# CHAPTER ONE
# INTRODUCTION

## 1.1 General statement and problem definition

Soil erosion is recognized as a critical global environmental problem that affects the livelihood of millions of people. Problems related to soil erosion; such as on-site productivity decline and off-site water resources impacts, among others, are obvious and severe in many locations particularly in Africa (Lal, 1993a, 1996b; El-Swaify, 1993; Collins, *et al.,* 2001; Okin, 2002; OMAFRA Staff, 2003; Kwanga and Iorkua, 2005; Descroix, *et al.,* 2008; Ananda and Herath, 2003 and Claassen, 2004). Soil loss continues to threaten agricultural production world wide despite several decades of conservation efforts by agricultural engineers, soil scientists and geomorphologists. The studies by

Jeje, (1973) ,Higgitt, (1991), Gbadegesin and Raheem, (2012) and Iorkua and Oche, (2012) clearly show that the incidence of erosion has increased to unacceptable levels in recent years, and reflect a growing perception of the potential hazards of erosion in addition to the actual worsening of erosion problems.

In Nigeria, every part of the country is affected by one type of soil erosion or the other, such that it is correct to assert that all types of land use surfaces are affected by soil erosion, even though the type, extent and severity may differ. Dickson (1987) and Eze (1996) identified sheet, gully, rill, wind and interrill (splash) erosion as the major forms of soil erosion affecting the country, attributing them to climatic and physiographic factors. Wind erosion is active in the semi arid (Sudan and Sahel savanna) north, while sheet and gully erosion is more severe in the wetter south.

Vegetation cover is an important factor in terms of differences in erosion, (Daura, 1995; Eze, 1996 and Wakiyama, *et al.,* 2010) but the extent of protection by different aspects of vegetation, including mulching, particularly in the humid tropics, needs to be investigated further. This is more so when several studies, for example, Faniran and Areola (1974) in Ibadan area; Jeje (1988) in Araromi Rubber Plantation in Ondo State, Stocking (1994) in Mondaro plantation, Zimbabwe and Hanson, *et al.,* (2004) in a coffee plantation in the tropics have reported severe erosion in forested areas. Soil erosion under forest has also been reported in Portugal (Terry, 1996); India (Calder, 2001); China (Zhou, *et al.*, 2002); Chile (Dussaillant and Concepcion, 2008) and Japan (Kazuki, *et al.*, 2008).

Moreover, most of the studies of erosion in the humid tropics dwelt on sheet and gully erosion with little or no attention to splash process. Examples of such studies include Grove (1956) and Ologe (1972, 1974) in the Zaria area; Ofomata (1984) in Enugu area; Olofin (1987) in Kano area; Jeje (1987), 1991) in parts of western Nigeria and Daura (1995) in the Ibadan area.

The relative neglect of splash study is attributed to the difficulty encountered in separating splash from flow, especially sheet erosion because both seem to occur together (Faniran and Jeje, 2002). At the same time, it is recognized that soil erosion is a sequential process involving soil detachment and transportation (Ellison, 1946 and Morgan, 1979). This is also the contention of Bryan (1974) who observed that erosion by water involved several distinct processes namely, raindrop/rainsplash, un-concentrated wash and concentrated wash, each of which can be studied separately.

The process of soil erosion begins with the detachment phase followed by the transportation phase (Van Dijk, 2002). The detachment phase is therefore an important process that needs to be understood because it is an initiating process of soil erosion. It has been shown to be an essential first step in the chain of processes leading to the loss of soil (Ross, 1993; Hudson 1995; Peterson and Hasholt, 1995; Van Dijk, 2002; and Kinnel, 2005; Bryan, 1979; Meryer, 1981; Sutherland, *et al.*, 1996; and Visser, *et al.*, 2004).

The present research is anchored on the fact that splash is very fundamental to the soil erosion process (Morgan, 1979; Imeson, 1977; Poeson and Torri, 1988 and Eze, 1996) because it initiates the soil erosion process, then increases the sediment load of runoff, destroys soil aggregate or structure, creates surface seals or crust which inhibits infiltration, creates splash pedestals or soil pillars and earth / rock pillars. More importantly, the study highlights the controlling factors in respect of the assessment of erodibility of soils, erosivity of raindrops and the erosion risk of vegetated surface.

## 1.2 Significance of the study

Increased anthropogenic pressure on land resources has led to the intensification of soil erosion and land degradation world wide, especially in the seasonally humid tropical areas. The system of agriculture in these areas frequently leaves the land bare for varying length of time, leading to various types of erosion, including rainsplash and surface wash. Un-concentrated runoff usually does not have enough power to detach and entrain most soil particles; it therefore relies on particles detached by rainsplash (Van Dijk, *et al*., 2003). However, there is the need for actual field measurement for real assessment and appreciation of the extent /intensity of splash erosion.

There are different aspects of splash erosion that are not well researched particularly in the humid tropical areas. Among these are the effects of slope on splash and wash processes which have only been recently investigated on terrace risers in Java, Indonesia (Van Dijk, *et al*., 2003). The relative importance of the various erosivity indices affecting splash and the impacts of tropical rains on the different soil properties calls for investigation regarding the best mode or method(s) of capturing rain splashed material in different climatic regimes.

Another area of contribution to knowledge is in respect of direct field measurement of erosion. In this connection, runoff plots have been shown to offer opportunity for controlled experiments as obtained in laboratories, even though only arbitrary boundaries can be set for the experiments. Hence, application of on-site (field) experiments to measure splash erosion underlies the significance of this present study.

## 1.3 The aim, objectives and scope of study

The aim of the study is to measure splash erosion in the field with a view to evaluating the effects of slope angle, mulch, soil textural characteristics and rainfall erosivity on components of splash detachment in the seasonally humid tropical area of Makurdi town, Central Nigeria

To achieve the above aim, a number of specific objectives were set; these include:

i. Measurement of the quantity of soil splashed at varied angles and under different cover materials in terms of downslope, upslope, and lateral splash, with a view to evaluating the effect of slope angle and soil cover on splash
ii. Evaluations of the effect of mulch cover on splash erosion.
iii. Assessment of the influence of selected elements of rainfall erosivity parameters (namely rainfall amount, intensity and kinetic energy) on splash.
iv. Identification of the soil textural classes that are crucial to splash detachment in the study area.

The factors controlling the working of splash erosion system include erosivity of rain, erodibility of the soil, nature of the slope (angle and length) and nature or degree of vegetation cover, including plant litter and mulch. To understand when and how much erosion is likely to occur by splash, these factors must be examined in detail and their relevant aspects identified more precisely. Accordingly, this study examined these factors under natural rainfall condition. Furthermore, the justification for assessment of the effects of mulch cover on splash erosion lies in the fact that Benue State is predominantly a rural setting with most of its inhabitants depending on arable crop production under some form of mulching or the other.

This study covered one wet season spanning the period between April and October, during which fifty - nine (59) rainfall events that produced splash were used for the study. Although soil material used in this study came from the same soil group, namely Typic Haplustuit and Orthic Acrisol, the dynamics of the interaction of the soil with the other factors varied.

## 1.4 The study area: physical characteristics and suitability

### 1.4.1. Introduction

This section focuses on the description of the study area. The geology, soil, climate (especially rainfall) vegetation and land use are discussed. The suitability of the site chosen for the study is also explained.

### 1.4.2 Location

This study was carried out in the Agrometeorological Station of Geography Department, located at the western part of the Benue State University, Makurdi, Benue State, Nigeria. The station is located at Lat. 7$^{o}$ 43' 44" N and Long. 8$^{o}$ 33' 31" at 91m asl. Benue State University is sited on the flood plain of River Benue, and stretches between ½ and 2 ½ kilometres along Gboko Road in Makurdi, the Benue State capital. The slopes are generally gentle on the flood plain, but the experiment was conducted with the use of soil trays that were filled with soil materials exposed to natural rains (Figs. 1.1 and 1.2). Makurdi, as one of the local governments in the State covers an area with a radius of 16 kilometers, less than half of which is built-up.

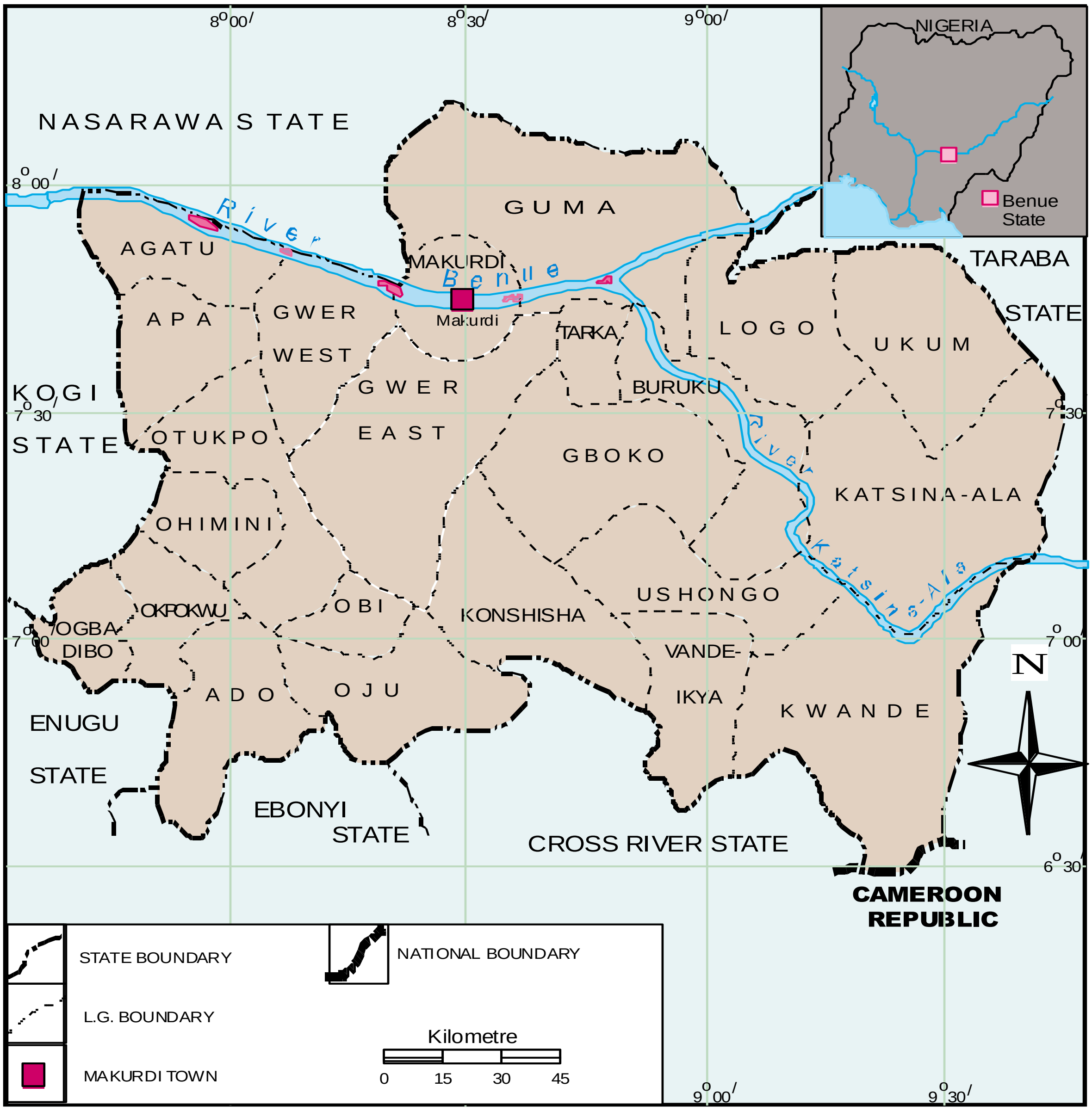


**Fig.**1.1. Map of Benue State
Source: Benue State Ministry of Lands and Survey, 2003


**Fig.** 1.2. Road network of Makurdi Town
Source: Benue State Ministry of Lands and Survey, 1979

### 1.4.3 Geology and soil

The study area is situated in the middle section of the Benue Trough, a major elongated geological rift structure filled with Cretaceous fine-grained, low permeability sediments deposited within a series of sub-basins. Many of the sediments have undergone low-grade metamorphism, and have been folded and faulted to varying degrees (Macdonald, 2001). The Benue Trough is bounded by the Jos Plateau granites to the north and the Cameroon massif to the south. Much of Benue State is underlain by mudstones and sandstones (Fig. 1.3), which vary in character across the State. In some places, the sandstones can be friable/unconsolidated and porous, while in other places, they are consolidated and fine grained. The Makurdi Sandstone forms part of one of the several thick lithostratigraphic units of the Turonian Eze-Aku group (Nwajide and Hoque, 1984). The unit occurs across more than 1000 $km^2$ of territory extending from the Makurdi area to central Benue State. In the section at Makurdi they form a thick sequence of felspathic sandstones interbedded with marine carbonaceous mudstone and limestone. The major geological formation of the study area (study site) is the Cretaceous sediments, made up of the false-bedded sandstones, consisting of poorly sorted thick unconsolidated feldspathic sandstones, which are white, pale, gray and sometimes stained red yellow, by iron oxides. The massive sandstones attain a thickness of up to 900m. The dominance of sand particles in the soil material decreases the influence of the clay fraction on its physical and chemical properties (FDALR, 1985; Abaa, 2004).

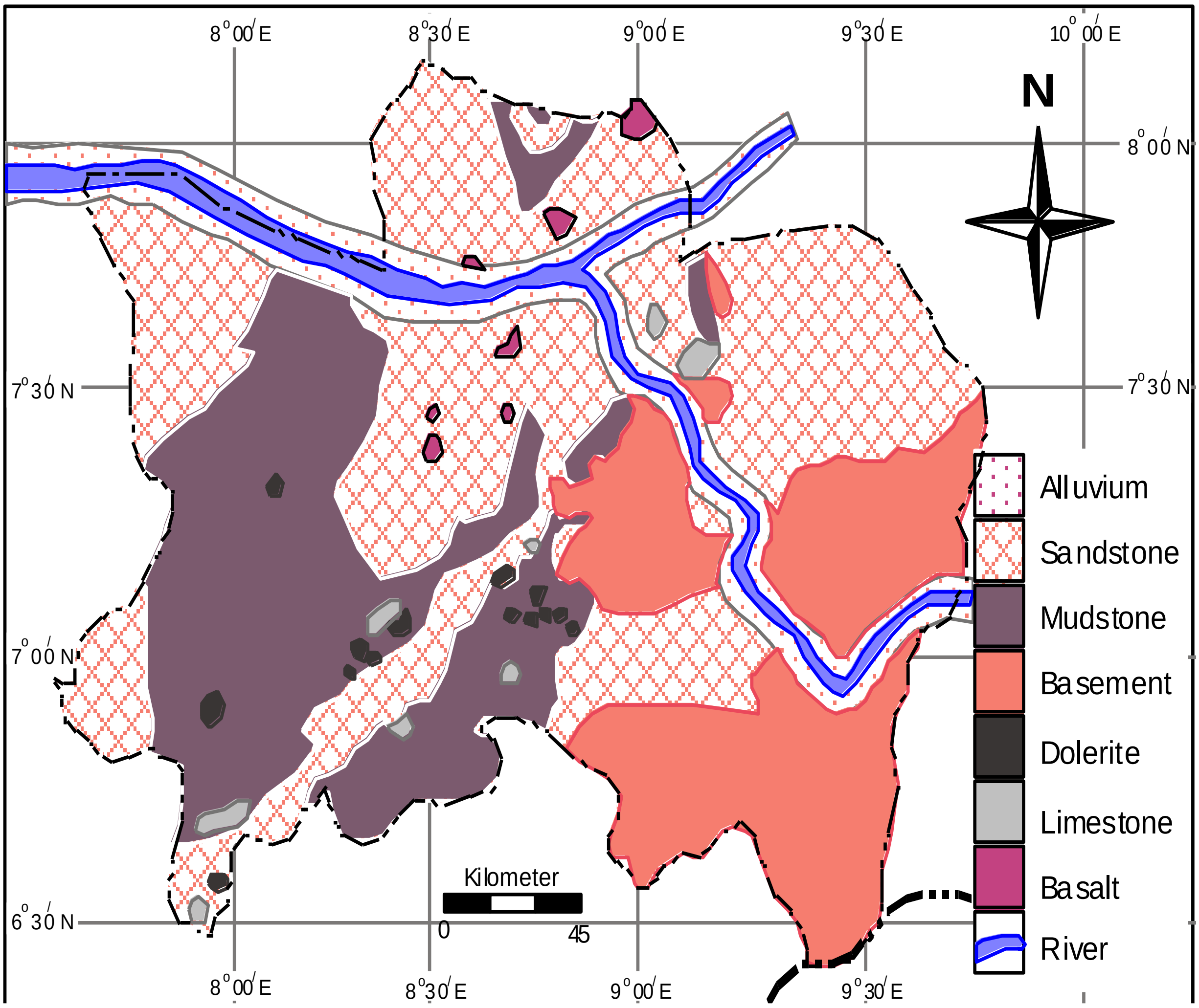


**Fig.** 1.3. Geology of Benue State
Source: Benue State Geological Survey Department, 2001

Soils of Benue State generally are mainly tropical ferruginous which vary over space with respect to texture, drainage and gravel content (Nyagba, 1995). The USDA and FAO classify the soils of the present study area as Typic Haplustuit and Orthic Acrisol respectively (FDALR, 1985). The soil survey report indicated the soils to be deep, well-drained with dark reddish brown sandy loam to sandy clay loam over dark red gravely clay loam. They are strongly acidic to moderately acidic with low to moderate organic matter content. The soils are also described in the report as having low to moderate (0.046) total nitrogen contents. The exchangeable cations are low to moderate for Ca (2.2), Mg (1.22), and Na (0.21) and moderate to high for K (0.24). The CEC values are low to moderate to high. The soils are cultivated annually. The crops usually grown in the area include sweet potatoes, cassava, and maize: they are grown either singly or intercropped.

Aneke (1991) studied the erodibility of soils of the study area, and reported that they are made up of seven types, namely lithosol, acrisol, luvisol, fluvisol, nitosol, cambisol and regosol with the soils of the study area belonging to the luvisol/cambisol group (Fig. 1.4).

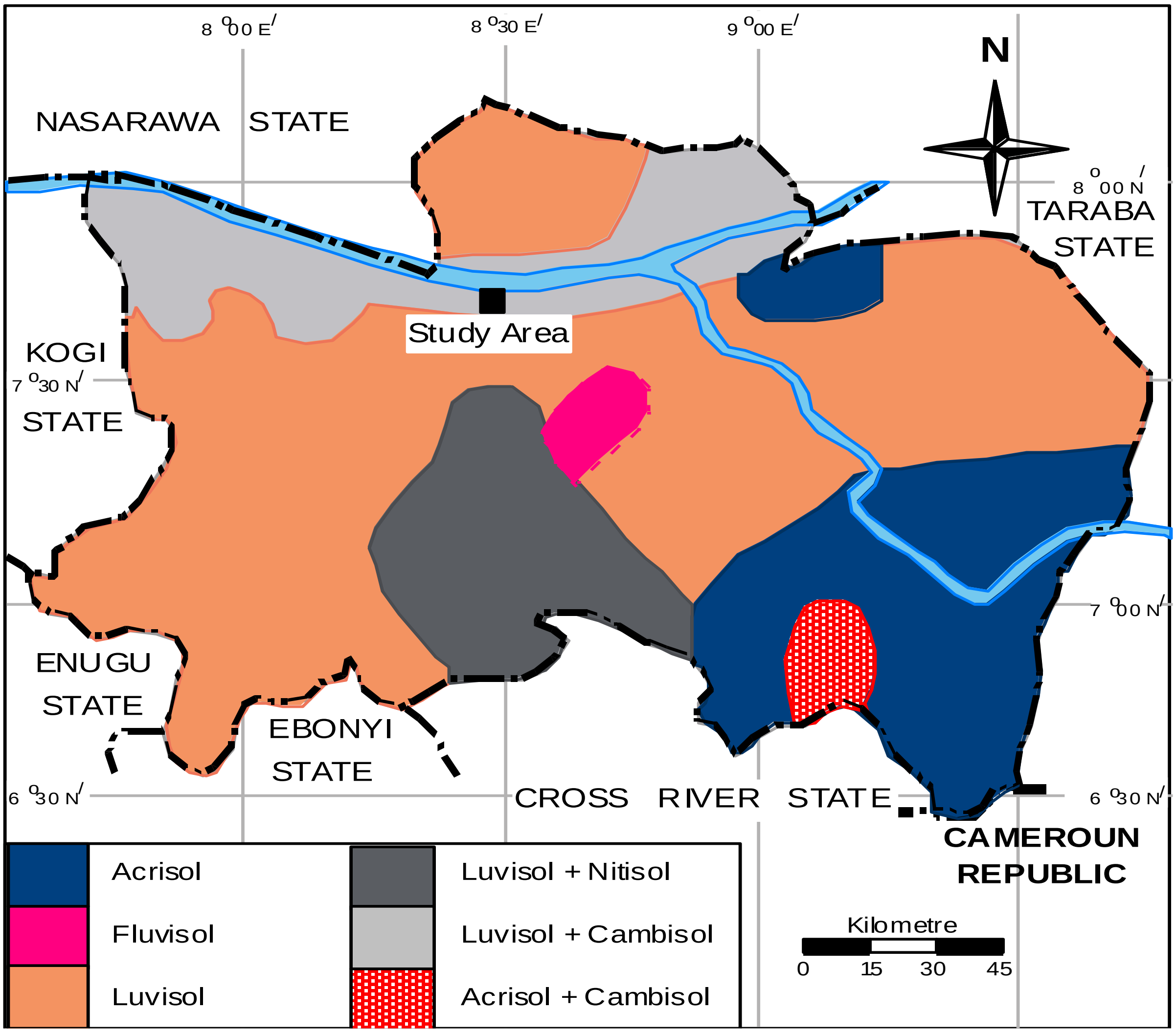


**Fig.** 1.4. Soils distribution of Benue State
Source: Benue State Ministry of Lands and Survey, 1985

Only the first 10cm layer of the topmost soil was studied, being the layer that is mostly affected by splash action (Morgan, 1978). The soil parameters studied include particle size, pH, organic matter content, iron II oxides, bulk density, total porosity, water holding capacity and water stable aggregate. A detailed typical profile description and textural and chemical characteristics of the study area are provided in Tables 1.1 and 1. 2. Highlights of the physico chemical characteristics of the soil shows that the soil is well–drained, dark brown, slightly acidic with a pH value of 5.95. The textural class of the soil is sandy loam, with considerable amount of organic matter, high percent sand and with low amount of clay. Bulk density is low as a result of absence of gravel and stone line. The loose, friable sandy loam component has low water holding capacity as a result of its porous nature. Permeability is high and water seepage to the depth is fast. The soil has moderate amount of iron concretion. The high structural stability to raindrop impact makes the soil to be susceptible to soil erosion.

**Table** 1.1 Typical soil profile of the Study Area

| Horizon | Depth (cm) | Description |
|---|---|---|
| AP | 0-28 | Grayish brown (7.5yr 3/2) fine sandy loam; moderate medium to course sub angular blocky; very friable; many roots; many pores; clear wavy boundary. |
| $Bt_1$ | 28-45 | Light brownish grey (10YR4/6) fine sandy loam; weak medium to coarse sub angular blocky; very friable; many roots; many pores; clear wavy boundary. |
| $Bt_2$ | 45-78 | Very pale grey (10YR 6/4) fine sandy loam; moderate medium to coarse sub angular blocky; friable; common roots; many pores; diffuse wavy boundary. |
| $Bt_3$ | 78-105 | Very pale brown (10YR5/6) fine sandy clay loam; moderate fine medium to coarse sub angular blocky; friable; common roots; many pores; diffuse wavy boundary. |
| $Bt_4$ | 105-143 | Very pale brown (10YR6/3) fine sandy clay; moderate coarse sub angular blocky; firm; few roots; many pores; diffuse wavy boundary. |
| BC | 143-180 | Light grey (2.5Y6/2) gravelly sandy clay; moderate coarse sub angular blocky; firm; few roots; many pores. |

Source: FDALR, 1985

**Table** 1.2. Typical physical and chemical analysis of the soil of the study area

| Horizon | Depth cm | Particle Size Analysis (%) | | | Texture | pH $H_20$ | KCL | OC (%) | Total N | Exchangeable Cations (me/100g soil) | | | Na | CEC | BS (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Sand | Silt | Clay | | | | | | Ca | Ma | K | | | |
| AP | 0-28 | 74 | 18 | 8 | SL | 6.0 | 5.2 | 1.97 | 0.07 | 3.7 | 1.3 | 0.31 | 0.18 | 8.5 | 65 |
| Bt1 | 28-45 | 66 | 16 | 18 | SL | 5.4 | 4.3 | 0.52 | 0.05 | 2.6 | 1.3 | 0.29 | 0.24 | 5.5 | 91 |
| Bt2 | 45-78 | 58 | 14 | 28 | SCL | 5.2 | 3.8 | 0.31 | 0.04 | 2.0 | 1.0 | 0.27 | 0.22 | 6.5 | 54 |
| Bt3 | 78-105 | 56 | 12 | 32 | SCL | 5.0 | 3.7 | 0.26 | 0.04 | 1.4 | 0.7 | 0.20 | 0.21 | 7.5 | 33 |
| Bt4 | 105-143 | 52 | 12 | 36 | SC | 4.9 | 3.7 | 0.21 | 0.04 | 1.2 | 0.5 | 0.22 | 0.22 | 8.5 | 25 |
| BC | 143-180 | 52 | 10 | 38 | SC | 5.0 | 3.7 | 0.21 | 0.04 | 1.9 | 2.5 | 0.20 | 0.21 | 11.0 | 41 |

Source: FDALR, 1985

### 1.4.4. **Climate**

Makurdi town experiences a wet and dry climate (Aw-Koppen Classification). The wet season lasts for seven months (April to October) with annual rainfall totals of between 900mm and 1500mm (Nyagba 1999). The annual mean rainfall ranges between 1050mm and 1200mm. Rainfall data collected at the Nigerian Meteorological Agency (NIMET) located in Makurdi town between 1996 and 2005 indicate a mean of 1119.3mm. Iorkua (1999) reported a mean of 1153mm from rainfall data of 1982-1996 collected at the same source. The data used for the current study for a period of 35 years, (1973-2007), from the same source showed a mean of 1193.4mm. 19 of these 35 years, including 2007, are considered to be wet rainfall years; with rainfall totals above 1193.4 (Fig. 1.7). 1978, 1984, 1998, 1999 and 2007 were very wet years with annual rainfall totals in excess of 1500. On the other hand, 1973, 1982, 1983, 1985, 1988, 1992, 1994 and 2003 - 2005 were very dry years experiencing less than 1000mm of rainfall (Fig. 1.7).

