] by plowing for cultivation with no plant cover protection. Figure 1 illustrates the measurement plot of Latif Cingozu and environing area.

2.3.2. Ornek Tepe Location

This location was the second place for our measurements. It was chosen in a protected steppe in order to observe the effect of land use in the region. This place has sandy soil (texturally almost 70 - 90% of sand content). The soil surface moisture was similar to that of the first location. The vegetation which consists of *astragalus, Artemisia, Festuca ovina* covers almost 60 – 80% of the soil surface. The surrounding area was exactly the same as the chosen plot. Figure 2 illustrates the measurement plot of Ornek Tepe and surrounding area.

2.4. The Set up of Catchers and Meteorological Station

2.4.1. Meteorological equipments

5 anemometers were attached to a holder bar at the heights of 0.50, 1.20, 2.20, 3.10 and 4.00 m to measure the wind speeds. A wind vane was located at the height of 4.00 m and for air temperature and relative humidity a special sensor was placed at the height of 3.70 m. Soil moisture was measured using TDR with measuring pins horizontally inserted at a depth of 3-5 cm top soil. Rainfall was measured using a tipping bucket which was set up at a height of 1 m at a distance of approximately 5 m from the holder bar. To determine the starting time and duration of saltation a saltiphone (Spaan and van den Abeele, 1991) was used. All the equipments were connected to data logger (model of CR1000). Figure 3 shows the above mentioned equipments in addition to a solar panel that provides continuous electricity to the data logger. The meteorological data were collected with intervals of 5 minutes, which means that there were 288 values per day for every meteorological factor.

Table 1. The main vegetation cover classes in Karapınar region based on the NDVI analysis

Classes	NDVI values
Very low vegetation cover dispersed (VLVC.D)	From – 0.8125 to – 0.2692
Low vegetation cover dispersed (LVC.D)	From – 0.2692 to – 0.1989
Low vegetation cover grouped (LVC.G)	From – 0.1989 to – 0.0966
Medium vegetation cover dispersed (MVC.D)	From -0.0966 to 0.0758
Medium vegetation cover grouped (MVC.G)	From 0.0758 to 0.8172

