ASSESSMENT OF HORIZONTAL WIND EROSION AND WIND EROSIVITY AND THEIR INTERRELATIONSHIP IN GOZALHALAG AREA, RIVER NILE STATE, SUDAN

MOTASIM HYDER ABDELWAHAB

Assistant Professor, Faculty of Agriculture Omdurman Islamic University, Omdurman

Abstract- This work was conducted in a bare land in River Nile State to assess the intensity of wind erosion measured by horizontal traps (IWEh) and wind erosivity (Wr) and their interrelationship for two climatic seasons during (August 2008-March 2009, August 2009-March 2010). IWEh was measured monthly in four directions, namely; West (W), North West (NW), North (N), and North East (NE). Wr computed by analyzed mean monthly climatic data. In two seasons the results showed that the IWE and Wr varied in frequency and direction even within the same climatic season. The following results of the first season will be presented as an example, the mean IWEh ranged from 99.9 (W) to 109.8 (NE) with a mean of 104.4 tons ha^{-1} day^{-1}, a standard deviation (STD) of 4.13 tons ha^{-1} day^{-1} and a coefficient of variation (CV) of 4%. The mean IWEh values for the main month effect ranged from 260 (Sept.) to 2.1 (Nov.) with a mean of 104.4 tons ha^{-1} day^{-1}, a STD of 97.49 tons ha^{-1} day^{-1} and a CV of 93.4%. Wr ranged from 0 (Nov., 2008) to 745.7 (Mar. 2009) with a mean of 310.4 $(m/s)^3$ and a CV of 66.7%. Wr decreased in the following order: Mar.> Feb.>Jan.> Oct.>Aug.>Dec.>Sept.>Nov. Wr accounted for about 42% of the variability of the IWE. In two seasons March as an example for winter season gave the higher Wr caused mainly by NW (27.6)%, and N (46.4)% directions respectively. Furthermore the higher percentage contribution of erosive winds in summer season (August) blowing mainly from SW (75% & 65.3%) for first and second season respectively. The IWEh and Wr measured in the second season was much lower than that in the first season; the overall mean IWEh and Wr values in the second season was 44% and 93% of that in the first season respectively, due to the higher monthly variability of Wr. Regression between IWEh and Wr gave a highly significant polynomial relationship, ($P< 0.05$, $r=0.649$ and $R^2=42\%$) and ($P< 0.05$, $r=0.681$ and $R^2=46\%$) for first and second seasons respectively.

Key words- Horizontal wind erosion, wind erosivity, Soil traps, climatic seasons and River Nile State.

I. INTRODUCTION

The River Nile State lies between latitudes 16° and 22° N and longitudes 31° 88′ and 35° 70′ E. It is dominated by hyper–arid and arid climatic zones with mainly two seasons, a hot summer from April to September and cold winter from October to March. The mean annual rainfall is less than 100 mm. and temperatures as high as 49° C is not uncommon in the period extending from April to June. Winds prevail from the north east with a mean maximum speed of 17.6 km/hr (Izzeldin and Ahmed, 2004). Under such climatic conditions wind erosion is the predominant desertification process. Wind erosion is governed by two main factors namely wind erosivity (WE) as an indicator of the ability of the wind energy to transport the detached soil particles and soil or wind erodibility as an indicator of the vulnerability of the soil mass to detachment by wind. Previous wind erosion studies were undertaken included assessment of the intensity of wind erosion (IWE) in El-Obeid (Khairelseid, 1998), north east Al-Butana (Haikal, 2005) and the central part of the Northern State (Abuzied, 2009). Hassan and Mustafa (2011) assessed and mapped wind erodibility of the soils of fifty geo-referenced farms widely spread in the River Nile State. They found that wind erodibility of these farms ranged from 0 to 470.4 tons/ha, their findings approved that the studied agricultural farms lie within the high erodibility class. Biro et al. (2013) analyzed and monitor the land use land cover (LULC) changes using multi-temporal Land sat data for the years 1979, 1989 and 1999 and ASTER data for the year 2009. In addition, efforts were made to discuss the impact of LULC changes on the selected soil properties. Three main LULC types were selected to investigate the properties of soil, namely, cultivated land, fallow land and woodland. Moreover, soil samples were also collected at two depths of surface soil from ten sample plots for each of the LULC type. For these soil samples, various soil properties such as texture, bulk density, organic matter, soil pH, electrical conductivity, sodium adsorption ratio, phosphorous and potassium were analyzed. The results showed that a significant and extensive change of LULC patterns has occurred in the last three decades in the study area. Further, laboratory tests revealed that soil properties were significantly affected by these LULC changes. The change of the physical and chemical properties of the soil may have attributed to the changes in the LULC resulting in land degradation, which in turn has led to a decline in soil productivity. Adam et al. (2014) assessed land degradation in Rawashda, area Gedaref state by using remote sensing, GIS and soil techniques. Abuzied et al. (2015) they assessed the extent of sand movement by saltation and surface creep in central part of the Northern state for three areas, namely Al-Baja, west of Al-Golied town and Al-Khowie using soil trenches. In the first season, the rate of sand movement in all months, excepting July in El-Khowi was significantly ($P < 0.001$) higher than that in Al-Golied. In July the rates were equal. The overall mean monthly rate at El-Khowi was 1.39 m^3/m-w,

