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*Full Length Research Paper*

# Mitigating soil erosion challenges through strategic land management in a region of Kwara State, Nigeria

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**This paper is an assessment of the roles of different land use types in controlling erosion rates in some parts of Kwara State. To accomplish this philosophy, data were therefore collected on individual rainfall characteristics, depth of erosion on each land use type and percentage plant covers on land use basis too. These data were then processed using both descriptive and regression techniques of analyses. The following therefore constitutes as the results observed as follows: (i) The components of rainfall total are very important in explaining and the prediction the rate of erosion on all land use types and subsequently the desired management types. (ii) The land use types studied respond differently to the forces of individual rainfall events, each land use type therefore requires a distinct management technique. (iii) Land use types covered by grasses to about 95% do not suffer any serious erosion attack. Similarly, undergrowth of grasses should be encouraged under the trees. This is because; grasses have the potential to break the powers of rainfall at ground level. However, tree covered land use type accelerate the incidents of erosion which is at variance with the traditional beliefs of checking erosion with it.**

**Key words:** Managing, landuse, control, soil erosion, problems.

## INTRODUCTION

Soil erosion rates on different land use types have been observed by a number of scholars in both the humid and temperate environments (Gregory and Wallings, 1973; Elwell and Stacking, 1974; Jeje and Nabegu, 1982; Oyegun, 1980; Jimoh, 1997, 2008) among others. But, the most important factor of erosion on all land use types is rainfall (McGree 1897; Oyegun, 1980; Jimoh, 1994, 1997). However, other factors of erosion include topography, geology and the land management techniques (Butzer, 1974; Kowal and Kassam, 1978; Jimoh, 1997, 2001). But, it is the total interactions of these factors on land use types that can sufficiently explain the erosion rates on different land use types (Jimoh, 1997a, 1997b, 2008; Coleman, 1981).

In the recent time in Nigeria, the incidences of soil erosion from various sources have constituted much nuisance to man's environment. This has been in terms of causing road accidents, blocking of both the artificial and natural drainage systems, pollution of road networks, burying of fertile soil surfaces, increase in water treatment costs, damage to buildings, fences and silting of reservoirs among others (Higgins and Kassams, 1981; Lewis and Lepele, 1982; Oyegun, 1980; Sutherland and Dejong, 1990; Jimoh and Ajewole, 2007) among others.

These occurrences emerged solely due to man's incessant interactions with the land surfaces (Lal, 1981; Smith and Wischmeier, 1962; Jimoh, 2005). Such interactions are tied to the identified numerous landuse mixes. The category of such use includes residential, commercial, industrial among others. However, these uses failed to make sufficient allowances to accommodate the accompanying stress on the environment. Thus, varying amount of soil loss occurs over all the land use types that later translate into a number of problems on their sites of deposits (Jimoh 1997). Interestingly, Toy (1982) has in clear terms specified or predicted the magnitude of impact of every disturbance initiated on human landscape.

This research effort therefore examines the forces of individual tropical rainfall events on the depth of erosion from the different land use types and the relevance of covers on each land use type in controlling erosion on each landuse type. To accomplish this task, the following specific objectives have been focused as follows.

(a) To study the relationship between the characteristics of tropical rainfall events and depth of erosion on different land use types.

**Table 1.** Depth and lithological description of geology in Ilorin.

| Thickness (cm) | Lithology |
|---|---|
| 0- 0.3 | Brown top soil |
| 0.3 - 0.9 | Laterite |
| 0.9 - 2.0 | Weathered micaceous crystalline rock |
| 2.0 - 4.0 | Kaolinized felspathic rock (clay) |
| 4.0 - 5.5 | Weathered micaceous quartzo-felspathic rock (clay) |
| 5.5 - 9.0 | White kaolinized felspathic rock (rock) |
| 9.0 -12.5 | Weathered schistose micaceous crystalline rock |
| 12.5 -13.0 | Quartzo-felspathic (pegmatic rock) |
| 13.0 - 16.5 | Weathered schistose, micaceous crystalline rock |
| 16.5 - 21.0 | Pegmatic |
| 21.0 - 28.9 | Granitic crystalline rock |

Source: Phillip Morris (Nig.) Ltd, Factory borehole No. 1.