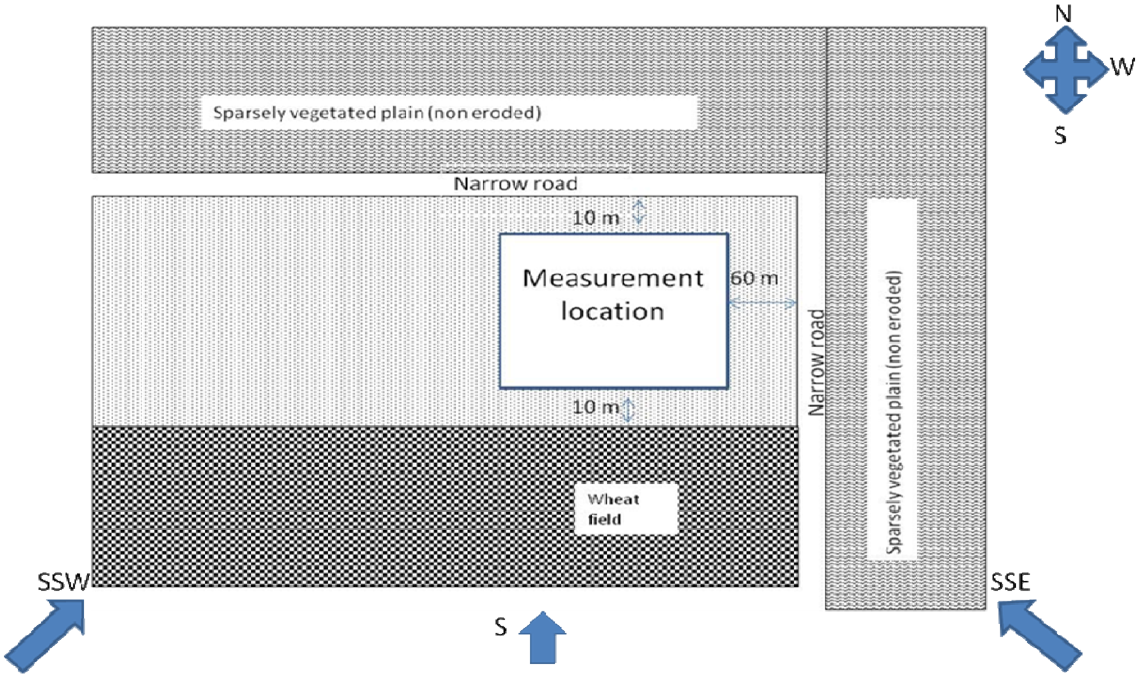

Figure 1. The Latif Cingozu location and surrounding area

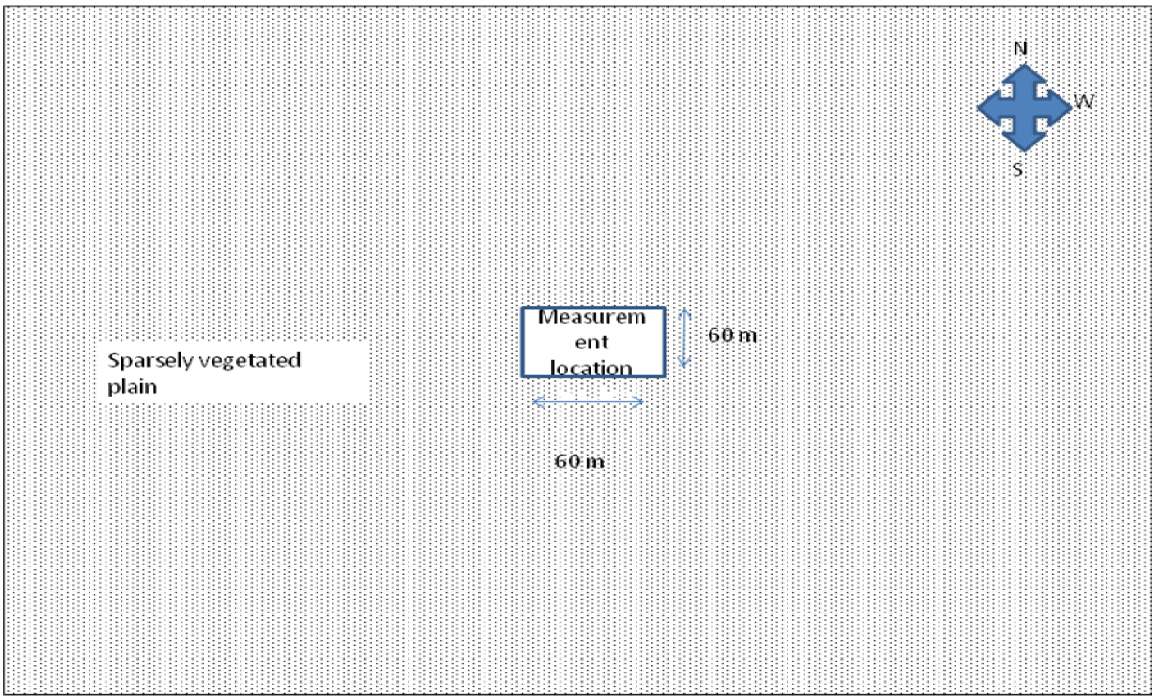

Figure 2. The Ornek Tepe location and surrounding area

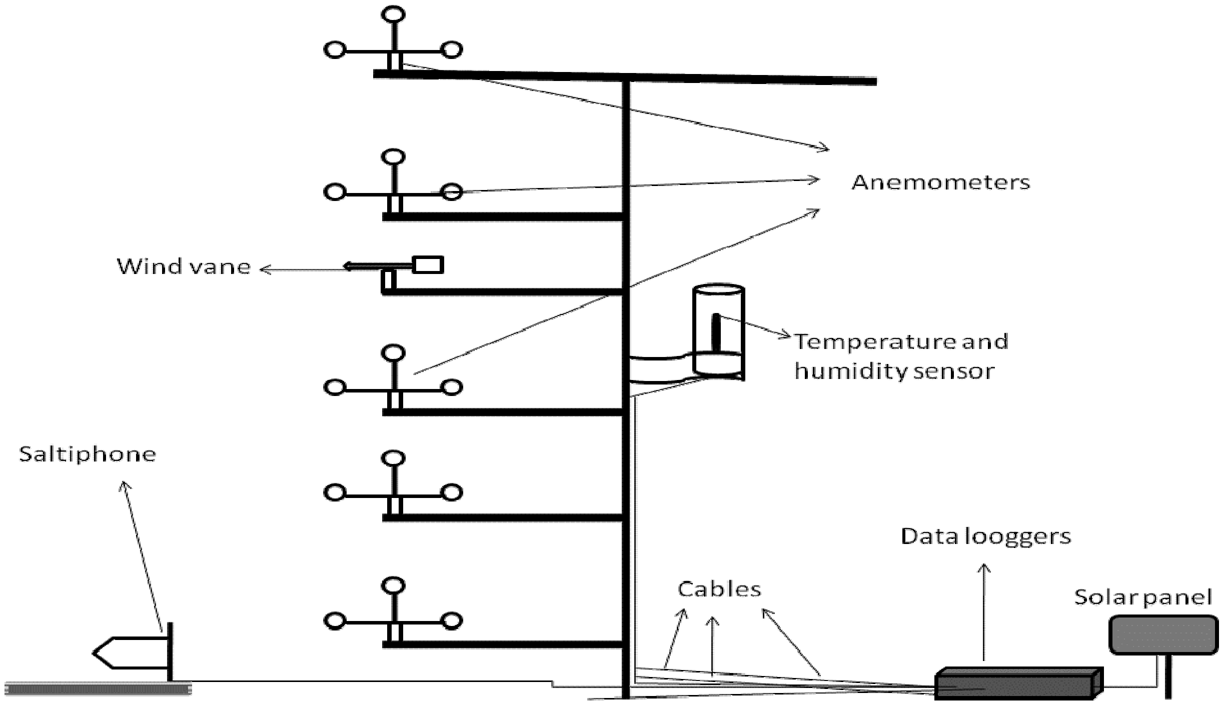

Figure 3. The meteorological equipments installed in the measurements locations in Karapınar – Turkey

2.4.2. Sediment Catchers

A total of 25 MWAC (Wilson and Cooke, 1980) catchers were placed in the field to catch the eroded sediment. To every catcher 5 bottles were attached at different heights (from 0.05 to 0.50 m). The set-up of the catchers was selected after analyzing the wind data. Despite the most erosive winds come from the south and southwest there are also high speed winds coming from other directions and because of that we opted for the setup shown in Figure 4. This setup allows us to get transect of measurements from each wind direction necessary to understand the mass flux distribution over the measurement plot.

2.5. The Calculation of Mass Transport

After every wind event, we weighed the bottles full with the known empty weight to obtain the trapped amount of the wind-blown sediment transport. Taking into account the area of inlet of the Wilson and Cooke bottles (0.0000503 m^2) and the time of the wind events during one week (from saltiphone data), the total mass transport in ($g/m^2/s$) was calculated. Then MathCAD software was used for fitting the Eq. [2] which was developed by Sterk and Raats in 1996 (Sterk, 1996) to make calculation of the total mass transport of wind erosion process. The fit was from 0 to 1 m since the highest bottle was attached to the holder at around 1 m (Eq. [3]).

