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ESTIMATION OF RAINFALL EROSIVITY IN SOUTHWESTERN NIGERIA

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ABSTRACT

The study assessed rainfall erosivity in southwestern Nigeria and compared site-specific rainfall erosivities obtained from commonly used indices. Pre-calibrated automatic weather stations were installed at three different locations across the study area and programmed to log rainfall amounts at five minutes intervals. Recorded rainfall data were downloaded monthly from the weather stations. 30-minute and 7.5-minute maximum intensity as well as rainfall energy were calculated. The EI_{30} *erosivity index was estimated as a product of rainfall energy and 30-minute maximum intensity while the* $AI_{7.5}$ *erosivity index was determined as a product of 7.5-minute intensity and amount of rainfall for each rainfall event. Modified Fournier index (MFI) rainfall erosivity was also estimated. Statistical correlations were drawn between* EI_{30} *and* $AI_{7.5}$*, and between* El_{30} *and MFI.. The* EI_{30} *distribution showed that rainfall in September 2012 was the most erosive (45988 MJmm ha hr mth) while* $AI_{7.5}$ *indicated that October 2011 had the highest erosivity (2994.46* cm^2/h*) in Ile-Ife. There were positive significant correlations between* EI_{30} *and* $AI_{7.5}$*. Positive significant correlations were also obtained between* EI_{30} *and MF. The study concluded that rainfall in the study area falls into the strong erosivity class. The* EI_{30} *and* $AI_{7.5}$ *indices are, therefore, suitable for the estimation of rainfall erosivity in Southwestern Nigeria. Further investigation of the soil loss and monthly erosivities as they relate to temporal rainfall aggressiveness is recommended.*

Keywords: monthly erosivities, EI_{30} ***distribution, 30-minute maximum intensity***

INTRODUCTION

In recent years, there has been an increasing concern over soil erosion and land degradation (Okorafor *et al*., 2017, Chude *et al*., 2020). Erosion occurs as a noticeable intrinsic natural process in undisturbed soil but accelerated erosion results from increasing agricultural activities and conversion of natural ecosystems for road construction, industrial or urbanization purposes. Not only may soil erosion cause a reduction in soil and land productivity (NSE-SPRPC, 1981; Oyedele, 1996; Salvati and Carlucci, 2013; Borrelli *et al*., 2017; Okorafor *et al*., 2017), but also the off-site effects in terms of siltation problem, pollution to water bodies, disruption of water supply and the damage of freshwater resources are noteworthy negative impacts (Murtedza and Chuan, 1993; Indarto and Mutaqin, 2016; FAO, 2019). A study by Den Biggelaar *et al*. (2003) suggested that on a global scale, about 12 to 15 tonnes ha^{-1} of soil is lost annually while Borrelli *et al*., 2020 predicted that about 23.4 Pg is specifically lost worldwide on agricultural lands every year. A total of 2.2 million tons of topsoil is lost to erosion annually in the UK (Environmental Agency, 2004). This translates to an annual agricultural production loss to the tune of USD 17.6 million (O'Neill, 2007). Therefore, mitigation, monitoring and assessment of erosion on a spatial and temporal bases is an important ecosystem service (Guerra *et al*., 2016).

In Nigeria, land deformation as a result of perennial erosion is a common scene in many communities. This is exacerbated by increased rainfall and flood events as a result of climate change and the increasing rate of unplanned urbanization. For instance, in separate studies, Ibitoye and Adegboyega (2012) identified the construction of buildings on steep terrains together with failed drainage projects as causes of increasing runoffs and gullies in Southwestern Nigeria while Egede (2013) indicated that pressures from the rising number of extractive industries, road constructions, and development of urban centres have induced accelerated erosion and soil loss in the southeastern states. There can also be movement of water into the subgrade through shallow groundwater (Adiat *et al*., 2017). Water reduces soil strength and compromises the geotechnical quality of materials used in the road (Daramola *et al*., 2018) and rail constructions, and thus their failures are inevitable. This is probably one of the important factors responsible for the high incidence of road failure in the rainy season compared to the dry season in Nigeria. Rainfall intensity and fluctuations (Adiat *et al*., 2017; Emmanuel *et al*., 2021), and erosivity, erosion-related rainfall characteristics, may therefore require serious consideration not only in the agricultural context but also in road and railway designs and maintenance plans.

Soil erosion is basically initiated by soil detachment. The detachment of soil is controlled by rainfall microphysical properties, and this translates to the shear forces of the falling raindrops, represented by the rainfall erosivity factor (Petkovesk and Mikos, 2004; Asadi *et al.*, 2008). Rainfall erosivity is defined as the potential ability of raindrops to detach soil particles and hence cause erosion. It is a link between the dynamic properties of rainfall, as a result of rainfall generating processes and their impact on soil. It is an indication of rainfall aggressiveness. This characteristic of rainfall is a function of its amount, duration, drop size and drop size distribution, velocity, intensity and kinetic energy. Among the factors influencing rain erosion hazards are relief effect, soil erodibility, soil cover, soil conservation and agroforestry; while rainfall erosivity plays a major role. These other factors however modify the erosive power of rainfall to determine the actual quantity of soil loss. Rainfall erosivity factor (R) in the universal soil loss equation (USLE) by Wichmeier and Smith (1978) or its revised form (RUSLE) by Renard *et al.* (1997) is generally recognized as one of the best parameters for the prediction of the erosive potential of raindrop impact (Laureiro and Coutinho, 2004). Young and Wiersma (1973) observed that reducing the raindrop impact energy by 89% resulted in a decrease in soil loss. Zhang *et al.* (2010) found that in China, a 1% increase in rainfall erosivity is associated with a 1% increase in soil loss. Also, emerging data point to the fact that the problem of erosion stems more from rainfall erosivity and soil management practices rather than the inherent erodibility of the soil (Panagos *et al*., 2015).