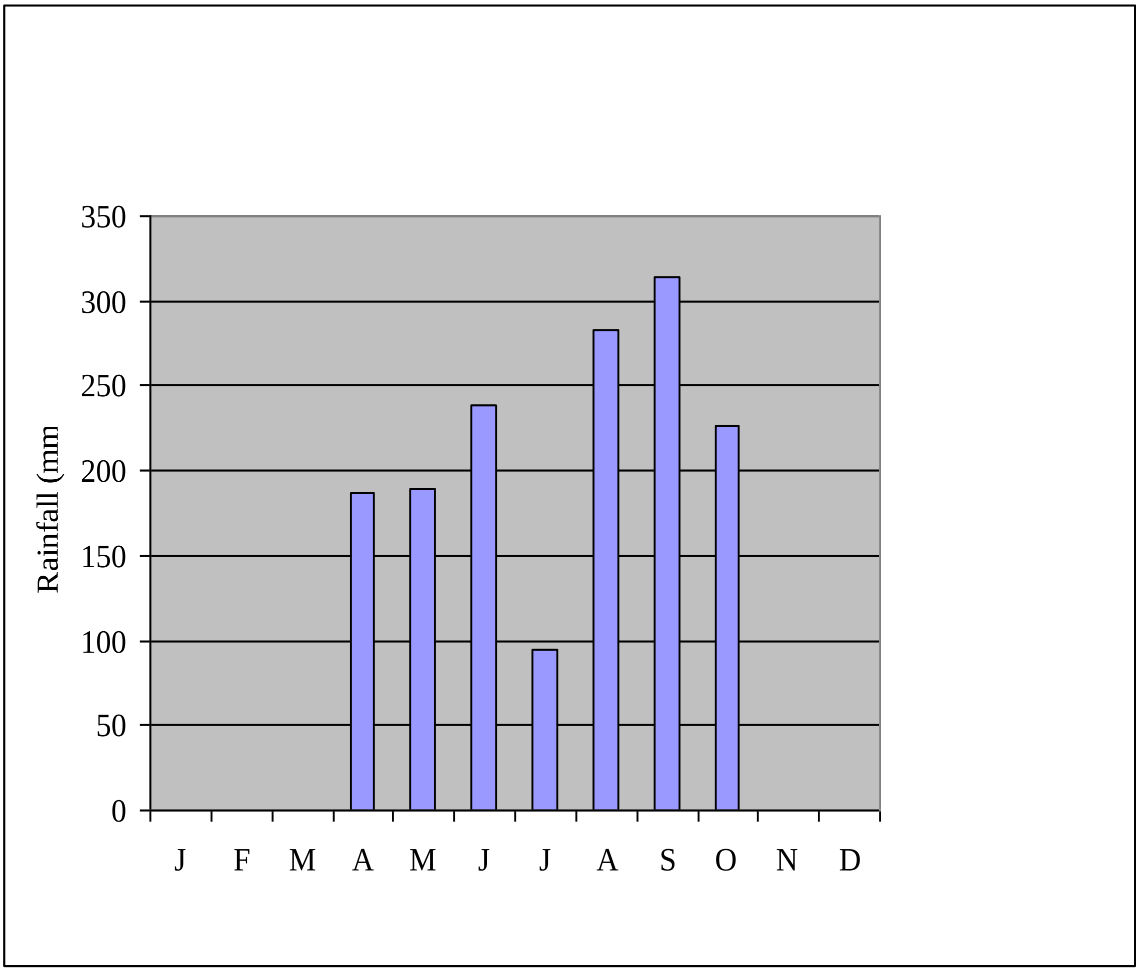


**Fig.**1.5. Total monthly rainfall record for 2007 for Makurdi.
Source. Field work 2007

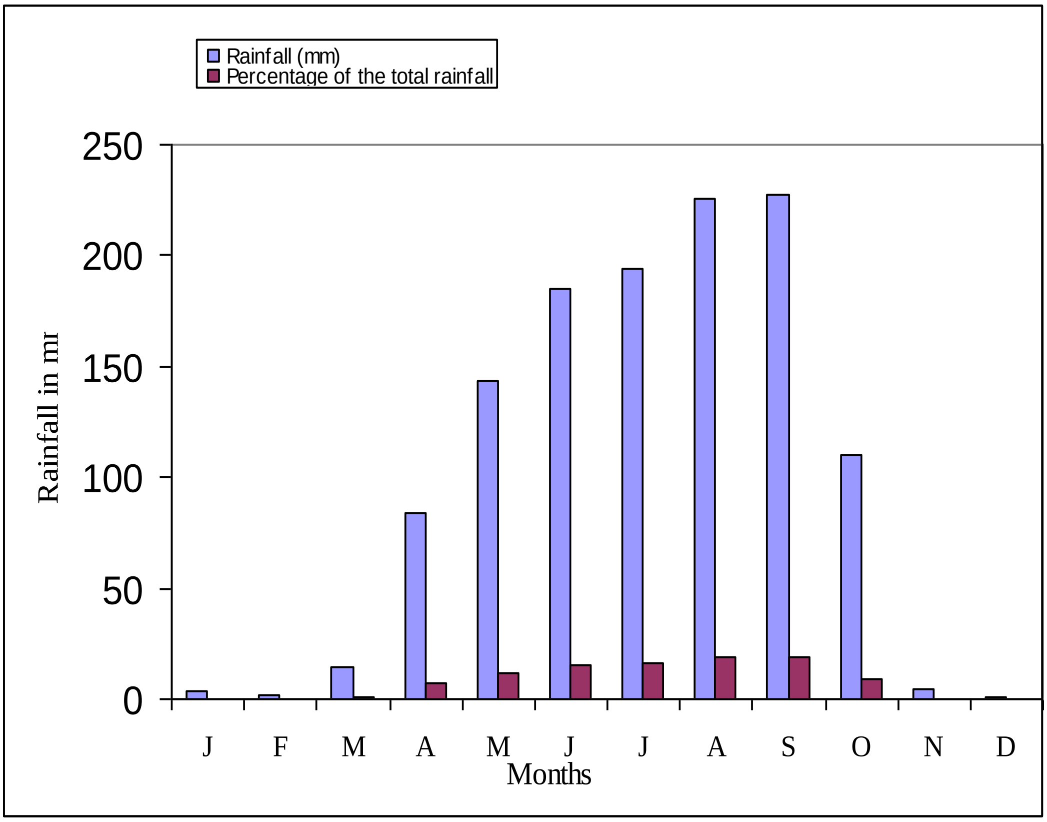


**Fig.** 1.6. Mean monthly rainfall in Makurdi 1973-2007

Source: Field work 2007

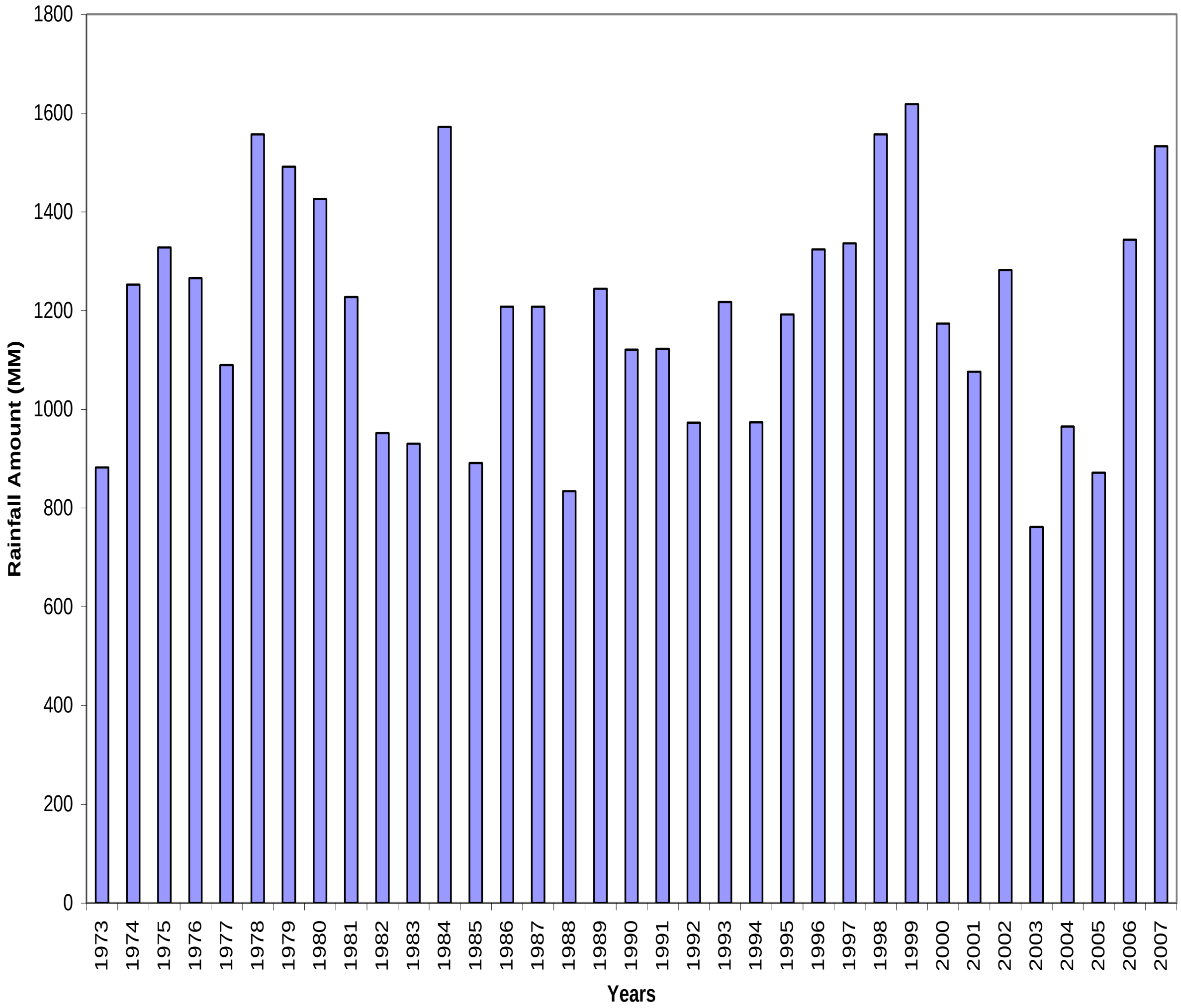


**Fig**. 1.7. Total annual rainfall in Makurdi, 1973-2007.
Source. Nigeria Meteorological Station, Makurdi, 2007

Figs. 1.5 and 1.6 show that the rains are highly seasonal. The onset of the rains is also variable. There is less than 1% of rainfall from the months of November to March, while 70% of the rains occur between May and October, and more than 42% in the 3 months of July, August September: August and September are the wettest months. Additionally, the rainfall data for 2007 showed marked reduction of rainfall in July (Fig. 1.5), in contrast with the 35 years mean displayed in Fig. 1.6.

The seasonal rainfall comes in form of intense, violent, convectional showers of short duration that strike the soil surface at different angles, especially at the beginning and the end of the rainy season. This kind of violent rainfall constitutes an active agent of detachment and transportation of soil, particularly where the surface is exposed (see Iorkua, 1999, 2006).

Another feature of the climate of this area is that it is only within the months of June to September that rainfall exceeds evapotranspiration. This means there is soil moisture deficiency in other months, leading to hardening of the topsoil and reduction in infiltration.

Temperatures are high throughout the year, averaging 27°C to 31°C though it may occasionally be as high as 37°C or more in some days in March and April, the hottest months of the year. The lowest monthly temperature is experienced in the months of July to September. The mean monthly minimum air temperature is however lowest during the period of hamattan-December to January (averaging 18.1°C) with the highest mean minimum in March-April (averaging 25.6°C). The mean maximum temperature ranges between 29.9°C during the hamattan to 37.7°C in March-April. High temperatures have effects both on the nature of rainfall and on the soils (Salau, 1989). For instance, it increases the convective nature of the rains and hardens the surface soils.

The surface soil temperature varies from month to month, corresponding to the monthly variations in the air temperature. The soil temperature is highest in April (33.42°C) and lowest in January (28.94°C) (Nyagba, 1995, 1999). However, there are less marked changes in soil temperature with depth. Except for the densely built-up area, the Benue State University campus is a microcosm of the Benue environment. It is therefore hoped that the result of the present study can be applied to the wider Benue environment, with minor variations.

### 1.4.5. Vegetation and landuse

Benue State lies in the southern Guinea Savannah. The vegetation generally consists of thick-barked trees of up to 10-15m high and tall grasses (1-3m) that grow in tussocks (Kowal and Knabe, 1972). Persistence clearance of the vegetation, particularly in densely populated areas, has led to the development of regrowth vegetation at various levels of seral development, but more importantly, parklands with grasses including, *Andropogon gayanus, Rottboellia cochinchinensis, Hyparrhenia rufa,Schizachyrium exile* and *Imperata cylindrica* of the *Gramineae* family, ideal for animal grazing during their early growth are found. These grasses grow very tall quickly, are coarse and tough on maturity and are the dominant materials used for the traditional thatch hut in Benue State. Shrubs such as *Newbouldia laevis* (*bignoncaceae*) used for fencing compounds; *Raphia sudanica, Cocos nucifera, Elaeis guineensis* and *Borassus aethiopum* of the *palmae* family may also be found either planted or growing wide. They are used as framework for thatch hut common in Benue state. Other trees of economic value are found scattered in the area or concentrated in preserved village, gallery or reserved forests. These include *Isoberlinia, gmelina*, mahogany, obeche, iroko, African pea, ogbono, *Daniellia oliveri, Vitellaria paradoxa, Prosopis africana, Parkia biglobosa* and *Burken africana*. These trees are used for timber, their edible fruits, and as legumes.

At Benue State University, the near natural vegetation is represented by the fenced forest housing the Botanical Garden (which is burnt on a yearly basis). Other areas within the campus are built-up, lawns, playing fields and a mosaic of grassland and fallow farmlands at various stages of seral regrowth. The Physical Geography Observatory Station was under crops like most other non-built portions of the Benue State University land.

Agriculture forms the backbone of the Benue State economy, engaging more than 70 percent of the working population (Nyagba, 1995). Bush fallow using simple tools is the dominant system, though mechanization and plantation agriculture/agroforestry are gradually gaining ground. The agroforestry system is common in Southern Benue State where population density is high.

Farms are generally small and fragmented, being less than one hectre. Crops grown include soyabeans, rice, groundnut, benniseed, citrus, oil palm, hot pepper and tomatoes as cash crops; and yam, cassava, sweet potatoes, beans, maize, millet, guinea corn and vegetables as food crops. Agricultural production in the State generally revolves around multi-cropping. Intercropping which is the long practiced system of growing more than one crop at the same time on a given plot or farm remains a dominant and very important feature of the agricultural landscape. The system provides an insurance against mono-crop failure and assures of a greater overall yield of crops per unit area. There has been a gradual shift from a grain and root crop economy to a tree economy in much of the State, mainly due to continued reduction in soil fertility partly as a result of soil erosion. There is very little irrigated agriculture despite the abundance of fadama and surface water.

In the Makurdi area, the urban and sub-urban dwellers usually engage in the cultivation of available pieces of land around their compounds as well as in poultry and other livestock keeping. These urban farmers concentrate in the production of vegetables, maize, rice, yam, groundnut, sweet potatoes and tobacco.

The practice of cultivation, particularly of the root crops (yam, especially) involves a system of land clearing towards the end of the rainy season in September or October when farmers weed fallowed plots and evenly spread the weeds to cover the land. Heaps are later made and the top of the heaps covered with rolled grass/weeds. The practice of mulching is repeated when the yam seedlings are planted. Mulching is also a necessary condition in the preparation of nurseries for vegetables (pepper, garden eggs) and citrus seedlings in Benue State.

## 1.5 Suitability of study area

The studies of splash, soil loss and other such experiments carried out so far in the country are concentrated in the South Western Nigeria (Oyegun, 1980; Lal, 1984; and 1998; Ahenaku, 1985; Osuji, 1989; Osuji and Sangodoyin, 1988; Eze, 1991, 1996 and Daura, 1995). Although there may not be marked differences in climates of the Western Nigeria and the present study area, the present study is a pioneering research work, the result of which is expected to stimulate further research of this nature in the area. The areas and aspects covered in the present study are scantly studied as depicted in the existing literature. For example, Eze (1996) studied the effects of different land use surfaces on splash detachment, while Lal (1998) studied drop size distribution in tropical storms in Ibadan. However, the areas of emphasis here include slope angles and mulch cover influences on splash detachment. Additionally, there is variation in the equipment and experimental design. Eze (1996) used the Morgan's splash cup in the field. This present study used soil trays with combined splash collectors under natural rainfall. The use of soil trays is based on many factors. One of them is the difficulty of getting varied slope angles within a manageable distance that will enhance the ease of monitoring.

The location of the study within Benue State University was also considered suitable for other practical reasons. The issue of security of the equipment was paramount. There was the prospect of getting assistance, both material, and personnel from Geography Department and the University at large. The prospect of continued research in the future in this place, both by the staff and students was also considered. The study area is about 7km from the Nigerian Meteorological Agency Station at the Nigeria Air Force Base, Makurdi, which has been keeping weather data since the early 1960. The study is also important for agricultural reasons. As a predominantly agrarian area, there has been increasing encroachment on the rural land, thus affecting the age old shifting cultivation and long fallow period. There is therefore the need to develop alternative methods of soil management for enhanced productivity, hence the relevance of this type of study in the present study area.

# CHAPTER TWO

# CONCEPTUAL FRAMEWORK AND LITERATURE REVIEW

## 2.1 Conceptual framework

### 2.1.1 Introduction

The study of splash erosion is an aspect of process - form studies in geomorphology. The renewed interest in process studies is possibly because of the failure of the cyclic models to explain the origin of specific landform systems and possibly due to discrepancies between the real world and existing models which can only be investigated by data collection (Goudie, 1990). Therefore the process school shifted emphasis from the cyclic or evolutionary theory to the dynamic equilibrium theory. According to Strahler (1952), the dynamic quantitative approach aims at expressing quantitative laws relating form to process. The focus of this study is on the impact of slope angle (form) on splash (process) among others. To understand the interrelationships of splash process on the one hand and slope and soil material on the other hand, the concept of the open system, derived from the general system theory is used in this study as the main conceptual framework.

### 2.1.2 The open system theory

The general systems theory developed from the search for generalization based on the whole rather than on individual parts. The concept attempts to explain the complex relationships existing between the various components of the geomorphic phenomena, for example, slope elements. This kind of thinking was pioneered by Horton (1945), Strahler (1952), Culling (1957), Hack (1960) and (Chorley, 1962). Efforts were made by these authors to apply general systems thinking theory to the study of geomorphology, with a view to examining in detail the fundamental basis of the subject, its aims and methods.

A system is a set of objects together with relationships between the objects and between their attributes. The key point about system is that, though it has attributes, these attributes with definite interrelationships operate together as a whole, in a unified way. Systems can be classified into isolated, closed or open system. An isolated system generates its own energy independently of other sources and so does not allow the entry of mass or energy into its well defined boundary. Closed systems on the other hand have clearly defined boundaries across which no import or export of materials or energy occurs. The closed system however allows exchange of energy with the exterior.

The third type of system, the open system, needs energy supply for its maintenance and preservation (Chorley, 1962) and is in effect maintained by a constant supply and removal of material and energy. Direct analogies exist between the classic open system and slope elements and all other form assemblages of a landscape. The open system recognizes the adjustment between form and process, an important principle in geomorphology. Other relationships which this system recognizes include process-process and form-form. Gilbert noted the process-form relation in his studies of the Henry mountains where slopes become adjusted to the forces on which their character depend. This form adjustment is brought about by the ability of an open system to self regulate itself.

The real value of the open system approach to geomorphology (Chorley, 1962) is that it throws the emphasis on the recognition of the adjustment, or the universal tendency towards adjustment, between form and process. Both form and process are studied, therefore, in equal measure, so avoiding the pitfall of ignoring process geomorphology. Applied to erosion processes and forms, the concept of the steady state in an open system focuses attention upon the relationship between dynamics and morphology.

Secondly, the open system approach encourages rigorous geomorphic studies to be carried out in those regions – and perhaps these are in the majority – where the evidence for a previous protracted erosional history is blurred, or has been removed altogether.

The open system thinking also directs investigation toward the essentially multivariate characters of geomorphic phenomena. While examining the interaction between slope angle and mulch with erosivity, attention is also focused to other factors, including the dynamics of soil (erodibility) responsible for splash erosion. The concepts of erosivity and erodibility are therefore central in this regard and are examined further below.

### 2.1.3 Erosivity and erodibility

Erosivity refers to the energy possessed by raindrops that causes erosion. It involves energy expenditure for breaking down soil cohesiveness, mobilizing soil particles and entraining them in overland flow (Jeje, 1987). This energy is very important in splash studies in the humid tropics where the rains are torrential in nature. To compute erosivity requires analyses of the drop size distributions of rain. Drop-size characteristics vary with the intensity of the rain, generally increasing with rainfall intensity. Morgan (1979) reported that this hold only for rainfall intensities up to 100mm $h^{-1}$. At greater intensities, median drop size decreases with increasing intensity, presumably because greater turbulence makes larger drop sizes unstable. The relationship between drop-size distribution and rainfall intensity also varies for rains of the same intensity but different origin. Another important factor of erosivity is rainfall kinetic energy or total energy available for detachment and transportation.

Results of studies on erosivity of rainfall reported by Van Dijk (2002) suggest that soil splash rate is a combined function of rainfall intensity and kinetic energy. A comprehensive assessment of the importance of these various factors influencing erosivity is essential because "our knowledge of the distributions of drop size and terminal velocity in natural rainfall is well ahead of our understanding of the way in which these interact to detach and transport soil particles by splash" ( Van Dijk, 2002; 131).

Erodibility, on the other hand, refers to the susceptibility of the soil to erosion. It is a function of soil aggregate stability, which is affected by different soil properties (Duike, *et al*., 2001; Descroix, *et al*.,2001; Idowu, 2003; Hammad, *et al*., 2005 and Valmis, *et al*., 2005). It defines the resistance of the soil to both detachment and transport. Although soil resistance to erosion depends in part on topographic position, slope steepness and the amount of disturbance created by man, for example during tillage, the properties of the soil are the most important determinants. Erodibility depends mainly on the physico-chemical properties of the soil (Lal, 1988), which determines the ease with which the soil is detached, entrained and transported by raindrop impact, and the shearing index of surface material. Leopold, *et al*. (1964) considered erodibility as a direct function of the intensity of rain, the infiltration capacity of the surfaces, the chemical and physical properties that control the disintegration of rocks and determine the cohesiveness of the soil, and the vegetation which directly affect both the stability and infiltrating capacity of the soil, while Aneke (1991) considered it (erodibility) to be the principal parameter of erosion. To him erodibility is dependent on colloidal content, density and mechanical structure of soil.

Many attempts have been made to devise a simple index of erodibility based on the properties of the soil as determined in the laboratory or the field. Some indices used include:

1. Static Laboratory Test Methods- Erodibility Index

$$(k) = \frac{\%Sand + \%Silt}{\%Clay}$$ (Bouyoucos, 1951)

2. Static Field Test Method- Erodibility Index

$$\frac{1}{\text{Mean shearing resistance x permeability}}$$ (Chorley, 1962)

The influence exerted by soil properties on the nature and rate of reaction of geographic processes has been recognized (Bryan 1974), but few attempts have been made to isolate and test the properties involved. As a result, serious misconceptions on the mode of soil influence persist in geographic literature. For example, the significance of texture has been over-estimated while the importance of aggregate characteristics has almost been ignored. There is still a lot to be learnt from studies involving the correlation between rainfall erosivity and soil properties. The present study is an attempt in this direction.

### 2.1.4 Erosivity of raindrops/rainsplash

The erosivity of a raindrop is conceptualized as a function of the drop size, mass, intensity, duration, amount, velocity, momentum and kinetic energy. Ellison, (1944a, 1947); Rose, (1960); Hudson, (1965); Morgan, (1982) and Van Dijk, *et al*. (2003) grouped these variables into indices such as storm rainfall depth; kinetic energy; amount of rainfall higher than threshold intensity and power function of rainfall intensity. The parameters of splash erosion on the other hand, include size, aggregate stability, bulk density, organic matter, clay content, soil shear strength, soil moisture condition; stone content, litter cover and vegetation cover (Bubener and Jones, 1971; Yamamto and Anderson, 1973, and Cruse and Larson, 1977). Splash is thus seen as a measure of both erosivity and erodiblity (Ghadiri and Payne, 1988). Splash will occur if the force provided by falling raindrops surpasses the resistance offered by the soil. This relationship between force of raindrops and resistance of soil is however affected by some other factors, including the slope angle and surface cover.

## 2.2 Literature review

### 2.2.1 Introduction

Process studies set out to explain relationships between slope form and process with a view to a better understanding of the origin of specific landscape elements (Goudie, 1990). The main approaches used in hill slope process studies include measuring the rate of erosion on a slope by a process or processes; measuring the velocity of operation of processes; and examining the fundamental mechanics of the operation of processes. This study is situated in the realm of the study of the rate of operation of a process, in this case, splash erosion; and the mechanics of the operation of splash as raindrops interact with soil properties and other factors to cause erosion in a sub-humid area of Makurdi. This section reviews previous research on different aspects of splash. The first four subsections deal with the definition of splash, measurement and mechanics of splash and splash studies both in the laboratory and in the field. The remaining sections examine the effects of factors of cover, slope, soil properties, rainfall and wind on splash.

### 2.2.2 Definition of splash

According to Eze (1996), the terms splash erosion, raindrop splash, splash process, detachment by splash, erosion by splash, pre-runoff erosion, or simply, splash, are often used synonymously in the literature, to depict the process of the lifting of soil particles by falling raindrops and their subsequent translocation. Some authors, including Schwab, *et al*. (1993); Salles and Poesen (2000); Legout, *et al*. (2005); Valmis, *et al*. (2005); and Assouline and Ben-Hur (2006), attempt to separate the detachment component (raindrop impact) from the transport component (rain splash). Legout, *et al*. (2005) were emphatic about this when they remarked that; "Raindrop impact detaches soil particles from the surface of the soil matrix. It produces detached material that can be transported by splash". Cheng, *et al*., (2008) were also of the opinion that "raindrops are erosive agents that initiate the movement of soil particles. As the first event of soil erosion, rain splash erosion supplies materials for subsequent transportation and entrainment".

The detachment process, caused by raindrop impact can be conceptually divided into a soil dependent sub-process- (the break down of aggregate)- and a rainfall dependent sub-process or the movement initiation sub-processes. For Morgan (1995); Faniran and Jeje (2002) and Van Dijk, *et al*. (2003), rain splash is an important detaching agent as well as transporting medium by impacting raindrops. This is done through three interrelated processes of compaction, splash and slaking. The effectiveness of the processes depend on factors of soil erodibility, rainfall erosivity, slope and cover (vegetation and mulch). This study examines the effects of these factors on splash.

Several researchers have stressed the importance of splash in terms of initiating the process of erosion through detachment of soil fragments by raindrop impact and transport by splash (Ellison, 1952; Rose, 1960, 1993; Baver, 1985; Kinnell, 1990; Summerfield, 1991; Morgan, 1995; Hudson, 1995; Peterson and Hasholt, 1995; Salles and Poesen, 2000; Van Dijk, 2002; Van Dijk, *et al*., 2003; Legout, *et al*., 2005 and Assouline and Ben-Hur, 2006). According to Van Dijk, *et al*. (2003), rainsplash (soil detachment and transport by impacting raindrops) is an important first step in soil erosion. The authors noted that unconcentrated runoff usually does not have enough power to actively detach and entrain soil particles, but particles detached by rainsplash may subsequently be transported by the flow. It was also the view of these researchers that on steep slopes, rain splash may be the dominant transport mechanism. However, many other researchers hold contrary view on this. Meyer (1981); Jeje (1987); Elliot, *et al*. (1991); Wan, *et al*. (1996); and Faniran and Jeje (2002); among others, point out that though splash may be important in detaching sediment, it is considered to be of limited significance in sediment transport. This study has, among other things, considered measuring the quantity of materials detached by splash.

### 2.2.3 Measurement of splash

The measurement of splash generally has continued to present problems to researchers over the years. Isolating the sub-processes involved in splash, particularly in the field (detachment, transport, upslope and downslope detached sediments, splash distance etc), is even more problematic (Van Dijk, *et al*., 2003 and Legout, *et al*., 2005). The difficulties of measuring splash erosion processes have, however aided the development of various techniques aimed at obviating the measurement problems.