(b) To investigate the effects of covers on erosion from land use types with a view to applying the appropriate managing techniques.

## Study area

Ilorin is a typical urban area in Nigeria and it was founded in 1967. The growth rate has been documented by many scholars notable among them is the work of Oyegun (1987). Since 1987, the city has grown both in physical size and in population too (Figure 1). For instance, the Endplan Group (1977) put the population of Ilorin at 400,000 and this made it then the sixth largest town in Nigeria. But, the estimated population by the 1991 census figure is about 572,178 and occupying an area of approximately 100 $km^2$. In the opinion of Oyegun (1987) the development rate is so fast that other land use types are giving way to built up areas. For example, the built up area have grown from 20.40 $km^2$ in 1963 to about 58.00 $km^2$ in 1982 while other land use types such as grass, fallow land and trees decrease in area of occupancy from 35.84 $km^2$ in 1963 to about 9.70 $km^2$ in 1982.

Essentially, Ilorin city, the study area is located on latitude 8° 30'N and longitude 4°35'E. The climate is the humid tropical type characterized by dry and wet seasons, with a mean a mean annual temperature of ranging from 25 to 28.9°C. Also, the mean annual rainfall is about 1150 mm exhibiting the double maximal pattern.

The geology is the basement complex rocks, and the rocks have undergone many processes of metamorphisms and magmatic intrusion. The rocks comprise of sedimentary rocks. Also, both primary and secondary laterites and alluvial deposits are present. This type of rock deposits is weak and therefore readily yields to agents of erosion (Jimoh, 1997). Phillip Moris (Nig. Ltd) best presents this scenario on the geology of the study area (Table 1, Factory borehole No. 1).

## MATERIALS AND METHODS OF STUDY

This work based largely on direct fieldwork investigation. Thus, the data required to accomplish the philosophy of this work are the climatic and the landscape factors. These data generation efforts lasted for one hydrologic session.

The climatic variables include the rainfall total, duration, intensity and kinetic energy. On the other hand, landscape variables include percent plant covers, depth of erosion and the physical characteristics of soils. Rainfall total was estimated with ordinary rainfall gauge, while the duration was based on stopwatch monitoring. On the other hand, the intensity was based on an equivalent such as A/D, where 'A' is the rainfall total and "D' is the duration of rainfall. To estimate the value of kinetic energy, the value of rainfall intensity is simply substituted into the formulae advanced by Hudson (1965) and Smith and Wischmeier (1962) respectively.

The percent plant covers was estimated with cover estimator having a dimension of 0.51 $m^2$ every fortnight. Sediment traps of similar dimension were sited on each surface, the output of which is separated into classes using particles separate analysis method after each rainfall event for all the land use types. Erosion rates were also estimated using erosion pins. The erosion pins were installed on land use basis especially after the required number of erosion pins has been determined. Snedecor and Cochran (1967) have advanced the equivalent for arriving at the required number of erosion pins. In line with this development, Jimoh (1994, 1997) have demonstrated the application of the equivalent with a rewarding result. In this study therefore, 89 pins, 10 pins, 9 pins and 10 pins were estimated for the erosion studies on bare, fallow land, grass and trees land use types in the study area respectively. These erosion pins were then carefully installed on each land use type so as to avoid the incidence of soil disturbance. After each rainfall event, erosion depth on each land use type was determined by closely examining the depth of exposed pins, which were later collated and recorded. Further, a composite soil samples were obtained from each land use type and analyzed for textural characteristics using the hydrometer technique of Bouyucos.

## RESULTS AND DISCUSSION

Interestingly, various measures of analysis have been

**Table 2.** Pairwise correlation coefficients between rainfall characteristics and depth of erosion on land use types.

| Depth of erosion on land use types | Rainfall total (mm) | Duration of rainfall (min.) | Rainfall intensity ($mmhr^{-1}$) | Rainfall kinetic energy ($joules/m^2$) |
|---|---|---|---|---|
| Bare | 0.90 | 0.34 | 0.79 | 0.79 |
| Grass | 0.84 | 0.31 | 0.72 | 0.72 |
| Fallow land | 0.88 | 0.35 | 0.76 | 0.76 |
| Tree covers | 0.72 | 0.25 | 0.64 | 0.64 |
| Road island | 0.83 | 0.24 | 0.53 | 0.54 |
| Road island (Deposits) | 0.73 | 0.48 | 0.64 | 0.64 |

Source: the Author. *All values are significant at 0.05 level.

adopted with far reaching results as follows.