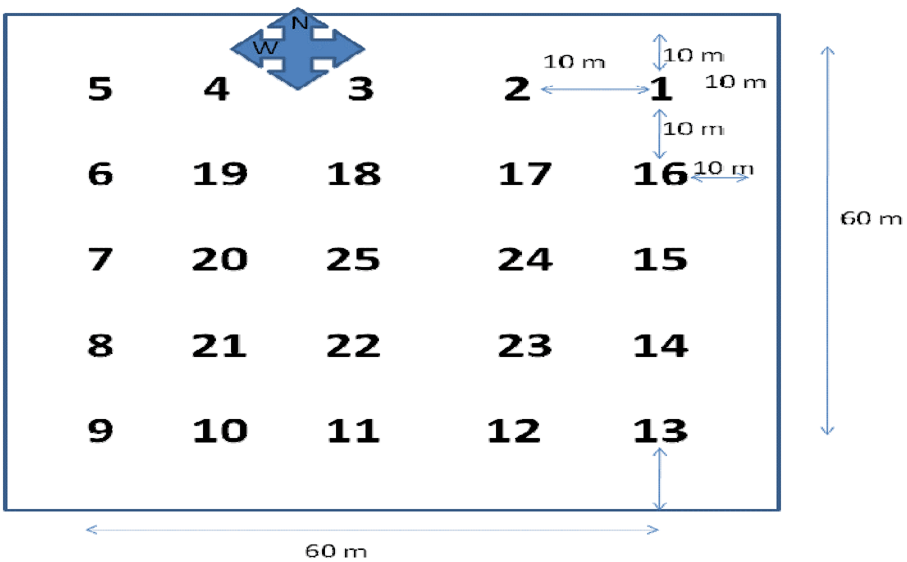

Figure 4 The setup of the 25 MWAC catchers in the measurement plot in Karapınar - Turkey

$$q(z) = a(z+1)^{-b} + c\exp(-\frac{z}{\beta}) \qquad [2]$$

where q(z) is mass flux (g. m^{-2} .s^{-1}) at height (z) and a, b, c and β are the regression coefficients of the model

$$Q_z = \int_0^h q(z)\partial z \qquad [3]$$

where, Q_z (Kg/m/s) is the total mass flux for every second at 1 m width, h is the maximum transport height which was in our measurements (1 m)

The total mass flux (Q) was calculated using the equation 4

$$Q = (Q_z \times t \times 100)/ef \qquad [4]$$

where Q is the total mass transport (Kg/m) , ef is the efficiency of MWAC catcher (4.9%) and

t is the total time of wind events (second).

2.6. Mapping The Mass Transport Over The Measurement Plot

Depending on the results taken from points of catcher locations, the geo-statistical program GeoStatistics for the Environmental Sciences software (GS+) was used to handle the spatial distribution of the mass flux transport over the measurement plots. Coordinates of the catcher locations were taken by GPS (Global Positioning System). Then using the final results of total mass transport (Q) for every catcher, the spatial distribution over the measurements plot was derived.

3. RESULTS AND DISCUSSION

3.1. Collected Data

The full meteorological data (by meteorological station), saltating time (by Saltiphone) and soil moisture (by TDR) were collected daily with intervals of 5 minutes. In Figures 5 thru 8 below plots of collected data against the time for the period from 1th thru 7th of March 2009 are illustrated. The software LOGGER-NET (Campbell Scientific's full-featured software) was used to prepare these figures. Figure 5 shows the Saltiphone data (numbers of saltating particles) against time (intervals of 12 hours). In this figure, whereas the number of particles recorded by the Saltiphone (maximum of 17500) was very high during the wind events of 6 and 7 March, for the rest the period this number was 0. Figure 6 shows the wind speed at 4 m height where it's easy to notice that the wind speed reaches its maximum values at the wind events of 6 and 7 March. Showing that the higher temperature was recorded during the wind events of 6 and 7 March and the wide differences in temperature of the day and night (maximum of these differences was 16º C degrees). Demonstrating that the soil moisture reached its minimum values at the time of wind events of 6 and 7 March, Figure 8 shows the soil moisture.

From Figures 5 and 6, it can be seen that the numbers recoded by saltiphone and the values of wind speed are not exactly parallel. For instance, whereas a high wind speeds (up to 9.5 m/s) recorded at the 1th of March, the saltiphone did not record any numbers of particles. The reason behind this contrast can be explained by the high moisture of the top soil at the 1th of March. These wet conditions attached soil particles to each other thus prevented them from blowing by wind. However, when the surface became dry (at 6 &7 March) the numbers of particles recorded by saltiphone and wind speed were exactly parallel. That is because with dry surface, easily erodible materials were present on the top soil. As it can be seen from the Figure 7, the temperature shows wide differences between the day and night. For example on 2th of March the difference between the maximum and minimum temperature degrees was 16 degrees.

