ASSESSING THE INFLUENCE OF THE CLIMATIC FACTORS (CF) ON THE SAND CONTENTS OF SOILS (SCS): EFFECTS ON EROSION

Uja, E.U[1], Okereke, N.A.A[2], Nwandikom, G.I[3], Madubuike, C.N[4], Egwuonwu, C.C[5]

[1,2,3,4,5]*Department of Agricultural and Bioresources Engineering, Federal University of Technology, P.M.B 1526, Owerri, Imo State, Nigeria.*

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Abstract *– This report assesses the influence of climatic factors on the sand contents of soils and the likely effects such could have on the erosion of the sand particles. The sites are located at the humid tropical South Eastern region of Nigeria with at least 60% sand. The climatic factors considered include maximum air temperature (MAT), rainfall amount (RA), solar radiation (SR), and sunshine (S). In the study, the sand contents, as dependable variable were correlated and regressed with the climatic factors, using the IBM SPSS Statistics Software. The sand contents correlated positively with the rainfall amounts but negatively with the maximum air temperature, the solar radiation and the sunshine hours. In the light of these observations, the rainfall amounts showcased itself of having considerable influence in the detachment, transportation and deposition phases of an erosion process, a phenomenum referred to as erosivity. On the other hand the maximum air temperature, the solar radiation and the sunshine hours apparently played their roles in-situ in evaporation of moisture from the soil, surface sealing and crusting which invariably affect the erodibility of the sand particles. Sunshine hours produced the best single parameter, non linear, power, model: Sand content= 2599.592-1.516(solar radiation). This model had comparatively the least standard error of estimate, SE, of 0.313. Correlation analyses carried out between the climatic factors revealed that the climatic factors usually work in synergy to effect an erosion process. The maximum air temperature, the solar radiation and the sunshine hours correlated positively with one another.*

Keywords: climatic factors, influence, erosivity, sand contents, synergy, erodibility.

1. INTRODUCTION

The danger posed by erosion on soils and the environment has continued to cause sleepless nights to researchers. In the light of this, the vulnerability of the Southeastern zone of Nigeria has been stressed [15]. According to the report, gully erosion has annually caused environmental problems and damages estimated at over $100million. Most of these gullies has been noticed to have occurred on bare soils surfaces created by human activities [2]. The consequence is that the bare soil surfaces are exposed to the vagaries of climatic factors (CF). These factors include internal or inherent factors as well as external factors that quite often support the internal factors to aggravate erosion processes.

The internal factors are the in-situ soil physical and engineering properties which basically include the soil particle size or soil texture. The texture of the soil tells as much as possible about the soil in one word [5]. Usually various particle sizes are found in soil namely: gravel (2mm – 20mm), sand (0.063mm-2mm), silt (0.002mm – 0.063m), and clay (particles less than 0.002mm) [10]. Sand particles by their nature are cohesionless aggregates of rounded, angular, subangular or angular fragments of more or less unaltered rocks or minerals. They flow freely in a dry state whereas in a wet state they form a cast which crumbles easily. This inert quality makes them prone to the erosion [5] .The soil at the study sites consists of 60.13% of sand.

The external factors, on the other hand are those factors that are not inherent on the soils but act on it, influencing its behavior, quite often shattering or detaching it into the delivery system of the erosion process. These factors include CF of rainfall, temperature, sunshine, solar radiation, and relative humidity [14]. The damage being posed by these CF on soils demands urgent attention. Heat related damages are steadily being meted out, not only to our soils but the environment and ecosystems. The earth is seen getting hotter day by day [1]; [6].

The soil has been referred to as the skin of the earth's crust and as such damages to it should not be allowed [8]; [12]; [13]; [16]. It is very expensive to lose the soil. It takes 300years to form just a centimeter of soil [4]**.** Though rainfall has been noted in its role and ability to cause erosion, referred to as erosivity [9], this study will attempt to identify other CF and how far the CF work in synergy to cause the erosion process.