Ellison (1944a)'s splashboard was criticized for its susceptibility to overland flow and wind disturbance. But the study increased our knowledge of detachment of soil by raindrops, transportation of detached particles by splashing and creation of turbulence in surface water thereby increasing the water's detaching and transporting capacities among other things. Modifications of Ellison's splash boards (to take care of the short coming of Ellison's board) have been described by Gabriels, *et al*. (1974b), Kwaad (1977), Goudie (1990), Wan *et al*. (1996), Providoli, *et al*. (2002) and Van Dijk, *et al*. (2003). The splash boards used by Providoli, *et al*. (2002), for example, were able to intercept downslope and upslope splash by two separate aluminum boards. They were also installed 3cm above the soil surface so as to allow surface runoff to pass underneath. A small roof protected the splashed material on the boards from rain impacts.

Other researchers have used painted pebbles on slopes during rainfall events, or used radioactive tracers $59_{fe}$, $49_{fe}$ to monitor splashed sediments in the field (Young and Holt 1968; Coutts, *et al*., 1968a; Young and Mutchler, 1969; Kirkby, and Kirkby, 1974; Mosley, 1974; Moeyersons, 1974 and Moeyersons and De Ploey, 1976). The use of painted pebbles is only useful in measuring total erosion by surface wash. It is not capable of distinguishing splash –displaced particles from overland flow movements. The radioactive tracer on the other hand revealed the possible effects of slope and wind direction on soil detachment by raindrop but did not allow estimate of the rate of splash erosion to be made while capable of posing environmental problems. Fournier (1958), Gorchioko (1977) and Bolline (1978) measured splash detachment – using funnels of various dimensions. Bolline (1978), for example used 52mm. diameter funnels buried into the ground to catch splashed soil particles. The equipment can check out splashing but is affected by flooding. It can be displaced by overland flow and can not separate splashed material into upslope and downslope components. The funnel also has the problem of not having a defined splash contributing area.

Legout, *et al* (2005) recently used splash rings, carefully designed to measure fragment size distribution. The rings were separated into upslope and downslope parts. It however fails to analyze the slope influence on splash. Poesen and Savat (1981) and Savat (1982) used weighing method to measure splash distances. The method is easy to use and allows rapid and accurate determination of splash distances. The method uses screen to catch splashed material. The equipment is however not capable of measuring materials splashed upslope and downslope while the use of plastic pans (Bryan, 1974; Eze, 1991) suffers from interference by wind, surface runoff, and has no contributing area.

Numerous authors have used splash cups of different sizes to collect information about the characteristics of rain splash (Poesen and Torri, 1988). The splash cup technique was firstly introduced by Ellison (1947) and used by Morgan (1978, 1982); Poesen and Torri (1988); Lal (1988); Lal and Elliot (1994); Nearing, Lane, Albert and Laflen (1990) Salles and Poesen (2000) and Van Dijk (2002). The Morgan’s cup is a good method of measuring splash in the field (Eze, 1996). The equipment is efficient in estimating absolute rate of splash. It has no problem of overland flow and disturbance by wind. But the splash cups are incapable of measuring upslope; downslope and lateral splash and are incapable of adequately evaluating the role of slope on the splash process. This is particularly true where the spatial distribution of splashed particles tend to be asymmetrical (Van Dijk, 2002). The cup also has the problem of accumulating water in the inner cylinder and catching tray during heavy rains and lacked detachable parts thus making it difficult to quantify temporal variation in inter-rill splash and wash transport. Van Dijk, *et al*. (2003) recently used a combined splash and runoff collecting system, modified slightly from the design by Wan, *et al*. (1996). It consist of a central soil tray with sediment collectors attached to all sides to separately measure sediment transport by wash and the respective directional components of splash on a sloping surface. The collectors are equipped with splashboards. The present study used this novel device, with modifications to suit the local environment. The instrument used in the present study has other advantages over the Morgan's Cup - the tray that carries the splash collectors rests on a table that is 20 cm above the ground. The splash collectors also have outer arms that are 30cm above the soil in the tray, thus eliminating out splashing.

### 2.2.4 Splash studies in the laboratory and field

Understanding of the physical processes causing detachment and transport by falling rain drops has improved considerably over the last two decades, mainly via laboratory experiments (Poesen and Savat, 1981; Ghadiri and Payne, 1986, 1988; Poesen and Torri, 1988; Sharma and Gupta, 1989; Wan, *et al*., 1996; Salles and Poesen, 2000 and Van Dijk, *et al*., 2003). Laboratory experiments have also improved the quantitative or mathematical description of wash processes (Moss, 1988; Kinnell, 1990; Proffitt and Ross, 1991 and Heiling, *et al*., 2001; Jomaa, *et al*. 2010). Rainfall simulation and disturbed soil samples have, in the main been used in connection with splash studies in the laboratory.

The laboratory studies permit precise control over variables controlling splash that is almost impossible to achieve under field conditions. Unfortunately, the results of laboratory studies are not readily translated to field situations. The manner some rainfall erosivity indices can be varied under the two systems of measurement (field and laboratory) is not uniform e.g. rainfall intensities, drop size distribution and kinetic energy (Van Dijk, *et al*., 2002a). The problems outlined above clearly demonstrate that to understand rainfall-driven erosion processes, experiments under natural rainfall are indispensable.

Morgan has been involved in splash measurement in the field during the last thirty years (Morgan, 1978, 1979, 1981, 1982, 1985, 1991, and 1995). Recently, Van Dijk and others have also been measuring different aspects of splash in the field in Java and other places (see Pederson and Hasholt, 1995; Wan, El-Swaife and Sutherland, 1996; Van Dijk, 2002; Van Dijk, *et al*, 2002a; Van Dijk, *et al*, 2002b; Van Dijk, *et al*, 2003; Van Dijk, *et al*, 2005 and Hammad, *et al*, 2005). Other researchers engaged in field measurement of different aspects of splash include Ahaneku, (1985); Eze, (1991, 1996); Lal and Elliot (1994); Lal (1998) and Providoli, *et al*. (2002).

### 2.2.5 The mechanics of splash erosion

The mechanics of splash erosion has received the attention of researchers and a few relationship have been established by Ellison (1947); Bisal (1960); Reizebos and Epema (1985); Summerfield (1991) and Pidwinry (1999); Heng, *et al*. (2009); Sander, *et al*. (2011); Ghahramani, *et al*. (2011) and Erpul, *et al*. (2012). Ellison showed that 75percent of soil splashed on a $10^0$ slope moved down slope while 25 percent 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 $25^0$ or greater, all the redistribution occurs in a downslope direction. Summerfield (1991) reports that on a low slope angle of $5^0$, about 60 percent of particles dislodged by raindrop impact move down slope; this increases to 95 percent on $25^0$ slopes. Van Herdeen (1967) and Poesen and Savat (1981) empirically defined upslope and downslope splash distances in their derivation of 'net splash' or the sum of the downslope and upslope materials. Yariv (1976) described the mechanism for the detachment of soil particles by raindrop, using a model based on three stages of dry soil, fluidized soil and soil covered with overland flow and noted the effect of liquid on the rate of detachment, particularly of the finer materials. Mermut, Luk, Romkens, and Poesen (1997) measured the rate of splash at varied rainfall intensities and with different soil materials. The rates ranged between 2.1 mg, $ha^{-1}$ at low rainfall intensities to 21.4-mg $ha^{-1}$. Splash erosion rate have also been investigated in areas affected by fire. Soto, Basanta, Benito, Perez, and Diaz-Fierros (1994); Soler, and Gallart (1994); Cerda (1998b); Robichaud and Brown (1999) and Providoli, *et al*. (2002) reported increased erosion by surface runoff due to fire alone. The increase is due to heat-induced water repellence and hence lower soil infiltrability (Debano, 1981). However, the effects of intervention in burnt areas may vary. For example, Providoli, *et al*. (2002) reported that post-fire clear-cutting does not seem to affect splash erosion. Their conclusion was that absolute splash erosion rates are site specific-being dependent on soil types-if the slope and method of extraction are held constant. This goes to emphasize the role of soil properties on splash.

### 2.2.6 The effects of vegetation and mulch cover on splash

The role of vegetation in geomorphic processes is well-documented (Faniran and Jeje, 2002; Collins, *et al*, 2004; Ohnuki and Shimizu, 2004; Schiettecatte; *et al*, 2008 and Parlak and Parlak, 2010). Vegetation, acting as surface cover, absorbs the energy of falling precipitation to the extent of essentially eliminating rainsplash erosion in certain circumstances. The canopies intercept rainfall; changes its volume, drop size, momentum, pathway and therefore erosivity, depending on the type and height of the species and the degree of coverage (Abrahams, Parson and Wainwright 1996). The role of surface cover in reducing splash erosion has been recognized by Farmer (1973); Imeson (1977); Bolline (1978); Morgan (1981, 1985); Ahaneku (1985); Eze (1996), and Iorkua (2012) among others. These authors have observed reduction in splash under plots of low-growing crops with dense canopy or grass-covered surfaces.

Eze (1996) studied splash erosion under different land use surfaces and his conclusion was that vegetation close to the ground is more effective in preventing splash than tall trees. The implication of this is that forest floors left unprotected by litter and undergrowth may also suffer, from splash erosion due to the fact that a large proportion of intercepted rainfall is later released which often cause serious damage to the soil in form of reduction of particle size, surface crusting and formation of earth pedestals, or earth pillars and general erosion. Moseley (1982) found that kinetic energy under canopy was 1.5 times higher than that of the rainfall in the open and splash values were 1.3 times greater under the canopy than in the open. Wiersum (1985) and Brand (1986) recorded increase of 157% in erosive power and 660% of splash by rainfall in tropical Java.

Related to vegetation in affecting splash erosion is mulching. Mulching has tremendous potential as a method for erosion control (Morgan, 1986; Lal 1993b and Cattan, *et al*, 2006). Oyegun (1980) and Salau (1989) have also highlighted the importance of mulching to include protecting the soil from rainfall impact especially if they reach 90 percent cover. According to them, mulching has effect on erosion and soil physical properties beside the other climatological effects. According to Thurston (1992), mulches can be especially important in tropical areas with heavy rainfall, as they improve water absorption and reduce rain splashing. Other scholars that have studied mulching in Nigeria include Lal (1976), and Thurston (1992). Mulching is the covering of a soil surface with either organic material such as cut grass, straw, leaves, stem, plant and domestic trash, with residues, dung, and sawdust, or inorganic materials like ash, sand, stones and opaque and transparent plastic (Salua 1989, Poesen and Lavee, 1990, David, 1992, Thurston 1992, Lombin, 1999, Brady, 2000 and Brady and Weil, 2002). The use of mulches provide many agronomic benefits, including protecting soil against erosion. Considering the value of mulches for erosion control among others, there is therefore the need for more of these studies in Benue state where majority of the working population depend on arable agriculture for sustenance. The present study examined the effect of mulch on splash under natural rainfall, using an adaptation of methodology recently used by Wan, *et al* (1996).

Rock fragments resting on the soil surface after they have been transported upward in the soil mantle by the action of low tillage tools or seed drills are also said to act like mulch in the erosion process (Meyer, *et al*, 1972; Box, 1981; Martinez-Zavala, *et al*, (2010). The effectiveness of mulch in reducing runoff and soil losses, however, depends on factors of rainfall erosivity, soil type and condition, steepness and length of slope, and the rate, position and type of mulch application (Foster, *et al*, 1982). The use of gravel and sand as mulch to conserve the sporadic and limited rainfall for reliable crop production is a traditional technique of soil conservation that is still practiced in the Loess area of China (Xiao-Yan Li, 2003). There is also the largely undocumented traditional system among the people of Benue State that involves mulching land before making heaps and mulching the heaps before and after planting yams.

Several natural mulch materials have been tested for controlling soil loss. These include hay, different kinds of crop residues, leaf litter, wood chips and gravel or crushed stones (Swanson, *et al*, 1965; Adams, 1996; Meyer *et al*., 1972; Singer and Blackard 1978; Jennings and Jarret, 1985; Gille, *et al*, 1986; Lopez, Cogo and Levien, 1987; Abraham and Erickson, 1989; and Poesen, *et al*, 1990). Poesen and Lavee (1990) in particular noted the effectiveness of different mulch sizes in reducing soil loss from soils susceptible to surface sealing during high intensity storms. They also noted the importance of position of mulch in topsoil and cross sectional area of the mulch material in reducing soil loss, while Poesen, *et al* (1990) reported that rock mulch is optimal if it is not embedded in the soil top layer. From existing literature, it can be hypothesized that about 4t ha**-1** of dry matter (DM) is needed to protect the soil from erosion and to conserve soil water (De Vieeschauwer, *et al*. 1980 and Adeoye 1984). Lal (1993) recommended mulch farming as a sustainable management for soil and water conservation in the semi humid zones because the mulch would protect soil surface from erosion. The studies quoted above did not use natural rainfall neither were they specific to splash.

### 2.2.7 The effects of soil properties on splash

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); Valmis, *et al*. (2005) and Mouzai, and Bouhadef (2011). 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 seal (Bryan, 1973), which can greatly reduce infiltration and enhance soil loss (Mermut, *et al*., (1997). Aggregation is however a dynamic property of soil being affected by earthworm activity and wetting and drying cycles (Bryan, 1974) among other factors. Wuddivira, Stone, and Ekwue (2009) investigated the interactive effects of clay and organic matter on aggregate breakdown and splash detachment under various wetting rates and antecedent moisture contents using six agricultural soils from Trinidad and concluded that the aggregate breakdown and splash distance of the medium clay-high organic matter soils were significantly lower than their high clay-low organic matter counterparts 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. Recently, the effects of aggregated soils on splash projection distance was investigated by Lequedois, *et al*. (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 and concluded that the coarser fragments, 50 to 200 μm, are transported in groups in splash droplets.

**2.2.8 The effects of rainfall on splash**

The effect of rainfall on splash has been investigated by Wan *et al*. (1996); Lal (1998); Salles and Poesen (2000); Van Dijk, *et al*. (2003); Hammad, *et al*. (2005); Legout, *et al*. (2005); Peterson and Hasholt (2005); Assouline and Ben-Hur (2006) and Yin, Xie, Nearing and Wang (2007). These studies revealed several rainfall sub-factors or parameters crucial to splash erosion, including rainfall intensity, momentum, velocity, drop size and kinetic energy. There is however no general agreement on which rainfall properties best describe the mass of sediment detached. The effect of raindrop impact on soil detachment has been attributed to the rain intensity (1) but more commonly to kinetic energy (KE), to momentum (M) or to some combinations of these (Salles and Poesen, 2000). The implication here is the influence of some of the sub-factors on each other. For instance, in calculating kinetic energy, drop size distribution is considered a function of precipitation intensity (Morgan, 1978; Bolline, 1978; and Lal, 1998).

Hudson (1995) stressed the importance of drop size distribution and impact velocity on rainfall erosivity. The drop size of natural rains varies considerably ranging from 0.1mm to an upper limit of 6mm. Kowal and Kassan (1978); Aina, *et al*. (1977); and Lal (1998) measured drop size distribution at selected locations in Nigeria. Lal (1998) found that the mode/mean drop size ($D_{50}$) of most storms received at Ibadan was about 2.22-2.50mm with an energy load of 2000-2500J/$m_2$ and momentum of about 300-450kg/m/s. Drop size distribution increases with rainfall intensity in a gradual manner, however, very low intensity rainfall contain some erosive rain drops (Van Dijk, *et al*., 2003). The simplest but significant rainfall erosivity parameter is therefore rainfall intensity (Ellison 1944a). However, some researchers including Farmer (1973) and Van Heerden (1967) demonstrated that rainfall intensity do not influence mean weighted splash distances. Govers (1991) also reported that the usually expressed relationship between splash detachment and high intensity rainfall may lead to an over estimation of splash sediments. This is contingent on the discovery that the relationship between splash and soil properties can be very complex for different rainfall intensities, a situation confirmed by Assouline and Ben-Hur (2006) who also found no significant relationship between soil loss and rainfall properties for intensities ranging from 10 to 103mm/$h^{-1}$. Petersen and Hasholt (1995) reported the use of arbitrary intensity thresholds by Hudson (>25mm/h in Africa), Morgan (>10mm/h in England) and Bolline (>1mm/h) to relate rainfall intensities to rainsplash.

The kinetic energy of raindrops comprises the major erosive factor of rainfall (Govers, 1991; and Hammad, *et al*., 2005). Kinetic energy is the energy of motion which falling raindrops transfer to soil particles which they come in contact with. There are differences in kinetic energy between simulated and natural rains. These differences relate to the drop size distribution and fall height of simulated and natural rains (Osuji, 1989 and Van Dijk, *et al*., 2003). The kinetic energy of simulated rainfall can be changed using drops of different sizes or fall height while in the field, the moments of natural rain drop size distributions increases with rainfall intensity in a gradual manner. This emphasized the importance of splash experiments under natural rainfall. Salles and Poesen (2000) expressed splash as a function of kinetic energy (KE) in the form Ds-a $KE^b$ where Ds is splash detachment, a and b are constants and KE is the kinetic energy of the rain. According to Free, (1960), b ranges from 0.8 for sandy soils to 1.8 for clays, while Quanash (1981) reported b values in the range of 0.8 to 1.3. According to Kinnel (1982), splash detachment increases with drop size than kinetic energy or momentum, while Govers (1991) stated that the use of kinetic energy as an erosion index leads to an underestimation of splash detachability during high intensity rains. Another aspect of the impact of rainfall on splash is the direction of strike by raindrop. As noted by Schwab, *et al* (1993), raindrop may fall on sloping land; it might be inclined rain, or vertical rainfall. The controversy on the relative importance of rainfall parameters calls for more studies of this nature, to further contribute to the debate on the issue.

### 2.2.9 The effects of wind on splash

The effect of wind on splash is felt in oblique rains and energy loads of storms. Wind seems to have an effect on the speed of raindrop and hence its kinetic energy (Peterson and Halshot, 1995). Moeyersons (1983) studied the effects of oblique rains on splash detachment. His conclusion was that oblique rains falling perpendicular on a sloping surface splashed as much sediment upslope as downslope. His study disproved the effect of slope on splash erosion. Other researchers (Lyles, *et al*., 1969; Disrud, 1970; Disrud and Kraus 1971; Leyles, *et al*. 1969; Poeson, 1981 and De Lima, *et al*., 1992) have concluded that increased wind speed increases kinetic energy of rainfall. It has been shown that interactions between rainfall obliquity, wind, and slope influence, spatial rainfall variation, and quantity and direction of splash transport affect upslope and downslope splash. Moeyersons (1983); Poesen (1986); Peterson and Halshot (1995); Erpul, *et al*. (2004) and Erpul, *et al*. (2008) also concluded that wind speed enhance energy output, but recommends studies on the influence of slope on energy levels.

### 2.2.10 The effects of slope angle on splash

Many studies have been carried out to address the relationship between splash and slope (Morgan, 1978; Bryan, 1979; Quanash, and 1981). The components of slopes often considered include length, roughness and steepness. Wan, *et al*. (1996) identified three types of splash-slope relationship and concluded that (1) splash rate increased with slope following linear functions; (2) splash rate increased with slope and then decreased after a peak splash rate was reached as described by polynomial functions (Bryan, 1979); (3) splash rate was not affected by slope (Morgan, 1978). According to Wan, *et al*., Morgan's position was shared by Mc Carty (1980), who did not believe that there is any significant relationship between detachability and slope. These authors considered factors of rainfall and soil properties as being more important to detachment than slope. Poesen (1987) reported higher splash on steeper slopes. Ebisemiju (1989), in a study in Guyana, observed that along very steep slopes with gradients over $20^{o}$, the dominant erosion process was rain splash. Wan, *et al*., (1996) partitioned total splash into directional components and showed that slope has a significant effect on these components: downslope and lateral splash components increased with slope while the upslope components decreased, reflecting variations of raindrop impacting forces and ponding depth with slope. This is also the position of Ellison (1952); Summerfield (1991); Schwab, *et al*. (1993) and Pidwinry (1999). Schwab, *et al*. (1993) noted that on sloping land, the splash moves farther downhill than uphill, not only because the soil particles travel farther, but also because the angle of impact causes the splash reaction to be in a downhill direction. However, experimental data from steep slopes, particularly with tropical soils are lacking in the literature (Wan, *et al*., 1996).

The review of literature has confirmed the importance of splash as an important initiating process of soil erosion. The sub-processes can be isolated and studied, particularly under laboratory settings. It also revealed that experiments under natural rainfall are essential to improve our understanding of rainfall-driven splash and wash transport processes, since results of laboratory studies are not readily translated to field situations.

Generally, the review identified continued attempts at developing appropriate techniques to measure splash. The efforts of researchers in this regard spans from the splash cups and trays of Ellison, and Morgan to splash box or boards or troughs and to the recently introduced composite board of Van Dijk.

The complex interrelationships of slope, soil properties and their individual and combined effects on splash, particularly the components of splash, have not received adequate coverage. This assertion is particularly true of the Nigerian environment, hence the need for the present study.

## CHAPTER THREE

## DATA COLLECTION AND ANALYSIS

### 3.1. Introduction

An open system can be studied using deductive approach. The assumption is that the internal state of any system and the state of its surroundings determine its response to external influence. In this case, the state of soil, slope, mulch cover and the rainfall parameters determine the splash erosion. This implies that the characteristics of the external input (rainfall) and the internal conditions of the system (landscape factors, for example slope angle and cover) must be known. This will help to predict the system output (soil loss through splash, in this case). Data were therefore collected for this study on the splash factors such as slope angle, mulch cover, rainfall parameters and soil properties.

### 3.2 Experimental design

#### 3.2.1 Splash

The equipment used in this research consists of a set of soil trays made from galvanized metal, with dimensions of 0.60 m x 0.30 m x 0.10m. At the down slope end of the tray, small holes were made to allow for drainage. Four separate detachable splash collectors were placed by the sides of the soil trays by 1.27cm flat rods attached to the bottom of the soil tray. Each soil tray was placed on a wooden table measuring 0.70m by 0.40m and 0.20m (Figs. 3. 1, 3.3). The slope angles 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.3.3). A 2.5cm pipe, with an opening of 3mm, with one section blocked and another open, was attached to the downslope section of each soil tray, a section reduced by 2mm, to allow for runoff. 2.5cm plastic pipe was attached to the open end of the rod to direct runoff into a collecting container (Figs. 3.1 and 3.2). A 5.8cm wide plastic attached to the down slope edge of the collector at an angle was used to cover the runoff collecting inlet to prevent splashed sediments from falling into the inlet (Fig. 3.2).