Looking at soil moisture for period of 1th thru 7th of March illustrated in Figure 8, it can be seen that after the first wind events on 6th of March the soil moisture decreased to its minimum value (0.214 %). That indicated that after eroding of the materials on the top soil the soil moisture sharply decreased. These results can be explained by the increasing of evaporation from the soil surface after the wind events because of the moving of cover protecting soil surface from high evaporation conditions. As a result, the soil moisture plays an important role during the starting of mass transport and after that, the amount of mass transport causes important effects on the soil moisture via increasing of evaporation.

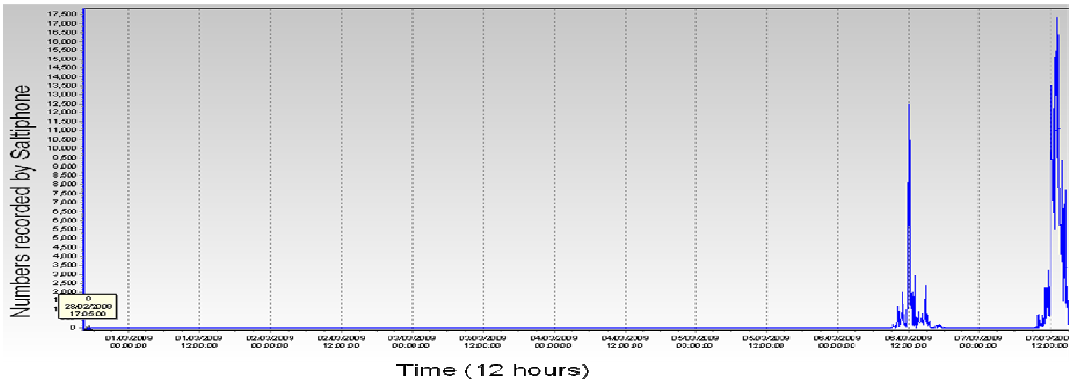

Figure 5. The Saltiphone data from 1 to 7 March 2009

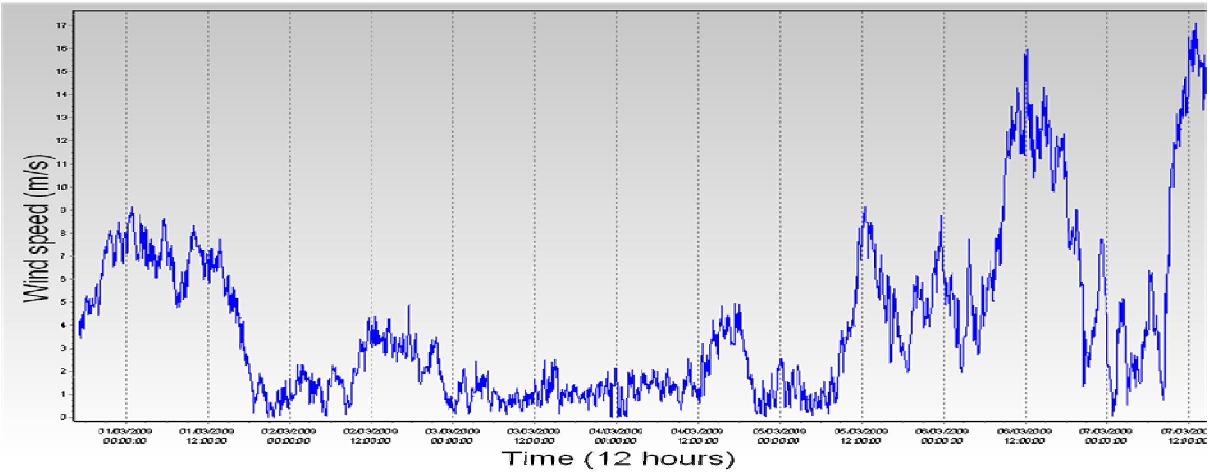

Figure 6. The wind speed at 4 m height from 1 to 7 March 2009

3.2. The Results of Mass Transport

After 5 strong wind events, at the Ornek Tepe measurement location, no sediment was collected despite the high wind speed conditions. That is because the silhouettes of well-developed vegetation protected the soil surface from strong wind by one side and its roots fixed the sand materials in another side preventing them from blowing by wind. However, in the Latif Cingozu location a huge amount of sediment was collected. Table 3 shows the amount of eroded material after the calculation using the Eqs. [2], [3] and [4]. The first two storms almost completely eroded the soil surface. So the amount of erodible materials was low in the following storms. This explained why the collected materials from the 8, 13 and 19 March were relatively low. Figure 9 shows the spatial distribution of mass transport over the measurement location of Latif Cingozu for the wind events of 6, 7 and 8 March 2009.

The results show that the area is very sensitive to wind erosion. It can be noticed easily that the eroded amount of sediment is critical at the points where the conditions are favorable for wind erosion. As seen from the figures above, the highest amount of mass transports is at the north side of the fields. That is because the eroded sediment came from the field of measurements itself and the erosive wind was coming from the south and south west. In different words, there were no erodible fields around the measurement plot. Therefore, following the wind direction erosion started at the southern part of the plot and higher deposition happened at the northern part of it. This significantly revealed the important role of the vegetation cover on the wind erosion process since no erosion happened at the well-vegetated plot. As a conclusion, the results implied the critical importance of land use policy of highly erodible and vulnerable soils such as sandy soils that cover the major part of Karapınar region.

