Soils and Nutrients Losses and Gains during Rainy Season in the Fadama of Semi-Arid Sokoto, Nigeria

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Abstract: A study was conducted to quantify the amount of soil and plant nutrients losses and gains during rainy season in the *fadama* land in the Sokoto semi-arid ecosystem, Nigeria. Field measurements revealed that about 33.3 tonne ha^{-1} of soil was moved from the adjacent uplands by run-off and wind and subsequently deposited in the *fadama*, while 22 ton ha^{-1} was removed from the *fadama* land during the period of the study (May-September). Over the same period, plant nutrients losses (in kg ha^{-1}) with the eroded soil amounted to 30.8 organic matter, 0.3 K, 9.0 Na and 0.07 available P. Nutrient gains (in kg ha^{-1}) amounted to 2.2 Total N and 4.4 Mg. Soil deposition was found to be greater than soil removal because of the gusty winds that accompany early and late rains. The major problem of erosion in the *fadama* lands is the deposition of sandy materials moved from the upland which are by far less fertile. The continuous deposition of these materials could render the fertile *fadama* infertile. Soil removal is not a very serious threat to the fadama as soil deposition because the land is often flat and covered with vegetation in almost all part of the year with little cover in the dry season and early part of the rainy season.

Key words: Nutrient losses, Erosion, *Fadama*, Semi-arid Sokoto and Rainy season

INTRODUCTION

Soil erosion is among the most chronic environmental and economic burdens in developing countries particularly those in the tropics; where in just a few hours torrential downpours can wash away tonnes of topsoil from a hectare of land. Large amounts of such removed valuable soil eventually accumulates in rivers, reservoirs, dams and other waterways where it is unwanted (National Research Council, 1993). The large quantity of soil removed is lost along with appreciable amounts of nutrients. The magnitude of nutrient depletion in African's agricultural land is enormous. Calculations by Smaling *et al*, (1997) indicate that an average of 660 kg N ha^{-1}, 75 kg P ha^{-1} and 450 kg K ha^{-1} has been lost during the last 30 years from about 200 million hectares of cultivated land in 37 African countries, excluding South Africa (Sanchez *et al.*, 1997).

The arable land of Sokoto State consists of a vast upland (*tudu*) and some *fadama* land (low-lying relatively flat areas in streamless depression or adjacent to streams/rivers). The upland soils are predominantly sandy (> 90 % sand) in texture (Singh and Babaji, 1989), therefore, very fragile and susceptible to serious soil erosion during both wet and dry seasons. Prabhakaran and Tambuwal, (1989) estimated that out of a total cultivable land of about three million in the erstwhile Sokoto State, some one million hectares are prone to soil erosion due to water and wind in different form and intensities. *Fadama* on the other hand are generally clayey and hydromorphic, they are the most productive lands of the State but ecologically sensitive and the most highly cultivated, both in the wet and dry seasons (Sigh, 1997). *Fadama* lands are subject to stripping and soil deposition by erosion as a result of its topographical characteristics (depression) (Yahaya and Ango, 2000). Studies on soil erosion of the *fadama* in Sokoto State are inadequate, and the information available is mainly qualitative. Quantitative estimation of the amount of soil eroded in *fadama* has not been done so far. This study was, therefore, undertaken with the aim of estimating soil and plant nutrients losses/deposited from the *fadama* land due to erosion caused by rains in Sokoto as a case study of north-western Nigeria.

MATERIALS AND METHODS

The Study Area

The experiment was conducted at the Usmanu Danfodiyo University *fadama* land located 50 meters west of the Usmanu Danfodiyo University, Sokoto convocation ground and about 10 km north of Sokoto town, the administrative headquarters of Sokoto State, Nigeria. The State is situated in the semi-arid, Sudan Savanna zone of the northwestern

Nigeria and shares common boundaries with Niger Republic in the north, Zamfara State to the east and Kebbi State to the South and West. It lies between latitude11^0 30^1 to 13^0 50^1 N and longitude 4^0 to 6^0E. The State experiences a short rainy season (June-September) and a long dry (October-May) season. The rainfall (wet season) starts between April and June and ends around October. The mean annual rainfall ranges between 450 mm to 600 mm (Anonymous, 2003). The rainfall is usually erratic, unpredictable and associated with periodic drought. The long dry season consists of a cold dry spell (November-January), the harmattan (dust-ladden strong winds from north-east through the Sahara desert) period, and a hot dry spell (February-May). The mean maximum temperature is about 40^0 C and 15^0 C mean minimum (Armborg, 1988; Yakubu and Singh, 2001).