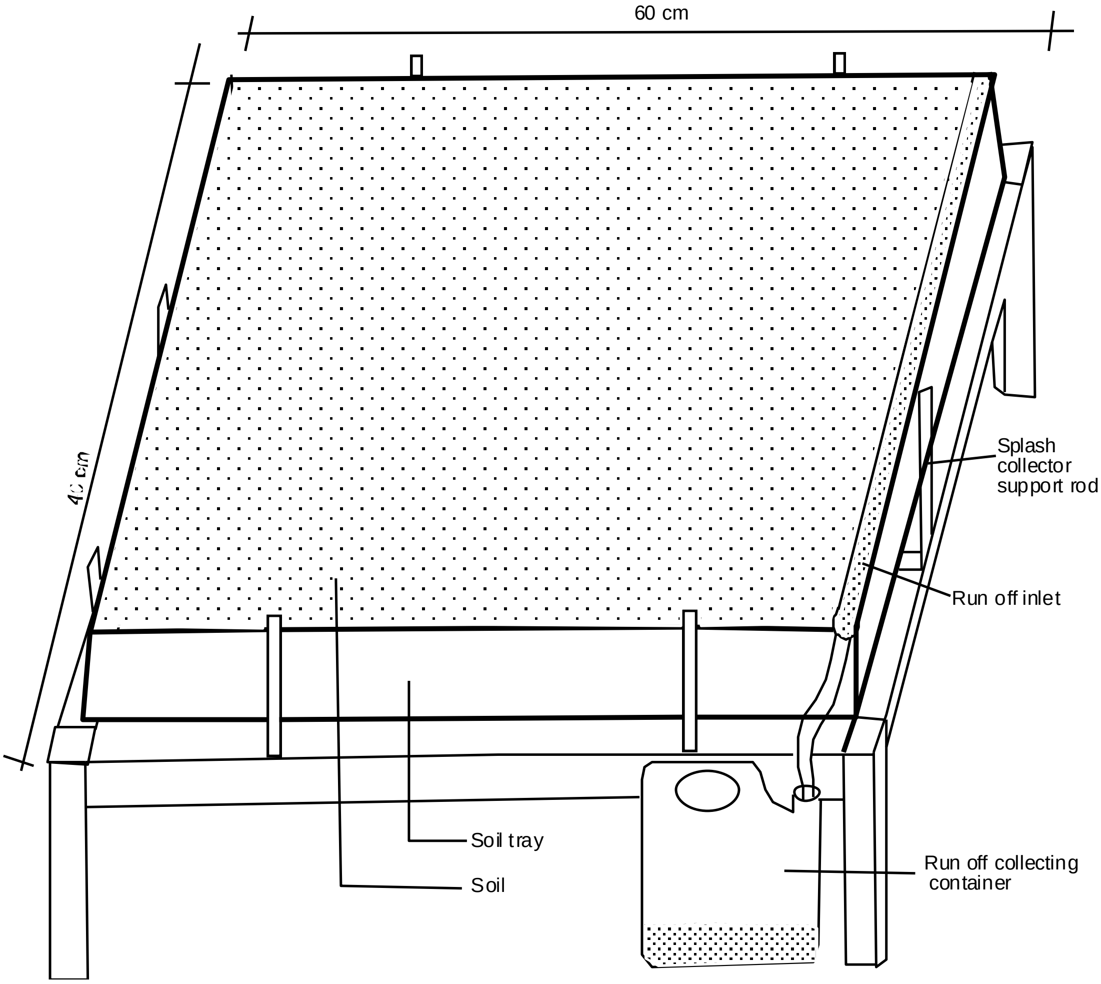


**Fig.** 3.1**.** Soil tray set on wooden table

Source**.** Field work 2007

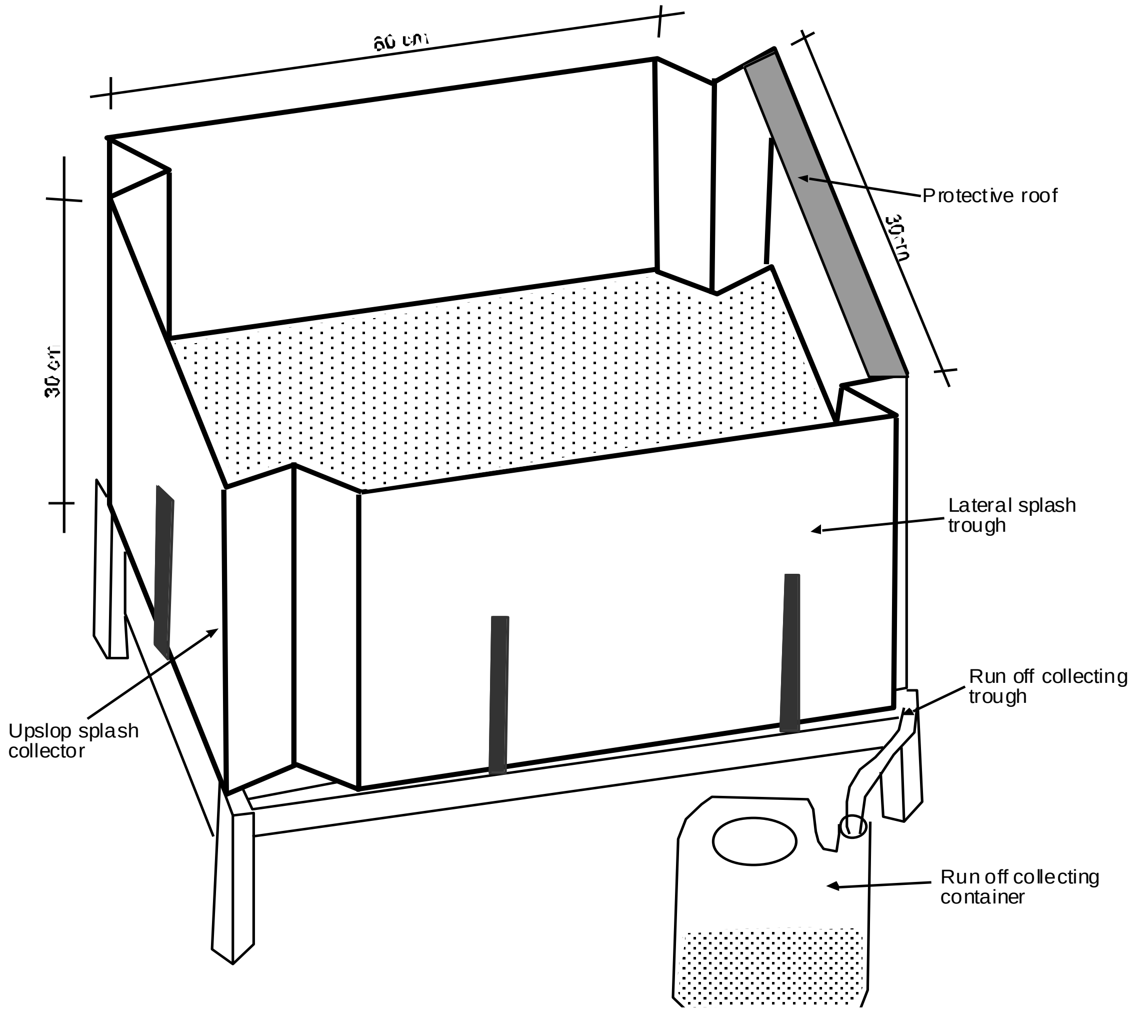


**Fig.** 3.2**.** Soil tray with splash collectors on table

Source. Field work 2007

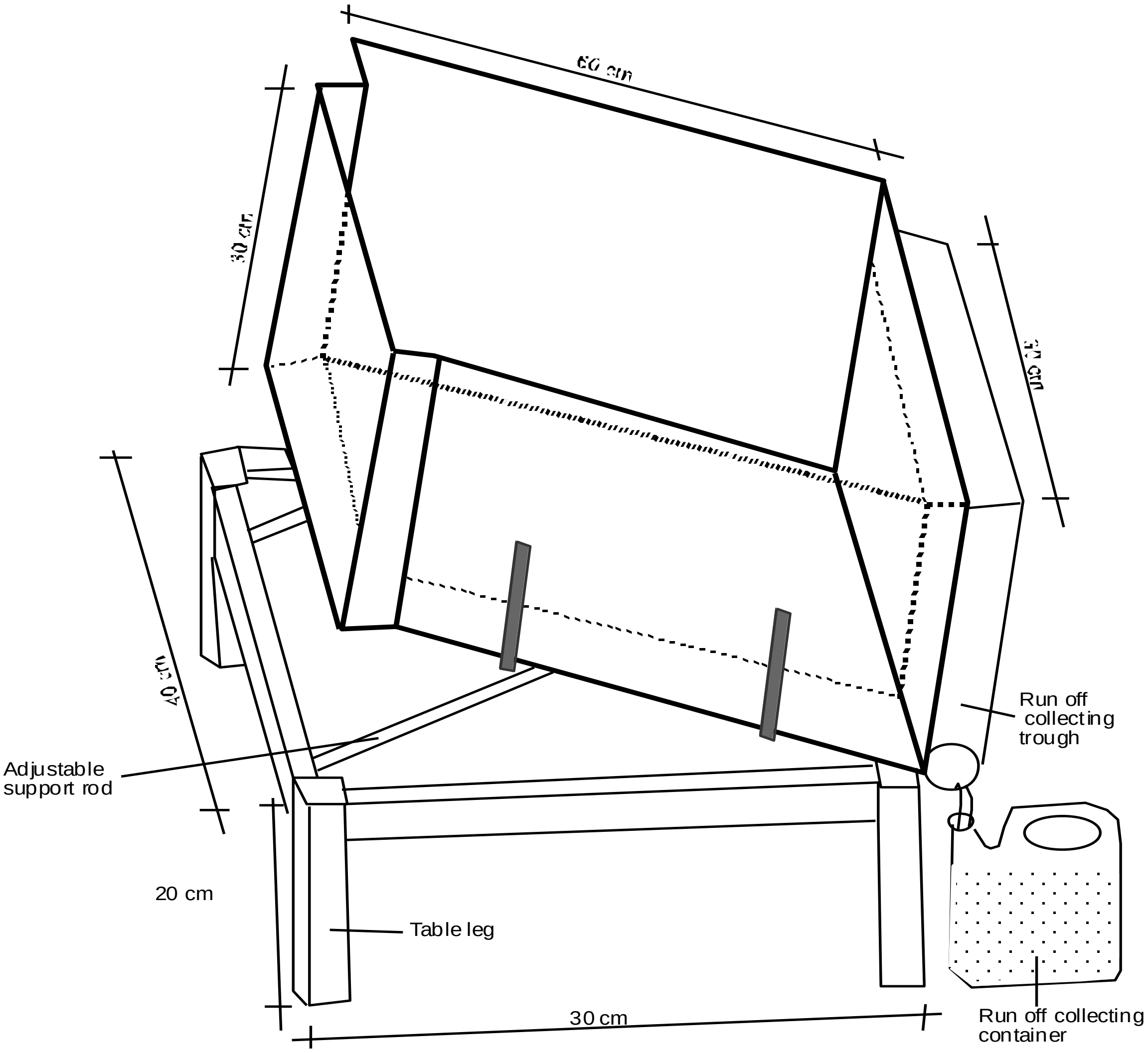


**Fig.** 3.3. Instrument raised at 25 degree slope

Source. Field work 2007

Furthermore, upslope, lateral and downslope splash collectors, constructed out of 3mm plastic, were attached to the soil trays in a vertical position. The lateral splash collectors have dimensions of 60cm (L) by 30cm (H) by 10cm (W) and 10cm (D) (Plate 3. 1). The upslope and downslope splash collectors have dimensions of 30cm (L) by 30cm (H) by 10cm (W) by 10cm (D).

The downslope collector was equipped with a protective roof (Plate 3.1), placed at an angle to prevent excessive ponding of splashed sediments in the collector by rain. This was necessary as this section was liable to be affected by the slope position. .1cm perforations were made above the floor of the splash collectors to allow drainage of excess rain water, while at the same time maintaining a water layer that prevented water and sediment from splashing back onto the soil in the tray or flowing out in suspension. A slight modification was done on the splash collecting equipment of the present study. 5 flat 2.5cm rods were attached at the bottom of the soil tray to house the splash collectors. Wooden tables were used instead of the water resistant plywood box used by Van Djilk *et al.* (2003). The use of tables was necessary as it enable the researcher to fix trays at determined angles within the experimental site. The materials used were assembled from three sources – 3mm plastic was used for the splash collectors; galvanized iron (for soil tray), 2.5cm flat iron (to sit the collectors) and 7.6cm angle rod (to fix the trays in place at the required angles); and hard wood for the tables on which the soil trays were placed. Further information on the set-up of this equipment can be found in Van Dijk *et al*., (2003).

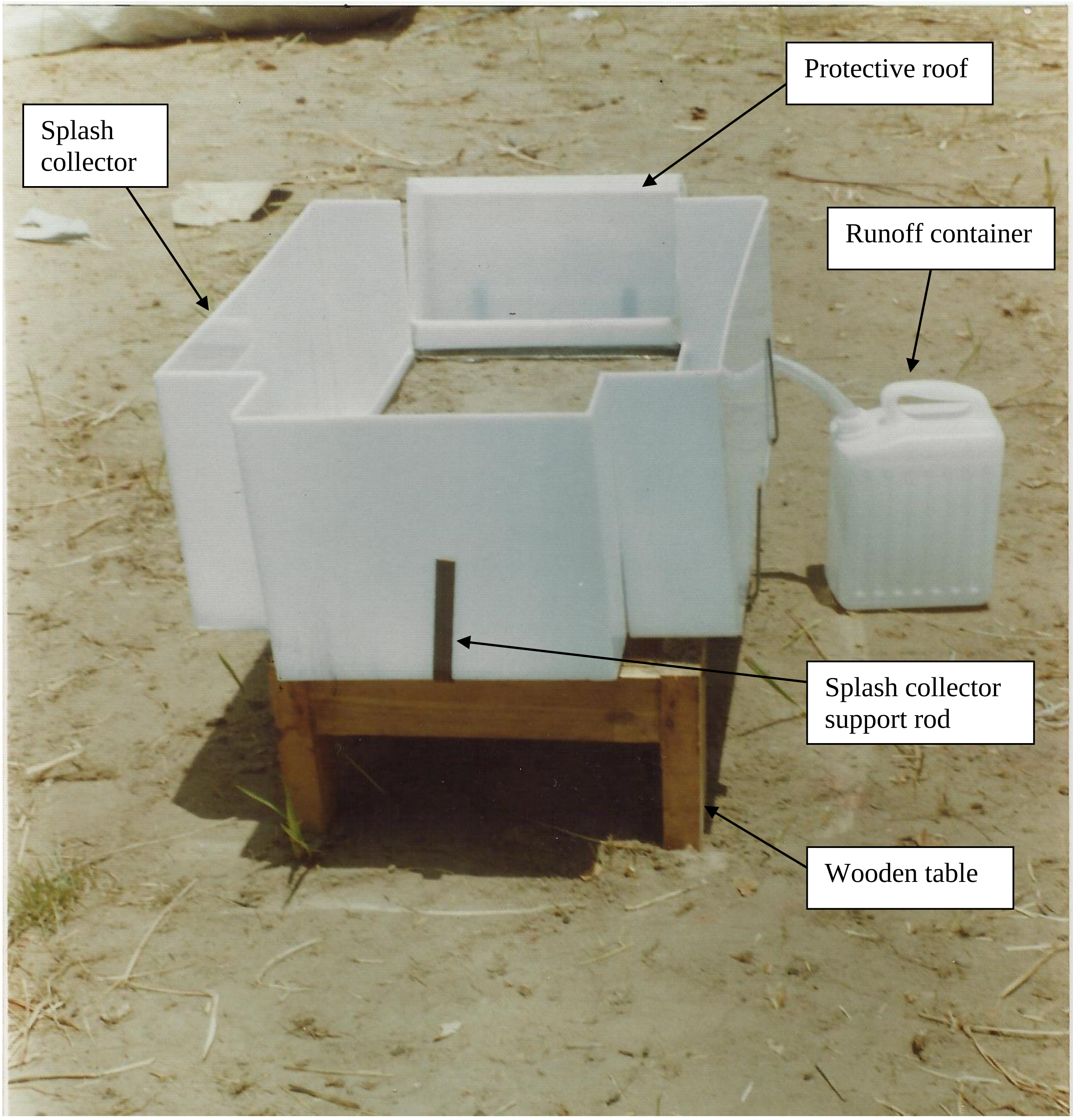


**Plate** 3.1. Complete set of tray with splash collectors attached

Source: Field work 2007

### 3.2.2 Rainfall

Rainfall was measured during the research with self recording rain gauge. The rain gauge, (Plate. 3.2), consisted of a calibrated Meter that recorded rainfall amount in millimeters and a rectangular rain gauge for collecting rain water. It has an open hole at the bottom that allowed falling rainwater into the gauge to drain out freely, while, at the same time, turning the knob that transmitted the amount of rain through a wire to the meter housed in the Stevenson Screen. The Meter had two sets of measurements. One set recorded individual rainfall event while the second one added up the figures to cumulatively record the annual total rainfall. The gauge was placed on a stand, fixed to the soil 40cm above the ground, to avoid the effect of splashing. The Meter readings were self displayed for 12 hours and then they disappear. Subsequent rainfall start recording at 0mm. However, the former records were stored in the Meter so that subsequent amount of rainfall was only cumulatively added to the previous figures.

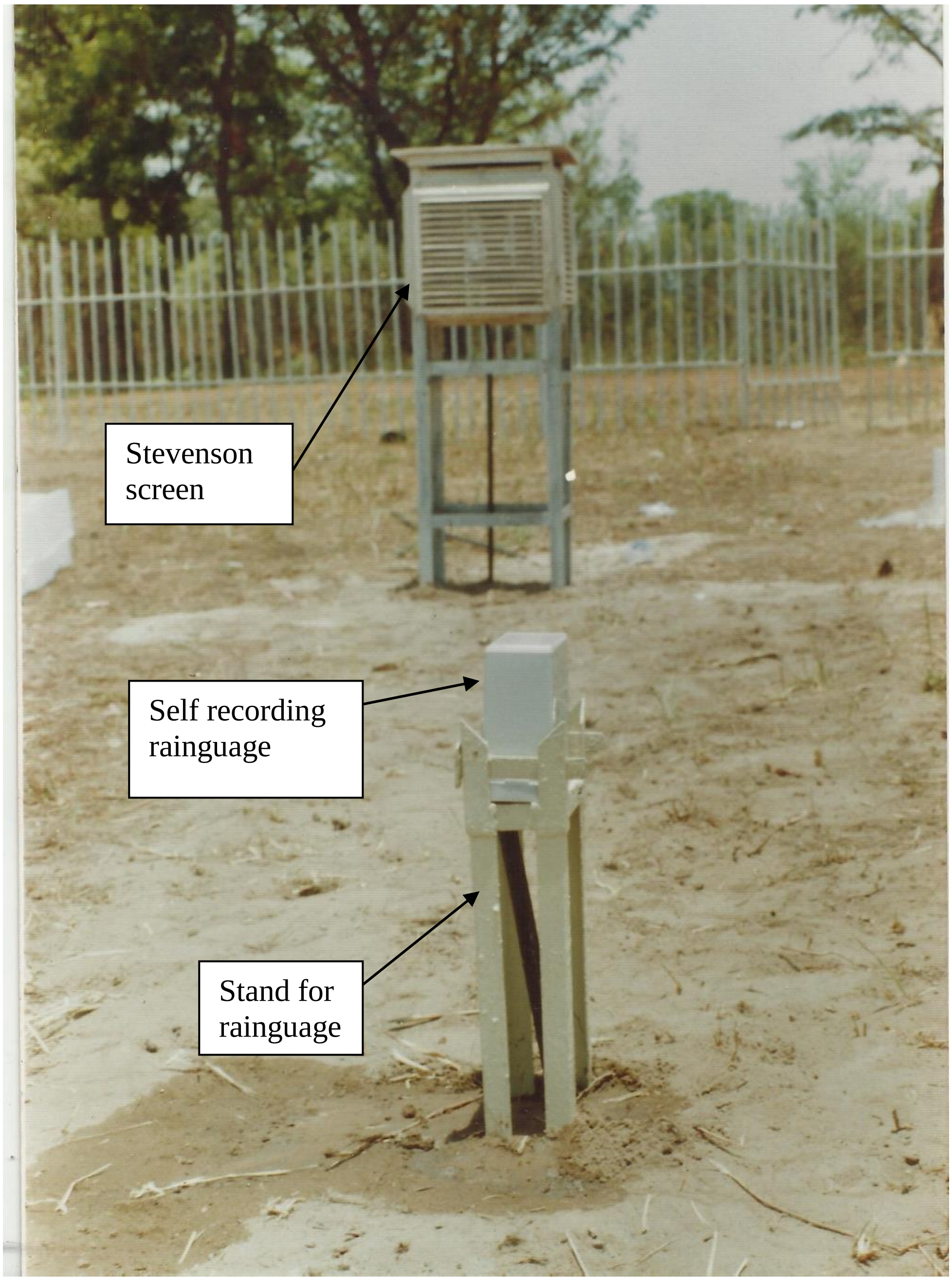


**Plate** 3.2 Stevenson screen and self recording rainguage

Source: Field work 2007

## 3.3 Experimental procedure for data collection

Twenty soil trays, each with four splash collectors (2 laterals and 1 each for downslope and upslope) were used in this study to evaluate the effect of slope and mulch on components of splash (Plate 3.3). A 4cm thick layer of coarse (8-30cm) sized gravel was placed at the bottom of each soil tray to facilitate drainage through holes at the downslope end of the tray (Plate 3. 4). A wetted piece of cloth was placed on the gravel (Plate 3. 5) and the tray was filled with soil to the apron and up to 2-3mm below the rims of the splash collectors (Plate 3. 6). The experiments were set up in March 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 the experiment. Some quantity of soil material was added in June and September to re-establish the original level. The addition of soil is consistent with the weeding and/or hoeing of agricultural land/crops in this area.