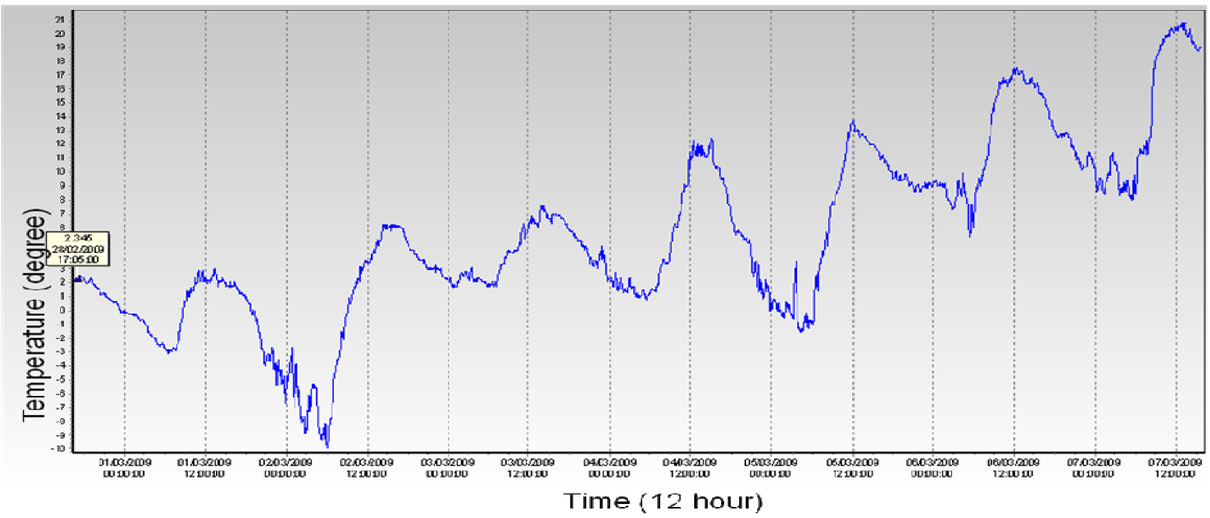

Figure 7. The temperature at the measurements location form 1 to 7 March 2009

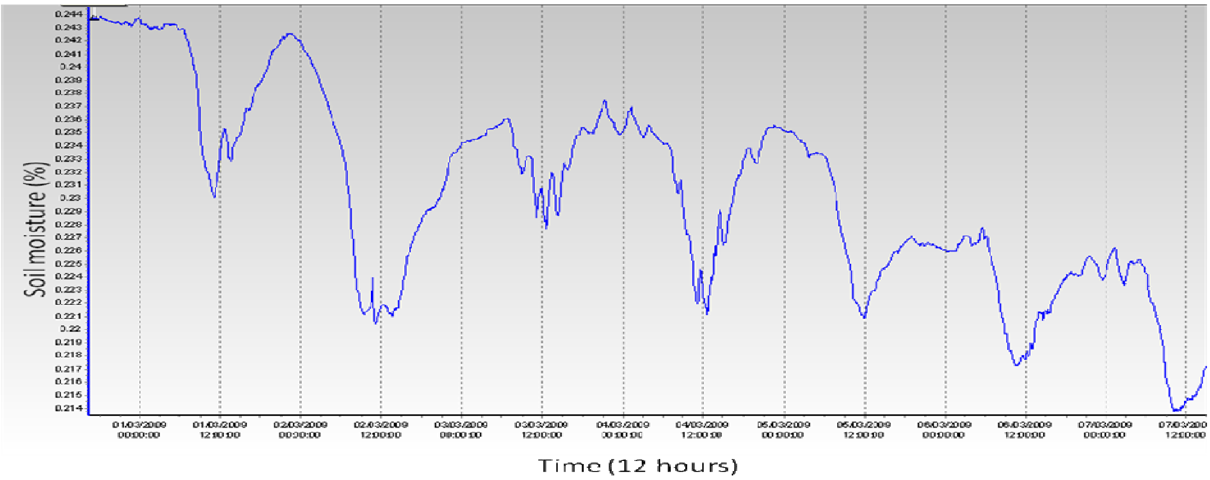

Figure 8. The soil moisture from 1 to 7 March 2009

Table 2. The eroded sediment from every catcher (using MathCAD software for fitting Eq. [2]

Coordinate		Total mass transport at 5 wind events (Kg/m)				
X	Y	06-Mar	07-Mar	08-Mar	13-Mar	19-Mar
545096	417390	362.187	488.8224	12.4245	27.7263	65.664
545086	417390	232.911	614.3904	10.8801	20.2041	69.7248
545076	417390	335.16	621.1872	8.5338	24.5889	76.7016
545066	417390	243.054	408.4416	8.1774	16.1973	50.0688
545056	417390	122.787	290.7936	4.2966	12.3039	32.8968
545056	417380	372.078	484.7616	10.5732	32.2434	85.0608
545056	417370	15.7815	109.4400	0.9999	2.7783	9.1152
545056	417360	2.646	11.4336	0.2376	0.5103	3.7152