Estimation of Soil Loss and/or Soil Deposit

The method of Gleason (1957) was adopted in estimating the amount of soil loss. Eight rods were fixed randomly within a 20 X 20 m^2 plot in the experimental area. The soil loss or soil deposition was estimated in terms of the height of exposed or covered portion of the rods on a fortnightly basis. The experiment lasted for 5 months (May to September, 2005).

Soil Sampling and Analysis

For estimating the nutrient content, composite soil samples were collected at the beginning and at the end of the experiment. The samples were air dried, gently crushed passed through a 2-mm sieve. The sub-samples were then used for the determination of texture, pH, total nitrogen, Exchangeable bases, organic matter, and available phosphorous.

The particle size distribution was determined by the Hydrometer method (Soil Survey Staff, 1996). Soil pH was measured in 1:2 soil/water suspensions with a glass electrode pH meter (Mclean, 1982). Sodium (Na) and potassium (K) were determined using flame photometer, while calcium (Ca) and magnesium (Mg) were determined using the EDTA titration method (Page *et al.*, 1982). Total nitrogen was determined using micro-Kjeldahl digestion distillation method (Jones, 2001). Organic carbon content of the samples was determined by the chromic modified Walkley-Black method (Nelson and Sommers, 1982). Available Phosphorus was determined by the Bray 1 method (Jones, 2001).

RESULTS AND DISCUSSION

The amount of Soil Loss or Deposition

The result of the cumulative monthly soil removal and soil deposited over the period of the study (May-September) is presented in Figure1. The amount of soil deposited in the months of May (22.7 ton ha^{-1}) and June (23.3 ton ha^{-1}) was more than the amount removed (20 and 20.9 ton ha^{-1} respectively). Higher soil depositions in these months may not be only due to rain but also as a result of gusty wind characteristics of onset of the rain in the area. This is supported by the report of (Yakubu and Singh, 2001) that in this part of the country (semi-arid region) early rains are often accompanied with gusty wind which could help to remove soil from one place and deposit in another place. As the amount of rainfall increases from May to July (45.4 to 176.3 mm) (Figure 2) the amount of soil removed also increases compared to the amount deposited. It could therefore be observed that soil removal in the fadama lands of Sokoto is mainly caused by rains through run-off while deposition is mainly caused by run-off and wind. In the month of August soil removed (16 ton ha^{-1}) was less than the amount of soil deposited (16.7 ton ha^{-1}). The reduction may have been as a result well established vegetation cover during the month. Soil cover and intensity of rainfall have been reported to influence soil removal and deposition in the semi-arid environment (Rattan, 1990). He further mentioned that in the semi-arid environment, rain water erosion often occurs because the rain, although low in quantity comes as very heavy storms. As the amount of rainfall decreases in September coupled with the gusty winds of late rains, the amount soil deposited became higher than soil removed.

It should be noted that a decrease in the height of a bar relative to the previous one in Figure 1 for soil removal and soil deposition indicates net deposition and net removal respectively. The bars in September (Figure 1) represent the cumulative soil deposited and soil removed over the period of the study (May-September) that is 33.3 and 22 ton ha^{-1} respectively. This is a considerable damage given the short period of the experiment (five months). The major problem of erosion in the fadama land at Sokoto is the deposition of sandy material moved from the upland. The sandy material is not fertile and as such continuous deposition may render the fertile fadama land infertile. Soil removal is not a very serious threat to the fadama compared to soil deposition because the land is often covered with vegetation in almost all parts of the year with little cover in the dry season and early part of the rainy season.

The steeper slope in the adjacent upland is also another contributing factor facilitating the transportation of soil by water through gravitational force which is further deposited in the flat fadama where the energy is no longer available to transport the particles deposited (Rattan, 1990). Little erosional soil removal in the fadama has been confirmed by Morgan (1986), who reported that dry structureless sandy upland soils are subject to stronger wind erosion than wet soils of the fadama because of the little cohesion to resist movement. The intensity of the rainfall may have played an important role in soil deposition/removal than total rain. The intensity of rainfall rather than the total rainfall is the most important factor governing erosion (Rama, 1972). The high amount of soil deposited may be due to the fact that the fadama land is generally flat and as such only small amount of soil could be loss through runoff. The good soil structure and plant cover during rainy season may have contributed to the little removal of soil in the fadama.