which was more than 4-fold that in Al- Golied (0.32 m^3/m-w). In the second season, the mean monthly rate was 1.69 m^3/m-w at El-Khowi, which was 3.8-fold, that of Al- Golied (0.44m^3/m-w) and 5.3-fold that of Al-Baja (0.32m^3/m-w). The lowest sand drift at Al-Baja site was attributed to the fact that Al-Baja land form is a sand sheet plain. The higher sand movement in the second season was due to the higher wind erosivity in that season as indicated by sand storm visibility ≤ 1 km. Abdelwahab and Mustafa (2016) assessed the intensity wind erosion (IWE) in a bare and cultivated land by Lucerne (Medicago sativa) . The IWE was measured monthly in four directions, namely; North East (NE), North (N), North West (NW), and West (W) using vertical (IWEv) and horizontal soil traps (IWEh) in Shaaldeenab village about 17 km south Atbara, River Nile State. They found the variation due to direction was much lower than the monthly; due to the higher monthly variability of wind erosivity. In bare lands, the overall mean IWEh and IWEV in the first season were 1.5 and 1.7 fold those in the second season, respectively. The ratio IWEv/ IWEh of the overall mean values in the first and second seasons was 1.9. The impact of Lucerne cover on soil erosion was colossal. The IWEh in the bare lands were 44.4 and 62.2 fold that of the cultivated fields in the two successive seasons. Growing summer and winter crops with appropriate crop residue management offer good land protection against soil erosion. Generation of wind erosion data is essential for designing wind erosion control methods, particularly in arid lands. Unfortunately till now very little studies give attention to winds data analysis that may contribute in carrying out ideal projects for combating wind erosion. The present study was undertaken to achieve the following objectives:

1. To generate comprehensive quantitative data on Wr and IWE in bare lands in Goz alhalag area, River Nile State, using horizontal trap (IWEh).
2. To investigate direction and monthly variation of the Wr and IWEh,
3. To generate the interrelationship between Wr and IWEh.

II. MATERIALS AND METHODS

2.1. EXPERMINT MATERIALS

The study was conducted in a bare land in Gozalhalag area, about 50 km south east Atbara town in the River Nile State to produce broad–base data on intensity wind erosion measured by horizontal traps (IWEh) and wind erosivity (Wr) in two successive seasons (August 2008-March 2009, August 2009-March 2010). Wr was calculated from knowledge of hourly erosive wind speed, direction and duration. These data were obtained from the Meteorological Authority, Ministry of Environment, Forestry and Physical Development, Sudan.

2.2. METHODS AND STATISTICAL ANALYSIS

Oil cans [25 cm (l) × 23 cm (w.) x 27 cm (h)] were used as horizontal sand traps for the measurement of wind erosion. They were buried in the soil leaving the open end level with the soil surface.IWE (ton/ ha/day) was assessed using three replicates horizontal traps in the following directions: West (W), North West (NW), North (N) and North east (NE). The horizontal traps were placed at a spacing of one meter from each others in triangle shape. Each month the horizontal traps were removed and sand was collected and weighed. These monthly IWE were determined for each direction during the two seasons. Horizontal traps collected soil particles transported by the three mechanisms of wind erosion, namely; saltation, surface creep and suspension.