The main objective of the study is to assess the influence of climatic factors on sand contents of soil in a bid to unfold the likely effect it could have on the erosion of the soil.

2. MATERIALS AND METHODS

2.1 The Study Sites

The study sites included Afikpo, Akaeze, Akwete, Bende, Egbema, Isieke-Ibeku, Isuochi, Okposi, Orlu, Owerri, Umuna, Okwele, Aba, Igbere, and Owutu-Edda, all in the former Imo State of Nigeria.

Table 1: The Representative Soil groups and their Locations

S/N	USDA	FAO	Parent Material	Location
1	Aqui Paleudult	Dystric Nitosol	Shale	Akaeze
2	Arenic Paleudult	Dystric Nitosol	Sandy Alluvium	Akwete
3	Eutric Tropofluents	Eutric Fluvisol	Shales and Sandstone	Egbema
4	Orthoxic Tropodult	Dystric Ferralsol	Coastal Plain Sands	Owerri
5	Gross Arenic Paleudult	Dystric Nitosol	Sandstone	Isuochi
6	Orthoxic Tropodult	Rhodic Ferralsol	Sandstone	Igbere
7	Plinthic Tropodult	Plinthic Acrisol	Shales	Okposi
8	Typic Dystropepts	Dystric Cambisol	Sandstone	Afikpo
9	Typic Dystropepts	Dystric Cambisol	Shale	Bende
10	Typic Hapludult	Orthic Acrisol	Shale and Sandstone	Okwele
11	Typic Tropaquepts	Dystric Gleysol	Shale and Sandstone	Isieke Ibeku
12	Typic Tropadquepts	Eutric Gleysol	Shale and Sandstone	Umuna
13	Typic Tropudalfs	Eutric Nitosol	Siltsyone	Orlu
14	Typic Tropudult	Dystric Ferralsol	Coastal Plain Sands	Aba
15	Typic Tropudult	Ferric Acrisol	Shale and Sandstone	Owutu-Edda

[7]

Table 2: The Sand Contents of the Soils

Site	Afikpo	Akaeze	Akwete	Bende	Egbema	Isieke Ibeku	Isuochi	Okposi	Orlu	Owerri	Umuna	Okwele	Aba	Igbere	Owutu Edda
Sand Contents (%)	69	29	54	37	31	41	92	84	79	86	35	50	80	80	55

[7]

Table 3: The Climatic Records of Imo State

Month	Max. Temp (^{0}C)	Rainfall amounts(mm)	Solar Radiation (W/m^2)	Relative Humidity (%)	Sunshine (hrs)
January	33.2	37.1	13.4	62	5.8
February	35.2	34.3	14.9	72	5.2
March	34.2	45.9	14.1	77	5.8
April	33.3	99.6	13.7	77	5.4
May	32.0	298.8	12.9	79	5.5
June	30.4	185.9	11.5	85	3.7
July	-	-	-	-	-
August	29.9	438.2	8.8	88	2.5
September	29.2	622.2	9.2	86	3.0
October	30.3	284.3	10.2	83	4.7
November	32.1	111.7	11.5	77	6.6
December	32.5	0.0	12.8	45	7.0

[11]

Table: 4 Summary of the CF

CF	Range
Maximum air temperature (^{o}C)	29.2-35.2
Rainfall amounts (mm)	34.3-622.2
Solar radiation (W/m^2)	8.8-14.9
Relative humidity (%)	45-88
Sunshine (hours)	2.5-7.0

[11]

2.2 Method of Data Analysis

The analysis was done using the IBM SPSS Statistics software [3]. The sand contents of the soils, as dependable variables were correlated with the each of the CF of maximum air temperature , solar radiation, relative humidity and sunshine hours, as independable variables. The outcomes that were significant at 0.05 (1-tailed) were noted. Also noted were the strength and nature of the relationship. Regression analyses were then conducted on the significant items using both linear and non-linear (curve estimation) methods. The respective model equations were gathered. The model equations were observed to identify the model equation that comparatively predicted the sand contents of the soils, with the least error of estimate (SE).

