



The Effect of Slope Gradient on Particle Size Distribution of the Splashed Soils

by

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Abstract

Soil erosion involves two interrelated processes of detachment and transportation of soil material. The detachment of soil material caused by raindrop impact is first and foremost a function of soil-dependent process. Benue State is a predominantly agrarian State, but is ravaged by soil erosion menace, particularly the removal of the top nutrient rich soil. This paper examined the effect of slope gradient on particle size distribution of splashed soils in Makurdi, Benue State. Data was collected on splashed sediments in an experimental station in Benue State University, Makurdi for some selected months of April, June, August and October in 2007. Sediment collectors were attached to 4 soil trays placed at an angle of 5, 15, 25, and 35 degrees to collect splash yield at the selected months upslope and downslope sides. The soils were oven dried, weighed and analysed for textural characteristics. The result showed that at the beginning of the rainy season in April, the sandy nature of the original soil was reflected in the particle size distribution of the splashed soil. Sand particles dominated at virtually all the slopes, both at the downslope and upslope section. The result also showed that there was dispersion, sorting and separation of soil aggregates with silt and clay dominating the splashed soil particularly as the rain progressed. The implication is that if the soils in the study area are exposed, the soil surface would be enriched by sand and stones resulting in breakdown of soil structure.

Keywords: Splash erosion, soil tray, sediments, dispersion, slopes, Makurdi

1. Introduction

Soil erosion involves two interrelated processes of detachment and transportation of soil material. The detachment of soil material caused by raindrop impact is first and foremost a function of soil-dependent processes such as aggregate breakdown and the wetting of aggregates, which induce slaking or micro-cracking (Le Bissonnais, 1996). The fundamental importance of aggregation in the soil erosion process has been recognized by Young (1972), Luk (1979), Cerda (2000) and Valmis *et al.* (2005). The aggregation parameters depend on the textural separates incorporated into the aggregates as well as on

the water-stability of aggregates. Soils of unstable aggregation tend to develop a dense and impermeable surface layer (Bryan, 1973), which can greatly reduce infiltration and enhance soil loss (Mermut, et al, 1997). Aggregation is however a dynamic property of soil which would be caused by earthworm activity and wetting and drying cycles among other factors (Bryan, 1974). Wuddivira, et al Ekwue (2009) observed that under various wetting rates and antecedent moisture contents the aggregate breakdown and splash distance of medium clay-high organic matter soils were significantly lower than those in high clay-low organic matter soils irrespective of wetting rate and antecedent moisture content. This implies that a threshold clay content exists beyond which an accompanying increase in organic matter is required to mitigate detachment mechanisms and erosion under intense rainfall. The importance of soil shear strength was also identified as a critical factor controlling detachability (Ekwue and Ohu, 1990).

Another important soil property affecting detachment is soil texture (Govers, 1991). Sand-rich soils tend to have poor aggregation and are more readily removed in splash than finer particles such as silt and clay. Farmer (1973) and Yariv (1976) explained that the resistance of clay to detachability appears to be high because raindrop energy has to overcome the adhesive bonding forces linking the clay particles before they are removed. The effects of aggregated soils on splash projection distance were also investigated by Lequedois, Planchon, Legout and Bissonnais (2005). The authors interpreted the measured masses of fragments splashed into the different rings using an approximate solution of the exponential splash distribution theory applied to the experimental design. They concluded that the coarser fragments, ranging from 50 to 200 μm , are transported in groups in splash droplets. In the present study, a mechanical textural analysis of the downslope and upslope components of the splashed soils was done in selected months of April, June, August and October, to reflect the beginning, middle and end of rainy season. The objective was to examine the effect of slope gradient on particle size distribution of the splashed soils in Makurdi, Benue State.

The mechanics of splash erosion has also received the attention of researchers (Ellison, 1947; Summerfield, 1991 and Pidwinry, 1999). Ellison showed that 75 percent of soil splashed on a 10° slope moved down slope while 25 percent moved upslope. According to Pidwinry (1999), on flat surfaces, the effect of raindrop impact is to redistribute the material without any net transport in particular direction. When slope become 25° or greater, all the redistribution occurs in a downslope direction. Summerfield (1991) reports that on a low slope angle of 5° , about 60 percent of particles dislodged by raindrop impact move down slope; this increases to 95 percent on 25° slopes. The problem of soil erosion has been reported by a number of authors, including; Ananda and Herath, 2003; Claassen, 2004; Kwanga and Iorkua, 2005; Descroix, Gonzalez, Viramontes, Poulénard, Anaya, Estesves and Estrada, 2008). One important way of checking erosion generally and splash erosion is through the use of mulch. This has been reported severally by many researchers (Cattan, Cabidoche, Lacas, and Voltz, 2006; Yan Li, 2003).