Wr calculated by using the index proposed by Skidmore and Woodruff (1968). The index was dependent on wind velocity. Skidmore and Woodruff (1968) analyzed the wind records of 212 locations in U.S.A. Only mean hourly wind speed greater than 5.4 m/sec were considered erosive and used in the study. The following wind erosivity (Wr) index was developed:

$$Wr_j = \sum_{i=1}^{n} v^3_{ij} f_{ij}$$

Where: V_{ij} = mean wind velocity above a given threshold velocity (5.4 m / sec) within the ith velocity group for the jth direction, f_{ij} = the duration of the wind within the ith velocity group for the jth direction expressed as a fraction of the total duration. $\sum_{j=0}^{j=15}$ = the summation of the Wr index for directions from j = 0 at the east direction and working anticlockwise so that j = 1 at ENE and j = 15 at ESE, $\sum_{i=1}^{i=n}$ = the summation of the Wr index for velocity groups from the first group i = 1 to the n group. The total magnitude for each month is given by the sum of the magnitudes from each direction and this gives a measure of the relative capacity of the wind to cause soil blowing. Not all winds were erosive, since feeble winds (Va < 5.4 m/s), which are tranquil, do not cause erosion, hence they were not included in the calculation of Wr. Analysis of variance and separation of means were undertaken according to Gomez and Gomez (1984). Empirical regression trend lines and their equations to examine the relationship between IWE and Wr were made by "Microsoft Excel 2003".

III. RESULT AND DISSCUSSION

1.1. IWEh and Wr in the First season (August 2008-March 2009)

Table 1 shows the effects of wind direction and month on the intensity of wind erosion measured by

horizontal traps (IWEh). For the main direction effect the mean IWEh ranged from 99.9 (W) to 109.8 (NE) with a mean of 104.4 tons ha^{-1} day^{-1}, a standard deviation (STD) of 4.13 tons ha^{-1} day^{-1} and a coefficient of variation (CV) of 4%. The mean IWEh by the NE wind was significantly greater than that produced by the W direction. However, it was not significantly different from that given by N or NW winds, which were not significantly different from that produced by W winds. The mean IWEh values for the main month effect ranged from 260 (Sept.) to 2.1 (Nov.) with a mean of 104.4 tons ha^{-1} day^{-1}, a STD of 97.49 tons ha^{-1} day^{-1} and a CV of 93.4%. Statistically, IWE_h was in the following significant order: Sept. > Aug. > Oct. > Mar. > Jan = Feb > Dec. = Nov.; the equal sign in this equality indicates not significantly different.

Table 1.Effect of direction and month on the IWEh (ton ha^{-1} day^{-1}) measured during the first season*

Direction	Months								
	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Mean
W	216.2	258	128.0	1.4	5.4	60	58	72.5	99.9 b
NW	224.1	260	130.0	2.3	9.0	66	58	75.4	103.1ab
N	229.0	260	129.3	2.2	2.1	67	64	84.1	104.7ab
NE	270.1	262	133.3	2.4	1.3	67	61	81.2	109.8 a
Mean	235 b	260 a	130.2c	2.1 f	4.5 f	65 e	60.3e	78.3d	

*Means followed by the same letter in the same row or column are not significantly different from each other at the 0.01 level by Duncan Multiple Range Test

Table 2 shows the percentage contribution of erosive winds in the various months. There were no erosive winds in November 2008. Wind erosivity ranged from 0 (Nov., 2008) to 745.7 (Mar.. 2009) with a mean of 310.4 $(m/s)^3$ and a CV of 66.7% depicted in Fig.1. Erosive winds showed monthly variation in frequency and directions. Wind erosivity decreased in the following order: Mar.> Feb.>Jan.> Oct.>Aug.>Dec.>Sept.>Nov. With respect to the seasonal overall mean data obtained by Wr gave 2483 $(m/s)^3$. Fig.2 shows the regression relationship between (IWEh) and (Wr). The regression relationship depicts a highly significant ($P < 0.05$, $r=0.649$) cubic, with positive correlation relationship. Wr accounted for about 42% of the variability of the IWE.