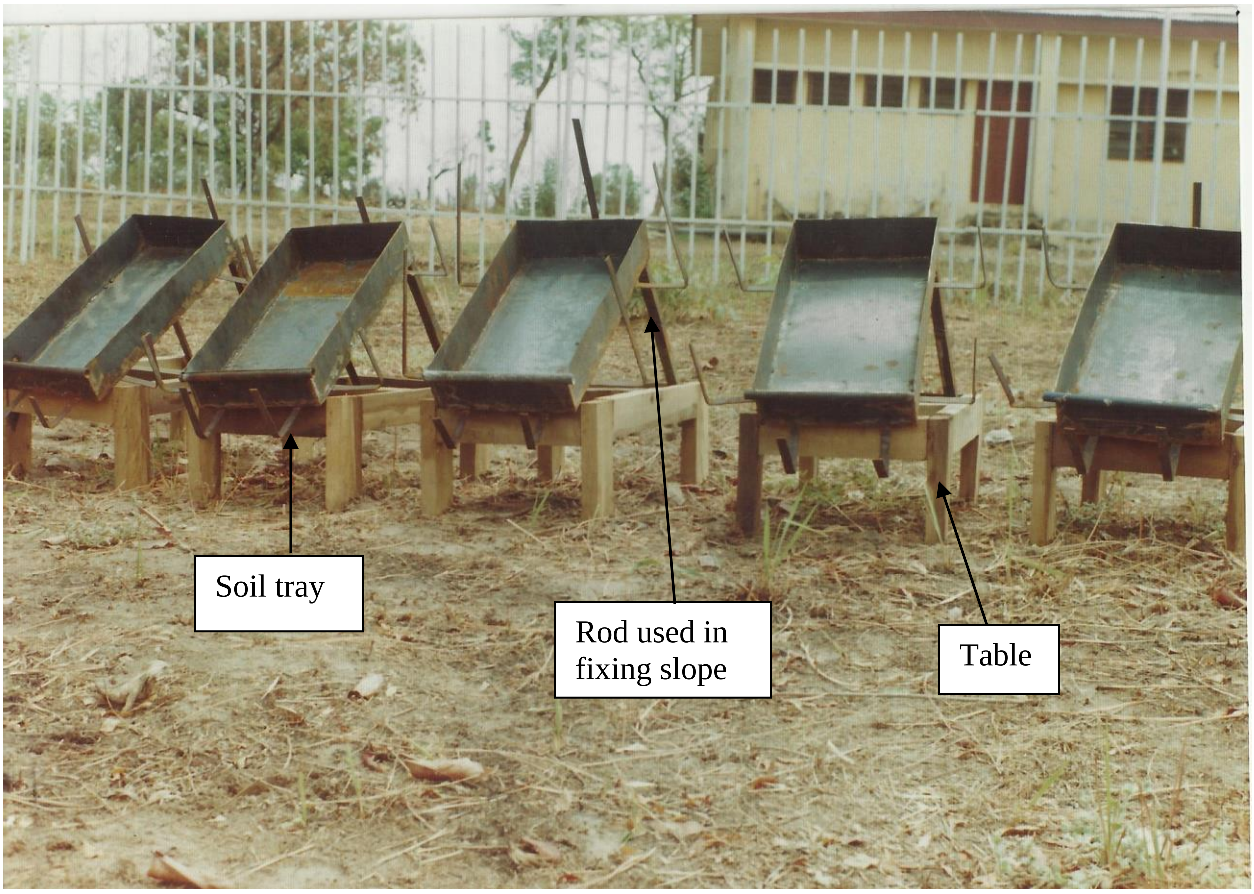


**Plate** 3.3. Empty trays on tables

Source: Field work 2007

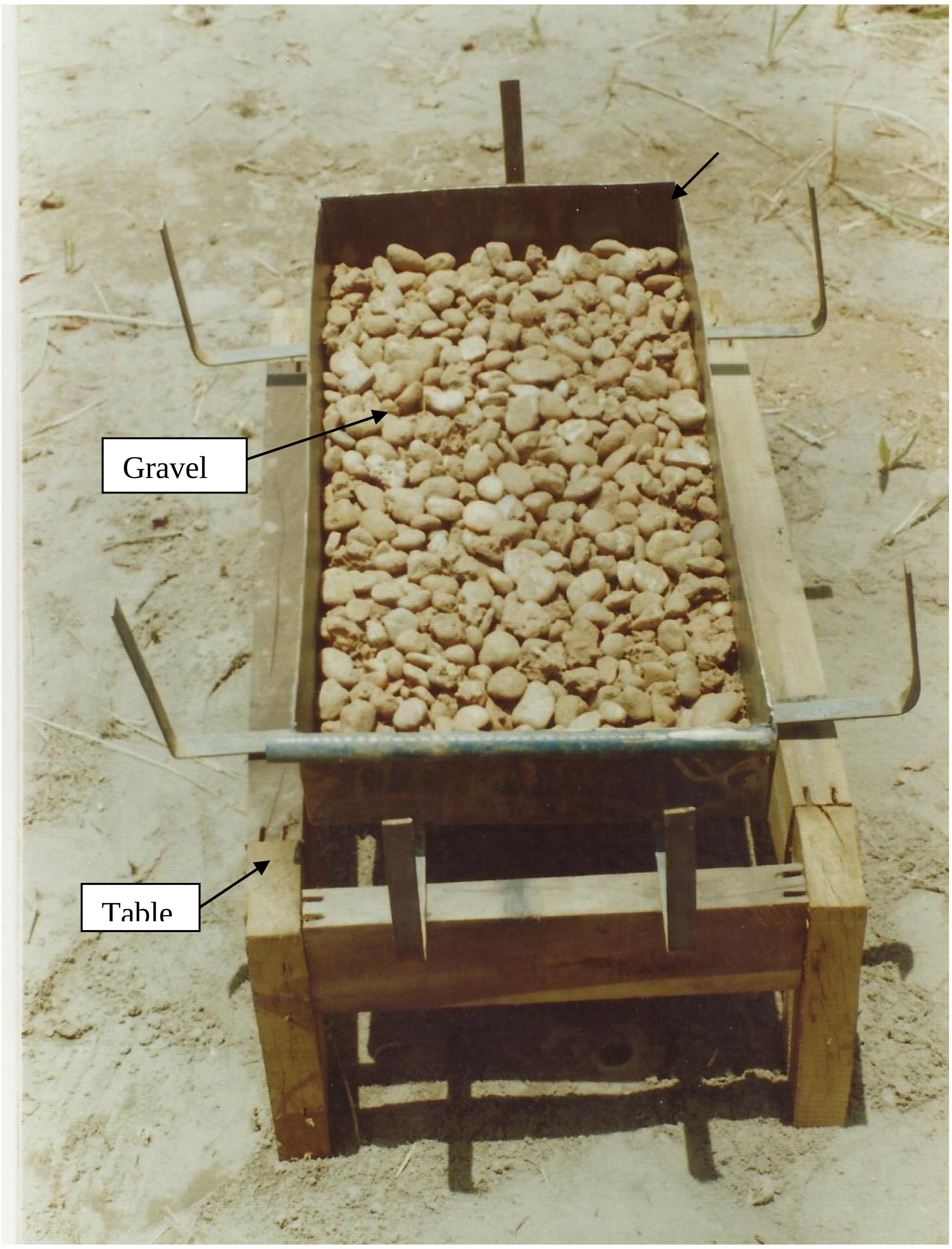


**Plate** 3.4. Soil tray with gravel inside
Source: Field work 2007

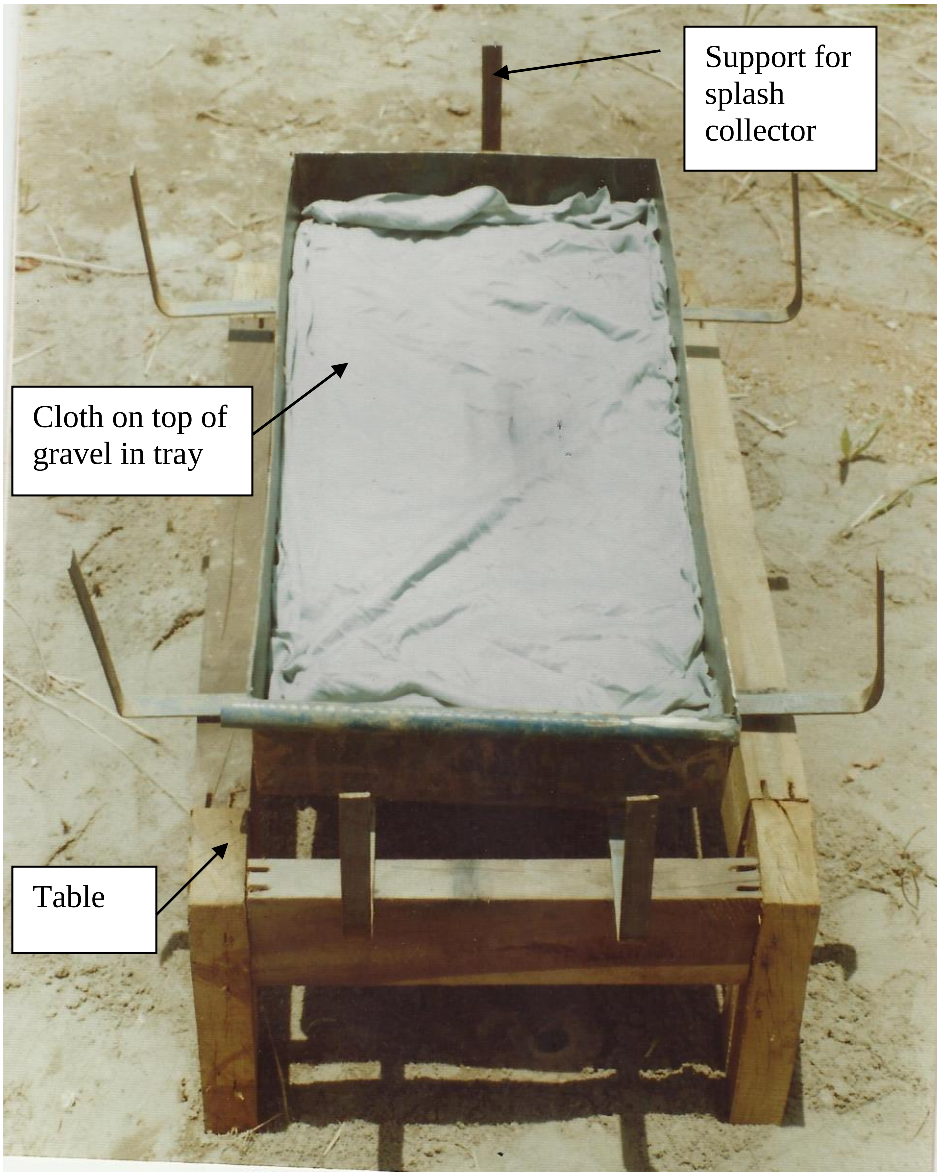


**Plate** 3.5. Cloth placed on top of gravel in the tray
Source: Field work 2007

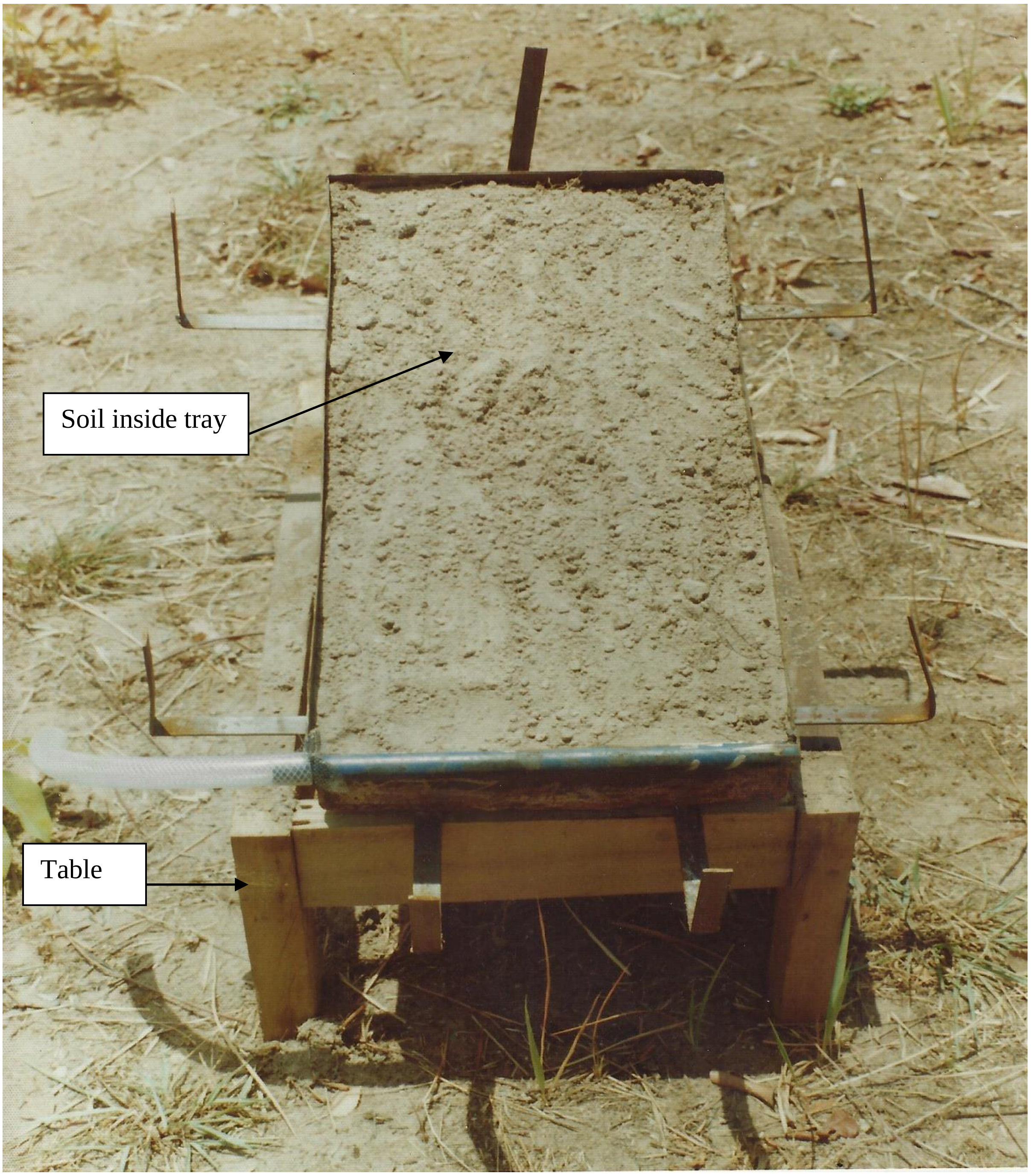


**Plate** 3.6. Soil tray filled with soil
Source: Field work 2007

Throughout the period of the data collection, the trays were left at the same spot and facing the same direction, but varied slopes (Plate 3. ($5^0$, $15^0$, $25^0$, and $35^0$ , angles representing cropped land and consistent in the spacing interval of 10 degrees) were used instead of Wan *et al's*., (1996) $0^o$, $5^o$, $15^o$, and $40^o$ and Van Dijk *et al's*, (2003) and $4^o$, $9^o$, $18^o$, $27^o$, and $36^o$ , respectively. 5 trays were placed at each of these slopes with one each serving as control, that is, without mulch cover. The remaining four at each of the angles were mulched with groundnut, soyabean, rice and grass residues, which were readily available in the area after the harvest of the crops (Plate 3.7).

Data collection spanned over a period of 7 months, commencing on April 7 and terminating on October 27, 2007. The 7 months period compared favourably with Eze's (1996) 8 months, from March to October 1993.

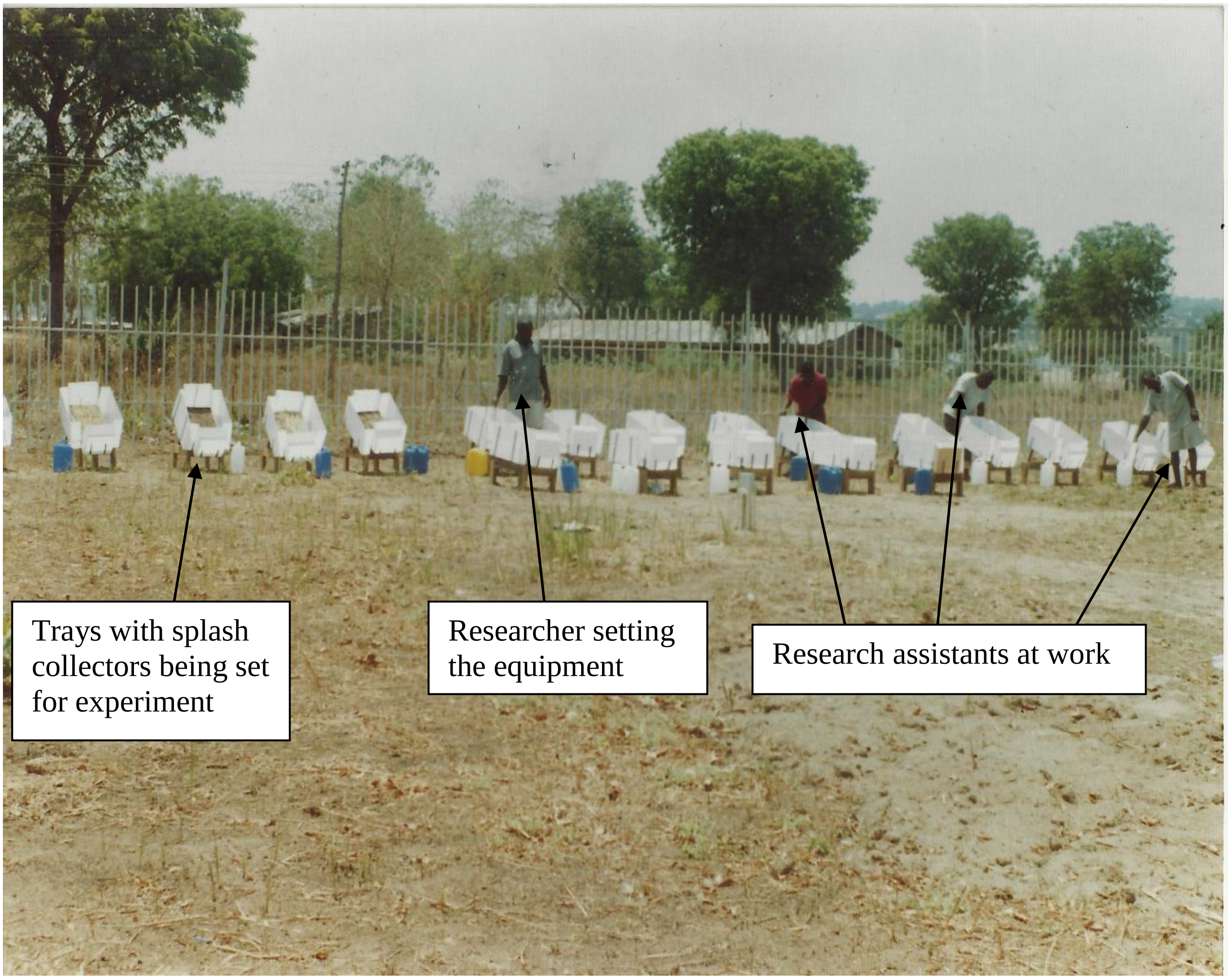


**Plate** 3.7. Final setting of the equipment for experiment

Source: Field work 2007

The soils used in the experiment were analyzed for the parameters shown in section 2.3, namely particle sizes, bulk and particle density, porosity, permeability, and organic matter. Only the first 10cm layer of the topmost soil was considered for sampling and analyses, being the layer that is mostly affected by splash action (Morgan 1978). In this study, soil condition was held constant. However, the splashed soil was further analysed to compare it with the original soil used in the experiment.

### 3.3.1 Data on rainfall characteristics

In addition to the data on splashed soil, data were also collected for this study on rainfall parameters of total amount, intensity and kinetic energy. Data could not be collected on the other rainfall parameters of $EL_{30}$, $A_{15}$ Peak intensity, kinetic energy (KE)> 25, amount and intensity product ($AI_m$) and antecedent precipitation index (API) because of the unavailability of the equipment to extract the information.

Rainfall amount was collected by the researcher at the Agro-Meteorological Station of Geography Department using the self-recording rainguage and ordinary raingauge. Total intensity was calculated directly from the amount, while the total kinetic energy was computed using Hudson's (1965) equation as follows:

$$K.E. = 29.8 - \frac{127.5}{I}$$

A rainstorm in this study was empirically defined as any rainfall that was capable of producing splash on the downslope splash collector at all the slope angles, on the control (without mulch cover) trays. The least volume of rainfall that produced splash at the downslope sections of the control was 4.6mm, recorded on the 1$^{st}$ August 2007. 70 rainstorms were measured during the experimental year, 59 of which produced over 98 percent of the total amount and 84 percent of the number of storms that caused splash erosion.

## 3.4. Data collection

Data were collected on four parameters, namely, splashed soil, soil properties, rainfall and mulch characteristics.

### 3.4.1 Splash detachment data

The soil tray described in detail in section 3.2 was the main equipment used in this study for the collection of splashed soil particles. A single soil tray had four detachable splash collectors attached to it, to sample upslope, downslope and lateral splashed sediments. A total of 20 soil trays, 4 used as control, and 4 each mulched with groundnut, rice, grass, and soyabeans at each of the four angles were used in this study. After every rainfall event that produced splash, measurements were taken for each soil tray. Each soil tray had maximum of three measurements, upslope, downslope and the two lateral sides combined to produce one measurement.

The splashed sediment were transferred after each storm event that produced splash from the splash collectors into stainless plates of $14cm^3$, taken to the laboratory, and oven dried at a temperature of $105^oC$ for 24hours in a mechanical oven and allowed to cool to attract air moisture before measurement. The weight of the oven dried splashed soil material was measured in grammes at the upslope, downslope and lateral sides for each rainstorm event with a digital weighing machine.

The monthly and annual gross totals at the varied angles and mulch treatments were converted directly to the surface area of $0.18m^2$ enclosed by the soil tray and divided by 1000 to convert to kilograms per metre square. The process involved two steps – g/1000 = kg; and kg/area = $kg/m^2$

Where

g = grams

kg = kilograms.

### 3.4.2 Soil properties

Data were also collected on the soil properties enumerated in section 3.2 using standard analytical procedures. The analysis was limited to the soil sampled from the first 10cm layer, a layer most prone to splash erosion.

Particle size distribution analysis was done using the hydrometer method (Buoyoucos, 1951), which is generally considered to be fast and accurate (Brady and Weil 2002). This method is based on continuous reduction of the density of the soil suspension with time at the rate the particles drop below the level of the hydrometer.

Bulk density and total porosity was determined for the top layer only. Bulk density and total porosity were determined using the method as outlined in Eze (1996), as follows:

$$Bd = \frac{M}{V}$$

Where

Bd- is the bulk density

M- Mass of oven dried soil in gram (g)

V- Volume of the soil in cubic meter (Cm3)

Total porosity (T) was calculated from dry density (Db) and particle density (Dp) as follows:

$$T = \frac{1-Db}{Dp} \times 100$$

The soil pH was determined with a pH meter (Grass electrode), the most accurate method of determining soil pH (Brady, 2000). This method can be used in the laboratory but can also be used reliably in the field. Data on soil organic matter were collected by first determining the soil organic carbon using the Walkey-Black wet oxidation method. The organic content was then calculated by multiplying the uncorrected value of organic carbon by a constant factor of 1.724 (Eze, 1996). The water-stable aggregate (W.S.A.) was determined by the wet sieving method.

### 3.4.3 Mulch cover characteristics

It was necessary to obtain information on mulch characteristics. Data were therefore collected on two aspects of mulch, the type of mulch material and the degree of mulch cover. The degree of mulch cover was determined by weighing the mulch material used to cover a soil tray with an area of $0.18m^2$. Crop residues of rice, groundnut soyabean and grass were used in the experiment. The selected residues were of the same quantity by weights. They were selected because they are easily available locally and so were collected after the crops had been harvested, during the dry season. Sixteen (16) soil trays were used to test the effects of mulch cover at four different slopes and four different types of mulch materials.

In addition, data were collected on mulch through interview. A total of 25 people, made up of mainly yam, vegetable and tobacco farmers were randomly selected and interviewed in and around Makurdi town and around the banks of River Benue within the town on the importance of mulching. The 25 people interviewed were made up of 15( 60%) yam farmers, 10 (40%) other farming activities that require mulching (vegetable and tobacco). They were interviewed on the benefits and/or effects of mulching on farming, the types of mulches used, the crops mostly mulched and the time and levels of mulching and the difficulties involved in mulching, among others.

### 3.4.4 Erosivity

Finally, the erosivity parameters of intensity and kinetic energy were computed using Hudson's Equation thus:

$$K.E. = 29.8 - \frac{127.5}{I}$$

Where KE is kinetic energy, I is intensity.

The cumulative total of rainfall was used directly to calculate the total intensity and total kinetic energy using Hudson's equation. This was because of the logistic problem arising from the absence of a recording chart in the self recording rainguage used.

## 3.5 Data analysis

The analysis of the data collected involved descriptive statistics such as mean, standard deviation, range, tables, graphs and percentages to examine the pattern shown by quantity of sediments splashed under varied rainfall parameters, slope angles, cover types and levels, and over time. From these statistics, relevant comparisons and summary of information needed for more advanced statistical testing were made.

The inferential statistics of multivariate analysis (multiple correlations and multiple regressions) on the other hand were used to throw light on the nature and strength of the interrelationships between dependent and independent variables studied and the extent of variations in variables between different treatments. To ascertain the statistical significance of the variations that existed over time, space and residues used, the Analysis of Variance (ANOVA) statistics and t-test were used.

## CHAPTER FOUR

## SPLASH DETACHMENT (VARIATIONS) UNDER DIFFERENT MULCH TREATMENT AND SLOPES

### 4.1 Introduction

This chapter examines rainsplash detachment at the various components of the slopes and mulch treatment. The slopes studied were $5^0$, $15^0$, $25^0$, and $35^0$ , at which data were obtained for downslope (DS), upslope (US), lateral (LS) and total (TOT) splash for varied types of mulch cover and time.

### 4.2 Spatial and temporal variations of splash

The focus of this study is to compare splash detachability on bare surfaces with those on mulched surfaces and to examine splash at the four slopes studied in terms of splashed material at the upslope, downslope, lateral and total dimensions. Splash erosion generally is a space and time dependent process, a conclusion drawn by Govers, (1991) and Eze, (1996), and so the process was examined over space, here represented by the varied slope angles ($5^0$, $15^0$, $25^0$, and $35^0$), and the components (upslope, downslope and lateral). Splash was also examined over time (during the 59 storms that recorded splash). These are in contradiction to the studies by Osuji and Sangodoyin (1989) which looked at variations in splashed material over one soil type and those of Morgan (1978, 1979, and 1982) which examined variations over one vegetation cover. Eze (1996) studied variations in both soil type and vegetation cover, while the present study examined spatial variations in components of splash at different slope angles, (similar to studies of Wan *et al*. (1996) and Van Dijk *et al*. (2003) as well as the effect of mulch cover on soil splash at varied slopes. This chapter examines whether there were any significant variations in splash over time and space; the nature of the variations as it relates to downslope, and upslope, and how these variations affect total splash; the effect of mulch cover on splash as well as the nature of the relationship between splash and soil particle size distribution.

### 4.2.1 Spatial variation of splash.

The data on quantities of soil splashed at the varied components of the splash collectors after each of the 59 storm events in grams/storm at different slope angles, and mulch covers are summarized and shown on tables 4.1 and 4.2. Slope by slope examination of the result showed that there was more splash upslope than downslope at the 5 degree slope. Table 4.1 reveals that 29.5, 2.4, 3.7, 3.7 and 2.1 grams of soil splashed from control, groundnut, rice, grass and soyabean mulch respectively, at downslope component as against the 41.2, 6.1, 3.4, 8.4, and 9.4 grams that splashed upslope from the corresponding mulch treatments on the 7$^{th}$ of April 2007. Similarly, on the 1$^{st}$ of June 2007, the data showed that upslope splash was 104.2, 25.8, 16.6, 28.8 and 19.5 grams of splashed material as against the corresponding figures of 66.5, 7.8, 7.9, 8.2 and 4.6 grams at control, groundnut, rice, grass and soyabean mulched trays respectively. There were few instances (for example, on the 29$^{th}$ April 2007, when more splash was recorded at downslope than upslope at the control and rice mulched trays) where the downslope splash was more than the upslope at 5 degree (Table 4.1). The general trend, however, was that of more splashes being moved upslope than downslope at the 5 degree angle.

**Table** 4.1. Splash in grammes at 5 degree slope over varied mulch treatments, dates and rainfall amount.

| Date | Rainfall amount(MM) | Slope component | Mulch cover | | | | |
|---|---|---|---|---|---|---|---|
| | | | Control | Groundnut | Rice | Grass | Soyabeans |
| | | DS | 29.5 | 2.4 | 3.7 | 3.7 | 2.1 |
| 7/04/07 | 23.3 | US | 41.2 | 6.1 | 3.4 | 8.4 | 9.4 |
| | | DS | 10.9 | 1.5 | 2.6 | 2.3 | 1.4 |
| 22/04/07 | 20.7 | US | 35.4 | 5.9 | 2.3 | 6.7 | 8.5 |
| | | DS | 53.7 | 41.0 | 20.5 | 36.3 | 41.9 |
| 27/04/07 | 113.0 | US | 157.9 | 68.8 | 52.5 | 75.8 | 37.6 |
| | | DS | 6.1 | 1.7 | 2.3 | 1.0 | 0.8 |
| 29/04/07 | 8.8 | US | 5.5 | 2.0 | 1.7 | 2.7 | 1.1 |
| | | DS | 47.2 | 10.1 | 9.0 | 3.4 | 4.0 |
| 01/05/07 | 38.4 | US | 82.1 | 22.7 | 15.5 | 22.2 | 7.2 |
| | | DS | 4.8 | 1.2 | 1.2 | 1.1 | 1.1 |
| 11/05/07 | 8.2 | US | 5.3 | 1.9 | 1.2 | 1.8 | 1.0 |
| | | DS | 17.8 | 1.1 | 2.8 | 1.8 | 12.9 |
| 22/05/07 | 10.8 | US | 35.1 | 2.1 | 4.5 | 7.7 | 5.6 |
| | | DS | 66.5 | 7.8 | 7.9 | 8.2 | 4.6 |
| 01/06/07 | 49.2 | US | 104.2 | 25.8 | 16.6 | 28.8 | 19.5 |
| | | DS | 49.1 | 9.2 | 3.6 | 5.1 | 2.5 |
| 10/06/07 | 51.3 | US | 63.3 | 26.7 | 13.2 | 16.4 | 8.8 |
| | | DS | 30.2 | 3.2 | 2.0 | 4.4 | 4.4 |
| 13/07/07 | 15.5 | US | 36.0 | 4.8 | 2.0 | 5.2 | 5.8 |
| | | DS | 44.2 | 10.9 | 22.9 | 17.3 | 6.9 |
| 16/08/07 | 41.6 | US | 49.9 | 13.0 | 26.7 | 19.6 | 12.9 |
| | | DS | 22.6 | 7.9 | 3.5 | 8.1 | 3.1 |
| 04/09/07 | 20.2 | US | 14.2 | 4.9 | 4.0 | 4.6 | 4.9 |
| | | DS | 18.8 | 5.4 | 3.5 | 5.4 | 3.9 |
| 08/09/07 | 27.9 | US | 13.1 | 10.1 | 3.8 | 10.0 | 6.0 |
| | | DS | 4.4 | 1.0 | 0.8 | 1.3 | 0.3 |
| 02/10/07 | 13.5 | US | 6.5 | 1.3 | 1.7 | 0.9 | 1.2 |
| | | DS | 13.4 | 5.7 | 5.8 | 11.3 | 4.8 |
| 20/10/07 | 70.5 | US | 20.8 | 22.5 | 12.2 | 12.2 | 11.0 |

**Source.**Field Work 2007

At steeper slopes (15, 25, and 35 degrees), the result showed that more splash was recorded at the downslope than upslope. For example, on the 8th of May 2007, (Table 4.2) splashes from trays without mulch (in grams) were 34.7 (DS) and 21.4 (US), at 15 degrees; 50.8 (DS) and 12.8 (US) at 25 degrees and 60.8 (DS) and 4.7 (US) at 35 degrees slopes, while the tray with grass mulch recorded 9.5 (DS) and 3.0 (US) at 15 degrees, 13.8 (DS) and 3.3 (US) at 25 degrees and 15.2 (DS) and 2.2 (US) at 35 degrees (Table 4.2). Generally, there was increase in downslope splash rate with increase in slope gradient, while the upslope splash rate decreased with slope gradient. This result supports the observations of Ghadiri and Payne (1988), Wan *et al*. (1996) and Van Dijk *et al*. (2003) on splash droplet distribution as affected by slope.

**Table** 4.2. Splash in grammes at 5, 15, 25 and 35 slopes over control treatment over varied components, total intensity and kinetic energy.

| Date 2007 | Rainfall amount(mm) | Total intensity | Total kenetic energy | Slope component | Slope angles 5 | 15 | 25 | 35 |
|---|---|---|---|---|---|---|---|---|
| | | | | DS | 29.5 | 35.1 | 53.4 | 58.3 |
| | | | | US | 41.2 | 25.8 | 17.2 | 7.3 |
| 07/04 | 23.3 | 19.97 | 23.42 | LS | 103.6 | 102.2 | 114.9 | 85.7 |
| | | | | T | 174.3 | 163.1 | 185.5 | 151.3 |
| | | | | DS | 10.9 | 22.1 | 38.0 | 56.6 |
| | | | | US | 35.4 | 24.9 | 15.3 | 9.8 |
| 22/04 | 20.7 | 8.45 | 14.72 | LS | 78.0 | 86.6 | 93.2 | 88.2 |
| | | | | T | 124.3 | 133.6 | 146.5 | 154.6 |
| | | | | DS | 6.1 | 10.4 | 14.6 | 12.8 |
| | | | | US | 5.5 | 4.0 | 1.4 | 0.3 |
| 29/04 | 8.8 | 1.76 | 00 | LS | 21.1 | 24.8 | 22.5 | 22.1 |
| | | | | T | 32.7 | 39.2 | 38.5 | 35.2 |
| | | | | DS | 28.3 | 34.7 | 50.8 | 60.8 |
| | | | | US | 23.8 | 21.4 | 12.8 | 4.7 |
| 08/05 | 25.5 | 7.29 | 12.31 | LS | 96.2 | 88.9 | 89.7 | 81.8 |
| | | | | T | 148.3 | 145.0 | 162.3 | 147.3 |
| | | | | DS | 4.8 | 6.5 | 10.5 | 8.2 |
| | | | | US | 5.3 | 5.0 | 4.9 | 1.2 |
| 11/05 | 8.2 | 5.47 | 6.49 | LS | 49.0 | 37.8 | 45.0 | 29.6 |
| | | | | T | 59.1 | 49.3 | 60.4 | 39.0 |
| | | | | DS | 17.8 | 40.1 | 47.1 | 68.9 |
| | | | | US | 35.1 | 45.4 | 33.1 | 23.4 |
| 22/05 | 10.8 | 21.60 | 23.90 | LS | 85.0 | 90.8 | 90.5 | 83.8 |
| | | | | T | 137.9 | 152.3 | 150.9 | 136.5 |
| | | | | DS | 89.6 | 134.5 | 184.2 | 184.4 |
| | | | | US | 89.4 | 14.3 | 96.7 | 23.1 |
| 03/06 | 45.1 | 11.28 | 18.50 | LS | 399.9 | 455.4 | 395.6 | 274.8 |
| | | | | T | 578.9 | 604.2 | 482.3 | 225.5 |
| | | | | DS | 49.1 | 79.8 | 113.4 | 159.5 |
| | | | | US | 63.3 | 68.1 | 9.1 | 24.3 |
| 10/06 | 51.3 | 25.65 | 24.83 | LS | 160.5 | 228.2 | 223.6 | 203.7 |
| | | | | T | 273.2 | 376.1 | 246.6 | 387.5 |
| | | | | DS | 30.2 | 34.3 | 58.3 | 65.5 |
| | | | | US | 36.0 | 21.9 | 9.1 | 4.3 |
| 13/07 | 15.5 | 6.41 | 9.91 | LS | 94.1 | 89.4 | 92.6 | 77.0 |
| | | | | T | 160.3 | 145.6 | 160.0 | 146.8 |
| | | | | DS | 44.2 | 59.6 | 76.8 | 100.3 |
| | | | | US | 49.9 | 40.5 | 23.7 | 14.9 |
| 16/08 | 41.6 | 33.28 | 25.97 | LS | 114.0 | 137.0 | 127.7 | 124.6 |
| | | | | T | 208.1 | 232.1 | 228.2 | 239.8 |
| | | | | DS | 22.6 | 40.2 | 52.7 | 45.6 |
| | | | | US | 14.2 | 14.4 | 4.4 | 0.0 |
| 04/09 | 20.2 | 14.90 | 20.75 | LS | 68.5 | 71.9 | 61.9 | 38.3 |
| | | | | T | 105.3 | 126.5 | 119.0 | 83.9 |
| | | | | DS | 13.4 | 116.3 | 177.0 | 169.7 |
| | | | | US | 20.8 | 46.9 | 24.1 | 12.2 |
| 20/10 | 70.5 | 18.80 | 23.02 | LS | 121.4 | 263.6 | 229.5 | 218.8 |
| | | | | T | 155.6 | 426.8 | 430.6 | 400.7 |

Source. Field Work 2007

The lateral splash rate, a measure of sediment redistribution, and total splash (combining downslope, lateral and upslope splash) also increased with slope angles though not very significantly, and only up to a peak at $15^0$ , and then decreased marginally. Table 4.2 showed that on over 90 percent of the rainfall events at the control (trays without mulch), lateral and total splash increased with slope up to $15^0$ and then decreased. For example, on 22nd May 2007, lateral and total splash for the control treatment were 85.0 and 137.9 grams at 5 degrees; 90.8 and 152.3 grams at 15 degrees; 90.5 and 150.9 grams at 25 degrees and 83.8 and 136.5 grams at 35 degrees. Also on 29th April 2007, lateral and total splash increased marginally from 21.1 at 5 degrees to 24.8 grams at 15 degrees and then decreased to 22.5 at 25 degrees and 22.1 at 35 degrees for the lateral splash. The figures for the total on the same date showed 32.7 grams at 5 degrees, 39.2 grams at 15 degrees, 38.5 grams at 25 degrees and 35.2 grams at 35 degrees. The pattern described above was very conspicuous at trays without mulch cover. The mulched surfaces did not show such variations. These conclusions are shown on Fig. 4.1 for the control treatment. The sequence of splash rates as observed for the $5^0$ slope was that upslope splash was generally greater than downslope. However, Summerfield (1991) reported that on a low slope of $5^0$, about 60 percent of particles dislodged by raindrop impact moved downslope; this increased to 95 percent on $25^0$ slopes. According to Pidwirny (1999) at slope of $25^0$ and greater, almost all the splashed sediments moved in a downslope direction. Ellison (1947) had earlier on showed that 75% of soil splashed on a $10^0$ slope moved downslope while 25% moved upslope.