2. Materials and Method

2.1 Study Area

This study was carried out in the Geography Department Agro-Meteorological Station located at the western part of the Benue State University on latitude $7^{\circ} 43' 44''$ N and longitude $8^{\circ} 33' 31''$ at 91m asl (Fig. 1) The geological formation of the study area is

comprised of the cretaceous sediments, made up of false-bedded sandstones and poorly sorted thick unconsolidated sandstones. The soils of the area are Typic Haplustuit and Orthic Acrisol. Monthly temperatures are high throughout the year, averaging 27°C to 31°C, though it may occasionally rise to 37°C in March and April. Annual rainfall total for the study area range from 900mm to 1500mm. The majority of the rural population around the study area engages in crop production as a means of livelihood. Land is therefore put under intense use and exposed to splash erosion with little or less mulch cover, especially after harvesting.

For data collection, 4 soil trays of galvanized metal, with dimensions of 0.60mx0.30m x 0.10m were used (see plate 1). On each side of a soil tray, detachable splash collectors were placed using 1.27cm flat rods attached to the bottom of the soil tray. The soil trays were placed on wooden tables measuring 70cm by 40cm and 20cm. The slope angles (5; 15; 25; 35 degrees) of the soil trays were fixed with the aid of two adjustable support rods attached to the bottom of the soil tray and the wooden table.

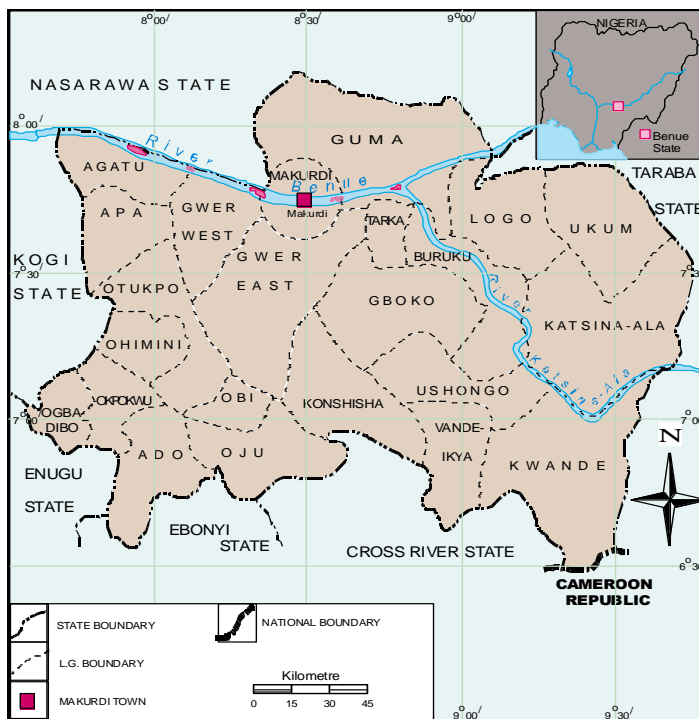


Fig.1. Benue State showing Makurdi Town

Source: Benue State Ministry of Lands and Survey, 2003

Further, upslope and downslope splash collectors constructed out of 3mm plastics were attached to the soil trays in a vertical position. The upslope and downslope splash collectors had dimensions of 30cm by 30cm by 10cm by 10cm. A 4cm thick layer of coarse (8-30cm) gravel was placed at the bottom of each soil tray to facilitate drainage through holes at the downslope end of the tray. A wet piece of cloth was placed on the gravel and the tray was filled with soil to the apron and up to 2-3mm below the rims of the splash collectors. The experiment was set during the dry season and the soil was neither sieved nor wetted before use. The initial moisture content, aggregation and the

other soil properties were determined before the commencement of measurements. Some soil material was added in June and September to maintain the regular soil level. The splash collectors were used to assess the distribution of splashed sediments. Rainfall was measured during the research with Wired Rain Meter.