Table 2. Percentage contribution of erosive winds blowing from a given direction in the total erosivity of the various months in the first season

Dir.	Aug.08	Sept.08	Oct.08	Dec.08	Jan.09	Feb.09	Mar.09
N	-	-	9.0	23.9	20.0	16.0	3.3
NNE	-	-	-	6.0	2.7	4.4	9.7
NE	6.9	16.2	23.1	13.0	10.0	-	4.5
NE/E	-	3.1	-	0.2	-	-	-
ENE	-	-	11.1	0.3	4.0	-	0.3
E/N	-	-	-	0.1	-	-	-
E	-	-	35.5	10.0	-	-	-
E/S	-	-	21.3	-	-	-	-
SE/E	-	4.6	-	-	-	-	-
SE	-	3.6	-	-	-	-	-
S	10.5	43.1	-	-	-	-	-
SSW	-	11.8	-	-	-	-	-
SW/W	3.9	-	-	-	-	-	-
SW	75.0	10.4	-	-	-	-	-
WSW	1.4	7.2	-	-	-	-	0.2
W/S	1.4	-	-	-	-	-	-
W	0.4	-	-	-	-	-	-
WNW	0.5	-	-	-	-	-	-
NW	-	-	-	-	-	42.5	27.6
NW/N	-	-	-	9.2	5.6	16.6	19.0
NNW	-	-	-	11.8	56.7	19.0	9.6
N/W	-	-	-	25.5	1.0	1.5	25.8
Total Wr	269.5	237.6	273.1	263.8	323.7	369.8	745.7

Fig.1 shows the monthly variation of wind erosivity indicator (Wr) calculated by the equation of Skidmore and Woodruff (1968) in the first season.

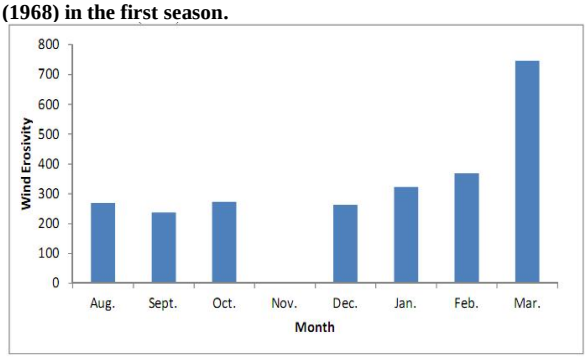
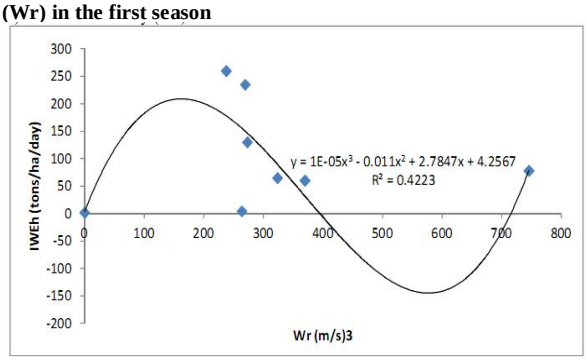


Fig.2. Regression relationship between intensity of wind erosion obtained by horizontal trap (IWEh) and wind erosivity (Wr) in the first season



1.2. IWE and Wr in the Second season (August 2009-March 2010)

Table 3 shows the effects of wind direction and month on IWEh. The mean IWEh values ranged 47.1 (W) to 49.2 (NE) with a mean of 46.3 tons ha^{-1} day^{-1}, a STD of 3.51 tons ha^{-1} day^{-1} and a CV of 7.6%. The mean IWEh produced by wind blowing from the four directions were not significantly different. The mean monthly data ranged from 2.3 (Sept.) to 97.3 (Aug.) with a mean of 46.3 tons ha^{-1} day^{-1}, a STD of 38.56 tons ha^{-1} day^{-1} and a CV of 83.2 %.. The monthly IWEh values were in the following statistically significant order: Aug. = Mar. > Jan = Feb. > Oct. = Dec.> Nov. = Sept. The IWEh measured in the second season was much lower than that in the first season; the overall mean IWEh value in the second season was 44% of that in the first season. There was also variation in the order of magnitude of monthly or the wind direction mean values.

Table 3.Effect of direction and month on the IWEh (ton ha^{-1} day^{-1}) measured during the second season*

Direction	Months								
	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Mean
W	116.9	1.7	18.4	4.3	30.0	55.8	59.7	91.2	47.1 a
NW	70.5	2.5	29.0	6.0	4.5	63.0	63.1	91.1	41.2 a
N	90.8	2.4	42.6	8.5	1.9	70.1	64.0	100.9	47.7 a
NE	111.1	2.4	18.4	1.2	33.4	64.2	64.6	97.9	49.2 a
Mean	97.3 a	2.3 d	27.1 c	5.0 d	17.5 cd	63.3 b	63.9 b	95.3 a	

*Letters as explained in Table1.