545056	417350	1.323	2.1312	0.1584	0.3780	1.3824
545066	417350	2.0475	4.0608	0.3663	0.6615	4.8600
545076	417350	2.2995	5.0688	12.4245	27.7263	65.664
545086	417350	2.709	6.1920	0.3267	0.2835	6.1992
545096	417350	2.0475	6.8832	0.3663	0.3969	7.2144
545096	417360	20.286	81.3600	0.9405	2.9484	5.7024
545096	417370	82.3095	282.9888	1.1682	3.9879	8.5968
545096	417380	144.585	249.1200	2.3958	7.4277	11.5344
545086	417380	143.577	739.0368	9.5337	30.5613	65.4264
545076	417380	184.1175	500.4288	3.8313	15.3657	48.6000
545066	417380	243.747	541.3824	9.9990	39.8412	115.8624
545066	417370	23.4675	93.600	0.5940	3.4587	8.8992
545066	417360	10.1745	8.5824	0.1386	0.9261	5.6376
545076	417360	4.977	21.3408	0.3168	1.9467	6.5664
545086	417360	7.7175	68.1696	0.2871	0.9072	4.6872
545086	417370	22.2075	264.1248	0.9009	3.4209	6.4368
545076	417370	16.4745	207.6768	0.4257	2.4381	5.1408

