A STUDY ON EROSION (CAUSES AND REMEDIES) BASED ON HYDROLOGICAL DATA

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Abstract: The project concentrates on an hydrological analysis. The analysis consists of rainfall, infiltration, Determination of runoff and sediment yield. The risque of erosion and the control measures are related to the slopes and land use. Therefore the first approach to erosion must be correct land use based on land classification.

Basically there are two types of mechanical protection works; Drainage and Storage. Realization of a drainage system will be very costly and therefore temporary storage is preferred. For farmland in flat areas hardly any measures are needed. For farmland on slopes temporary storage can be effected by applying tillage with ridges within contour bunds. Along roads infiltration pits should be constructed and in areas with houses, the solution to avoid runoff will be water harvesting.

Key Words: erosion study, causes and remedies, hydrological data

1. INTRODUCTION

Beasley State "Erosion by water is the result of energy developed by the water as it falls toward the earth and as it flows over the surface of the land. In the erosion process, soil particles are detached from the soil mass and transported to another location" (Beasley, 1980).

Factors which influence erosion are climate, soil, topography and land use. The amount of erosion is depending on a combination of the power of the rain to cause erosion and the ability of the soil to resist the rain impact (Hudson, 1957). The role of raindrops lies in the detachment of soil particles. Raindrops are furthermore sealing the soil surface and so reducing infiltration and increasing runoff. The vegetation cover normally reduces the momentum of energy of raindrops and so prevents surface sealing. The direct removal of soil by raindrop splash seems only to be important on small plots. Runoff is important in the process of transport of the detached soil particles.

If runoff in concentrated it becomes erosive on its own, due to the tracing force of the water near the bottom of the stream. That tracing force is related to the velocity of the water and so indirectly to the slope of the stream.

2. FORMS OF EROSION

2.1 Sheet Erosion

Sheet erosion is characterised by the detachment and removal of soil, more or less evenly over the affected area. Raindrop splash is responsible for the detachment of the soil particles. Flow over the surface which takes place when the rate of rainfall exceeds the rate of infiltration of water into the soil is responsible for the transport of the detached soil particles.

2.2 Rill Erosion

As water concentration in small flows in the field, rill erosion occurs. Rills are small narrow channels which cut into the soil surface and create a dense network on the affected slope.

2.3 Gullies

Further concentration of surface runoff can develop gullies. Gullies are normally defined as surface channels formed when rills combine and develop to the extent that they cannot be eliminated by normal tillage operations.

3. FACTORS INFLUENCING EROSION

The most widely method of soil loss prediction is the universal soil loss equation

$$A = R \times K \times L \times S \times C \times P$$

Where: A = annual soil loss Kg/m^2
R = soil erosivity factor
K = soil erodibility factor (related to infiltration)
L = Slope length factor
S = Slope gradient factor
C = Cropping management factor
P = erosion control practice factor

The equation was developed to estimated long term average annual soil loss. Therefore its application to a specific year or storm may not be appropriate.

4. HYDROLOGICAL ANALYSIS

Based on data collected in the study area that was installed in order to collect data on hydrology, based on data obtained from the meteorological service, Imo River Basin Authority and Techno-Synesis, and based on the contribution of the students to the project, a hydrological analysis of factors influencing erosion in South-eastern Nigeria was carried out. The analysis consist of:

- Rainfall analysis
- Infiltration analysis
- Determination of runoff and sediment yield.

4.1 Rainfall Analysis

The mean annual rainfall in Owerri is 2191 mm/year. The typical rainfall distribution shows the pattern of a dry season (wintertime) and a rainy season, which usually starts in March/ April and last till October/November.

During the wet season the moist south westerly monsoon from the Atlantic prevails. The wet summer period is interrupted in July and August by a period of lower rainfall. This interruption is caused by any area of high pressure coming from the southern hemisphere, influencing the weather in Nigeria.