Table 4 shows the percentage contribution of erosive winds in the various months. Erosive winds showed monthly variation in frequency and directions. Wr ranged from 193.2 (Dec., 2009) to 401.3 (Mar. 2010) with a mean of 288.6 $(m/s)^3$, and a CV of 22.5%., depicted in Fig.3. Erosive winds showed monthly variation in frequency and directions. Wind erosivity decreased in the following order: Mar.> Feb.>Aug.> Oct.> Sept.> Jan.> Nov.>Dec. With respect to the seasonal overall mean data obtained by Wr gave 2309.3 $(m/s)^3$. Fig.4 shows the regression relationship between (IWEh) and (Wr). The regression relationship depicts a highly significant ($P < 0.05$, $r=0.681$), cubic with positive correlation relationship. Wr accounted for about 46% of the variability of the IWE.

Table 4. Percentage contribution of erosive winds blowing from a given direction in the total erosivity of the various months in the second season

Dir.	Aug.09	Sept.09	Oct.09	Nov. 09	Dec.09	Jan.10	Feb.10	Mar.10
N	-	-	-	26.7	30.2	36.8	12.2	46.4
NNE	-	-	-	-	28.5	10.8	2.8	0.8
NE	2.8	-	5.6	15.5	38.4	10.2	3.5	2.6
NE/N	-	-	-	17.6	-	-	-	-
NE/E	-	-	-	-	-	3.7	-	-
ENE	-	21.7	15.4	14.0	-	-	0.1	1.6
E/N	-	-	-	5.0	-	-	3.0	-
E	-	24.4	10.2	5.0	-	1.5	-	19.6
ESE	-	-	43.4	-	-	-	-	-
E/S	-	-	-	-	-	12.1	-	-
SE/E	-	-	12.2	-	-	-	-	-
SE	-	-	6.4	-	-	-	-	-
S	15.4	-	-	-	-	14.5	-	-
SSW	-	-	-	-	-	-	-	-
SW/S	-	-	-	-	-	-	-	-
SW	65.3	52.3	-	-	-	-	-	-
WSW	-	-	-	-	-	-	-	
W/S	-	-	-	-	-	-	-	-
W	-	1.6	-	-	-	-	-	-
WNW	-	-	-	-	-	-	-	-
NW	16.5	-	-	-	-	3.1	1.2	1.5
NW/N	-	-	-	6.3	-	4.1	12.7	-
NNW	-	-	6.8	-	-	-	50.0	1.8
N/W	-	-	-	9.9	2.8	3.2	14.5	25.7
Total Wr	292.5	266.3	268.5	262.2	193.2	262.4	362.9	401.3

IV. DISCUSSION

IWE and Wr showed monthly variation in frequency and directions in two seasons. For the main direction effect the mean IWEh by the NE wind was greater than that produced by the W direction in two successive seasons. In the first season ranged from W to NE with significant effect and not significantly in second season. Furthermore the mean IWE values for the main month effect ranged from Nov. to Sept. and from (Nov. & Sept.) to Aug. in first and second season, respectively.

Fig.3 shows the monthly variation of wind erosivity indicator (Wr) calculated by the equation of Skidmore and Woodruff (1968) in the first season.

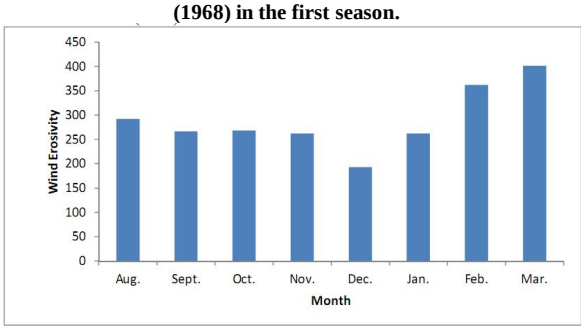
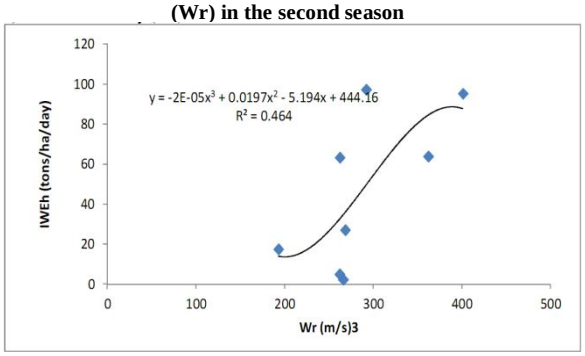