The velocity of rainfall hitting the soil surface produces a high amount of impacting kinetic energy, which can dislodge the soil particle. The energy of a rainfall event also depends on rainfall intensity and the amount of rainfall at each intensity (Wischmeier and Smith, 1958; Renard and Freimund, 1994). Previous studies have shown that soil losses from cultivated land were directly proportional to rainstorm energy and 30 – minutes maximum intensity (EI_{30}) (Wischmeier and Smith, 1958). The sum of these values for a given period cumulate into a numerical measure of the erosive potential of rainfall within the period. The importance of rainfall erosivity in the assessment of soil erosion risks stems from the fact that, unlike other natural factors that affect soil erosion, the erosive capacity of rainfall is not subject to human modification (Salako, 2003; Angulo-Martinez and Begueria, 2009), and it is potentially the most devastating. Relying on commonly used Representative Concentration Pathway, RCP (4.5) based scenarios (IPCC, 2013) that indicated more intense rainfall, it has even been predicted that rainfall erosivity index higher than 500 MJ mm ha^{-1} h^{-1} yr^{-1} in parts of Europe is possible by the year 2050 and also a global annual increase of 27 -34.3% by 2070 (Panagos *et al*., 2017 and Panagos *et al*., 2022).

Essentially, two types of indices have been developed for estimating erosivity in different regions of the world under different conditions and scales of analysis. The first category relies on the amount, intensity and kinetic energy of a given rainfall event, hence, we have EI_{30} (Wischemeir, 1959), rainfall kinetic energy greater than 25 MJ/ha, KE>25 (Hudson, 1971), and rainfall amount and maximum intensity, AIm (Lal, 1976) as common examples. For a reliable estimation, these indices require rainfall data with high spatial and temporal resolutions, hence data are often obtained from recording rain gauges with at least 15 minutes time intervals. The second category of an index such as Fournier (1960), and Modified Fournier Index (MFI), Arnoldus (1980) is based on monthly and yearly records of rainfall. Correlations of MFI with Wichmeier and Smith, (1978) EI_{30} erosivity index have shown positive results in parts of the world (Yu and Rosewell, 1996; Ferro *et al*., 1999). Hence, it is commonly used where long-term high-resolution rainfall data are not available.

However, Wichmeier and Smith (1978) and Renard *et al*. (1997) recommended long years of data of rainfall of at least 22 years and from many stations for estimation of erosivity index. This was meant to account for spatial and temporal variability, including cyclical return periods of rainfall. However, due to a lack of fine-resolution rainfall data, Qiang *et al*. (2020) and Panagos *et al.* (2015), as well as Angulo-Martinez (2009), have used 10-year and even as low as two-year data for estimation of R used in developing erosivity factor map in Europe and comparison of spatial interpolation methods in Ebro basin of Spain.

This current study was conceived to be a long-term assessment of erosivity in the region but for damage to installed recording weather stations after a few years of installation. In Nigeria, records of erosion and consequent disruption of the landscape are on the increase. Unfortunately, few and no recent studies on the erosive potential of rainfall exist. Southwestern Nigeria in particular, is a region characterized by intense and relatively long periods of rainfall annually. The pressures emanating from the increasing erosion rate suggest that rainfall erosivity should be estimated from available data to guide further studies and to evolve appropriate soil conservation and management strategies. The objectives of this study were to assess rainfall erosivities for the study area and to compare site-specific rainfall erosivities obtained from commonly used indices.

MATERIALS AND METHODS

Automated weather stations (Spectrum watch dog 900 ET) (Plate 1) were established in different locations in southwestern Nigeria representing different agroecological zones. These are the Teaching and Research Farm, Obafemi Awolowo University, Ile-Ife (07° 33' 34" N 4° 33' 51" E) - rainforest; Ilejemeje local Government headquarter, Iye-Ekiti (07° 55' 79" N 5° 16' 54" E) – derived savanna; and Oke Ogun Polytechnic, saki The Polytechnic Ibadan, Saki Campus, (08° 48' 81" N 3° 24' 41" E) – Southern Guinea savanna. For the purpose of high temporal resolution, a logging interval of 5 minutes was set. The rainforest zone (Ile -Ife) was formerly dominated by thick forests but has now been reduced to secondary forests with fallow regrowth or replaced by perennial and annual crops. The savanna zone (Iye - Ekiti and Saki) consists of areas occupied by tall grass and short scattered trees. Data from Obafemi Awolowo University were collected from September 26, 2011, to December 31, 2013, while data from Iye – Ekiti and Saki were collected from July 11 2012 to December 31 2013 and from October 21 2012 to December 31 2013 respectively. Differences in dates and duration of data collection were a result of technical issues relating to the functioning of the installed weather stations. The climate of the study area is characterized by tropical rainfall with distinct wet and dry seasons. The wet season starts from mid-March to late October and the rainfall pattern is bimodal with peaks in June/July and September/October while the dry season runs from early November to early March (Adejuwon *et al*., 1990; Adepitan *et al*., 2017).

Processing of rainfall data

Maximum 30-minutes and 7.5 minutes rainfall amounts were processed in Microsoft Excel for the determination of maximum 30-minutes and maximum 7.5 minutes rainfall intensities. According to Wischmeier and Smith (1958), intensities greater than 25 mm/h are needed for a significant amount of erosion to occur while Stocking and Elwell (1976) identified a distinct erosive event as a storm when total rainfall exceeds 25 mm/h and the event is separated by at least 2 hours of no rain. Wischmeier and Smith (1978), also omitted rains less than 12.7mm in erosivity index computations. A similar approach has also been used by Renard and Freimund (1994) as well as Yu and Rosewell (1996) in making iso-erodent maps. Hence, in this study, only rainfall events total amount of 12.7mm or greater were used. In some cases, a short burst of 6mm rain in 15 minutes was also included as suggested by Foster *et al*. (1981). By applying the erosive rainfall events thresholds, the data for the three stations used in this study contained 154 erosive events.