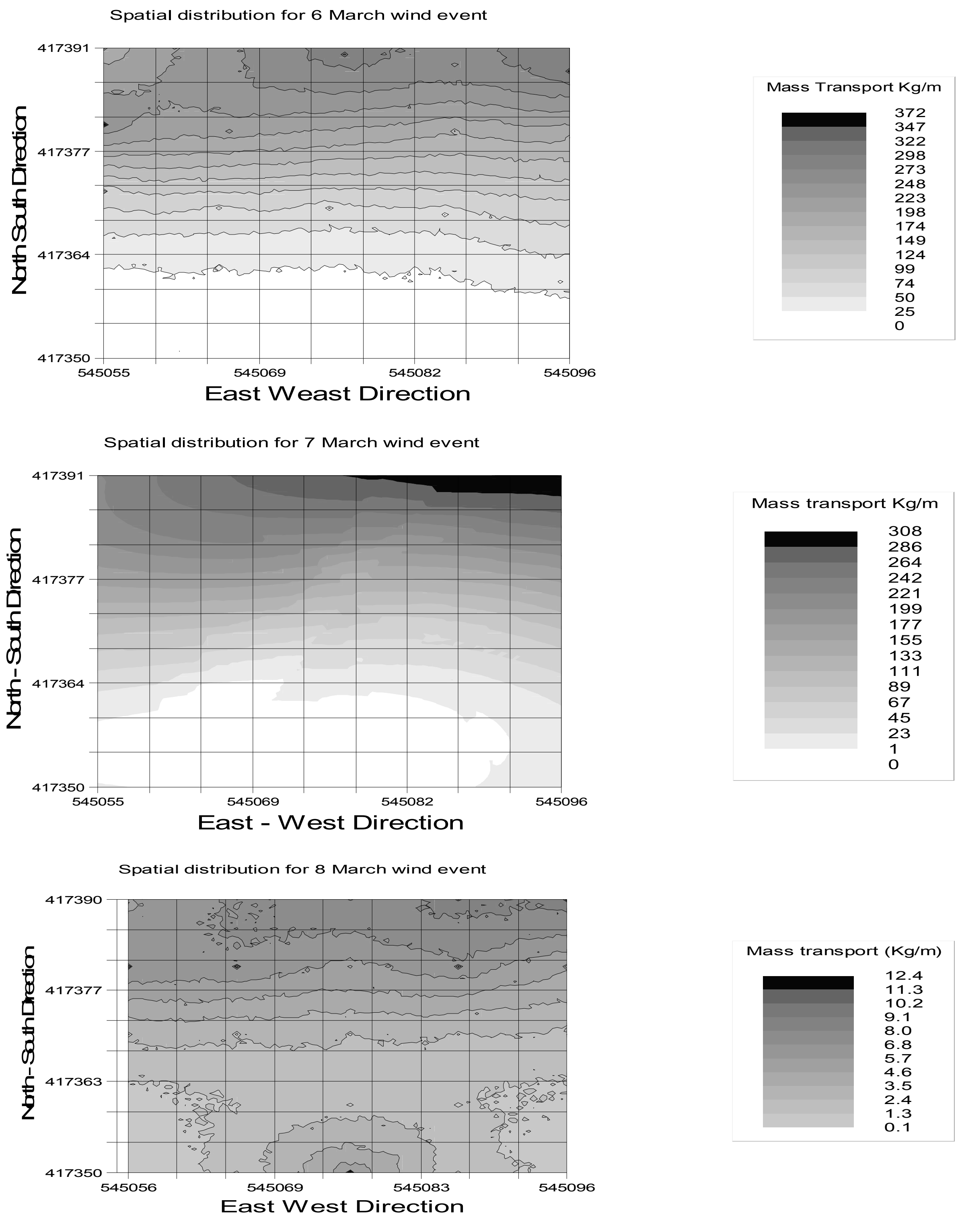

Figure 9. The mass transport distribution over the measurement plot (Kg/m) for wind erosion events of 6, 7 and 8 March 2009 on Latif Cingozu measurement location in Karapınar

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