Fig.4. Regression relationship between intensity of wind erosion obtained by horizontal trap (IWEh) and wind erosivity (Wr) in the second season



The variation due to direction was much lower than monthly; .The IWEh measured in the second season was much lower than that in the first season; the overall mean IWEh value in the second season was 44% of that in the first season, the same result corresponding to the wind erosivity. Wr measured in the second season was 93% of the first season, due to the higher monthly variability of wind erosivity. This effect was attributed to the higher wind erosivity in the first season; and the nature of the River Nile State conducive to high variability of winds due to the majority of the state was bare, with few windbreaks beside the prevalent climatic conditions including high temperature, low and erratic rainfalls. The wind erosivity was 2483 and 2309.3 $(m/sec)^3$ for the first and second seasons, respectively (Abdelwahab and Mustafa, 2012).

The study area was characterized by mainly two climatic seasons, a hot summer from April to September and cold winter from October to March. August as an example for summer season the IWE values were caused mainly by S and SW winds, which were stronger winds but shorter in duration, these winds are that slow down progress of desert towards south. March as an example for winter season obtained the higher Wr in two successive seasons caused mainly by NW, and N directions respectively. Whereas the lowest Wr produced in the month of Nov. (0) in the first season, with considering to second season the lowest Wr produced by the Dec. & Nov. caused mainly by NE and N, respectively. This finding agrees with previous findings Abuzied (2009) and Farah (2003), with emphasized on minimum sand transport recorded in November and December. Indeed the prevailing N. winds caused high IWE in Jan. (NNW), Feb. (NW) and Mar. (NW), and days of dust storms. Finally, the high temperature effects on pressure and wind velocity in summer caused the transportation of heavier and denser particles opposite effect of low temperature in (Oct., Nov. and Dec.).

The regression between IWE and Wr gave a highly polynomial relationship, significant ($P< 0.05$, $r=0.649$) and ($P< 0.05$, $r=0.681$) for first and second seasons respectively. Wr accounted for about 42% and 46% of the variability of the IWE; for first and second season respectively. High and positive correlation can be explainable by the direct effect of Wr on the IWE. Wr is the main causes of IWE, wind speed plays as shared factors between them. So there are many other factors (causes) determined the occurrence and severity of IWE. To assess IWE as function of computed Wr by using extracted regression equation depends on large data and long periods. So there is actual need to more research in this field.

IV. CONCLUSIONS AND RECOMMENDATIONS

In two seasons the results showed that the IWE and Wr ($v > 5.4$ m/sec) varied in frequency and direction within the same climatic season. The results showed higher monthly variability, particularly in the first season due to the difference in Wr. The wind erosivity was 2483 and 2309.3 $(m/sec)^3$ for the first and second seasons, respectively

March as an example for winter season (October-March) obtained the higher Wr in two successive seasons caused mainly by NW, and N directions respectively. Whereas the lowest Wr produced in the month of Nov. (0) in the first season, with considering to second season the lowest Wr produced by the Dec. & Nov. caused mainly by NE and N, respectively, then the minimum sand transport recorded in November and December, this finding agrees with previous findings Abuzied (2009) and Farah (2003). Instead of that the north winds are prevailing in winter months. Whereas the high percentage contribution of erosive winds in summer season (April - September). August as an example for summer season the Wr values were caused mainly by S and SW winds, which were stronger winds but shorter in duration, these winds are that slow down progress of desert towards south .The high temperature effects on pressure and wind velocity in summer caused the transportation of heavier and denser particles opposite effect of low temperature in (Oct., Nov. and Dec.).

The IWEh and Wr measured in the second season was much lower than that in the first season; the overall mean IWEh and Wr values in the second season was 44% and 93% of that in the first season respectively. This effect was attributed to the higher wind erosivity in the first season; and the nature of the River Nile State conducive to high variability of winds due to the majority of the state was bare, with few windbreaks beside the prevalent climatic conditions including high temperature, low and erratic rainfalls.