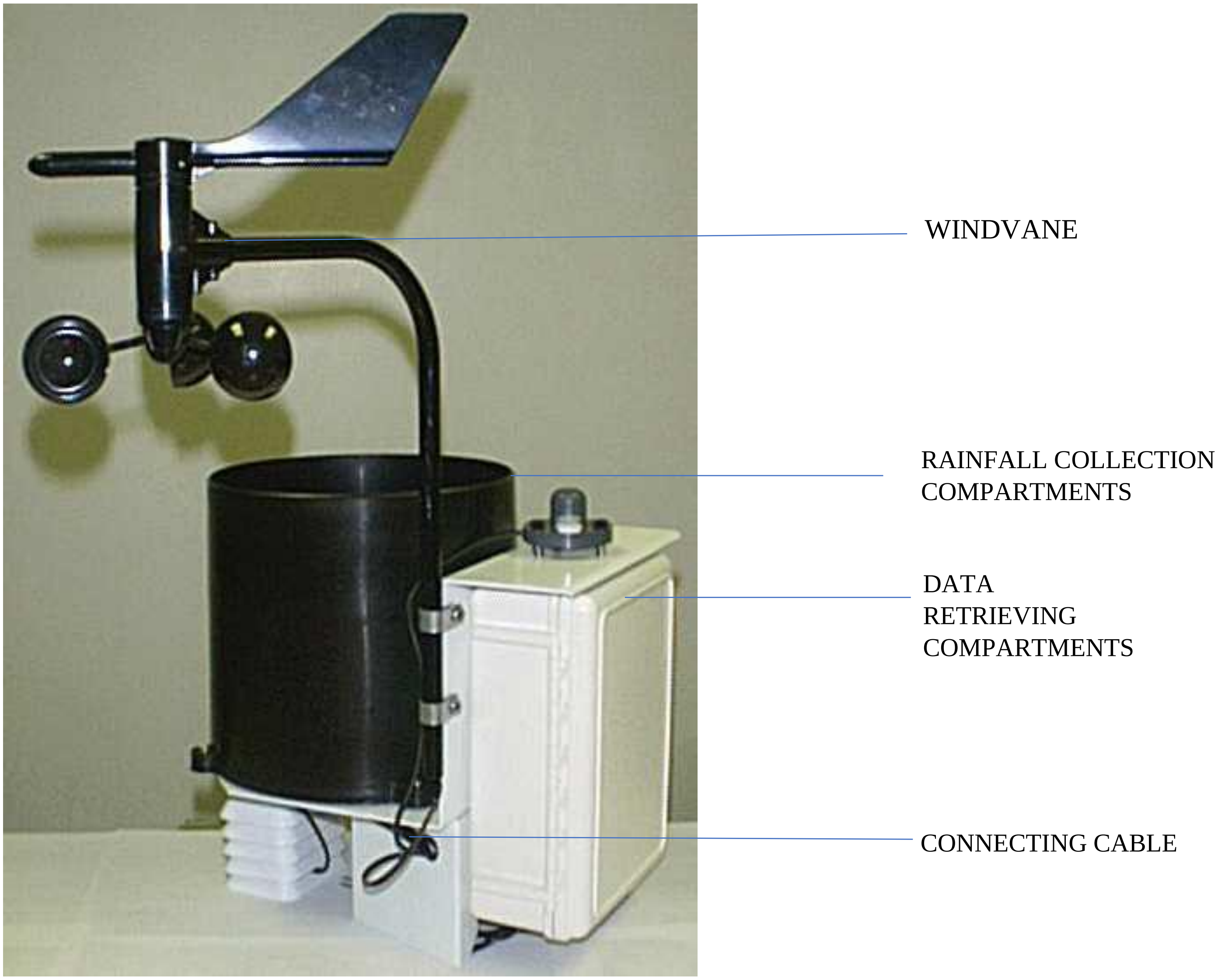


Plate 1: Unmounted Spectrum Weather Station (Spectrum watch dog 900 ET)

Rainfall intensity

Rainfall intensity was calculated as a relationship between rainfall amount and time increment. The 30-minute intensity (I_{30}) was taken as twice the maximum rainfall amount recorded in 30 minutes intervals in an erosive event. Thus, it was calculated as described by Brown and Foster (1987) :

$I_{30} = A_{30}/0.5h$, ------------------------------ (1)

where A (mm) is the maximum 30-minute rainfall depth and h is hour. On the other hand, 7.5 - minute maximum intensity was calculated based on the maximum amount of rainfall in 7.5 minutes period. Since the weather station recorded all the weather data only in 5 minutes time intervals, 7.5 minutes of rainfall amount was gotten by proportion. Subsequently, the 7.5 - minute rainfall intensity was calculated as:

$I_{7.5} = (A_{7.5}/7.5) \times 60$, ---------------------- (2)

where $I_{7.5}$ is 7.5 - minute maximum intensity and $A_{7.5}$ is 7.5 - minute rainfall amount.

Rainfall kinetic energy

To compute the kinetic energy of the storm, rainfall from the stations was analyzed and divided into small times of uniform intensities. For each period, knowing the intensity of the rain, the kinetic energy at each intensity was estimated using the equation:

$E_s = 0.119 + 0.0873\log_{10}I_s$, ------------ (3)

where E_s is the energy of a segment of the storm in MJ/ha and I_s is the intensity of rainfall in mm/h

The energy obtained in equation 3 was multiplied by the amount of rain received in each time increment and summed up to give the total energy for the storm as shown in equation 4.

$E = \sum E_sV_s$, ------------------------------ (4)

where E is the total rainfall energy and V_s is the storm segment rainfall depth.