The monthly rainfall in the neighborhood of Owerri is plotted for 1986 (Fig. 1). This year is characterized by high monthly rainfall in July, September, October. These high values are mainly caused by a few heavy rainstorms (100 – 165 mm/day). Rainfall intensities (quantity of rain falling in a given time) were derived from the automatic rain-recorder in Owerri.

The maximum rainfall amounts for time intervals of different length, from the period January 1983 – November 1986 were derived from time intervals 0.2, 0.4, 0.7, 1.0, 2.0, 3.0, 6.0.

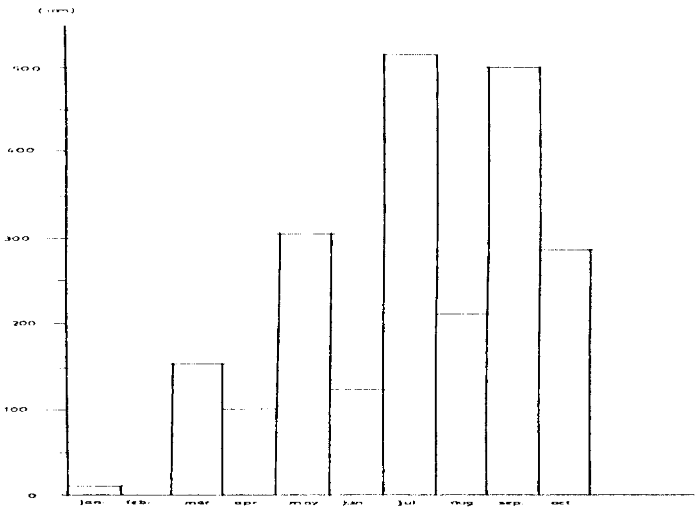

Fig. 1. Monthly Rainfall in Nekede in 1986

12.0 and 24.0 hours. For each time interval the highest amount of rainfall was taken and the mean rainfall intensity was calculated. The rainfall intensities for different time intervals are plotted (Fig.2). Extrapolation of the curve connecting the points gives the mean rainfall intensities for time intervals smaller than 12 minutes. The accuracy of the mean intensities for a time interval shorter than 12 minutes is small because the time of observation is relative short and because the curve has to be extrapolated far.

However with the present data these values are the most realistic approach of actual mean intensities. The mean rainfall intensities for different time intervals are given in the following Table 1.

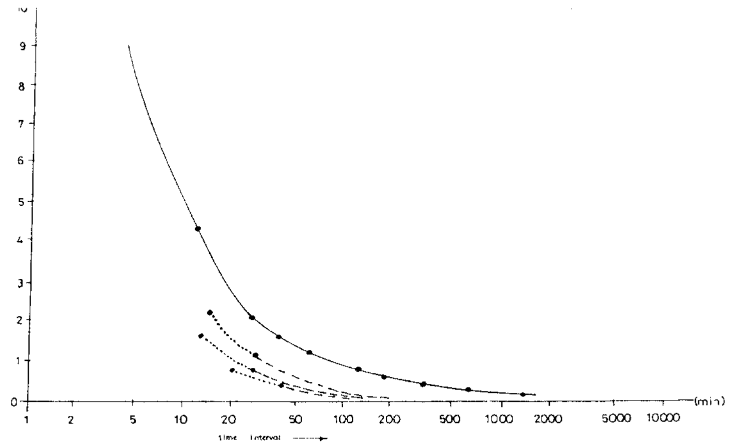

Fig. 2. Mean Rainfall Intensities at Different Time Intervals in Owerri

Table 1. Mean Rcinfall Intensity

Time interval	Mean rainfall (mm/min)	Mean rainfall (mm/hour)
24 hour	0.08	4.8
12 hours	0.8	4.8
1 hour	1.4	84
30 minutes	1.9	114
15 minutes	3.6	216
10 minutes	4.9	294
5 minutes	7.7	462

Since the mean rainfall intensities from this Table 1 are maximum intensities in a period of 4 years, they can be considered as approximations of rainfall intensities with a return period of 4 years.