3. RESULTS AND DISCUSSIONS

3.1 Results

Table 5: Results of Correlation analysis of the Sand contents of the soils with the climatic factors

Factors[a]	Correlation	P-Value*
Sand / Max. Temp	-0.614	0.022
Sand/Rainfall	0.576	0.041
Sand/Solar radiation	-0.707	0.007
Sand/Rel. humidity	0.230	0.248
Sand/Sunshine	-0.538	0.044

* Correlation is significant at 0.05 level (1-tailed)

[a]Threshold values of the Max. air temp was 29.2^{0}C, Rainfall was 34.3mm,Solar radiation was 8.8W/m^2, Relative humidity was 88% and that of Sunshine hours was 2hours.

Table 6: Strength and nature of relationship between the Sand contents of the soil and the climatic factors

Factors	R	Nature of the Relationship	R^2	Strength of the Relationship
Sand /Max. temp.	-0.614	Negative	0.376	Moderate
Sand/Rainfall	0.576	Positive	0.332	Moderate
Sand/Solar radiation	-0.707	Negative	0.500	Medium
Sand/Sunshine hours	-0.538	Negative	0.290	Low

Table 7 : Model Gathering (Maximum Air Temp versus Sand Content of Soils.)

Model Equation	R^2	Standard error of estimation
Linear: Sand content = 279.605-7.041Max.temp	0.376	18.166
Logarithmic: Sand content = 842.817-227.628 In(Max. temp)	0.384	18.056
Inverse: Sand content = -175.642 + 7334.146 $\left(\frac{1}{Max.temp}\right)$	0.391	17.951
Quadratic: Sand content=1822.215+1.503(Max. temp)^2+103.503Max.temp	0.428	18.451
Cubic: Sand content=1822.215+1.503(Max. temp)^2+103.503Max.temp	0.428	18.451
Power: Sand content=73043908.42-4.096 In(Max. temp)	0.356	0.345*
Exponential: Sand content = 2924.485-0.127Max. temp	0.350	0.347

*Sand content=73043908.42-4.096 In(Max. temp) is hereby selected.