Rainfall erosivity indices

The rainfall erosivities that were estimated in this study include:

EI_{30} (Wischmeier and Smith, 1978, Renard *et al*., 1997), $AI_{7.5}$ (Lal, 1976) and the Modified Arnoldus Index (Arnoldus, 1980)

EI_{30} erosivity index

The EI_{30} is designated as R in the Revised Universal Soil Loss Equation (RUSLE), which is a product of total rainfall kinetic energy and its 30-minutes maximum intensity. The monthly erosivity was calculated as the sum of individual event erosivity for the month while annual erosivity was determined as:

$R = 1/n \sum \sum (EI_{30})_k$, ------------------- (5)

where R is the average annual erosivity, n is the number of years of records, EI_{30} is the rainfall erosivity of a single event and k is the number of erosive events.

$AI_{7.5}$ Erosivity index

The $AI_{7.5}$ Erosivity index is a product of the total amount of rainfall in a rainfall event and the maximum 7.5 - minute intensity. The monthly $AI_{7.5}$ index was calculated as the sum of all events $AI_{7.5}$ for the month while the annual erosivity was determined as:

$R = 1/n\sum\sum (AI_{7.5})_k$, -------------------- (6)

where R is average annual erosivity, n is no of years of records, $AI_{7.5}$ is rainfall erosivity of a single event and k is the number of erosive events.

Modified Fournier Index (MFI)

The Modified Fournier Index based on Arnoldus (1980) is expressed as:

$MFI = \sum p^2/P$, ------------------------- (7)

where p is monthly rainfall amount, P is annual rainfall amount

RESULTS AND DISCUSSION

Total monthly EI_{30} erosivity distribution

Table 1 showed monthly rainfall distribution varied across the study locations. The highest rainfall was recorded in Ile –Ife, a rainforest belt, while Saki which is typically a guinea savanna belt had low rainfall during the period over which the study was carried out. By applying the erosive events thresholds (Wichmeir and Smith, 1958; Foster *et al*., 1981), the data for the three stations in this study contained 154 erosive events. The three years over which erosivity values were estimated in Ile- Ife, June; July; September and October had very high rainfall erosivity (R) compared to other months of the year (Figs. 1 – 2). This position was substantiated by high erosivity values recorded in September 2012 and 2013. Rainfall erosivity in October 2011 (20352.2 MJmm/ha hr mth) was about 21 times the value recorded in November of the same year (953.6 MJmm/ha hr mth). Similar to results obtained in 2011, very high erosivity values were recorded in September – October 2012 and 2013 in Ile-Ife and Iye – Ekiti but according to Carvalho (2008) rainfall erosivity in Saki was in the medium class High erosivity values comparable to September and October were obtained in June and July for the year 2012 in Ile-Ife, the year 2013 in Iye-Ekiti and for July 2013 in Saki. On the other hand, very low or zero R were estimated in August in Ile – Ife and Iye – Ekiti while in Saki, no erosive storm for erosivity estimation was captured in the month. These months with high erosivity correspond to months that had peak rainfall. This is characteristic of Southwestern Nigeria's rainfall pattern.

Table 1: Monthly rainfall distribution of the study area

Months	Ile-Ife			Iye-Ekiti			Saki		
	2011	2012	2013	2011	2012	2013	2011	2012	2013
January	-	0.0	21.7	-	-	6.7	-	-	6.5
February	-	79.4	78.4	-	-	16.2	-	-	0.3
March	-	8.3	113.6	-	-	108.9	-	-	5.7
April	-	25.5	117.7	-	-	204.9	-	-	10.0
May	-	125.9	-	-	-	209.3	-	-	22.1
June	-	258.3	-	-	-	225.3	-	-	5.9
July	-	216.7	-	-	57.0	234.5	-	-	43.3
August	-	41.0	-	-	58.6	31.3	-	-	5.9
September	15.6	274.0	296.9	-	262.0	287.4	-	-	17.2
October	314.5	278.9	296.9	-	195.4	111.9	-	35.9	8.4
November	39.6	79.3	28.0	-	47.4	1.0	-	8.4	0.3
December	0.2	0.5	37.3	-	0.2	0.0	-	0.0	0.0

Nigeria rainfall pattern. A similar trend was observed by Qiang *et al.* (2020) who indicated that rainfall amount, energy and erosivity were similarly distributed and positively correlated in the UK. This was also corroborated by Panagos *et al.* (2015) who reported that monthly erosivity was strongly correlated to changes in monthly precipitation. Ufoegbune *et al.* (2011) also reported high erosivity values for months with peak rainfall amounts with the use of the modified Fournier Index in the Ogun river basin. The high erosivity recorded in September and October may contribute to significant soil loss during this period because the preceding month, a period of rainfall cessation, is traditionally a period of land preparation for late-season farming. This is because the period of rainfall cessation commonly referred to as August break is used for land preparation in readiness for late-season farming anchored on September – October rainfall. The pulverization of soil during this break may result in a sharp rise in erosivity in September – October when rainfall amount was high and increased erosion and soil loss. High erosivity values in September and October could be more damaging to soil than in June and July since plant growth in cropped areas would have been luxuriant in the latter, providing enough surface canopy to shield the soil. However, in September and October, the loss of plant canopy covers owing to harvest and the gradual dropping of plant leaves as the dry season advances, exposes the soil to a more direct impact of rainfall. The direct impact of rainfall on the soil surface could potentially result in high soil loss in the early and late months of the year (January, February, March, November and December), despite low erosivity. The distribution of erosivity has a substantial impact on soil production at different locations. Saki, along with other communities in the Oke-Ogun area of Oyo State, located in the Nigerian Southern Guinea Savanna zone, is recognized as the food basket of Oyo State and even the Southwestern region (Sangotegbe *et al.*, 2012; Olutegbe and Fadairo 2016). Studies on some reference soils in the Oke-Ogun area placed them within moderate to high susceptibility to erosion but this limitation can be minimized further with adequate management such as alley cropping (Gbadegesin and Akinbola, 1995).

Therefore, despite the inherent limitation of the soil to erosion, the soil productivity in this location may be attributed, among other factors, to comparatively low rainfall erosivity in Saki, a climatic erosion determinant that may be shared by other communities in the Oke-Ogun area. A further study that quantifies soil loss directly from a field experiment in the study area and correlates the soil loss data with monthly rainfall erosivities is germane in the estimation of the erosiveness of rainfall in all the months of the year.