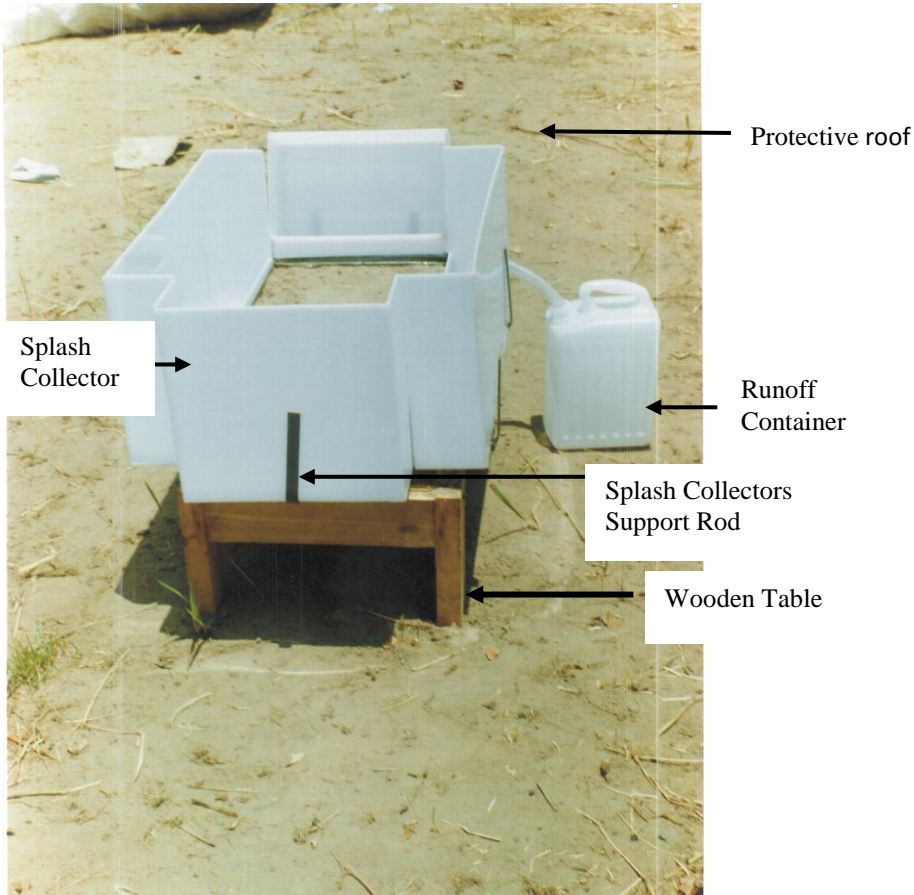


Plate 1: A typical soil tray used in the study

After every rainfall event, the splash sediments produced were transferred into stainless plates of 14cm^3 , and oven dried at a temperature of 105°C for 24hours to a constant weight before analysis. The weight of the oven dried soil material splashed for the months of April, June, August and October were measured with a digital Meter balance. Tables and percentages are used to analyze the data collected.

The laboratory design was used to collect data on the textural characteristics of soil using the hydrometer method (Buoyoucos, 1961). The first analysis was limited to the soil of the Geography Department Agro-Meteorological Station, the same soil used in the soil trays. Only one sample from the first 10cm layer, a layer most prone to splash erosion was used for the analysis. The analysis was done so that comparisons could be with the splashed soils' textural characteristics. Thirty-two (32) samples of the splashed sediments

representing 8 each at 5°, 15°, 25°, and 25 were analysed. The 32 samples came from splashed sediments in the four sampled months of April, June, August and October (ie 4 at US and 4 at DS, for the 4 months respectively).

3. Result and Discussion

Raindrop splash usually causes the dispersion, redistribution and decomposition of soil aggregates, thus sorting and separating soil clods into finer particles. There was therefore sorting of aggregates into textural groups which was dependent on texture, cover, slope and rainfall intensity.