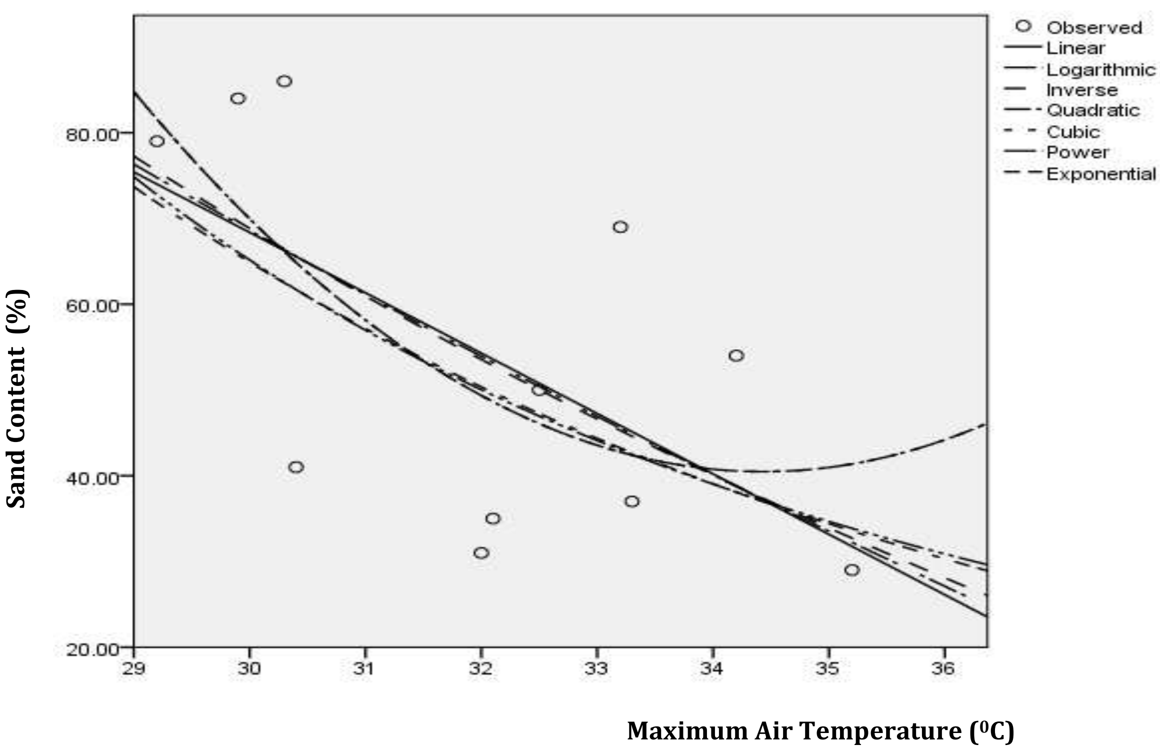

Fig. 1: Sand content (observed and predicted values) versus maximum air temperature.

Table 8: Model Gathering (Rainfall amount versus Sand content of Soils)

Model Equation	R^2	Standard error of estimation
Linear: Sand content = 39.924+0.068Rainfall amount	0.332	19.9055
Logarithmic: Sand content = 5.096+10.004 In(Rainfall amount)	0.207	21.680
Inverse: Sand content = 61.710 -637.944 $\left(\frac{1}{Rainfall\ amount}\right)$	0.087	23.269
Quadratic: Sand content=42.706+5.634E-005(Rainfall amount)^2+0.033Rainfall amount	0.339	21.165
Cubic: Sand content=60.758-1.719E-006(Rainfall amount)^3+0.002(Rainfall amount)^2-0.361Rainfall amount	0.459	20.690
Power: Sand content=21.643+0.170 In(Rainfall amount)	0.171	0.415
Exponential: Sand content = 38.965+0.001Rainfall amount	0.286	0.386*

* Sand content=38.965+0.001Rainfall amount is hereby selected.