On a yearly basis, however, the erosivity (45987.7 MJmm/ha hr mth) in September 2013 was almost 3 times that of September 2012. In October 2011, rainfall erosivity (20352.2 MJmm/ha hr mth) was close to what was obtained in October 2012 (19814.4 MJmm/ha hr mth) while in October 2013, the erosivity value (2504.7 MJmm/ha hr mth) was lower than previous years (Figs. 1- 2). Hence, erosivity values in September-October, 2013 were higher than those in September–October 2012. Similarly, in Iye-Ekiti, erosivity in September and October 2013 (Fig. 2b$_1$ and b$_2$) was more than 5 and 4 times than in September and October 2012. According to Fig. 3, October 2012 received no erosive rain, therefore Saki did not follow the trend observed in the other two stations from September – October. This is because Saki was a relatively dry station (Akinwumi, 2015).

Rainfalls in January, February, March and April 2012 generally had lower erosivity than the same months in 2013’s (Fig. 2). While there was no erosive rain in January 2012, erosivity of about 1114.7 MJmm/ha hr mth was recorded in January 2013. In the meantime, February 2013 was 2.3 times more erosive than February 2012. In March and April 2012, there was no erosive rain, but in

March and April 2013, there were 2903.6 and 7737.4 MJmm/ha hr mth, respectively. The similarity in erosivity distribution between Ile-Ife and Iye-Ekiti may be attributed to similarities in rainfall pattern, and convectional rainfall, resulting in the same rainfall microphysical characteristic, which is a strong factor in erosivity assessment. Iye-Ekiti is also closer to Ile-Ife than Saki. It can be observed that except for March, April and October 2013, the estimated erosivity in Ile Ife was generally the highest followed by Iye – Ekiti.

Total Monthly $AI_{7.5}$ Erosivity Distribution

June-July and September – October had peak erosivity, similar to what was observed for the EI_{30} index (Figs. 4 -6). High $AI_{7.5}$ was recorded for February, May, June and July 2012; October 2011; 2012 and September 2013 in Ile-Ife while September 2012 and 2013 had a consistently high $AI_{7.5}$ in Iye-Ekiti. For example, October 2011 was about 10 times more erosive than November 2011 in Ile-Ife while in Iye-Ekiti, September was about four times more erosive than November. Similar observations were equally made for June and July 2012 in Ile – Ife and 2013 in Iye -Ekiti. Similarly, high $AI_{7.5}$ rainfall erosivity was recorded for March, April and May 2012 in Iye – Ekiti. High $AI_{7.5}$ in these months reflected high rainfall amounts in the period and it is supported by Vitto *et al*. (1999) and Salako (2008). Similar to this finding, Qiang *et al*. (2020) also observed the highest rainfall erosivity in mountainous regions with the highest rainfall in a five-year study in the UK. Generally, months with peak $AI_{7.5}$ monthly erosivity were the months with peak EI_{30} values across the study areas.

However, there were obvious slight departures in $AI_{7.5}$ from the EI_{30} index. For example, October, 2011 had the highest $AI_{7.5}$ erosivity value (2944.46cm^2/h) in Ile -Ife, followed by October, 2012; September, 2013; June, 2012; July, 2012; whose values were 2886.03 cm^2/h, 2750.6 cm^2/h, 2009.87 cm^2/h, 1751.38 cm^2/h, respectively (Figs 4 – 5).

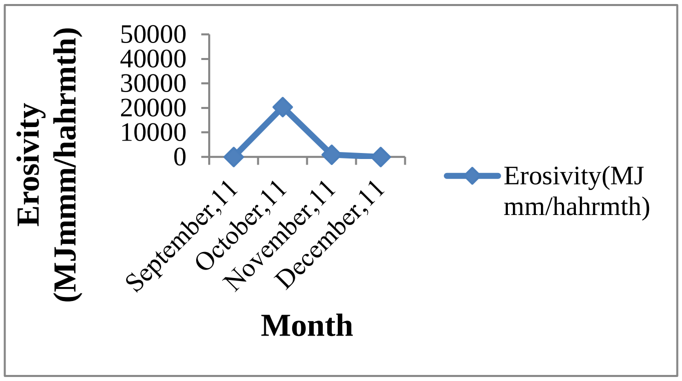
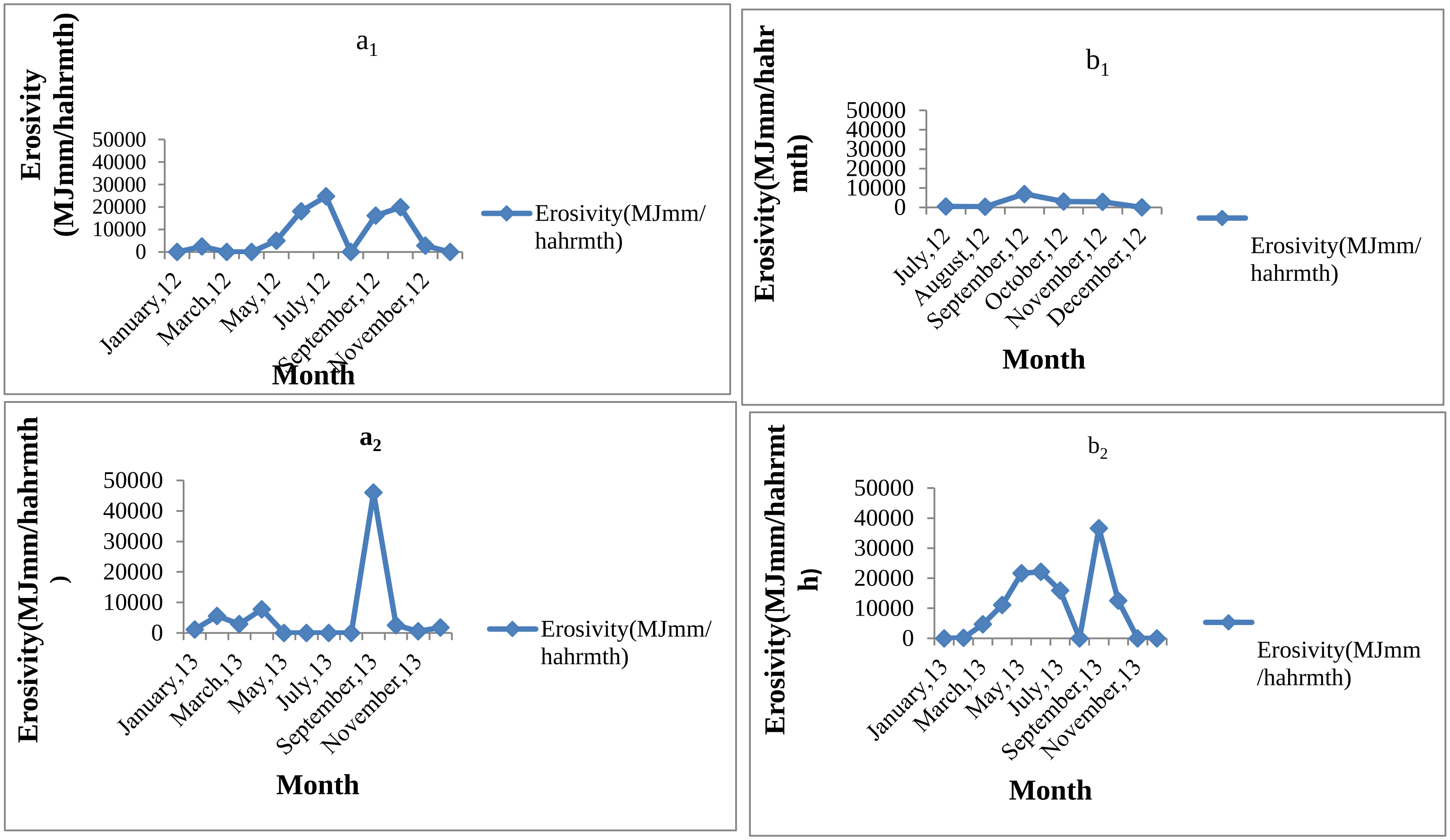