**Roles of individual rainfall on depth of erosion under different land use types**

Some levels of correlation coefficients have been established between the components of the individual tropical rainfall events and the rate of erosion on the different land use types (Table 2).

The components of rainfall such as rainfall total, duration, intensity and kinetic energy have correlation coefficients of 0.90, 034 and 0.79 with the depth of erosion on bare land use type. While their coefficient of determination ($r^2$) are 0.81, 0.12 and 0.62 respectively. In essence, rainfall total, duration, intensity and kinetic energy have explained about 81, 34, 79 and 79% the depth of erosion on bare land use type. In the case of grass land use type, the correlation coefficients between the components of rainfall total, duration, intensity and kinetic energy with the depth of erosion on the grasses surface type are 0.84, 0.31, 0.72 and 0.72, respectively. The $r^2$ values of these correlation coefficients are 0.71, 0.10. 0.52 and 0.52, respectively. These components of rainfall such as rainfall total, duration, intensity and kinetic energy have explained about 71, 10, 52 and 52% of the depth of erosion on this land use respectively. Again, rainfall total is most efficient in explaining the depth of erosion on grassland use type. In the case of fallow land use type, the components of rainfall total, duration, intensity and kinetic energy have correlation coefficients of 0.88, 0.35, 0.76 and 0.76 with the depth of erosion on this land type. Their $r^2$ values are 0.77, 0.12, 0.58 and 0.58, respectively. Rainfall total alone has explained about 77% of the depth of erosion on this land use type. While duration, intensity and kinetic energy of the individual rainfall events have explained 12, 58 and 58% the depth of erosion on this land use type respectively. Finally is the tree covered land use type where the components of rainfall such as rainfall total, duration, intensity and kinetic energy have correlation coefficients of 0.72, 0.25, 0.64 and 0.64 with the depth of erosion on this land use type respectively. The $r^2$ values of these correlation coefficients are 0.52, 0.06 and 0.41 respectively. Rainfall total alone has explained about 52% of the depth of erosion on this land use type. While the duration, intensity and kinetic energy of rainfall have explained about 6, 41 and 41% respectively of the depth of erosion on fallow land use type. But, the correlation coefficients between the components of individual rainfall such as rainfall total, duration, intensity and kinetic energy with the depth of erosion are 0.83, 0.24, 0.53 and 0.54 respectively. Their $r^2$ values are 0.69, 0.06, 0.28 and 0.29 respectively. Thus, rainfalls total component alone explained about 69% of the depth of erosion on the road island land use type. While duration, intensity and kinetic energy of rainfall have explained 6, 28 and 29% respectively of the depth of erosion on this land use type. Further, the correlation coefficient between the components of rainfall total, duration, intensity and kinetic energy with the weight of sediment deposits along the road islands is 0.73, 0.48, 0.64 and 0.64, respectively. Their $r^2$ values are 0.53, 0.23 and 0.41, respectively. Thus, rainfall total alone has explained about 53% on the weight of sediment deposits along the road islands. While duration, intensity and kinetic energy of the individual rainfall have explained 23, 41 and 41% respectively of the weight of sediment deposits along the road islands.

Deposits of sediments along the road islands are moved from the surfaces of the road island. For instance, a correlation coefficient of 0.83 have been found between the weight of deposits of sediment along the road islands and the depth of erosion thus, about 68.9% of the sediment deposits are believed to have been moved from the surface of the road islands and deposited beside them. The remaining 31.1% of the sediment deposits along the road islands are either brought by the surface run-off during the incidence of rainfall, free blowing winds put in motion due to the violent motions of vehicles on the highways among others.