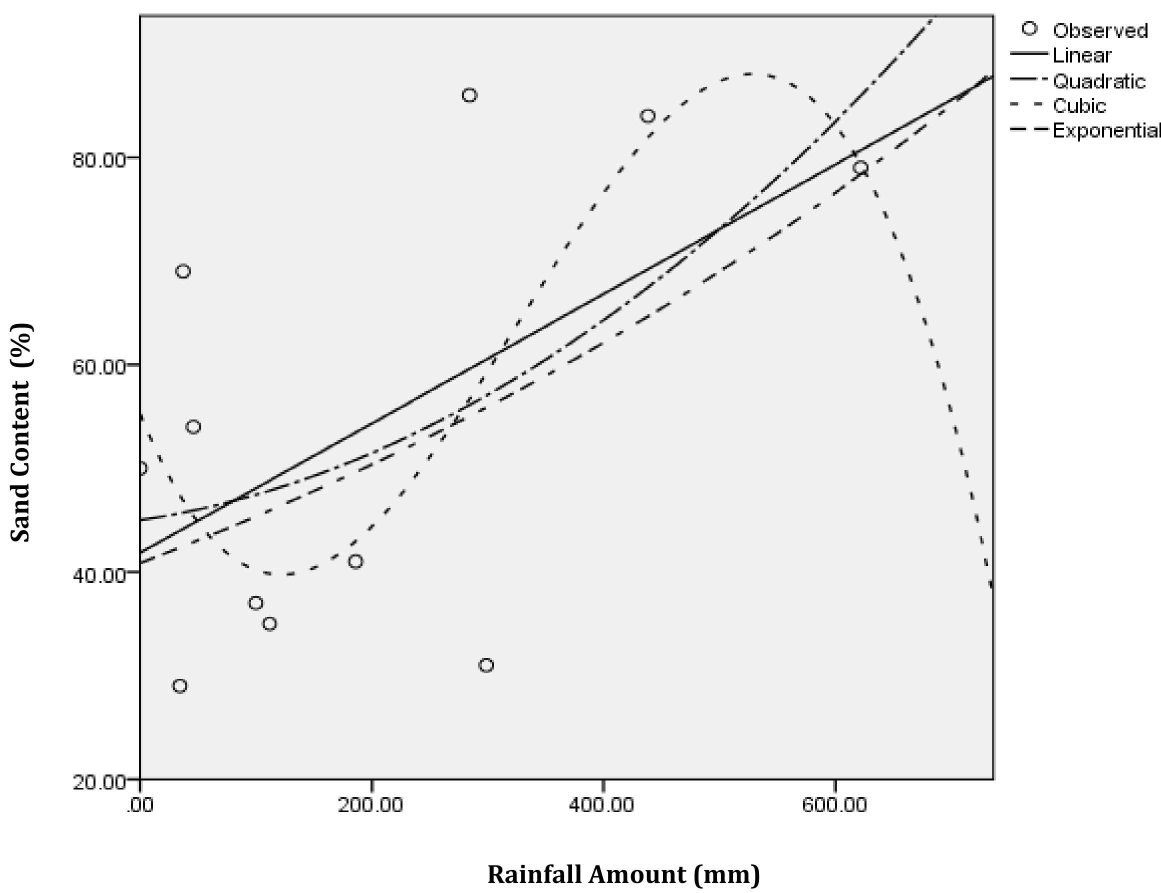

Fig. 2: Sand content (observed and predicted values) versus Rainfall amount.

Table 9: Model Gathering (Solar radiation versus Sand content of Soils)

Model Equations	R^2	Standard error of estimation
Linear: Sand=146.437-7.638Solar radiation	0.500	16.262
Logarithmic: Sand content = 276.808-89.845 In(Solar radiation)	0.523	15.893
Inverse: Sand content = -33.376 +1028.383 $\left(\frac{1}{Solar\ radiation}\right)$	0.540	15.601
Quadratic: Sand content=349.242+1.516(Solar radiation)^2+43.207Solar radiation	0.556	16.252
Cubic: Sand content=349.242+1.516(Solar radiation)^2+43.207Solar radiation	0.556	16.252
Power: Sand content=2599.592-1.592 In(Solar radiation)	0.470	0.313*
Exponential: Sand content=259.555-0.136Solar radiation	0.453	0.318

* Sand content=2599.592-1.592 In(Solar radiation) is hereby selected.