Fig. 1: Total monthly distribution of EI_{30} erosivity index at Ile - Ife in 2011



Figures 2 a_1, a_2 and b_1, b_2 showing EI_{30} rainfall erosivity in Ile- Ife and Iye - Ekiti in 2012 and 2013

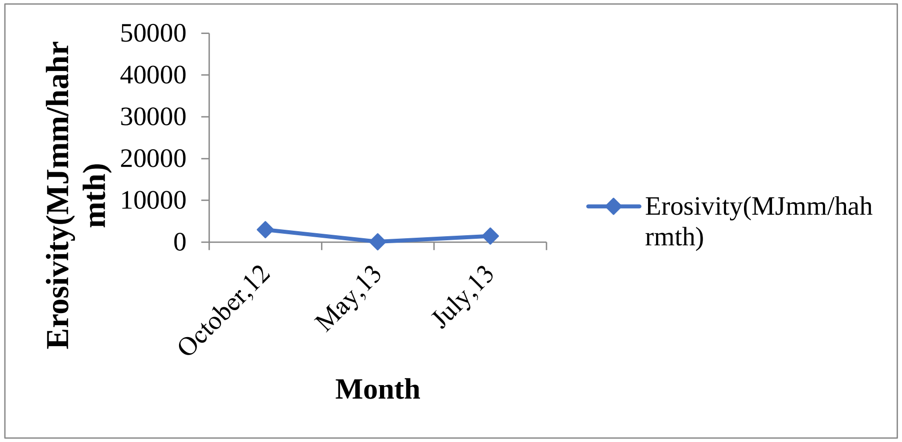


Fig. 3: Total monthly distribution of EI_{30} erosivity index at Saki 2012 and 2011