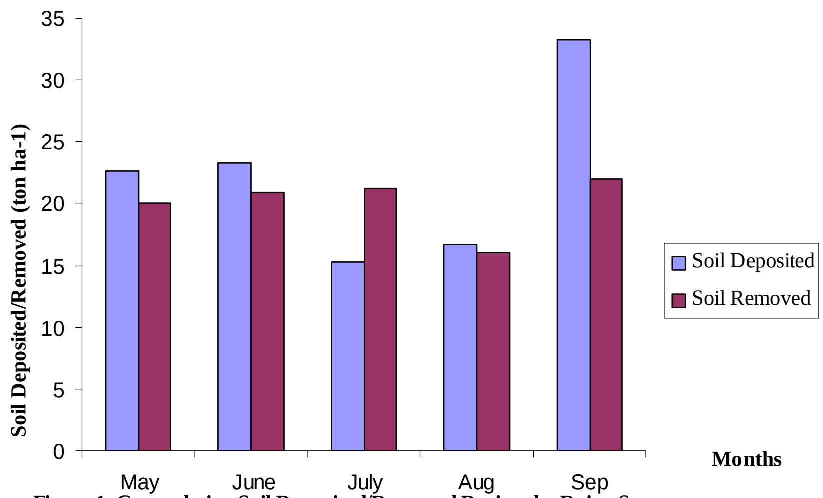

Figure 1. Cummulative Soil Deposited/Removed During the Rainy Season from Fadama Land at Sokoto, Nigeria

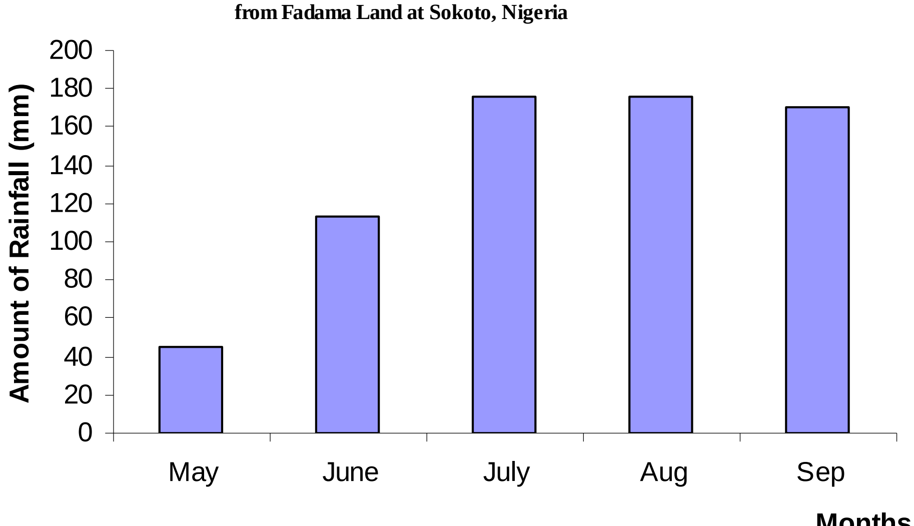

Figure 2. Monthly Rainfall Data for Sokoto (May-Sept.2005)

Nutrients Loss and or Gain Along with the Soil Removed or Soil Deposited

The amount of nutrients loss and or gained during the experimental period is presented in Table1.The content of various nutrients were generally low due to probably the deposition of sandy soil of the upland as reported by (Singh and Babaji,1989).The nutrients loss for the period of the study were 30.8 kg ha^{-1} (Organic matter), 0.07 kg ha^{-1} (available P), 2.9 kg ha^{-1} (Sodium), 9.0 kg ha^{-1} (Potassium), 0.3 kg ha^{-1} (Magnesium), while the gain in nutrient is 2.2 kg ha^{-1} of nitrogen and 4.4 kg ha^{-1} of calcium (Table1).This means that the nutrients that are lost from the fadama land by rains could not be compensated through the amount of soil deposited which comes mostly from the upland. This also attests to the fact that the soils of the upland are less fertile and consequently bring about reduction in fertility level of the fadama. Beasley (1972) and Rama (1972) in their studies also found out that often, particles of fine sand were carried away and deposited on vast stretches of neighbouring fertile and rich land (fadama). The mean annual losses of plant nutrients per hectare from runoff plots in the upland at Samaru, Nigeria over four years period were 16-34 kg cations (Ca, Mg, K and Na) and 8-12 kg N (Kowal, 1970b). Yakubu and Singh (2001) reported losses of 265 kg organic C, 44 kg total N and 58 kg exchangeable bases (Ca, Mg, K and Na) per hectare per year from an upland soil in Sokoto. Ojanuga (1986) reported losses of 14-40 kg N, 820 kg Ca, 187 kg Mg, 93 kg K and 7 kg P per hectare per year in Southern Nigeria due to soil erosion.