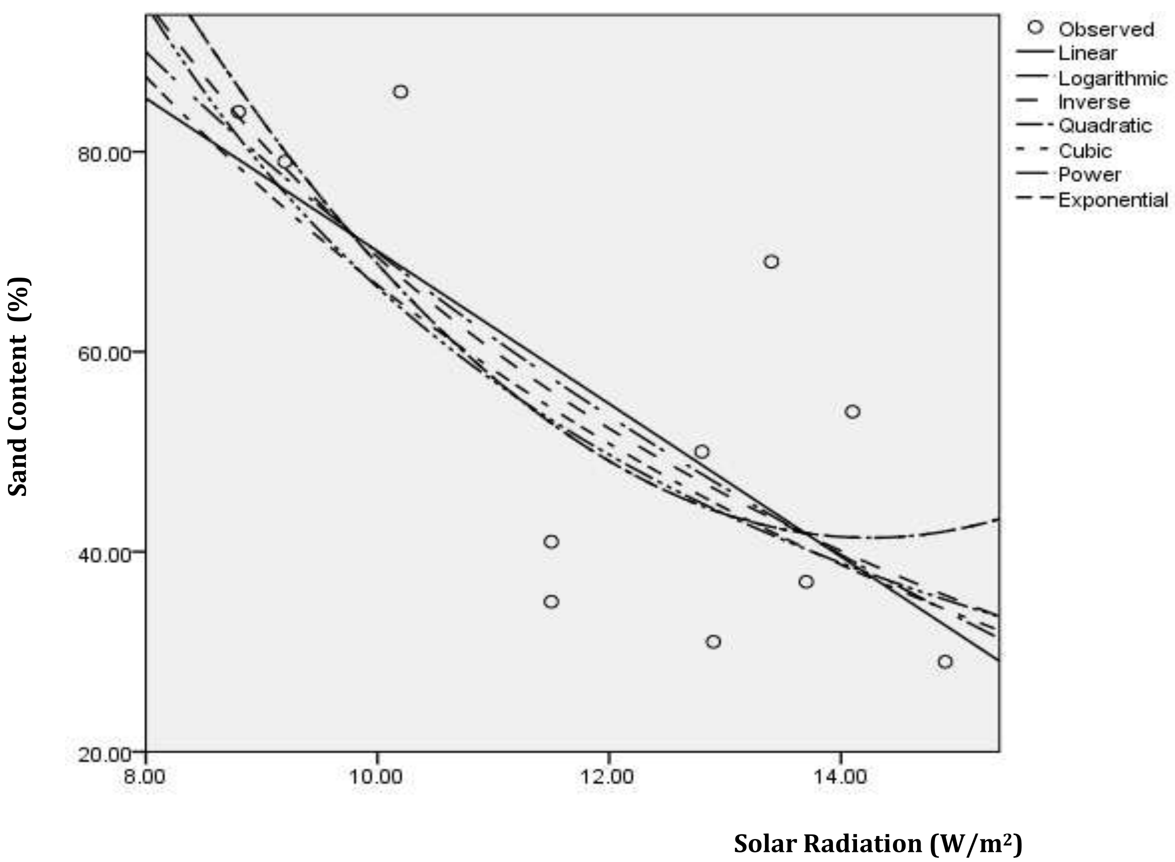

Fig. 3: Sand content (observed and predicted values) versus Solar radiation.

Table 10: Model Gathering (Sunshine hours on Sand content of Soils).

Model Equation	R^2	Standard error of estimation
Linear: Sand=95.444-8.241Sunshine hours	0.290	19.389
Logarithmic: Sand content = 113.495-37.860 In(Sunshine hours)	0.322	18.947
Inverse: Sand content = $19.697 + \left(\frac{1}{156.667 Sunshine\ hours}\right)$	0.342	18.656
Quadratic: Sand content=149.047+2.685(Sunshine hours)^2-33.383 Sunshine hours	0.344	19.768
Cubic: Sand content=217.483-0.719(Sunshine hours)^3+13.163(Sunshine hours)^2-81.546 Sunshine hours	0.349	21.053
Power: Sand content=139.266-0.651 In(Sunshine hours)	0.272	0.367*
Exponential: Sand content=101.119-0.140 Sunshine hours	0.238	0.375

* Sand content=139.266-0.651 In(Sunshine hours) is hereby selected.