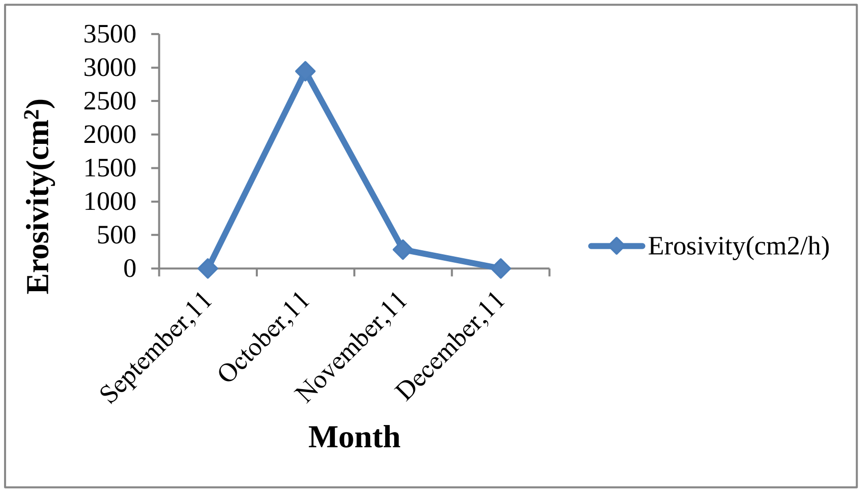
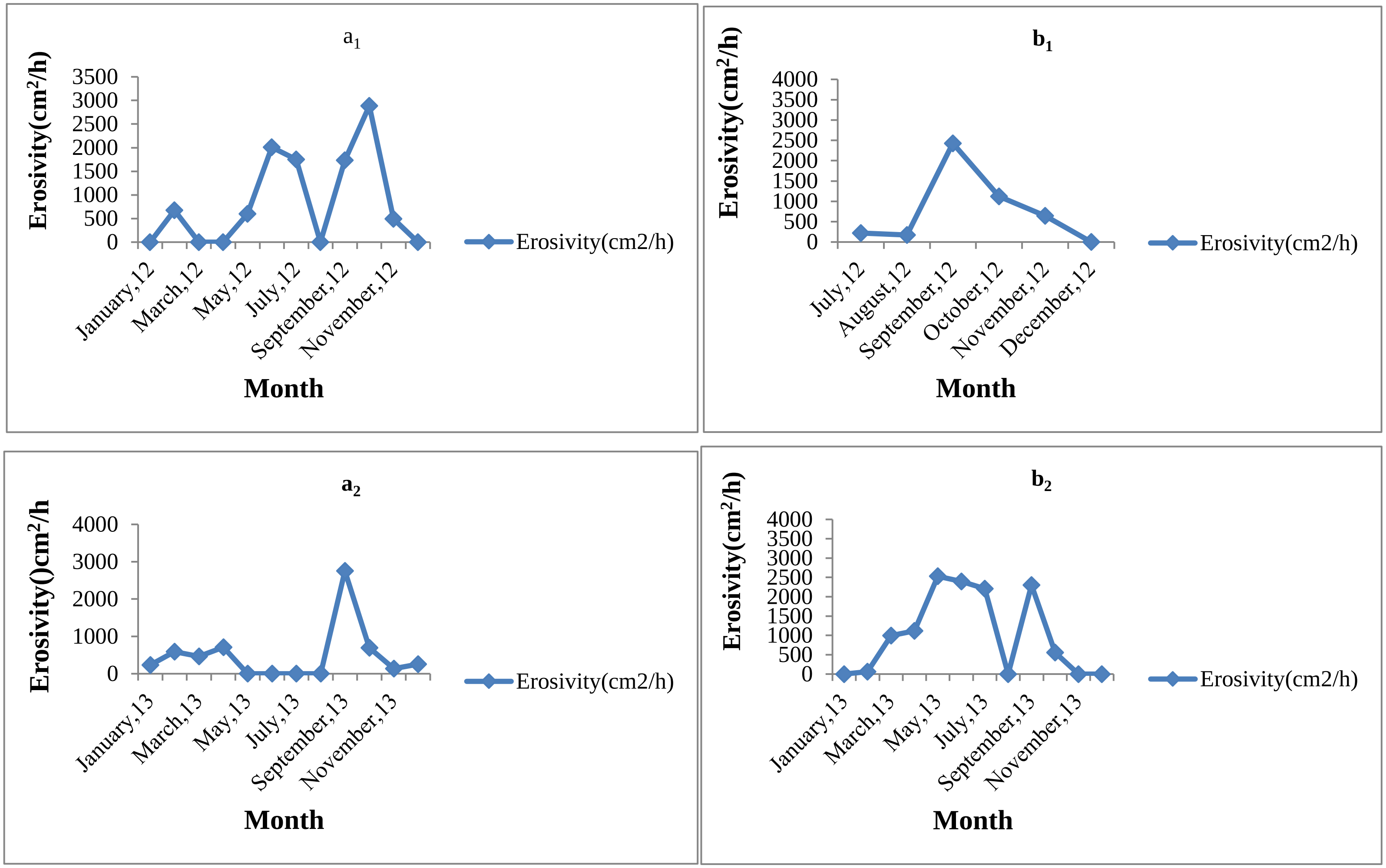


Fig. 4: Total monthly distribution of $AI_{7.5}$ erosivity index at Ile - Ife in 2011



Figures 5 a_1, a_2 and b_1, b_2 showing $AI_{7.5}$ rainfall erosivity in Ile- Ife and Iye - Ekiti in 2012 and 2013

On the other hand, during the same period, September 2012 was the most erosive month (45987.7 MJmm/ha hr mth) with the EI_{30} index (Fig.1), followed by other months, a pattern different from the $AI_{7.5}$ index. A marked difference in trend was also observed between EI_{30} and $AI_{7.5}$ distributions in Iye-Ekiti as shown in Figures 2 and 5. May 2013 (2528.742 cm^2/h) was the most erosive month based on the $AI_{7.5}$ index while it was September 2013 based on the EI_{30} index. However, in Saki, there was no difference between the two indices (Figs. 3 and 6). This could be because only a few erosive storms were captured in the erosivity estimation.

The reason for the difference between $AI_{7.5}$ and EI_{30} indices' monthly spread is because erosivity from both indices relies on different rainfall characteristics. Though both indices have intensity as one of the variables in R estimation, the different time steps in intensity required for erosivity estimation in the two indices can cause significant variations in their responses to rainfall. Even when the same time intensity was used, Wang *et al*. (2014), noted that the effect of intensity was not straightforward in a short–duration rainfall of high intensity and a long-duration low-intensity storm, since both contribute to rainfall erosivity. Similarly, it has been reported that using different equations for energy terms in EI_{30} has resulted in variations in the erosivity factor (Vantas *et al*., 2019). Salako (2007) indicated that the high erosivity of $AI_{7.5}$ in Ibadan was due to higher rainfall intensity. The EI_{30} index, on the other hand, was mainly influenced by the kinetic energy of rainfall events which is driven majorly by raindrop size (Sharma, 1996; Cerda, 1997).

Correlation of EI_{30} with $AI_{7.5}$ and modified Fournier erosivity indices.

The correlation coefficients (Table 2) of EI_{30} with the $AI_{7.5}$ index showed a highly significant ($p < 0.01$) positive correlation between the two erosivity indices in the three study areas. The correlation coefficients of $r = 0.891$(Ile Ife), $r = 0.816$ (Iye-Ekiti) and $r = 0.970$ (Saki) showed that both indices have a similar capacity to quantify the potential of rainfall to cause erosion in southwest Nigeria. Obi and Salako (1995) also noted that $AI_{7.5}$ will be good for erosivity estimation in southeastern Nigeria but suggested multiplying EI_{30} by a factor of 1.6 would make the model a good index for the tropics.