Effect of Soil Deposition or Removal on Particle Size Distribution and pH

The effect of soil deposition or removal on particle size distribution and soil pH is presented in Table 2. The result of the particle size distribution shows an increase in the sand content and a decrease in silt and clay content of the soil. The increase in sand and a decrease in clay content may be attributed to the sandy materials brought from the surrounding upland. The upland soils are predominantly sand (>90 %) in texture as described by Singh and Babaji, (1989). The increase in sand content and a decrease in clay may lead to poor structural development in the fadama soils and consequently a reduction in water retention. The change in soil pH is small as the soil reaction indicates neutral reaction in the soil both at the beginning and at the end of the experiment. The slight increase in soil pH may be due to deposition of calcium material through dust that accompanied the early and late rains. The gain in total nitrogen and calcium content may also be attributed to the addition of materials brought from the adjacent uplands.

Table 1: Organic matter and soil nutrients lost or gained through erosion

Parameter	Nutrient Balance*	Nutrients loss/gain (kg ha^{-1})
Organic matter (g Kg^{-1})	-0.14	30.8
Total nitrogen (g Kg^{-1})	+0.003	2.2
Exchangeable bases (Cmolkg^{-1})		
Ca	+0.15	4.4
Mg	-0.05	0.3
K	-1.05	9.0
Na	-0.57	2.9
Available P (mg kg^{-1})	-0.01	0.07

***** = Difference between nutrient content of the soil at the end and at the beginning of the experiment

- = nutrient loss **+** = nutrient gain

Table 2: Changes in particle size distribution and pH of soil deposited or removed

Parameters	Period of the Experiment	
	At the beginning (May)	At the end (September)
Sand %	88.27	90.96
Silt %	9.89	7.31
Clay %	1.84	1.73
pH	6.81	6.86

CONCLUSION

Soil is one of the vital resources necessary for human existence; unfortunately it is under the menace of erosion. Erosion in the *fadama* of Sokoto includes deposition of soil as well as the removal of soil. The amount of soil deposited (33.3 ton ha^{-1}) in the *fadama* land is by far greater than that removed (22 ton ha^{-1}) during the period of study. This shows that the effect of erosion in *fadama* of Sokoto environment is more of deposition than removal. Soil deposition was found to be greater than soil removal or loss because resistant forces are greater than erosive forces in the fadama. Soil deposition in the flat lands of fadama is often influenced by gusty winds that accompanied early and late rains, while soil removal or loss is greatly influenced by rains through run-off. The deposition of erosional debris (sandy materials) in the fadama is one of the major damages resulting from erosion. Relatively fertile soils of the fadama land are often covered with less fertile material carried by runoff and wind from the upland. Many a times, particles of fine sand are carried away by wind and deposited on vast stretches of neighbouring fertile and rich land, rendering them useless for any crop growth as a result of change in the soil texture and fertility.

RECOMMENDATION

The most effective means of controlling soil erosion is to maintain a protective cover on the soil surface. The maintenance of a protective cover on the surface of soil is the key to management for wind control just as it is for water erosion. Vegetative cover is cheap; and close growing crops such as grasses and legumes, once they established, provide excellent protection. Vegetation reduces wind velocity at the soil surface and absorbs much of the force exerted by the wind. Soil particles are also trapped by vegetation; thus preventing avalanching of soil particles downwind. In semi-arid areas, inadequate moisture and periodic drought reduce the periods when growing plants provide good soil cover and limit the total quantities of plant residues produced. Proper management of available residue offers one of the most important opportunities for high level soil and moisture conservation. Farmers could therefore be advised to maintain proper soil vegetative cover in order to reduce the effect of erosion in fadama land as well as maintain its productivity. Planting of grasses like vertivar that can survive during dry season could checkmate the problems that accompany first rain.

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