In the first season wind erosivity ranged from 0 (Nov., 2008) to 745.7 (Mar. 2009) with a mean of 310.4 $(m/s)^3$ and a CV of 66.7%. Wr decreased in the following order: Mar.> Feb.>Jan.> Oct.>Aug.>Dec.>Sept.>Nov. With respect to the

second season Wr ranged from 193.2 (Dec., 2009) to 401.3 (Mar. 2010) with a mean of 288.6 $(m/s)^3$, and a CV of 22.5%. Wr decreased in the following order: Mar.> Feb.>Aug.> Oct.> Sept.> Jan.> Nov.>Dec.

The windbreaks which were established recently in Gozalhalag area should be properly managed because of the severe blowing of the southerly winds.Comprehensive studies on Wr, IWE, wind velocity and direction should be undertaken in the early stages of establishing a scheme to help in making design of the shelterbelt. Still little quantitative analyzed meteorological data is available. There is need to establishing new meteorological stations to give a good cover for the state.

REFERENCES

[1] Abdelwahab, M.H. and Mustafa, M.A. 2012. Assessment of Wind Erosion in Bare and Lucerne-cultivated Lands in South East Atbara, River Nile State, Sudan. Sudan Journal of Desertification Research 5(1): 88-100.

[2] Abdelwahab, M.H. and Mustafa, M.A. 2016. Assessment of Wind Erosion in Bare and Lucerne-cultivated Lands in South Atbara, River Nile State, Sudan: The International Journal of the Environmental and Water; Vol.5, Issue 2: 87-94.

[3] Abuzied, H. M. 2009.Mapping and Assessment of Wind Erosion in Central Northern State, Sudan Ph.D. Thesis, Desertification and Desert Cultivation Studies Institute, University of Khartoum, Sudan

[4] Abuzied, H.M., Mustafa, M.A. and Hamid, A.A. 2015. Rate of Sand Movement by Saltation and Surface Creep in the Central Part of the Northern State, Sudan., Sudan Journal of Desertification Research 7 (1): 40-51.

[5] Adam, A.H., Elhag, A.M., Salih, A. and Adam,S.M. 2014. Land Degradation Assessment in Rawashda Area, Gedaref State, Sudan Using Remote Sensing, GIS and Soil Techniques. International Journal of Scientific and Research Publications Vol. 4(2): 1-9.

[6] Biro,K., Pradhan, B., Buchroithner, M. and Makeschin, F. 2013. Land use/ Land cover Change Analysis and it is Impact on Soil Properties in the Northern Part of Gedarif Region, Sudan. Land Degrad. Develop. 24: 90-120.

[7] Farah, A. M. 2003. Wind Erosion in Khartoum State. Ph.D. Thesis. Faculty of Agriculture, University of Khartoum, Khartoum, Sudan

[8] Gomez,A. K. and Gomez, A. A. 1984. Statistical Procedure for Agricultural Research, International Rice Research Institute (I.R.R.I), of Phillipean

[9] Haikal, Sami Mohamed S. 2005. Assessment and Mapping of Wind Erosion in North East Butana Area. Ph.D. (Desertification and Desert Cultivation) Thesis, University of Khartoum, Sudan

[10] Hassan, A.A. and Mustafa, M. A. 2011. Assessment and mapping of wind erodibility of Aridisols and Entisols in the Nile State, Sudan. Sudan Journal of Desertification Research 3(1): 49-61.

[11] Izzeldin, S.I. and Ahmed, S.H. 2004. A proposed Plan of Action for Research on Desertification in the Sudan: Northern and Nile States. The National Forum of Scientific Research on Desertification in the Sudan Al Sharga Hall, University of Khartoum, Khartoum, Sudan 16-18 March, 2004: 325pp.

[12] Kheirelseid, Abdel Mohsin R.1998. Wind Erosion Study in North Kordufan, El-Obeid. Ph.D (Agric.) thesis, University of Khartoum, Khartoum, Sudan

[13] Skidmore, E.L. and Woodruff, N.P. 1968. Wind erosion forces in the United States and their use in predicting soil loss. USDA Handbook No. 346, 42 pp, Washington DC

★★★