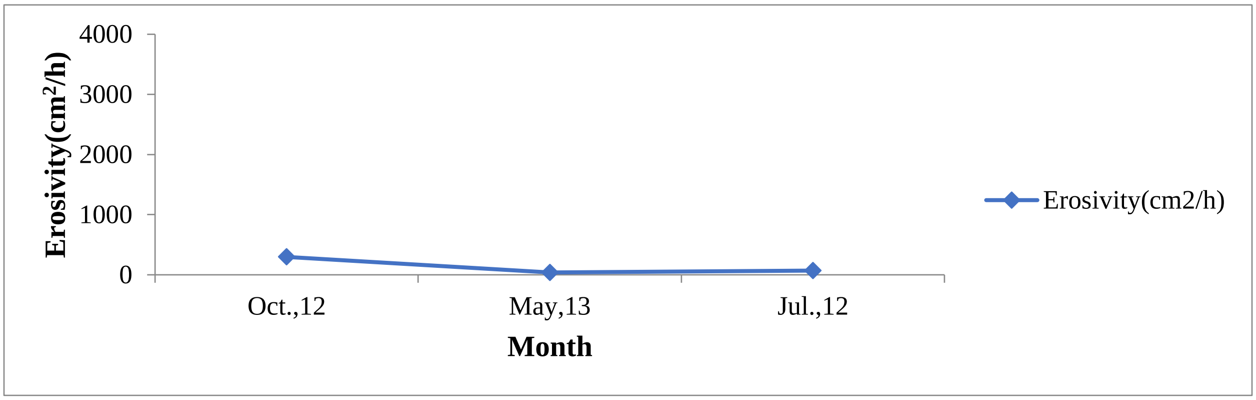


Fig. 6: $AI_{7.5}$ Monthly Erosivity in Saki in 2012 and 2013

This result corroborates Alipour *et al.* (2012) in which both indices had the same value of r = 0.84 ($p < 0.01$) when they were correlated with sediment yield in Namak Lake Basin of Iran and hence were both recommended as good indices for the area. Eslami *et al*. (2013) also concluded that with a strong positive correlation of EI_{30} and $AI_{7.5}$ with sediment yield in the Khouzestan province of India, the two indices were able to adequately estimate rainfall erosivity. This means that both indices are good at estimating rainfall erosivity in the study area. It is worthy of note that the high positive correlation of EI_{30} with $AI_{7.5}$ which was primarily designed in tropical climates showed that EI_{30} is equally good for erosivity estimation in tropical climates contrary to some beliefs (Favis – Mortlock, 1998; Benavidez *et al*., 2018) that USLE/RUSLE and hence EI_{30} are only reliable in the USA, with an essentially temperate climate.

This result is supported by Stocking and Elwell (1973) who indicated that EI_{30} is a good index for erosivity estimation since it computes EI_{30} only for storms yielding 12.5 mm or more of rain and with a maximum 5-minute intensity greater than 25mm/h. Since only a storm having a minimum intensity of 25mm/h was used in this study, and with a good positive correlation $AI_{7.5}$ designed for a tropical climate, EI_{30} is also a good index for southwestern Nigeria just as the $AI_{7.5}$ index. The correlation coefficients between EI_{30} and Modified Fournier indices in all the locations of the study indicated positive significant correlations between the two indices. This is consistent with what Alipour *et al*. (2012) observed in Iran where a correlation coefficient of r = 0.80 ($p = 0.01$) was established between EI_{30} and MFI. However, the correlation of EI_{30} with the Modified Fournier index is weak in Iye-Ekiti. This could mean that the energy and intensity of rainfall events as represented by the EI_{30} index in this location are significantly more important than just the sum of monthly and annual rainfalls depicted by the modified Fournier index. This showed that $AI_{7.5}$ is better for erosivity estimation in Iye – Ekiti than the modified Fournier index.

Table 2: Pearson correlation coefficients of EI_{30} with $AI_{7.5}$ and modified Fournier erosivity indices

	$AI_{7.5}$	**MFI**
Location	← r	→
Ile -Ife	0.891^{**} $EI_{30}=0.0073AI_{7.5}+225.57$ $r^2 = 0.79$	0.637^{**} $EI_{30}^{=0.0032MFI+ 3.50}$ $r^2 = 0.41$
Iye – Ekiti	0.816^{**} $EI_{30}=0.078AI_{7.5}+331.4$ $r^2 = 0.67$	0.479^{*} $EI_{30}^{=0.0016MFI – 0.92}$ $r^2 = 0.89$
Saki	0.970^{**} $EI_{30}^{=0.092}\ AI_{7.5}^{\ -\ 2.21}$ $r^{2\ =\ 0.88}$	0.994^{**} $EI_{30}=0.0085MFI+2.88$ $r^2 = 0.99$

***. Correlation is significant at the 0.01 level (2-tailed).*

**. Correlation is significant at the 0.05 level (2-tailed*)

CONCLUSION

The study assessed site-specific rainfall erosivity for the study area. The results showed that EI_{30} and $AI_{7.5}$ as well as EI_{30} and modified Fournier indices were well correlated. This implies that EI_{30} is appropriate for use in Southwestern Nigeria contrary to the belief that the index is limited to temperate climates. However, the relation between EI_{30} and modified Fournier was somehow weak, especially in Iye–Ekiti. Annual soil erosivity values also indicated that erosivity in the study areas fell within the strong rainfall erosivity class. To mitigate soil loss, it is suggested that land preparation in months preceding peak erosivity months should be minimum or no tillage so that the soil is not pulverized and exposed to an erosive rainstorm in the months with a sharp rise in rainfall erosivities. A further study that provides empirical data of soil loss from the field directly in all the months of the year will serve to establish the relationship of these erosivity indices with actual soil loss and further ascertain the suitability of the modified Fournier index in the zone.

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