The result of the current study is graphically depicted on Fig. 4.1 for the control treatment. The figure shows that at 5 degrees, upslope mean splash was marginally more than downslope whereas the position was reversed at 15 degrees where downslope splash was more than upslope splash, but again marginally. The difference between downslope and upslope splash became marked at 25 and 35 degrees where 66% and 75% respectively of splash were moved downslope. The figure also shows that at 25 and 35 degrees, the downslope splash was more than half the lateral splashes at these slopes.

The data in Appendix 4 was summarized using descriptive statistics. The result presented in Table 4.3, reveals that whereas the mean splash at the downslope of the control was 40 grams that at the upslope was 20 grams, implying that more materials moved downslope. The downslope section also recorded a maximum of 285 grams of sediments as against the 174 grams recorded at the upslope. Table 4.3 further reveals that the difference between the minimum and maximum splashed sediment at both downslope and upslope was significant at the 0.05 level. The reason for the significance of the difference between the minimum and maximum splashed materials was the wide variations in the amount of rainfall recorded during the data collection period. The factor of the rainfall as it controlled quantity splashed also explained the wide dispersion as shown in Table 4.3.

**Table** 4.3. Means and standard deviations of splash over different mulch cover

| Type of mulch and slope | Min | Max. | Mean | Standard Deviation | Significance |
|---|---|---|---|---|---|
| Control without mulch (DS) | 40 | 285.2 | 40.018 | 47.0968 | .000 |
| Control without mulch (US) | 00 | 174.7 | 20.414 | 27.5993 | .003 |
| Control without mulch (LS) | 4.8 | 825.9 | 97.3403 | 106.7654 | .473 |
| Control without mulch (T) | 7.3 | 1136.2 | 163.7331 | 168.9506 | .589 |
| Groundnut Mulch (DS) | 00 | 89.0 | 9.6195 | 14.2590 | .000 |
| Groundnut Mulch (US) | 00 | 68.8 | 5.6581 | 9.0660 | .005 |
| Groundnut Mulch (LS) | 00 | 160.1 | 22.6962 | 28.4815 | .163 |
| Groundnut Mulch (T) | 00 | 298.7 | 37.9280 | 49.0323 | .159 |
| Rice mulch (DS) | 00 | 72.7 | 8.6275 | 12.2676 | .000 |
| Rice mulch (US) | 00 | 57.5 | 5.0801 | 7.9932 | .003 |
| Rice mulch (LS) | 00 | 125.8 | 20.6699 | 25.5512 | 822 |
| Rice mulch (T) | 00 | 218.5 | 34.2818 | 42.9481 | .631 |
| Grass Mulch (DS) | 00 | 90.2 | 9.3805 | 13.7980 | .000 |
| Grass Mulch (US) | 00 | 75.8 | 5.6314 | 9.3346 | .000 |
| Grass Mulch (LS) | 00 | 134.4 | 20.4678 | 24.7760 | .893 |
| Grass Mulch (T) | 00 | 260.4 | 35.5665 | 44.8652 | .567 |
| Soyabean Mulch (DS) | 00 | 65.5 | 7.3720 | 11.1175 | .012 |
| Soyabean Mulch (US) | 00 | 54.6 | 4.3148 | 7.0144 | .376 |
| Soyabean Mulch (LS) | 00 | 141.2 | 17.186 | 21.6455 | .276 |
| Soyabean Mulch (T) | 00 | 234.5 | 28.35 | 37.8969 | .394 |

Source. Field work, 2007

There were, similarly, consistent wide variations between quantity of materials splashed over the control and those over the mulched surfaces as reflected on the means shown on the table. But the mulched surfaces produced near uniform quantities at downslope and upslope of 9.6 and 5.6 grams for groundnut; 8.6 and 5 grams for rice; 9 and 6 grams for grass and 7 and 4 grams for soyabeans mulch respectively (Fig. 4.1).  Table 4.4, shows that more splashes were recorded in the upslope direction in April, May, June, September and October for the control treatment.

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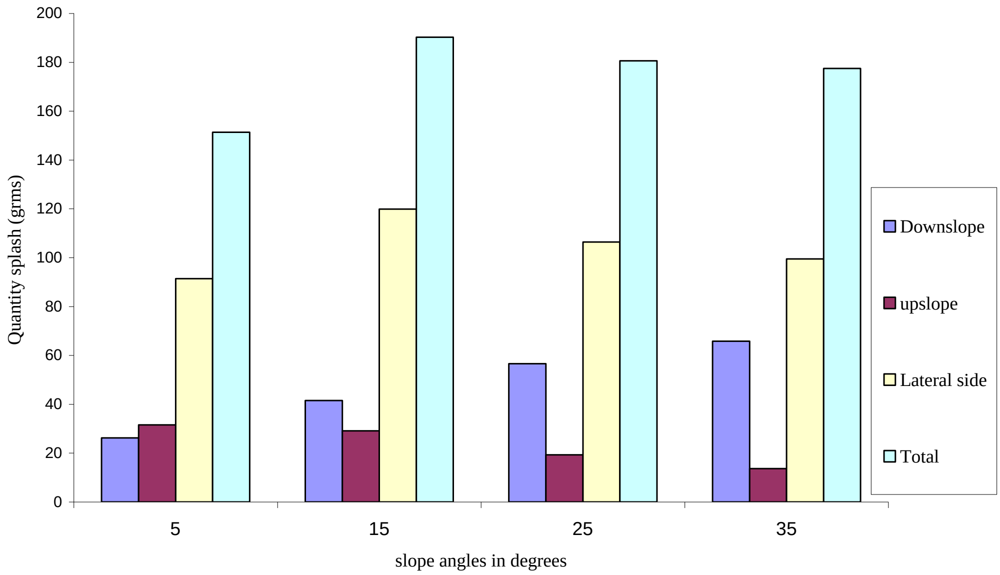


**Fig.** 4.1: Mean annual components of splash at downslope, upslope, lateral side and total at control at varied angles.

Source. Field work 2007

**Table** 4.4 No of storms per month and mean monthly splash in grams at the control tray at 5 $^{o}$ and 15$^{o}$ slopes

| months | | | Components of splash at 25 $^{o}$ | | | | Components of splash at 15$^{o}$ | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| April | No. of storms | Total rainfall | Downslope | Upslope | Lateral side | Total | Downslope | Upslope | Lateral side | Total |
| May | 5 | 186.5 | 34.64 | 59.78 | 128.86 | 238.68 | 52.88 | 47.64 | 241.90 | 342.42 |
| June | 7 | 154.5 | 25.13 | 42.40 | 101.01 | 168.54 | 41.74 | 37.08 | 109.41 | 188.23 |
| July | 8 | 224.6 | 40.06 | 50.84 | 164.93 | 255.85 | 56.50 | 53.69 | 175.14 | 285.36 |
| August | 8 | 94.4 | 24.86 | 14.47 | 65.31 | 104.66 | 28.67 | 9.10 | 56.90 | 95.07 |
| September | 10 | 282.7 | 30.68 | 20.72 | 75.77 | 127.17 | 51.37 | 18.44 | 78.00 | 145.50 |
| October | 11 | 303.0 | 24.66 | 25.46 | 77.98 | 128.19 | 37.32 | 23.52 | 95.27 | 155.90 |
| October | 10 | 224.2 | 3.26 | 7.03 | 26.12 | 36.43 | 22.27 | 14.29 | 82.65 | 119.21 |

**Source**: Field work, 2007

**Table** 4.5. No of storms per month and mean monthly splash in grams at the control tray at 25 $^{o}$ and 35 $^{o}$ slopes

| | | | Components of splash at 25 $^{o}$ | | | | Components of splash at 35 $^{o}$ | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Months | No. of storms | Total rainfall | Downslope | Upslope | Lateral side | Total | Downslope | Upslope | Lateral side | Total |
| April | 5 | 186.5 | 90.72 | 36.36 | 186.20 | 313.28 | 78.62 | 42.42 | 203.58 | 324.62 |
| May | 7 | 154.5 | 43.84 | 29.86 | 112.41 | 187.24 | 64.03 | 12.99 | 103.18 | 180.19 |
| June | 8 | 224.6 | 89.01 | 32.03 | 182.51 | 292.61 | 114.74 | 19.13 | 150.53 | 281.75 |
| July | 8 | 94.4 | 39.36 | 3.30 | 53.13 | 95.64 | 42.56 | 2.35 | 42.54 | 85.71 |
| August | 10 | 282.7 | 56.28 | 9.00 | 73.07 | 136.55 | 58.60 | 5.58 | 58.63 | 120.58 |
| September | 11 | 303.0 | 47.76 | 15.30 | 77.63 | 140.69 | 55.80 | 8.79 | 62.46 | 123.30 |
| October | 10 | 224.2 | 29.12 | 9.13 | 60.00 | 98.25 | 46.08 | 4.12 | 75.56 | 126.26 |

Source. Field work, 2007

Visual observation by the researcher during some storms showed that there was ponding of sheet flow in the downslope area of the $5^0$ slope. The water layer most likely had a cushioning effect and shielded soil from splashing.

The effect of ponding of sheet flow had earlier been documented by Moss and Green (1983); Proffitt and Rose (1991) and Wan *et al*. (1996) in their studies. Water flows faster at the upslope areas and so the effect of ponding was not experienced. The magnitude of the upslope and downslope splash rates across any boundaries along the slope is dependent on the significance of the cushioning effect of the water layer on soil surface. The splash at $5^0$ slope may also have been markedly affected by the combined effects of wind and the direction the droplets strike the soil.

The effects of wind and the direction of strike by droplets were observed during some of the storms. The effect of the droplets on direction of splashed soil has been documented by Schwab *et al*. (1993). However, the effects of wind and/or direction of rain droplets were not investigated in the present study. The implication of the present result is that, at lower slopes ($5^0$) and below, the effect of slope was not the only determining factor in the direction of movement of splashed soil.

At steeper slopes, there was continuous increase of splash downslope with increasing slope gradient (Tables 4.4 and 4.5). In terms of comparison between downslope and upslope splash, no month recorded more splashes at the upslope than downslope from the slope of $15^0$ and above. This was also the conclusion of Van Dijk *et al*. (2003) who noted in their study that downslope splash increased with slope gradient, whereas upslope splash decreased with increasing slope. According to these authors, lateral splash did not show any obvious trend along the same lines. As in the present study, Van Dijk *et al*. (2003) noted decrease in the upslope splash with slope increase. Figs. 4.2, 4.3, 4.4 – 4.8 show the mean splash pattern for the various mulch treatments. Fig. 4.2 and 4.3 are line graphs indicating the patterns of relationship that exist between the various components of splash and slope at control and the combined treatment.

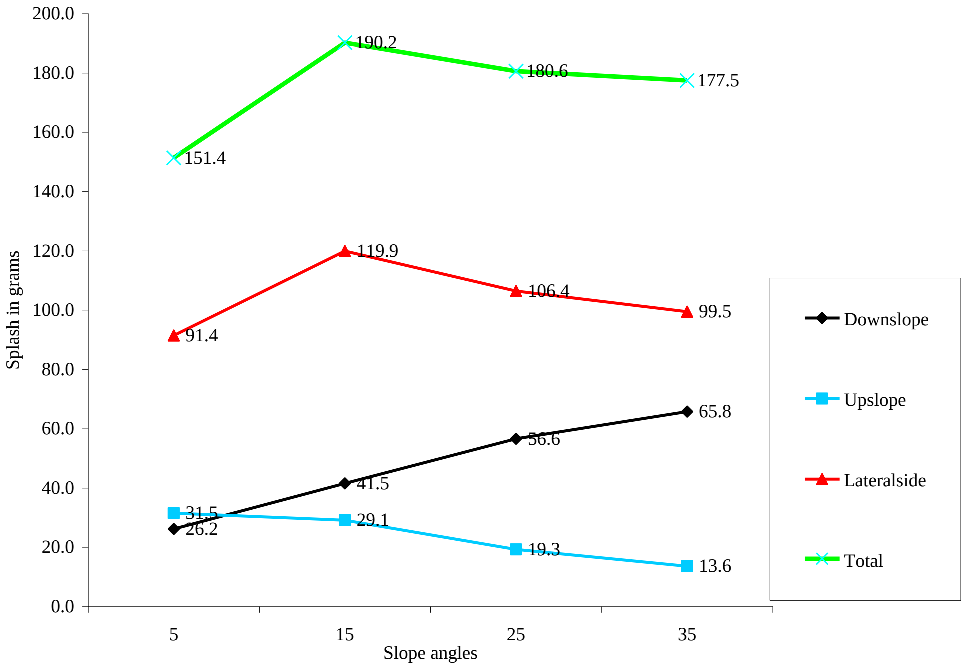


**FIG.** 4.2 Effect of slope angle on splash rate at control (trays without mulch)

Source: Field work 2007

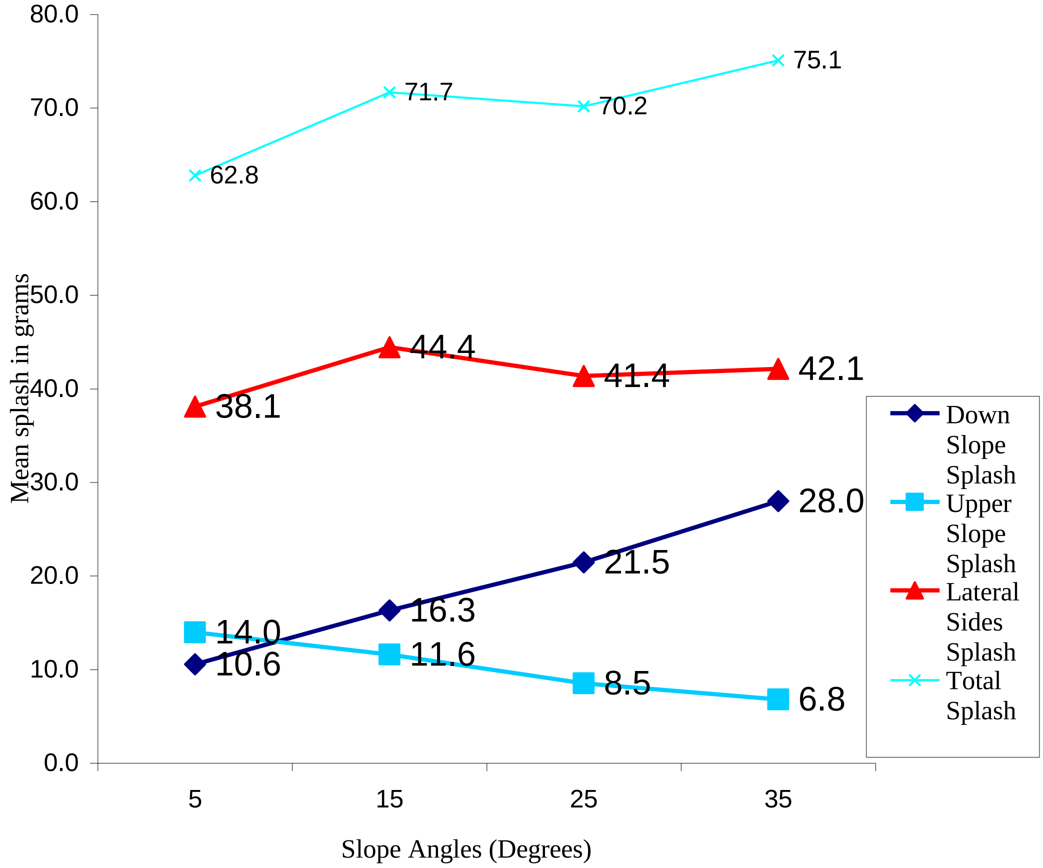


**Fig.** 4.3 Effect of slope angle on splash rate (for trays with mulch and those without mulch)
Source: Field work 2007

It was necessary to make comparisons between individual slopes at the three components of downslope, upslope and total splashes. This is shown on Tables 4.6, 4.7 & 4.8. The Tables reveal that there were no significant differences statistically (at 0.05 level) in the amount of splash at slopes between 5 and 15 degrees; 15 and 25 degrees; and between 25 and 35 degrees at the downslope.

**Table** 4.6. Multiple comparisons of downslope component of splash between pairs of slopes

| | | | Mean difference (I-J) | Std. Error | Sig. | 95% Confidence Intercal | |
|---|---|---|---|---|---|---|---|
| Dependable Variable | (I) Slope | (J) | | | | Lower Bound | Upper Bound |
| Down Slope Splash | 5 | 15 | -16.1288 | 8.2980 | .210 | -37.4467 | 5.1890 |
| | | 25 | -28.6102 | 8.2980 | .003 | -49.9280 | -7.2923 |
| | | 35 | -39.0220 | 8.2980 | .000 | -60.3399 | -17.7042 |
| | 15 | 5 | 16.1288 | 8.2980 | .210 | -5.1890 | 37.4467 |
| | | 25 | -12.4814 | 8.2980 | .435 | -33.7992 | 8.8365 |
| | | 35 | -22.8932 | 8.2980 | .030 | -44.2111 | -1.5754 |
| | 25 | 5 | 28.6102 | 8.2980 | .003 | 7.2923 | 49.9280 |
| | | 15 | 12.4814 | 8.2980 | .435 | -8.8365 | 33.7992 |
| | | 35 | -10.4119 | 8.2980 | .592 | -31.7297 | 10.9060 |
| | 35 | 5 | 39.0220 | 8.2980 | .000 | 17.7042 | 60.3399 |
| | | 15 | 22.8932 | 8.2980 | .030 | 1.5754 | 44.2111 |
| | | 25 | 10.4119 | 8.2980 | .592 | -10.9060 | 31.7297 |

The mean difference is significant at the .05 level
Source. Field work 2007

Table 4.6 further reveal that the variations in splash at slopes between 5 degree on the one hand and 25 and 35 degrees on the other were statistically significant (at the 0.05 confidence level) at the downslope area. In the same way, splash at 15 degree was only significantly different from that at 35 degree.

At the upslope area, it was only between 5 and 35 degrees of slopes that significant differences in splash were recorded. No significant difference was recorded in between any of the pairs of slopes at the total splash level.

**Table** 4.7. Multiple comparisons of upslope component of splash between pairs of slopes

| | | | Mean difference (I-J) | Std. Error | Sig. | 95% Confidence Intercal | |
|---|---|---|---|---|---|---|---|
| Dependable Variable | (I) Slope | (J) | | | | Lower Bound | Upper Bound |
| Upper Slope Splash | 5 | 15 | 3.1883 | 5.0975 | .924 | -9.9072 | 16.2839 |
| | | 25 | 10.7482 | 5.1200 | .153 | -2.4052 | 23.9016 |
| | | 35 | 15.7474 | 5.4562 | .020 | 1.7303 | 29.7644 |
| | 15 | 5 | -3.1883 | 5.0975 | .924 | -16.2839 | 9.9072 |
| | | 25 | 7.5599 | 5.1416 | .456 | -5.6491 | 20.7688 |
| | | 35 | 12.5590 | 5.4765 | .100 | -1.5102 | 26.6283 |
| | 25 | 5 | -10.7482 | 5.1200 | .153 | -23.9016 | 2.4052 |
| | | 15 | -7.5599 | 5.1416 | .456 | -20.7688 | 5.6491 |
| | | 35 | 4.9992 | 5.4974 | .800 | -9.1239 | 19.1222 |
| | 35 | 5 | -15.7474 | 5.4562 | .020 | -29.7644 | -1.7303 |
| | | 15 | -12.5590 | 5.4765 | .100 | -26.6283 | 1.5102 |
| | | 25 | -4.9992 | 5.4974 | .800 | -19.1222 | 9.1239 |

The mean difference is significant at the .05 level
Source. Field work 2007

As shown on Table 4.8, no significant difference exists between any of the angles with total splash. Total splash rates increases with slope to some point and then decreases.

**Table** 4.8. Multiple comparisons of total component of splash between pairs of slopes

| | | | Mean difference (I-J) | Std. Error | Sig. | 95% Confidence Intercal | |
|---|---|---|---|---|---|---|---|
| Dependable Variable | (I) Slope | (J) | | | | Lower Bound | Upper Bound |
| Total Splash | 5 | 15 | -37.1983 | 31.2043 | .632 | -117.3633 | 42.9666 |
| | | 25 | -27.1424 | 31.2043 | .820 | -107.3073 | 53.0226 |
| | | 35 | -23.3237 | 31.2043 | .878 | -103.4887 | 56.8412 |
| | 15 | 5 | 37.1983 | 31.2043 | .632 | -42.9666 | 117.3633 |
| | | 25 | 10.0559 | 31.2043 | .988 | -70.1090 | 90.2209 |
| | | 35 | 13.8746 | 31.2043 | .971 | -66.2904 | 94.0395 |
| | 25 | 5 | 27.1424 | 31.2043 | .820 | -53.0226 | 107.3073 |
| | | 15 | -10.0559 | 31.2043 | .988 | -90.2209 | 70.1090 |
| | | 35 | 3.8186 | 31.2043 | .999 | -76.3463 | 83.9836 |
| | 35 | 5 | 23.3237 | 31.2043 | .878 | -56.8412 | 103.4887 |
| | | 15 | -13.8746 | 31.2043 | .971 | -94.0395 | 66.2904 |
| | | 25 | -3.8186 | 31.2043 | .999 | -83.9836 | 76.3463 |

The mean difference is significant at the .05 level
Source. Field work 2007

The increase in downslope splash rates and decrease in upslope splash rates with increasing slope gradient can be understood from the stand point of mechanics. Raindrop impact created a series of normal forces perpendicular to the soil surface and shear forces parallel to the soil surface as noted by Wan *et al*., 1996. These forces interact and cause sediment movement. At the lower slopes, normal forces are stronger and so the distribution of splashed sediments will be determined by factors other than slope. As slope gradient increases, both the normal and shear forces in the upslope direction decrease and the shear forces in the downslope direction increases, additionally due to gravitational pull in the downslope direction, resulting in a decreased upslope splash rates and increased downslope splash rates.

It was also necessary to have a picture of the total soil loss for the months and the whole year so that monthly comparisons could be made. This is depicted in Tables 4.9 and 4.11-4.12. Table 4.9 showing gross annual splash for different mulch treatments and slopes in $kg/m^2/yr$. Significant differences ($p < 0.05$) were observed in quantity of splashed sediments on bare and mulched surfaces. Total splash loss was generally higher at control, that is, trays without mulch cover, with a peak of 58.5 $kg/m^2/yr$ recorded at $15^0$ slope. This means there is no relationship between total splash detachment and slope gradient in the present study.

**Table** 4.9. Annual gross splash loss from different mulch treatments and slopes, in kg/ $m^2$/ yr

| S/N | Mulch treatment | slope Angle | | | |
|---|---|---|---|---|---|
| | | $5^0$ | $15^0$ | $25^0$ | $35^0$ |
| 1. | Control (without mulch) | 46.48 | 58.49 | 55.49 | 54.13 |
| 2. | Ground nut mulch | 11.9 | 11.27 | 11.09 | 12.09 |
| 3. | Rice mulch | 9.97 | 11.03 | 11.62 | 12.0 |
| 4. | Grass mulch | 12.08 | 10.11 | 11.88 | 12.43 |
| 5. | Soya beans mulch | 6.9 | 9.58 | 9.97 | 9.99 |

Source: Field work, 2007**.**

Unlike the study by Wan, *et al*. (1996), that showed linear kind of relationship between slope and total splash, the present study reveals that the total splash output (combining upslope, downslope and lateral sides) from the studied plot of $0.18m^2$ increased with slope and then decreased after a peak splash rate was reached at $15^0$ slope. This was also the conclusion of Bryan (1979) and Sutherland, *et al*. (1996). There was however linear increase and decrease in the components of splash (downslope and upslope splash) with slope respectively.

The result revealed that total splash detachability was not just affected by slope gradient and orientation, but may also be influenced by other factors including surface sealing, infiltration, and wind intensity and direction. Soil loss generally could be transport limited or detachment limited. The limiting factors include surface sealing, infiltration, slope angle and rainfall characteristics. At lower slopes, the erosion is usually transport-limited, whereby not all detached sediments are transported. For steeper slopes, the erosion process becomes detachment limited, where fewer materials are detached but all detached sediments are transported, conclusions drawn by several other authors including Foster, 1990; Nearing *et al*., 1990; Wan *et al*., 1996 and Assouline and Ben- Hur, 2006. The result obtained in the present study at the control treatment was not replicated at the mulched trays. Both the almost perfect relationship of increase in downslope splash with slope gradient and the near perfect relationship of decrease in splash with slope gradient were not reflected like that with the mulched treatment. In the same vein, the increase in splash at the lateral and total splashes with gradient up to a point and then gradual decrease did not occur at the mulched treatment. There was really no uniform pattern on the mulched surfaces.