In Fig. 2 results of estimates of rainfall intensities based on measurement of runoff from testplots in 1987 are plotted as well. Those results will lead to curve with a different frequency (return period). In May the average rainfall during 4 days is 17 mm/day. For fallow plots the runoff is 4% of the rainfall.

In August the average rainfall during 10days is 33 mm/day. For fallow plots the runoff is 64% of the rainfall. In September the average rainfall during 10 days is 21 mm/day. For fallow plots the runoff is 49% of the rainfall.

From (Hudson, 1957) it appears that for Africa there is a threshold level in intensity of rainfall causing erosion of 25 mm/hour. Rainfall with a lower intensity is not erosive since it infiltrates completely.

To satisfy the figures of May it appears that rainfall with intensity of 25 mm/hour during 40 minutes (17mm/day) is the maximum shower that can infiltrate completely. Showers with a higher intensity will give rise to runoff. In August 36% of the rainfall infiltrates. Based on an infiltration rate of 25 mm/hour the mean rainfall is computed as 100/36x25 = 69.4 mm/hour. The average rainfall is 33 mm/day, so the maximum shower that fulfils the condition of 64% runoff is a shower with an intensity of 69.4 mm/hour during 28.5 minutes; showers with intensity will give rise to higher percentage of runoff.

In September 51% of the rainfall infiltrates that brings us to a mean rainfall – intensity of 100/51x25 = 49.0 mm/hour. In September the average rainfall is 21 mm/day. The maximum shower that fulfils the condition of 49% runoff is therefore a shower with an intensity of 49 mm/hour during 25.7 minutes. Showers with a higher intensity give rise to a higher percentage of runoff. Comparison of those results based on an infiltration rate of 25 mm/hour with the graph of mean rainfall during different time intervals with a return period of 4 years shows that the characteristics of tropical rainfall being rainfall of high intensity during short periods, are not shown that way. Therefore the graphs calculated from results of testplots were then based on the assumption that the infiltration rate amount 50 mm/hours

That extends the curve for May to an intensity of 50mm/hour during 20 minutes for August to an intensity of 98 mm/hour during 12.9 minutes. Those figures fit much better to the characteristics of tropical rainfall. Another thing that should be noted is that the rainfall of May is not erosive. The mean activity of erosion can be expected in July, August and September. The convective rainfall then is of a high intensity and limited to small areas.

4.2 Infiltration Analysis

The relation between rainfall and runoff can be measured at test plots. So far those measurements were carried out as daily measurements.

The distribution of the runoff during the day can be decided if a runoff hydrograph is measured. Up to now that hydrograph could not be measured since the water level recorder, that was available to measure the runoff, did not have the same accuracy as the rainfall recorder which had a 24 hours drum.

The infiltration rate at fallow testplots (slope 9%) was estimated as explained in the rainfall analysis. The estimate is that the infiltration rate on such a slope will be close to 50 mm/hour.

Furthermore it was measured on these testplots that plots where crops were grown using the traditional tillage practice with mounds, have a runoff which is half the amount of fallow plots. So on farmland with a slope of 10% the infiltration rate will be in the order of 80 – 100 mm/hour. That infiltration rate can be compared with direct measurement of infiltration, using the double ring infiltrometer. Infiltration tests were carried out near Nekede in sub areas of a small catchment area. The sub areas have a different landuse or vegetation, and therefore different infiltration characteristics.

One sub area has no infiltration since it is the corrugated roof of a building. In another sub area, the compound in front of the building, only one infiltration test could be performed because at other occasions the crust on the surface cracked so that readings could be taken.