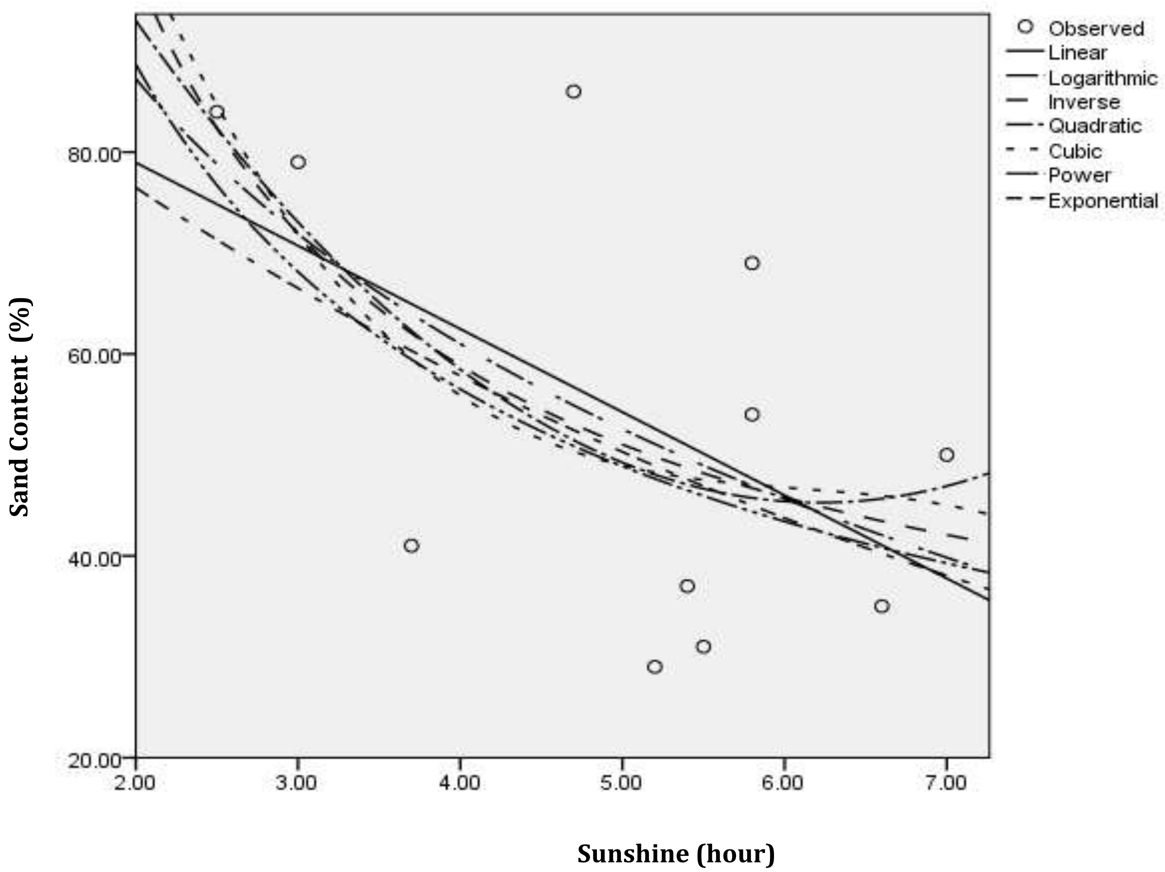

Fig. 4: Sand content (observed and predicted values) versus Sunshine hours.

Table 11: Regression analysis of the significantly correlated factors of sand content of the soil and the climatic factor of Solar radiation.

Climatic Factors and Soil Properties	Nature of relationship	R^2	SE	F	Model Equation -Power*
Sand content and Solar radiation	**Negative**	**0.470**	**0.313**	**7.977**	**2599.592-1.592 In(Solar radiation)**

***Predicted values of the sand content ranged from 89.23 to 9.61%.**

Table 12: Correlation and Nature of Relationships of the CF.

Factors	R	Nature of the Relationship	P-value	Strength of the Relationship
Max. temp/Rainfall	-0.830	Negative	0.001	Good
Max. temp/Solar Radiation	0.951	Positive	0.000	Very good
Max. temp/Sunshine hours	0.682	Positive	0.010	Medium
Rainfall/Solar radiation	-0.833	Negative	0.001	Good
Rainfall/Sunshine hours	-0.807	Negative	0.001	Good
Solar radiation/Sunshine hours	0.697	Positive	0.009	Medium

3.2 Discussions

Tables 3 and 4 showed that the study had been carried out within the following ranges of the climatic factors: Maximum Air Temperature (29^0C to 35.2^0C), Rainfall amounts (34.3mm to 622.2mm), Solar radiation (8.8 to 14.9W/m^2), Relative Humidity (45% to 88%), Sunshine hour (2.5hours to 7.6 hours).