Generally, rainfall total component of individual rainfall events is the most efficient in explaining the depth of

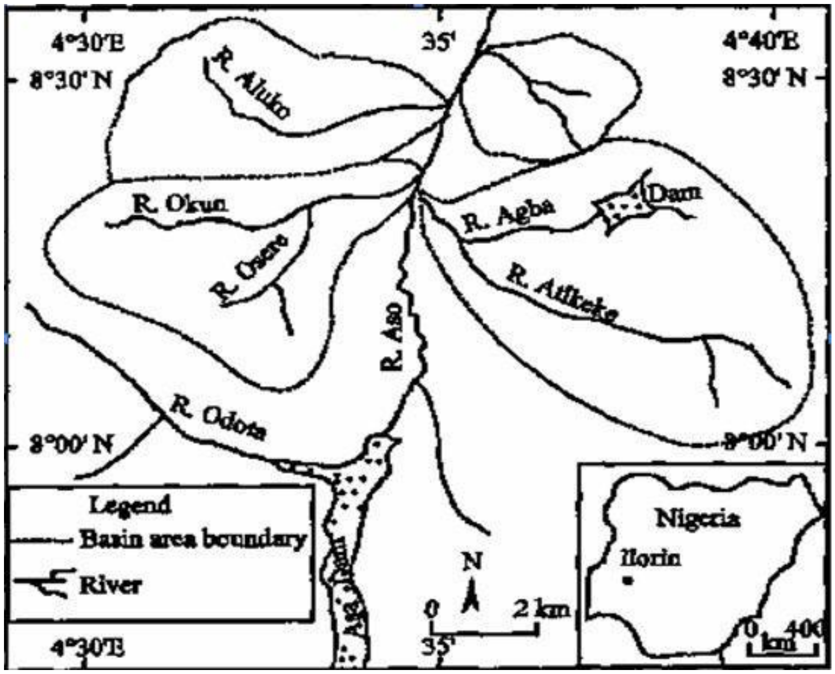


**Figure 1.** Ilorin, showing the four drainage basins as the study area. Source: Oyegun (1986).

**Table 3.** Annual soil loss from different land use types in Ilorin.

| Different land use | Soil loss (Kg x 10/ha /p.a) | Mean annual cover (%) |
|---|---|---|
| Bare | 237.70 | - |
| Grass | 68.50 | 74.9 |
| Fallow land | 103.10 | 57.5 |
| Trees | 134.70 | 28.6 |

Source: The author.

erosion on all the land use types in Ilorin, Nigeria. However, other components of the rainfall such as duration, intensity and kinetic energy equally contributed towards explaining the depth of erosion on all the land use types in Ilorin, Nigeria.

## Effects of covers on land erosions

The relevance of cover in the discussion of landuse erosion is subsumed in the position of Cook and Doornkamp (1974). These workers estimated a possible tolerance threshold of the rate of soil loss from land use types in an area. For example, the accepted tolerant range estimated from land use types range between one and five tons per acre per annum (22.6 x $10^2$ and 118.4 x $10^2$ kg/hectare per annum (Cook and Doornkamp, 1974). Thus, values of soil loss that exceed this ranges are intolerable and therefore are regarded as being potentially liable to erosion problems (Table 3).

The values of sediment materials generated on each land use type were much higher than the tolerance ranges of Cook and Doornkamp (1974). For instance, it is evident that the bare land use type is the most vulnerable to the incidence of erosion. The tree covered land use type follows this, which is in at variance to popular views about the ability of trees to break the impact of raindrop energy and thereby reduce erosion problems. Earlier work such as Young (1971) had emphasized on the risks inherent about over reliance on trees as a means of erosion checks in a tropical environment. Finally, fallow land and grassland use types respectively have equally responded variably to the forces of rainfall. In this view, grassland use types are the potent for checking the incidences of erosion in Ilorin. This is due to its ability to break the impact of rainfall at ground level, thereby rendering the powers of rainfall irrelevant to sediment generation from this land use type.

Generally, both bare and tree land use types are very active erosion landuse areas. If however, these landuse types are to benefit from the effects of vegetal covers, bare land use area must be adequately covered with grasses while, land areas under trees should be kept covered consistently with grasses to over 95% (Table 4).