For practical reasons only the final infiltration rates are listed in Table 2:

Table 2. Infiltration Rates

Sub area	Final infiltration (mm/min)	rate (mm/hour)
compound	0.5	30
path bare	3.2	192
gully bottom	4.2	252
path vegetated	10.8	648
field between ridges	16.0	954
bush	25.0	1500

Comparison of the results of the infiltrometer with the estimates derived from the testplots shows a big difference.

For farmland the figures are 960 mm/hr and 80 –100 mm/hour respectively. Part of the difference can be explained by the fact that the final infiltration rates are a function of slope. The final infiltration rate of a slope of 10% is approximately 4 times as high as for a slope of 10%. Another reason for deviation of the results

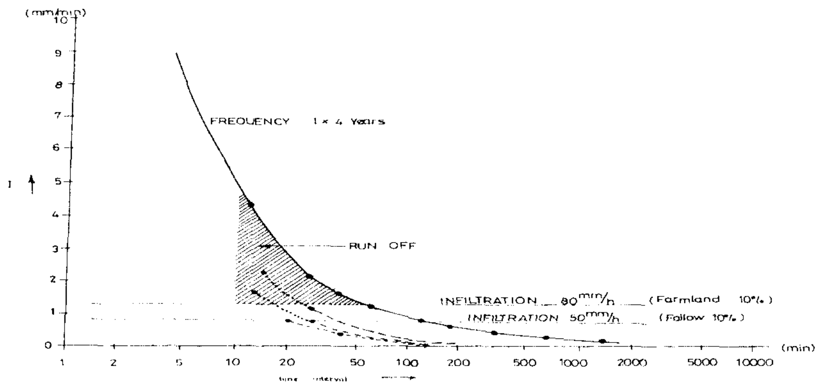

Fig. 3. Mean Rainfall Intensities at Different Time Intervals in Owerri

might be that the surface crust is damaged when direct measurements of infiltration rates are carried out. The results of testplots show better the effect of sealing of the soil to raindrop impact.

Based on the results obtained so far it is estimated that the infiltration rate for farmland on slopes of 10% equal approximately 80 mm/hour and that the infiltration rate for farmland in flat areas equal approximately 400 mm/hour. Finally it should be remembered that the infiltration rate of constructed areas (roads and houses) is zero.

4.3 Runoff and Sediment Yield

Comparison of the rainfall with infiltrate rates shows the following (Fig. 3): For flat areas there is hardly any contribution to be expected from farmland. For farmland on slopes of 10% the runoff to be expected has a mean intensity of 294 –80 = 214 mm/hour during a period of 10 minutes. The total amount of water that has eventually to be stored temporarily thus equals 36 mm.

For constructed areas the maximum contribution of rainfall to runoff will be with an intensity of 294 mm/hour during 10 minutes. Resulting in amount of water that has eventually to be stored of 49 mm. Those figures are based on an intensity of rainfall with a return period of once in 4 year. Rainfall with a lower frequency will also give rise to runoff but in smaller amounts. The problem of erosion thus is defined as a problem that occurs a couple of times per year during short periods.

The runoff of farmland will concentrate due to the topography of the area. The runoff of constructed areas is bound to those area and has no relation to the topography.

Finally the runoff will flow into a natural drain. The runoff will carry sediment as well. Partly as transport agent for detached soil particles of sheet erosion and partly because of its own capacity to carry a sediment load eroded by the tracing force along the bottom.

In order to decide upon the amount of sediment that leaves the area measurements were carried out. The runoff and sediment yield were measured in two selected drainage basins. The selected basins were the river basin of Imo river