The results from the correlation analysis as indicated in Tables 5 ad 6 showed that there was no correlation between the sand content of the soil and Relative humidity while it was obvious that the sand content of the soil correlated positively with the Rainfall amount, with the strength of the relationship being moderate. Through the regression analyses carried out using linear and non-linear (Curve fit) methods as could be seen in figures 2, it was noticed that when the rainfall amounts increases, the sand content also increases. This portrayed the devastating nature of the rainfall amounts that usually lead to the detachment, transportation and depositions of the sand particles in the erosion process. As the rainfall amounts increases, the propensity of soil detachment increases as well as the build-up of erosive concentrated overland flow which culminates to increases in the depositions of the erosion process.

A negative relationship was observed between the sand contents of the soils and the maximum air temperature, the solar radiation and the sunshine hours as shown also in Table 5. Unlike the cases with the rainfall amounts, the sand content of the soils decreases with increases in the maximum air temperature, the solar radiation and the sunshine hours as could be seen in figures 1, 3 and 4 respectively. This observation indicated that the maximum air temperatures, the solar radiation and the sunshine hours played their roles at the pre-detachment phases of the erosion process. These climatic factors, the air maximum temperature, the solar radiation and the sunshine, apparently influenced the sand content in a manner that made the sand particles prone for detachment into the delivery system, thereby enhancing their erodibility potentials. They heat up the sand, possibly shrinks and separate the particles, making them prone to detachment, transportation and deposition of the erosion process. This outcome is in line with the findings obtained by [9]. In the findings soils with high sand contents of 40 to 60 per cent are considerably erodible. The soils at the study sites contain 60 per cent sand contents.

The climatic factors observably played their roles in synergy. Investigations done on this, by conducting a correlation analyses between the climatic factors, had unfolded such, as could be seen in Table 12. The rainfall amounts correlated negatively with each of the other climatic factors, the maximum air temperatures, the solar radiation, the sunshine hours, while the air maximum temperatures, the solar radiation and the sunshine hours correlated positively with one other. The nature and strength of the relationships could also be seen. The maximum air temperatures, the solar radiation and the sunshine appeared to have played complementary role in the evaporation of moisture from the land and sea. This evaporated moisture latter fall as erosive rains, which the rainfall amounts had portrayed.

From Tables 7, 8, 9, 10, and 11, the best single parameter, non-linear, Power, predictor model for the sand content is given as Sand content=2599.592-1.516(solar radiation), which have comparatively the least value for the standard error of estimate, SE, of 0.367.

4. CONCLUSION

The climatic factors of air maximum temperature, rainfall amounts, solar radiation, and sunshine had influenced the sand content of the soils in a various patterns. All the patterns apparently supported erosion, playing a role in the detachment phase or the deposition phase of the erosion process. Rainfall amounts play significant role on deposition phase because it provides the delivery system of the erosion process. The more the magnitude of the rainfall amounts, the more the erosivity, the more likely the sand to eroded. At often times, almost all the contents of the sand had been eroded and deposited, within the magnitude of the rainfall amounts of 34.3mm to 622.2mm. The other climatic factors, the air maximum temperature, the solar radiation and the sunshine hours, play dual roles. They work in synergy to remove moisture from the sand, making the sand to crumble and yield in motion to any external forces. Of the moisture evaporated also, rainfall originates to easily carry the defenseless sand particles into the erosion delivery system. The heating on the sand makes them behave like individual particles and when the rain falls, these sand particles easily flow with the torrent of the runoff. These influences had been contained within the ranges of air maximum temperature, 29.2^{0}C to 35.2^{0}C, Solar radiation, 8.8W/m^2 to 14.9W/m^2, and Sunshine hours, 2.5hours to 7.0hours.

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