The result of the analysis as presented on Table 1 showed that at the beginning of the rainy season in April, the sandy nature of the original soil (78.24%) was reflected in the particle size distribution of the splashed soil. Sand particles dominated at virtually all the slopes, both at the downslope and upslope section (least 73.6% at 25° to 85.6% at 15°). This was also the conclusion of Mermut *et al.* (1997) in their study of soil loss by splash during rainfall from two loess soils. There was general reduction in percentage of sand particles as the rain progressed but consistently with more sand in the downslope than upslope sections. There was however increased enrichment of silt and clay in the splashed soil, particularly at the upslope section. The variations in the monthly amount of rainfall did not affect the distribution.

Table 1: Particle size distribution of splash Eroded soils (%) at upslopes and downslopes (i) 50 slope

	Months		Primary Particles (%)			Total Monthly Rainfall
	Slope		Sand	Silt	Clay	
Original soil			78.24	14.0	7.76	
Splashed soil	April	US	81.6	13.2	5.2	187.0
		DS	83.6	11.2	5.2	
	June	US	61.4	19.2	19.4	238.5
		DS	67.4	19.2	13.4	
	August	US	61.6	19.0	19.4	283.1
		DS	73.6	19.0	9.4	
	October	US	67.4	19.4	13.2	226.0
		DS	67.4	17.4	7.2	

(ii) 15° slope

	Months		Primary Particles (%)			Total Monthly Rainfall
	Slope		Sand	Silt	Clay	
Original soil			78.24	14.0	7.76	
Splashed soil	April	US	79.6	15.2	5.2	187.0
		DS	85.6	11.2	3.2	
	June	US	65.4	17.2	17.4	238.5
		DS	69.4	19.2	11.4	
	August	US	61.6	19.0	19.4	

		DS	75.6	17.0	7.4	283.1
	October	US	61.4	19.4	9.2	226.0
		DS	67.6	19.0	13.4	

(iii) 25° slope

		Months	Primary Particles (%)			Total Monthly Rainfall
		Slope	Sand	Silt	Clay	
Original soil			78.24	14.0	7.76	187.0
Splashed soil	April-	US	73.6	17.2	9.2	
		DS	75.6	17.2	7.2	
	June	US	67.4	19.2	13.4	238.5
		DS	71.4	17.2	11.4	
	August	US	67.4	19.2	13.4	283.1
		DS	73.4	17.2	9.4	
	October	US	63.6	21.0	15.4	226.0
		DS	69.6	17.0	13.	

(iv) 35° slope

		Months	Primary Particles (%)			Total Monthly Rainfall
		Slope	Sand	Silt	Clay	
Original soil			78.24	14.0	7.76	187.0
Splashed soil	April-	US	77.6	15.2	7.2	
		DS	83.6	11.2	5.2	
	June	US	69.6	19.2	11.2	238.5
		DS	73.6	17.2	9.2	
	August	US	71.4	19.2	9.4	283.1
		DS	77.4	15.2	7.4	
	October	US	65.6	17.0	17.4	226.0
		DS	73.6	19.0	9.4	

Source: Fieldwork 2007

The present result showed that there was dispersion, sorting and separation of soil aggregates with silt and clay dominating the splashed soil particularly as the rain progressed. The implication of the result is that if the present study area is exposed, it would have its soil surface enriched by sand and stones and there will be breakdown of the soil structure. This was also the conclusion of Poeson and Savat (1978) and Eze (1996) who reported the removal of fine grains during splash experiment in their researches.

The analysis of the textural classes of splashed soil showed that cumulatively, there was higher content of silt and clay in the detached soil than the original soil. The implication of this result is that in the present study, sand particles are not more susceptible to rain detachment than clay and silt particles. The fourth hypothesis which stated that “sand particles are more susceptible to rain detachment than other soil textural classes” was therefore not accepted.

4. Conclusion

Re - sorting of splashed soil occurred, such that more of silt and clay moved upslope while more of the larger and coarser sediments moved downslope. However, in terms of cumulative erosion, silt and clay materials were more susceptible to detachment than sand. The findings of this study agreed with those of Kwaad (1977), Poesen and Savat (1978) and Eze (1996) that surfaces affected by splash are enriched by sand and stones. This result showed that if exposed to raindrops, soils of the study area will lose much of the silt and clay that are important in soil nutrients, including moisture retention capacity of the soil. For an agricultural area, there is need to protect the surface against raindrop impact.

5. References

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