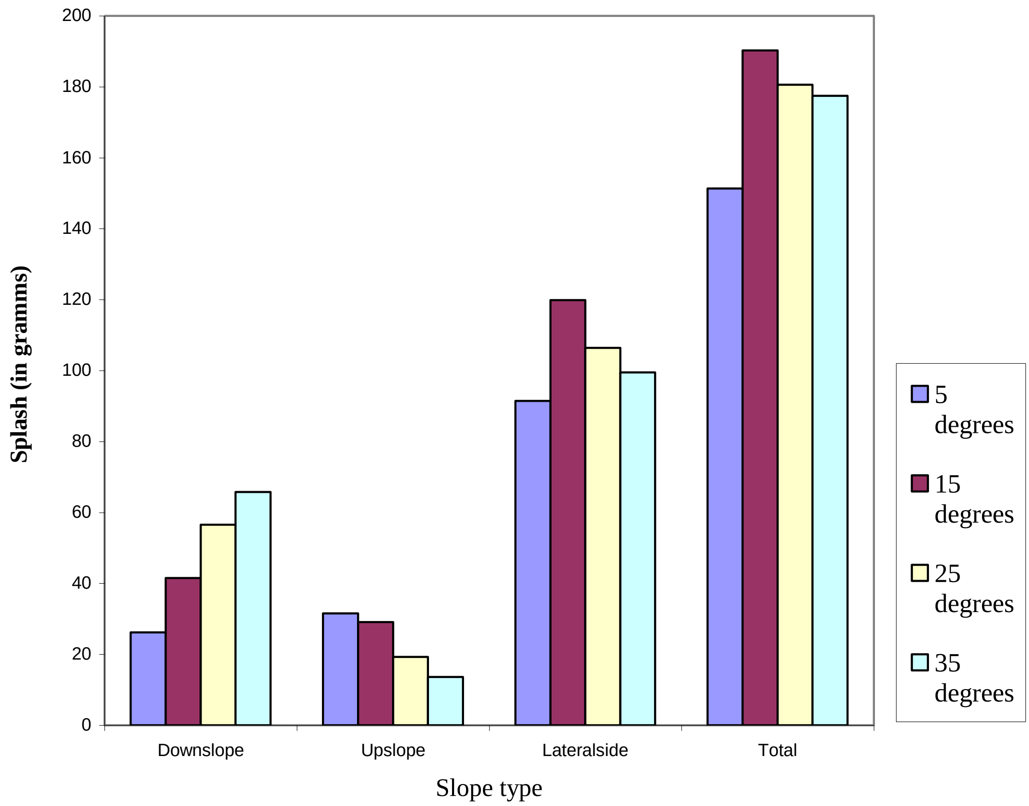


**Fig.** 4.4 Mean annual splash showing the relationship between slope angle and splash rate at Control (trays without mulch)
Source: Field work 2007

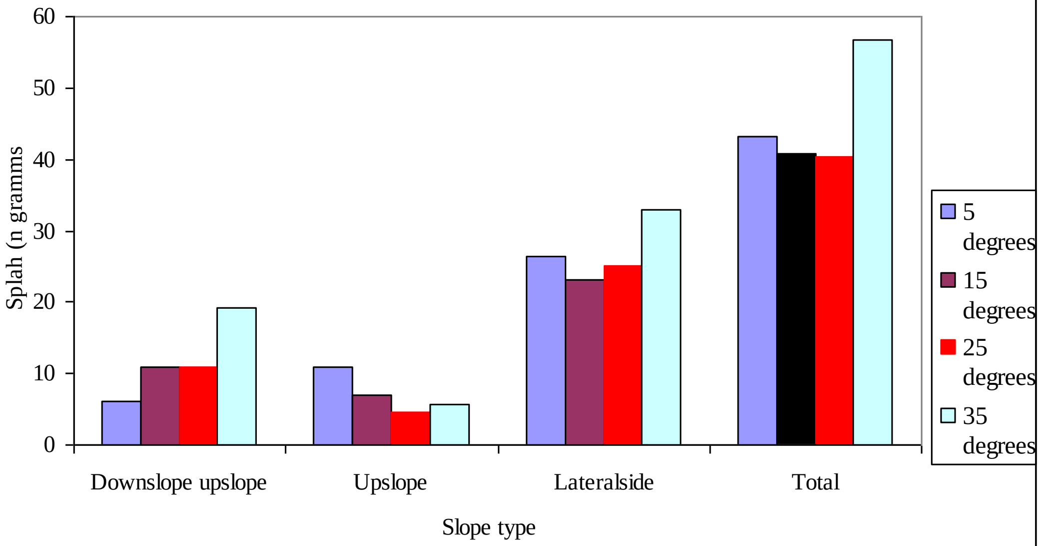


**Fig.** 4.5 Mean annual splash showing the relationship between slope angle and splash rate with Groundnut mulch

Source: Field work 2007

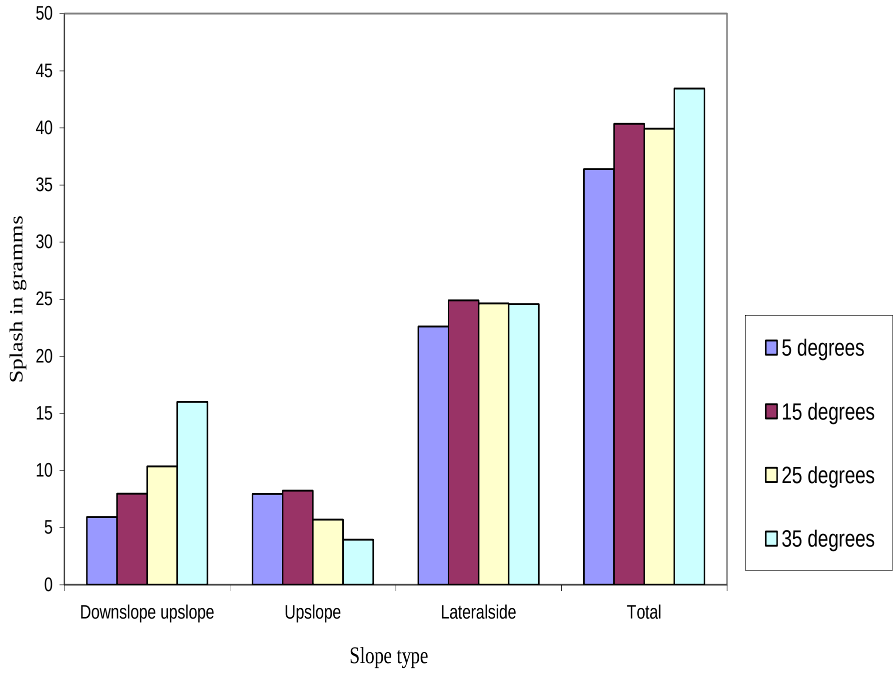


**Fig.** 4.6 Mean annual splash showing the relationship between slope angle and splash rate with rice mulch
Source: Field work 2007

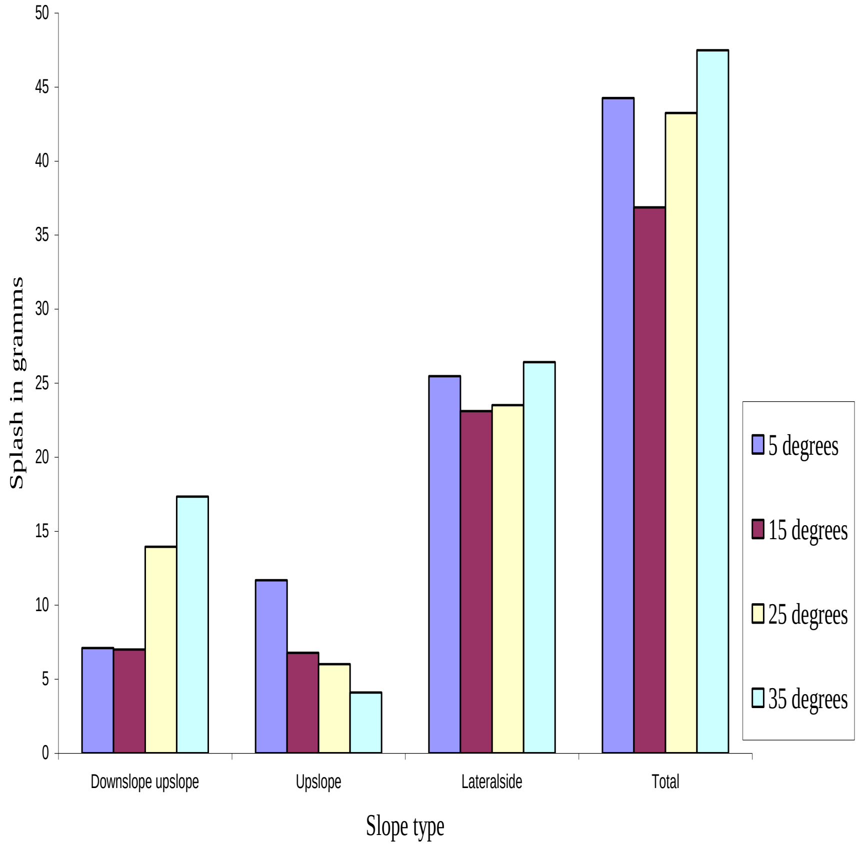


**Fig**.4.7: Mean annual splash showing the relationship between slope angle and splash rate with grass mulch

Source: Field work 2007

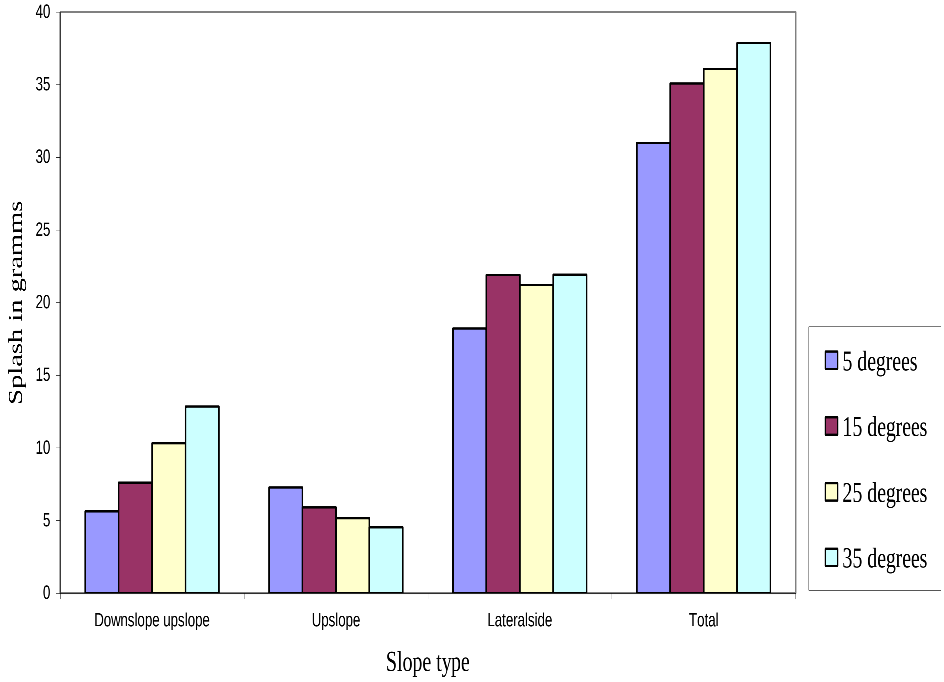


**Fig.** 4.8: Mean annual splash showing the relationship between slope angle and splash rate with soyabeans mulch
Source: Field work 2007

### 4.2.2 Spatial variations in splash with mulch cover

The effect of cover (mulch) on splash was glaring as shown by Table 4.9 and graphically on Figs. 4.4 – 4.8. The result of the analysis as displayed in Table 4.9 showed that splash from bare surface at each slope was more than the quantity from the four mulch treatments at the same slope combined. The table showed gross splash rates at control trays were 46.5, 58.5, 55.5 and 54.1 $kg/m^2/yr$ at 5°, 15°, 25° and 35° slopes respectively. The splash rates from mulched surface (groundnut) were 11.9, 11.27, 11.09 and 12.09 $kg/m^2/yr$ at 5°, 15°, 25° and 35° slope respectively, whereas the least, from soybeans mulch were 6.9, 9.58, 9.97 and 9.99 $kg/m^2/yr$ at 5°, 15°, 25° and 35° slope respectively. On the other hand, the highest splash from mulched surface was 12.4 $kg/m^2/yr$ at $35^0$ slope on grass mulch. This translates to just 26.7% and 21.25% of the highest and least splash on the bare surface respectively. Table 4.9 further revealed that combining the splash quantity from mulched trays yielded 40.9, 41.9, 44.6 and 46.5 $kg/m^2/yr$ of splash at 5, 15, 25 and 35 degrees respectively. This picture is clearly displayed on Figs. 4.4 – 4.8 where the downslope splash at the control (Fig.4.4) is much higher than the lateral and total splash at the mulched treatment (Figs. 4.5 – 4.8).

Furthermore, the ANOVA technique (Table 4.10) was used to test the statistical significance of the variations between mulched and control (without mulch) surfaces at the downslope, upslope, lateral and total levels. The result of the ANOVA showed that there was significant difference at 95% confidence level between detachability at the control (without mulch) and mulch treatment at the four levels. The implication of the result is that at the downslope, upslope, lateral and total components; there was significant variation in splash between mulched and bare surfaces**.**

**Table** 4.10. ANOVA to compare components of splash from different mulch treatments

| Direction | Source of variance | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| Down Slope | Between Groups | 225763.626 | 4 | 56440.907 | 85.376 | .000 |
| | Within Groups | 661747.165 | 1001 | 661.086 | | |
| | Total | 887510.791 | 1005 | | | |
| Upper Slope | Between Groups | 38490.050 | 4 | 9622.513 | 38.799 | .000 |
| | Within Groups | 229657.809 | 926 | 248.011 | | |
| | Total | 268147.859 | 930 | | | |
| Lateral Sides | Between Groups | 962956.208 | 4 | 240739.052 | 76.052 | .000 |
| | Within Groups | 3193926.850 | 1009 | 3165.438 | | |
| | Total | 4156883.058 | 1013 | | | |
| Total | Between Groups | 2720142.426 | 4 | 680035.607 | 82.868 | .000 |
| | Within Groups | 8280088.136 | 1009 | 8206.232 | | |
| | Total | 11000230.562 | 1013 | | | |

Source. Computed from fieldwork, 2007

The effect of the various mulch materials used in checking splash erosion was also compared. The result indicated that the differences between the mulched materials used in this study were not statistically significant at the 0.05 level. The pattern is reflected on Figs. 4.4 – 4.8 that gave the annual means. The figures showed that groundnut mulch showed little variations in splash at the four components at all the slopes (Fig. 4.5). The other mulch materials failed to show clear differences, for example, the lateral splash from rice, grass and soyabeans mulch treatments at the four slopes showed the same trend. This result may be due to the fact that the mulch materials used had sizes that were near uniform. Poesen and Lavee (1990) have cited experimental results from similar research over the years ( for example Fletcher and Beutner, 1976; Yair and Lavee, 1976; Singer and Blackard, 1978; Abrahim and Rickson, 1989; and Palis, *et al*., 1990) detailing the effect of size of mulch on soil loss generally. Their conclusion, which Poesen and Lavee (1990) confirmed, showed that the larger the size of the mulch materials, the higher the soil loss, meaning that the size of mulch materials affect the effectiveness of the mulch material used. In the present study, the differences in the sizes of the residues used do not show significant variations in splashed materials among the different mulch treatment. From the analysis therefore, significant variations were found only between control treatment and the other mulched surfaces, at all the components of upslope, downslope, and lateral slope as well as total splashes. The preceding result showed that the quantity of splash from mulch surfaces at all the components was significantly less than splash from bare surface.

The quantity of splashed soil (total) for each month during the experimental period was computed and compared on the basis of the slopes studied on the one hand and mulch treatment on the other. This data is presented on Tables 4.11-4.12. Table 4.11 showed that the mean monthly splash was highest on the control surface at all the months, and with $15^0$ slope recording the highest splash in all the months except June and July. Cumulative monthly splash was 7.5, 8.4, 8.3 and 8.0 kg/ $m^2$/yr at 5, 15, 25, and 35 degrees respectively in May at the control level, that is, without mulch. The month of July recorded 4.1, 3.7, 3.7 and 3.3 kgs/ $m^{2/}$yr at the same slopes at control.

During the month of July, the trays mulched with groundnut residue produced the following result – 0.2, 0.2, 0.3, and 0.3 kg/ $m^2$ /yr at 5, 15, 25, and 35 degrees respectively (Table 4.11). Even at the peak of the rainy season in June, only 3.6 $kg/m^2/yr$ of splash was recorded on rice mulch (Table 4.11) at 35 degree slope angle, as against the 13.0 $kg/m^2/yr$ of splash that was collected at 25 degree in the same month of June. Monthly pattern followed the annual pattern, that is, splash increased with the rains and reached a peak in June. For the study area, June also represents the peak of the farming system when over 70% of the land may have been covered with vegetation. The incidence of splashing may have significantly reduced.

The importance of cover (mulch) was also investigated through the interview conducted with farmers in the area. The result of the interview revealed that mulching as a traditional practice is applied on land being prepared for cultivation. In this wise, the grass/land is weeded or slashed and evenly spread on the weeded portion. This is usually done towards the end of the rainy season (about September/October). Mulching can also be used in plantation, where the weeds/undergrowth, the pruning of the trees (plantation trees) are left around the tree stands to protect and/or decompose to add nutrients to the soil. The practice of mulching is not limited to the present study area alone for as noted by Xiao-Yan Li, 2003, mulching is also used as a traditional technique in the loess area of China for soil conservation. The Chinese use gravel and sand as mulch to conserve the sporadic and limited rainfall for reliable crop production.

All the people (100%)interviewed on this said the practice of mulching was meant to conserve water, prevent the land/soil from getting hardened/backed up and provide materials that could be used in mulching heaps when the heaps are made at a letter date. They also claim that when mulched, heaps and ridges were not reduced through beating by rainfall; an indirect reference to splash erosion. This practice is important in Benue State as the area experiences marked wet and dry seasons.

The materials used for mulching varied according to

1. the local materials available,
2. the crops being mulched,
3. the labour available to source for the materials in and around the farms, and
4. the stage at which the mulching is done.

Trees with broad leaves are mostly avoided as they act as inhibition to germination and/or prevent penetration of the shoots. The young tobacco transplanted is however completely covered with broad leaves to prevent excessive evaporation and scorching heat from the sun. Before germination, the seeds' beds of tobacco and other vegetables are completely mulched and this can be with any available material.

The yam farmers interviewed said that there were three levels of mulching done on a yam farm. The stage of land preparation when the grasses/shrubs may be slashed or weeded and spread on the land; the preparation of heaps/ridges when the dry weeds/grass is rolled and placed on top of the heaps with a little soil to keep it in place; and at the stage of planting the yam seedlings. It was the view of the people interviewed that the levels of mulching and/or size/volume of the mulch used vary with the stage at which the mulching was done, generally reducing progressively from the land preparation to the planting of seedlings due to reduced need for it. The researcher was told that in place of mulching, some farmers may plant beans at the top of the heaps, apparently to serve the same purpose. The beans protect the heaps upon leafing and add nutrients (nitrogen) to the soil. The beans are also harvested for use (as food) before yams are planted. The practice of mulching as described above is limited to land actually prepared and cultivated at about September – December in the case of yams. Where yam heaps cultivation is done with the commencement of rainfall in about April – May, mulching was not be considered necessary by the farmers. When asked why it is not done at this time, 60% of the farmers were of the opinion that with the rains, there was no need for the protection against heat and preservation of moisture. The remaining 40% gave two related reasons. Firstly, to hasten the process of making heaps this late, the grass is burnt. And secondly, as a result of the above reason, it becomes difficult to get the materials to use for mulching. This is where the aspect of erosion control is ignored by the farmers, most likely due to ignorance, for 60% of the farmers said they mulch to conserve moisture and reduce heat. Mulching is also done on a limited level on vegetable farms, particularly at the stage of preparation of nursery. The seeds are evenly spread on prepared heaps/ridges and covered lightly with soil and mulched. The remaining 40% of the farmers, the tobacco and vegetable farmers however said that if not mulched, the rainfall/irrigation water will wash both the soil and the seeds.

**Table** 4.11. Comparison of monthly gross splash loss over control (without mulch), groundnut and rice mulch treatments over the four slopes treatments in kg/m$^2$ /yr

| Month | Control (without mulch) | | | | Groundnut mulch | | | | Rice Mulch | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Slope Angles | | | | Slope Angles | | | | Slope Angles | | | |
| | $5^0$ | $15^0$ | $25^0$ | $35^0$ | $5^0$ | $15^0$ | $25^0$ | $35^0$ | $5^0$ | $15^0$ | $25^0$ | $35^0$ |
| April | 6.63 | 9.51 | 8.7 | 9.02 | 1.62 | 1.61 | 1.98 | 2.52 | 1.56 | 1.77 | 1.41 | 1.42 |
| May | 7.49 | 8.37 | 8.32 | 8.01 | 1.8 | 1.92 | 1.53 | 2.38 | 1.5 | 2.06 | 1.85 | 1.86 |
| June | 7.49 | 8.37 | 8.32 | 8.01 | 2.41 | 1.83 | 2.31 | 3.26 | 1.94 | 2.56 | 3.23 | 3.6 |
| July | 4.07 | 3.70 | 3.72 | 3.33 | 0.34 | 0.28 | 0.22 | 0.19 | 0.21 | 0.17 | 0.25 | 0.27 |
| August | 7.07 | 8.08 | 7.59 | 6.70 | 1.56 | 1.68 | 1.04 | 1.57 | 2.29 | 1.58 | 1.71 | 2.09 |
| September | 7.83 | 9.53 | 8.6 | 7.54 | 3.21 | 3.02 | 2.87 | 3.53 | 1.81 | 2.24 | 2.27 | 1.66 |
| October | 2.02 | 6.62 | 5.46 | 7.01 | 0.97 | 1.0 | 1.14 | 1.89 | 0.66 | 0.63 | 0.84 | 1.09 |

Source: Field work, 2007

**Table** 4.12. Comparison of monthly gross splash loss over control (without mulch), grass and soybeans mulch treatments over the four slopes treatments in kg/$m^2$ /yr

| Month | Control (without mulch) | | | | Grass mulch | | | | Soybeans mulch | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Slope angles | | | | Slope angles | | | | Slope angles | | | |
| | $5^0$ | $15^0$ | $25^0$ | $35^0$ | $5^0$ | $15^0$ | $25^0$ | $35^0$ | $5^0$ | $15^0$ | $25^0$ | $35^0$ |
| April | 6.63 | 9.51 | 8.7 | 9.02 | 1.86 | 1.51 | 1.98 | 1.93 | 1.39 | 1.52 | 1.58 | 2.13 |
| May | 7.49 | 8.37 | 8.32 | 8.01 | 1.55 | 1.77 | 1.99 | 2.02 | 1.22 | 1.73 | 1.47 | 1.83 |
| June | 7.49 | 8.37 | 8.32 | 8.01 | 2.07 | 2.0 | 2.65 | 3.32 | 1.79 | 2.10 | 2.23 | 2.43 |
| July | 4.07 | 3.70 | 3.72 | 3.33 | 0.39 | 0.28 | 0.28 | 0.25 | 0.29 | 0.21 | 0.22 | 0.20 |
| August | 7.07 | 8.08 | 7.59 | 6.70 | 2.12 | 1.29 | 1.41 | 1.6 | 1.18 | 1.31 | 0.99 | 0.85 |
| September | 7.83 | 9.53 | 8.6 | 7.54 | 3.16 | 2.31 | 2.58 | 2.69 | 1.64 | 2.11 | 2.39 | 1.65 |
| October | 2.02 | 6.62 | 5.46 | 7.01 | 0.94 | 0.96 | 0.98 | 0.61 | 0.63 | 0.69 | 1.1 | 0.91 |

Source: Field work, 2007

The result of splash detachment obtained in the present study on bare surface was compared with what had been done worldwide. The studies reported in Table 4.13 spanned over a number of years, and were conducted over varied periods of time and with different types of soils. But the result confirmed similar observations by Eze (1996) who noted in his study that the rate of splash erosion from bare surface in Nigeria was generally high (Table 4.13). The table showed that apart from the study by Van Dijk *et al*. (2003), which recorded 61.3 $kg/m^2/yr$, the other notable amounts are recorded in Nigeria. The nature of the rains in Nigeria and the nature of land use might be responsible for the high rate of splash in the country.

**Table** 4.13. Variations in splash detachment from bare surfaces World wide

| Investigator | Soil Texture | Splash, kg/ $m^2$/ yr | Country |
|---|---|---|---|
| Sreenivas *et al*. (1947) | Clayey Soil | 6.42 | USA |
| Fournier 1958 | Sandy Soil | 2.32 | Burkina Faso |
| Bolline (1980) | Loamy Soil | 41.5 | Belgium |
| Frochlich and Slupik (1980) | Loamy Soil | 10.74 | Poland |
| Lal (1980) | Sandy Soil | 44.0 (4months) | Nigeria |
| Morgan 1981 | Sandy Soil | 37.0 | U.K. |
| Soyer etal (1982) | Clayey Soil | 28.4 | Zaire |
| Osuji & Sangodoyin (1988) | Sandy Soil | 16.67 (2 months) | Nigeria |
| Eze (1996) | Sandy Loam | 99.39 (8months) | Nigeria |
| Wan *et al* (1996) | Silt Clay | 5.31 | Hawaii |
| Van dijk *et al* (2003) | clay Loam | 61.3 0.8/99 Rainy Season | Indone sia |
| Legout *et al* (2005) | Silt Loam | 20.6 ($tho^{-1}$) (29 $mmh^{-1}$ Sim.r/f | France |
| Iorkua (2007) **xx** | Sandy Loam | 58.44 (7months) | Nigeria |
| Kazuki (2oo8) | Clay Loam | 7.38 (5months) | Japan |

**xx** Present Study.
**Source.** Adapted from Eze (1996)

### 4.2.3 Temporal variations in splash.

The variation in splash was not only noticed at the slopes as discussed in the previous section of this chapter, but there were also periodic. These temporal variations are presented on Tables 4.11 and 4.12, showing the monthly gross (total) splash loss from different mulch treatment and slope in $kg/m^2/yr$ and the mean monthly splash loss (components) at the different slopes and mulch treatment. The Tables present interesting results. Gross splash over all the slopes and mulch treatments were lowest in July. This was also true of the mean monthly splash. Eze (1996) also recorded lowest total splash in July. The explanation usually given is that July marks the middle of the rainy season in most parts of Nigeria, including the present study area, and is a period when the soil gets saturated and aggregated by the process of slaking and surface crusting, processes that encourage runoff and reduce splash, a conclusion similar to that drawn by Bryan, 1969; and Daura, 1995. Furthermore, in the present study, July recorded the lowest mean monthly rainfall. The reduced rainfall might also have contributed to reduction in splash during this month. The amount of monthly rainfall recorded for 2007 did not reflect the mean for the 35 years. There was an increase in mean monthly rainfall from April with a peak in September, unlike the 2007 rainfall where July recorded the least amount of rainfall during the year.

Gross total splash was highest during the month of June, though April recorded the highest mean monthly splash. The implication of this result was that gross and mean splashes were functions of the frequency and magnitude of splash producing rainfall events. In this study, the magnitude of splash causing rainstorm was more important. For example, June and April did not receive the highest number of rainstorms, yet they recorded the highest total and mean splash rates respectively. Whereas April had only 5 storms, June had 8 as against the 11 that occurred in September, 10 each in August and October. The highest amount of rainfall received during 2007 per storm was 113.0mm on April 27$^{th}$. Many researchers on splash including Lal, 1976; Wolman and Miller, 1960; Morgan, 1981; and Eze, 1996 had contended that rain that causes severe erosion might be just a single storm or 2 or 3 storms which could be concentrated within a single month.

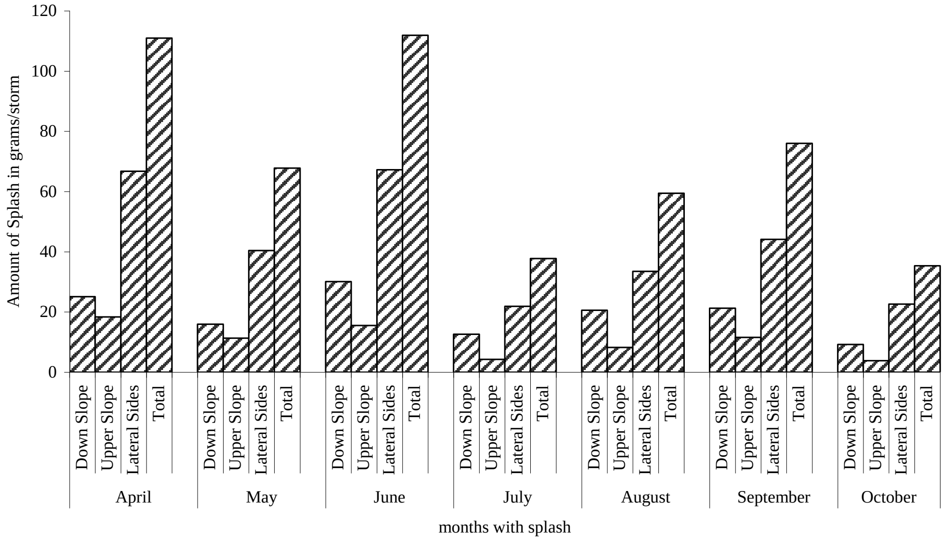


**Fig.** 4.9: Mean monthly Splash in grams/storm from April-October

Source: Field work 2007

The mean monthly splash was also presented on Fig. 4.9. The figure showed that the rate of mean monthly detachability was maximum at the beginning of the rainy season, particularly during the first three months. This trend decreased during the last four months of rainfall. The reasons for this included the fact that the beginning of the rainy season was characterized by short duration storms of high intensities, an opinion shared by Osuji and Sangodoyin, 1989; and Eze, 1996. As the rainy season progresses, there is reduction in the amount of rainfall per storm, the rains generally being more frequent but less intense. But for the same amount of rainfall, the differences in soil detachment may be attributed to mainly differences in slope gradient, surface cover and the direction and magnitude of rainfall impacting forces. This conclusion is obvious from the preceding sections. What this means is that factors of slope gradient and mulch cover should be taken into consideration in any attempt at erosion control in the humid tropical area. This is more so as the factors of rainfall parameters may be beyond our control.