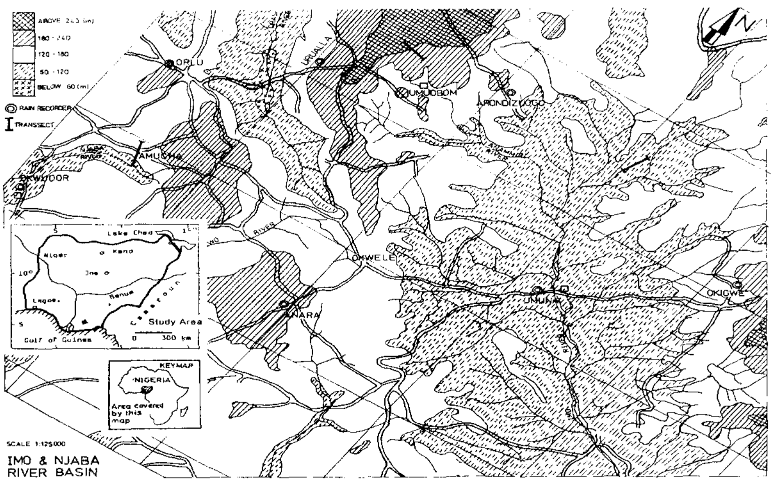

Fig. 4. IMO and NJABA River Basin

with a seize of approximately 460 km^2 and a sub basin of 30 km^3.

Since the sub basin of 30km^2 is reacting rather fast on rainfall and peak discharges often occurred during the night, it is not possible to measure directly the peak discharges. However they could be estimated using indirect methods. In 1987 a relation between the water level of the river and the discharge was derived and another relation between water level of the river and concentration of sediment was derived as well.

In that way it was possible to compute the sediment yield of the river. It is felt that the preliminary results, a soil loss of 1.2 t/ha/year for the sub basin and a soil loss of 0.5 t/ha/year for the basin of 460 km^2, are sufficiently reliable to work with.

Comparison of results of test plots, which show a soil loss of 60 -–200 t/ha/year for fallow plots and half of those amounts for farmland on slopes of approximately 10%, with the sediment yield of a drainage basin shows a considerable difference. The differences should be partly related to an area coefficient for rainfall, partly to vegetative cover, partly to differences in soil and partly to differences in slopes. Soil loss from the steeper shopes will be deposited in flatter areas. A relative small amount is leaving the area through the rivers. Comparison of the results of testplots with those of the drainage basins calls for classification of land.

5. RESULTS AND DISCUSSION

From the study in appeared that erosion is amongst other factors dependant of slope. Control measures therefore should be related to slopes as well. So the first approach to erosion control must be a correct landuse based on land classifications (agronomic measures). The control measures in the form of mechanical protection works are related to the slope as well.

Basically there are two types of mechanical protection works; Drainage and Storage. Due to the fact that rate of infiltration is high in the study area, there is no natural drainage system other than the rivers. The study area has a extremely low drainage density. The shortest distance between the boundary of the catchment and the natural drain is approximately 5 km.

To build a drainage system therefore will be very costly. The answer for erosion control measures in the study area seems to be storage. This study intends to supply the design criteria for those measures. Both in farmland areas and constructed areas there is hardly awareness of storage as solution to erosion problems. For farmland on slopes of approximately 10% the principle of storage is applied by the ministry of agriculture and Techno-Synesis in the current sheet erosion project. A piece of farmland is enclosed by contour bunds and within these bunds rotational farming takes places using tied ridging for tillage. Runoff and soil loss are then neglectable. For constructed areas the answer could be: Infiltration pits along the roads and water harvesting for area with houses. If one succeeds to avoid any runoff, then not only the problem of sheet erosion will coped with but the slopes of gullies most likely will not develop any further as well.

6. CONCLUSION

Bare sandy soil on a 9% slope exposed to rainfall showed runoff to 10% of the rainfall on annual basis. The monthly distribution of runoff followed the monthly distribution of rainfall. The monthly distribution of soil loss also fol lowed the monthly distribution of rainfall. Soil loss from bare soil with ridges down the slope, and from smooth bare soil without ridges did not show a significant difference. Comparison of infiltration rates measured with double ring infiltrometer (DRI) seem to show reduction of infiltration rate due to surface crusting. Calculation of infiltration rates from rainfall – runoff events yields lower values, more realistic under sheet erosion.

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