Grass has however distinguished itself as the best protection of the land use area from erosion problems during individual tropical rainfall events. Kowal (1972) has observed similar views, Fournier (1972), Oyegun (1983) and Jimoh, 1994, 1997, 1998). However, the required

**Table 4.** Monthly sediment generation and percent plant covers on land use types.

| Months | Total rainfall | Bare land use type | | Grass land use type | | Fallow land use type | | Tree land use type | |
|---|---|---|---|---|---|---|---|---|---|
| | | Sediment yields (g) | Cover (%) | Sediment yields (g) | Cover (%) | Sediment yields (g) | Cover (%) | Sediment yields (g) | Cover (%) |
| March | 20.5 | 68.5 | 0 | 49.9 | 35.0 | 72.8 | 8.0 | 52.1 | 0.0 |
| April | 31.2 | 99.6 | 0 | 180.9 | 50.0 | 82.1 | 21.0 | 161.5 | 5.0 |
| May | 108.2 | 330.6 | 0 | 132.5 | 80.0 | 252.9 | 38.0 | 226.5 | 18.0 |
| June | 193.3 | 643.6 | 0 | 230.6 | 79.2 | 310.3 | 63.0 | 263.9 | 18.5 |
| July | 133.6 | 449.6 | 0 | 102.1 | 90.0 | 194.4 | 68.0 | 335.9 | 19.2 |
| August | 152.5 | 255.0 | 0 | 62.7 | 92.8 | 86.7 | 80.7 | 165.2 | 45.3 |
| Sept. | 281.6 | 299.4 | 0 | 0.0 | 95.0 | 59.4 | 90.0 | 44.4 | 60.3 |
| October | 206.4 | 230.7 | 0 | 0.0 | 98.9 | 0.0 | 95.0 | 95.3 | 62.5 |
| Mean | 140.9 | 297.13 | 0 | 94.84 | 74.90 | 132.58 | 57.439 | 168.10 | 28.60 |
| STD | 82.7 | 173.89 | 0 | 77.74 | 22.12 | 101.09 | 32.91 | 96.73 | 22.67 |

Source: The author.

amount of plant cover for protecting land use areas from erosion risks are often not given or stated. In this research effort, it can possibly be argued that if landuse area covered by grasses to about 95% just before the commencement of rainy season soil loss from land use areas will be reduced considerably throughout the year. This is because, at such percent plant covers, the quantity of soil loss from landuse areas was zero (Table 4).

Part of the efforts of this research work was to locate landuse areas that are predisposed to soil loss after each rainfall event. This is with a view to given a better attention to soil conservation practices and more effective erosion control measures. It is clear from Table 4 that above that decrease in the rate of soil loss is usually due to increase in ground cover and vice versa. In this regard, plant cover of about 95% was considered adequate for effective erosion control in Ilorin. This is because, at such plant covers, the rate of soil loss from land use areas is zero. That is, the land use areas sufficiently shaded from the direct forces of the tropical rainfall events, the same soil loss decrease in quantity due to increase in the percentage grass cover. Cooke and Doomkamp (1974), Oyegun (1980, 1983) and Jimoh (1994, 1998) have made similar observations.

Generally, the mature and type of surface covers greatly influence the rate of soil loss from landuse types after each tropical rainfall event.

## The summary and planning implications of this work

This work endeavours to evaluate the strength of rainfall in the initiation of erosion on different land use types and hence, highlight the most susceptible landuse type. Subsequently, the need to adopt management techniques on appropriate landuse types. Thus, the following constitute as the major findings of this research work:

a) The most important characteristics of tropical rainfall that is of direct relevance are the correlation coefficients 0.90, 0.84, 0.88 and 0.72 which occurred between the factor of rainfall total amount and the depth of erosion on the bare, grass, fallow land and trees respectively.

b) Grasses are the most potent for checking water erosion on all landuse types. This is due to the ability of the grasses to break the powers of rainfall at ground level (Table 3).

c) An acceptable way of checking erosion on landuse types is to cover the surfaces with grasses to about 95% before the commencement of the rainy season.

(d) Increase in the incidence of rainfall leads to the growth of plant cover. This in effect leads to a decrease in the rate of soil loss on each land use type (Table 4).

## Conclusion

Erosion problems on different land use type have constituted much nuisance in the cities. The depth of erosion on these land use types is usually over a long period of time before any meaningful impression is made on the landscape.

Thus, this research work has elucidated the role of tropical rainfall on the depth of erosion on the different land use type in the study area. And, it has been observed that rainfall total amount as a component of individual rainfall events is very vital in explaining the depth of erosion on the land use types with a view to suggesting the appropriate management techniques in Ilorin, Nigeria.

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