In terms of the variations in components of splash, Fig. 4.9 reveals that mean downslope splash was highest in June; it was also moderate in the months of April and September. Splash was lowest in October and July at all the components. The monthly mean splash per storm is a better index of comparing the monthly splash. As shown on Fig. 4.9, the month of April with only 5 storms produced the highest mean splash at the lateral, downslope and upslope sections. It also recorded the highest single storm (113.0mm) that generated over 1kg of soil at all the components (downslope, upslope and lateral) combined at 15 degrees slope.

These differences were subjected to statistical analysis to ascertain the significance of the variations (at 95% confidence level) in the values during the year to see if any pattern will emerge in the data. The result of the analysis showed that mean downslope splash in April was only significantly different to that in July and October; downslope splash in May differs significantly from that of only June; downslope splash in June on the other hand differ significantly from those of May, July and October mentioned above. Downslope splash in August was statistically different from that of October, while splash in September significantly differs, from that of October. Similar analysis of the upslope splash shows that only the months of April, October and July displayed marked significant differences in splash with a number of other months. The means for July and October were very low while that of April was quite high.

## 4.3 Particle size distribution of splashed soils.

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.

In this study, a mechanical textural analysis of the downslope and upslope components of the splashed soils was done at the control (trays without mulch) in selected months of April, June, August and October, to reflect the beginning, middle and end of rainy season. The aim was to examine the effect of slope gradient on particle size distribution of the splashed soils.

The result of the analysis as presented in Tables 4.14- 4.15 show 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 (81.6,83.6 and 78.24 at upslope, downslope and original respectively, (Table 4.14) dominated at virtually all the slopes, both at the downslope and upslope section. 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 (for example, from 85.6 and 79.6% at downslope and upslope respectively at $15^0$ in April, sand particles reduced to 67.6 and 61.6% respectively in October (Table 4.14) 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 over the upslope section at the 25 and 35 degree slopes (Table 4.15).

**Table** 4.14. Particle size distribution of splashed soils (%) under control (without mulch) over upslope and downslope at $5^0$ and $15^0$ slopes

| | Months | Slope Component | % primary particles at $5^0$ | | | % primary particles at $15^0$ | | |
|---|---|---|---|---|---|---|---|---|
| | | | Sand | Silt | Clay | Sand | Silt | Clay |
| Original soil(pre experiment) | | | 78.24 | 14.0 | 7.76 | 78.24 | 14.0 | 7.76 |
| | April | US | 81.6 | 13.2 | 5.2 | 79.6 | 15.2 | 5.2 |
| | | DS | 83.6 | 11.2 | 5.2 | 85.6 | 11.2 | 3.2 |
| Splashed Soil | June | US | 61.4 | 19.2 | 19.4 | 65.4 | 17.2 | 17.4 |
| | | DS | 67.4 | 19.2 | 13.4 | 69.4 | 19.2 | 11.4 |
| | August | US | 61.6 | 19.0 | 19.4 | 61.6 | 19.0 | 19.4 |
| | | DS | 73.7 | 19.0 | 7.4 | 75.6 | 17.0 | 7.4 |
| | October | US | 67.4 | 19.4 | 13.2 | 61.4 | 19.4 | 9.2 |
| | | DS | 75.4 | 17.4 | 7.2 | 67.6 | 19.0 | 13.4 |

US = Upslope; DS = Downslope
Source. Field work 2007.

**Table** 4.15. Particle size distribution of splashed soils (%) under control (without mulch) over upslope and downslope at $25^0$ and $35^0$ slopes

| | Month | Slope component | % primary particles at $5^0$ | | | % primary particles at $5^0$ | | |
|---|---|---|---|---|---|---|---|---|
| | | | Sand | Silt | Clay | Sand | Silt | Clay |
| Original soil(pre experiment) | | | 78.24 | 14.0 | 7.76 | 78.24 | 14.0 | 7.76 |
| | | US | 73.6 | 17.2 | 9.2 | 77.6 | 15.2 | 7.2 |
| | April | DS | 75.6 | 17.2 | 7.2 | 83.6 | 11.2 | 5.2 |
| Splashed Soil | | US | 67.4 | 19.2 | 13.4 | 69.6 | 19.2 | 11.2 |
| | June | DS | 71.4 | 17.2 | 11.4 | 73.6 | 17.2 | 9.2 |
| | | US | 67.4 | 19.2 | 13.4 | 71.4 | 19.2 | 9.4 |
| | August | DS | 73.4 | 17.2 | 9.4 | 77.4 | 15.2 | 7.4 |
| | | US | 63.6 | 21.0 | 15.4 | 65.6 | 17.0 | 17.4 |
| | October | DS | 69.6 | 17.0 | 13.0 | 73.6 | 19.0 | 9.4 |

US = Upslope; DS = Downslope

Source: Field work 2007.

The present result shows 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 Kwaad (1977), Poeson and Savat (1981) 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 physico-chemical analysis of the soil used for experiment was carried out to evaluate the influence of these characteristics on splash in the area. The same analysis was also carried out on splashed sediments over the downslope at 5 degrees over the months of April, June, August and October to compare it with the pre-experiment characteristics. The result is presented in Table 4.16.

The detachment of soil material caused by raindrop impact is fundamentally a function of soil-dependent processes such as aggregate breakdown. 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 such as those of the study area tend to develop a dense and impermeable surface seal which can greatly reduce infiltration and enhance soil loss. Another important soil property affecting detachment is soil texture. Sand-rich soils (Table 4.16) tend to have poor aggregation and are more readily removed in splash than finer particles such as silt and clay. This was also the conclusion of Govers, 1991) in his own research. Bulk density is low as a result of absence of gravel and stone line. The loose, friable sandy loam soil has low water holding capacity as a result of the porousness of the mineral fractions. Permeability rate is high and water seepage to the depth is fast. The soil has moderate amount of ironic concretion. The high structural stability to raindrop impact makes the soil to be easily susceptible to soil erosion. The land could be susceptible to high splash erosion.

**Table** 4.16. Physco-chemical characteristics of the soil used for experiment and splashed sediments at the downslope at 5 degrees for the months of April, June, August and October

| | Months | Particle size distribution | | | pH | | Other soil characteristics | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | % sand | % silt | % Clay | H20 1:1 | Kcl 1:2 | Org Carbon % | Org Matter % | Bulk density g/cm$^3$ | Porosity g/cm$^3$ | Permeability Cm/s | Water Content (W%) |
| Pre-experiment analysis of Studied soil | | 78.24 | 14.0 | 7.76 | 5.95 | 5.20 | 0.86 | 1.49 | 1.42 | 0.63 | 2.16 x 10$^{-3}$ | 0.17 |
| Splashed | April | 83.6 | 11.2 | 5.2 | 6..30 | 4.50 | 0.63 | 1.09 | 0.70 | 0.40 | 2.60X10$^{-3}$ | 14.0 |
| sediments at | June | 67.4 | 19.2 | 13.4 | 6.35 | 4.88 | 0.66 | 1.18 | 1.37 | 0.31 | 2.75X10$^{-3}$ | 13.6 |
| selected | August | 73.6 | 19.0 | 9.4 | 6.35 | 4.80 | 0.67 | 1.16 | 1.25 | 0.32 | 2.77x10$^{-3}$ | 15.3 |
| months | October | 75.4 | 17.4 | 7.2 | 6.30 | 4.50 | 0.57 | 0.99 | 1.36 | 0.36 | 2.46x10$^{-3}$ | 18.9 |

Source. Field work 2007

# CHAPTER FIVE

# RELATIONSHIP BETWEEN SLOPE AND RAINFALL PARAMETERS ON DOWNSLOPE, UPSLOPE, LATERAL AND TOTAL SPLASH

## 5.1 Introduction

Chapter four focuses on rainsplash detachment at the downslope, upslope, lateral and total components of 5, 15, 25 and 35 degrees with different mulch treatments. It is observed in the chapter that slope has significant influence particularly on downslope and upslope splash. Some reasons are also advanced for these influences. In this chapter, attention is focused on the strength of the influence of the factors of rainfall parameters and slope on downslope, upslope, lateral and total splash. This chapter is therefore concerned with measuring the strength of the relationship between variables studied i.e., measuring the dependence of components of splash on the independent variables of slope and rainfall parameters. The relationship is examined here using two different statistical techniques.

The influence of the rainfall amount, intensity and kinetic energy on materials splashed downslope, upslope, lateral side and the combined total materials splashed is verified in the first section of the chapter, using correlation statistical technique. The second section deals with the assessment of joint causal relationship between the dependent and independent variables using the multiple regression technique.

## 5.2 Relationships between the independent variables of rainfall Parameters and slope and splash variables over control trays.

The relationship between the independent variables of rainfall parameters of intensity, total amount and kinetic energy as well as slope gradient and the dependent splash variables was examined using correlation analysis. The result in Table 5.1 shows that of the 16 correlation coefficients, 14 were significant at the 0.05 level, representing 87.7%. The result of the correlation further revealed that the independent variables of rainfall amount, total intensity, and total kinetic energy had strong correlation with the materials splashed at the downslope, upslope, lateral side and combined total materials.

**Table** 5.1**.** Correlation values for rainfall parameters (amount, intensity, total kinetic energy) slope gradient and splash detachment at control

| | Correlation values (r ) | | | |
|---|---|---|---|---|
| | Downslope | Upslope | Lateral side | Total |
| Rainfall Amount | 0.771 | 0.706 | 0.805 | 0.844 |
| Total Intensity | 0.582 | 0.572 | 0.585 | 0.625 |
| Total Kenetic Energy | 0.492 | 0.413 | 0.465 | 0.497 |
| Slope Gradient | 0.308 | -0.261 | 0.000x | 0.040x |

Source: Field work 2007
x: Not significant

Further details of the correlation showed that total amount of rainfall had a correlation coefficient of 0.771 and a coefficient of determination or $r^2$ of 59% with downslope splash. This result showed that total amount of rainfall alone explained 59% of variations in the amount of splash downslope. Similarly, the relation between total rainfall amount and total materials splashed showed a correlation coefficient r= 0.844 and a coefficient of determination of 0.712 or 71%.

Furthermore, there was a moderate positive correlation coefficient between total rainfall and upslope with an r and $r^2$ values of +0.706 and 0.498 (50%). The implication is that total rainfall amount alone explained only half or 50% of the variations in splash at the upslope level. The remaining fifty percentage may be explained by other factors, including the effect of wind on rain drops.

However, rainfall intensity and total kinetic energy had only moderate to low positive correlation with splash at the downslope, upslope, total and lateral sides. For example, total intensity had a rather moderate positive correlation coefficient with an r and $r^2$ values of +0.625 and 0.393 (39%). Total kinetic energy had a weak positive correlation coefficient with an r and $r^2$ values of +0.413 and 0.173 (17%) with splash at the upslope side. This result reveals that rainfall intensity alone is able to explain only 17% of the variations at the upslope section of splash. Unarguably, the total amount of rainfall is the most important rainfall parameter determining factor affecting the overall quantity of materials splashed per unit area.

Slope gradient on the other hand had a weak positive correlation and a weak negative correlation with downslope and upslope splash with an r and $r^2$ values of + 0.308 and 0.095 (10%) with downslope and -0.261 and 0.068 (7%) with upslope respectively. Slope gradient did not have any significant relationship with lateral and total splash at the control level i.e., trays without mulch cover.

What can be deduced from the foregoing is that independent variables also have influences on one another. For example, the total amount of rainfall may influence both the intensity and kinetic energy. It is therefore important to examine the joint contributions of these variables on splash at the various levels.

The multiple correlation technique was also used to examine the relationship of splashed materials at the various mulched surfaces with the independent variables of total rainfall amount, total intensity, kinetic energy and slope gradient. Generally, all the mulched surfaces had rather moderate to strong positive correlation with total rainfall amount but a decreasing weak to very weak positive correlation with total intensity and total kinetic energy respectively. The result further reveals that there was either no significant relationship or very weak positive to weak negative relationship with slope gradient. For example, groundnut mulch at lateral and total splash had strong positive correlation coefficient of +0.850 and +0.854 with an $r^2$ of .072 (72%) and .0729 (73%). But the same groundnut mulch at the lateral and total components had correlation coefficient with total intensity and total kinetic energy of r and $r^2$ values of + 0.507 and +0.478 or 0.277 (28%) and 0.228 (23%) respectively. However, groundnut mulch did not have any significant relationship with slope gradient.

## 5.3 Joint influence of the independent variables of rainfall parameters and slope on splash at the different components over control trays

This section examines the joint contributions of the independent variables of rainfall parameters and slope on materials splashed at the different components on trays without mulch cover using the multiple regression technique, at the downslope, upslope, lateral side and total splash.

### 5.3.1 Relationship between slope and rainfall parameters on quantity of materials splashed downslope over control treatment

At the downslope, the independent variables (slope, total intensity, total kinetic energy and total rainfall amount) were regressed against splash. The joint contribution of these independent variables to variations in splash at the downslope section was found to be significant.

The factors of slope gradient, total rainfall amount, total intensity, and total kinetic energy explained 70% of the variations in downslope splash at the control with the slopes considered in the study. However, the effect of total kinetic energy was negatively significant as a factor. The remaining (30%) percent not explained may presumably be due to other factors like the influence of slope gradient on ponding and surface crusting/sealing which is a potent factor in reducing splash as well as erosivity factors of drop size velocity and momentum. Salles and Poesen (2000) in a similar study reported that the momentum multiplied by the drop diameter was the best rainfall index for soil splash detachment by several rainfall indices in field measurements.

The equation explaining the relationship between splash at the downslope and the independent variables noted above is of the form:

$y = -22.71 + 0.708x_1 + 0.248x_2 - 0.157x_3 + 0.308x_4$

Where:

$y$ = downslope

$x_1$= rainfall amount

$x_2$ = total intensity

$x_3$= total kinetic energy

$x_4$ = slope

### 5.3.2 Relationship between slope and rainfall parameters on quantity of materials splashed upslope over control treatment

The variation in splash with slope was also investigated using the multiple regression statistics at the upslope section, using the same independent variables as in section 5.3.1. It was however necessary to ascertain whether or not the observed variations in detachment among the slopes was statistically significant. To achieve this objective, the analysis of variance technique was employed.

The result shows that factors of total rainfall amount, total intensity, total kinetic energy and slope gradient significantly influenced splash at the upslope direction. The regression of the independent variables on upslope splash shows that jointly, they explain 62% of the variations in upslope splash with slope gradient. 38% of the variation is not explained by the independent factors examined in this study.

The factors not explained include the effects of wind and/or the direction of strike of rain droplets, among others. Studying the effects of oblique rain drop angles on splash, Moeyersons (1983) and (Schwab, *et al.*, 1993), discovered that, rains falling perpendicular on a sloping surface splashed as much sediments upslope as downslope. Their study disproved the effect of slope on splash erosion where it is noted that upslope splash is usually less than downslope splash.

All the variables, slope gradient, total rainfall amount, total intensity and total kinetic energy, used in the regression, were found to be significant at the 0.05 level. While rainfall amount and total kinetic energy were positively significant, slope gradient and total kinetic energy were negatively significant.

The implication of the result is that slope and total kinetic energy negatively relates with splash detachment, meaning that as slope gradient increases, there is decrease in splash detachment at the upslope, whereas increase in rainfall and total intensity means increase in splash with slope gradient. The equation reflecting this relationship is of the form:

$y = 12.337 + 0.638x_1 + 0.444x_2 – 0.352x_3 – 0.261x_4$

Where:

$y$ = upslope splash

$x_1$ = rainfall amount

$x_2$= total intensity

$x_3$= total kinetic energy

$x_4$ = slope angle

The significance of the result show that as slope gradient increases, there is decrease in splash detachment at the upslope, and increase in splash detachment with increased slope at the downslope.

### 5.3.3 Relationship between slope angle and rainfall parameters on lateral materials splashed over control treatment

The relationship between lateral splash output and the independent variables of slope gradient, total rainfall amount, total intensity and total kinetic energy was also subjected to the multiple regression test. The result of the test portrays the statistical significance of the variations in total splash. It shows that this relationship is highly significant at 0.05 levels. The regression of the independent variables on splash shows that jointly, these independent variables explain 67% of the variations in lateral splash with variation in slope gradient.

However, only the factors of total rainfall amount, total intensity and total kinetic energy significantly relates with variations in splash with slopes. The other independent variable of slope gradient do not relate significantly with total splash at the varied slopes. Morgan (1978) and Mc Carty (1980) in their separate studies did not see any relationship between total splash and slope gradint. It was noted in chapter four that total and lateral splash increased with slope to a peak and then decreased (see section 4.2.1). The relationship between the independent variables of slope gradient, total rainfall amount, total intensity and total kinetic energy with lateral splash is of the form:

$y = 4.197 + 0.753x_1 + 0.293x_2 – 0.269x_3 + 0.000x_4$

Where

y = lateral splash

$x_1$ = rainfall amount

$x_2$= total intensity

$x_3$= total kinetic energy

$x_4$ = slope angle

### 5.3.4 Relationship between slope gradient and rainfall parameters on total materials splashed over control treatment

The relationship between lateral splash output and the independent variables of slope gradient, rainfall amount, total intensity and total kinetic energy was also subjected to the multiple regression statistics. The result of the analysis reveals that this relationship is highly significant at 0.05 level. The regression of the independent variables on lateral splash indicates that jointly, the independent variables explains 74% of the variation in lateral splash with variation in slope gradient. However, only the factor of slope gradient that does not significantly relates with variations in splash with slope orientation. The other independent variables of total amount of rainfall, total intensity and total kinetic energy relate significantly with total splash at the varied slopes, though total kinetic energy relates negatively. Morgan (1978) and Mc Carty (1980) in their separate studies also did not see any relationship between total splash and slope gradient. The relationship between the independent variables of slope angle, rainfall amount, total intensity and total kinetic energy with total splash is of the form:

$$y = -5.010 + 0.805x_1 + 0.326x_2 - 0.277x_3 + 0.640x_4$$

Where

$y$ = total splash

$x_1$ = rainfall amount

$x_2$= total intensity

$x_3$= total kinetic energy

$x_4$ = slope angle

## 5.4 Joint influence of the independent variables of rainfall parameters and slope on splash at the different components of the mulched surfaces

The multiple regression analysis was also done on the four mulched surfaces. The results of the regression on the individual mulched surfaces conform to the general pattern of all the different mulches. It shows generally that, at the downslope, rainfall amount and slope gradient are the most significant contributing factors, being significant at the 0.05 level for all the mulched surfaces.

For example, rainfall amount, total intensity, total kinetic energy and slope gradient jointly explains 63% of the variations in downslope splash with groundnut mulch. But it is only rainfall amount and slope that are significant as factors responsible for the variations. The relationship between the independent variables of slope gradient, total rainfall amount, total intensity and total kinetic energy with downslope splash with groundnut mulch is of the form:

$$y = -8.132 + 0.799x_1 + 0.055x_2 - 0.128x_3 + 0.244x_4$$

Where

$y$ = downslope groundnut splash

$x_1$ = rainfall amount

$x_2$= total intensity

$x_3$= total kinetic energy

$x_4$ = slope angle

Further examination of the result on the groundnut mulch at the levels of total and lateral splash shows that total rainfall amount, total intensity, total kinetic energy and slope gradient jointly explains 73% and 74% respectively of the variations in total and lateral splash with groundnut mulch. However, it is only total rainfall amount and slope angle are significant factors responsible for the variations. The relationship in the case of total splash at this level and mulch cover is of the form:

$$y = -7.253 + 0.901x_1 + 0.028x_2 – 0.089x_3 + 0.066x_4$$

Where

$y$ = total groundnut splash

$x_1$ = rainfall amount

$x_2$= total intensity

$x_3$= total kinetic energy

$x_4$ = slope angle

The results of the regression on the rice mulch at the lateral and total levels reveal that total rainfall amount, total intensity, total kinetic energy and slope gradient jointly explain 68.7% and 68% respectively the variations in splash at these components. Total amount of rainfall and slope angle act significantly to explain the variations. The relationship between the independent variables of slope gradient, total rainfall amount, total intensity and total kinetic energy with total splash with rice mulch is of the form:

$$y = -8.456 + 0.786x_1 + 0.252x_2 – 0.218x_3 + 0.050x_4$$

Where

$y$ = total rice splash

$x_1$ = rainfall amount

$x_2$= total intensity

$x_3$= total kinetic energy

$x_4$ = slope angle

Similarly, 53% of the variations in downslope splash with rice mulch are explained by the joint contributions of rainfall amount and slope, being the only significant of the independent factors influencing splash at that level. The relationship between the independent variables of slope gradient, total rainfall amount, total intensity and total kinetic energy with downslope rice mulch splash is of the form:

$y = -6.475 + 0.651x_1 + 0.169x_2 – 0.126x_3 + 0.248x_4$

Where

y = downslope rice splash

$x_1$ = rainfall amount

$x_2$ = total intensity

$x_3$ = total kinetic energy

$x_4$ = slope angle

Total rainfall amount and slope angle are also significant at the components of lateral and total splash of the other mulched surfaces of grass and soyabeans, significantly explaining 73%, 73.9% and 69.1%, 68% of variations in grass and soyabeans respectively. On all the mulched surfaces, the significance of slope is positive at the downslope and negative at the upslope section. The conclusion is in line with earlier conclusion in chapter four that with increased slope gradient, there is increased amount of materials splashed downslope and vice-versa for upslope Total intensity and total kinetic energy has no significant influence on splash of the mulched surfaces.

## 5. 5 Conclusion

This chapter shows that three (3) independent variables made up of slope gradient, total rainfall amount and total intensity are the most significant factors in the explanation of components of splash detachment variations in the study area. The statistical models used show that the most important factor which exerts the strongest influence on at least the two components of splash, (downslope and upslope) is slope gradient. Slope gradient combines with rainfall amount and intensity to explain 70% of variations in downslope splash while all the independent variables explain 62% of upslope splash. But while slope gradient relates with splash positively at the downslope, it relates with upslope splash negatively. Rainfall amount is another significant parameter. It is important at all the components. Of the mulched surfaces on the other hand, rainfall amount and slope are the most significant contributing factors, being significant at the 0.05 level on all the downslope and upslope sections of all the mulched surfaces.

The highly significant contribution of rainfall to splash erosion as observed in Makurdi agreed with previous studies on water erosion, including those of Hudson (1965), Daura (1995) and Eze (1996). However, for the same amount of rainfall, the differences in soil detachment may be attributed to the differences in slope gradient, cover (mulch) type and the direction of rainfall impacting forces. What this points to is the fact that factors of slope gradient and mulch cover should be taken into consideration in any attempt at erosion control in the humid tropics. This is more so as the factor of rainfall may be out of our control.

# CHAPTER SIX

# SUMMARY AND CONCLUSIONS

## 6.1 Summary

This study examined components of rainsplash detachment at varied slopes and mulch treatment. The slope gradients considered were $5^0$, $15^0$, $25^0$, and $35^0$ . The study was carried out at the Agro meteorological station at the Benue State University, Makurdi. Only the soil at the station was used for the study. Soil trays, filled with soil material with detachable splash collectors at the lateral, upslope and downslope sides were used for the data collection on splash. At each slope, four sets of soil trays were mulched with four different plant residues (groundnut, grass, rice and soyabeans) while one set was used as control (without cover). In all, 20 soil trays were used with 5 each at the slopes studied. Measurements of splash were taken throughout the duration of the rainy season spanning the period from April to October, 2007. In all, 59 rainfall events that produced splash were studied. The spatial and temporal variations in detachment between the components of one tray on the one hand and slopes and mulch treatments on the other were analysed and the factors accounting for the variations established.

The study shows that slope gradient had significant effect on the upslope and downslope components of splash. Downslope increases with slope while upslope component decreases, reflecting variation of raindrop impacting forces and ponding depth with slope. The study also reveals that mulching significantly reduced splash. However, there are no significant variations resulting from the mulch materials used. The study also reveals that farmers in the study area use different residues for mulching, to conserve moisture and reduce heat. The way the mulch is discarded however, suggested that the effect of mulching for erosion control was not sufficiently appreciated.

## 6.2 Findings

From the analysis carried out, the following findings were established.

1. Splash erosion can be isolated from other forms of erosion and studied under natural rainfall. It is an important initiating process in soil erosion. It is also possible to isolate the downslope and upslope components in the field for study. This finding is important for conservation purposes.

2. Gross splash, on the average, was over 46 $kg/m^2/yr$ for all the angles without mulch cover as against the average of 10 $kg/m^2/yr$ for the mulched surfaces. The implication of this finding is that splash contributes significantly to the volume of soil in runoff, apart from causing erosion on its own. This is because splashed sediments are not only transported by runoff, they also aid in removing more sediments by enhancing friction in runoff. The increased volume of soil in runoff causes the silting up of streams, dams and canals. This emphasizes the importance of the study of splash erosion with a view to creating conditions that inhibits the initiating process of soil erosion. Furthermore, this finding shows that mulching is an effective way of reducing splash erosion in the study area and should therefore be encouraged. This practice is relatively cheap as plant residues to be used is usually discarded and can be sourced locally.

3. Downslope splash transport is an important process of sediment transport in interrill erosion and may occur in short and steep slope settings, which are typical of many interrill areas in agricultural fields in the study area.

4. Mean monthly splash per storm was high at the onset of the rainy season in Makurdi in April, whereas gross splash was highest in June, the middle of the rainy season. This finding is also important for erosion control in this area. The beginning of the rainy season is the period when planting is just commencing and the crops had not produced enough leaves to cover the land and protect it against splash erosion. If farmers know this, they will not burn the plant residues generated during the land preparation time so that it could be used as mulch at planting time.

5. Downslope splash increased with slope gradient whereas upslope splash decreased with slope gradient.

6. The lateral and total splash increased with slope from angle 5 degrees to a peak at angle 15 degrees and then gradually decreased.

7. The least rainfall that produced splash was 4.6mm. 4.6mm therefore represented critical rainfall/threshold rainfall in the present study.

8. There were no significant differences in the effect of the type of mulch material used on the splash rates in the present study. In other words, the four mulch types reduced splash almost uniformly. The implication of this finding is that farmers can use any of these residues that are available locally. This is important because not all the crops from which the residues were used are produced everywhere or by all farmers in the study area.

10. 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.

## 6.3 Suggestions for further studies

Several issues emerged in the course of this research that requires further investigations. Among them are:

(1) Construction of square soil trays (the present study used rectangular trays) to actually ascertain the extent of splash at the lateral sides and therefore have a better basis of comparison between the splashes at the four sides. Soil trays could be constructed in such a way that all the sides are equal, that is, downslope, upslope and lateral sides. This could aid better directional comparison of splash at the four sides, and the effect of direction of wind studied.

(2) The present study only investigated components of splash using one soil type. There is the need to use different soil types to study the effect of soil characteristics on splash.

(3) Simulation studies are very important in the understanding of splash. Such studies can isolate erosivity indices for study. It will also help better understanding of the effect of rainfall intensities on varied slopes The research could be conducted with simulated rainfall for the isolation of the effects of specific rainfall intensities on splash detachment.

4. The need for the experiment to be replicated is also imperative. This will take adequate care of the variations in rainfall characteristics over the years and how the variations affect splash

## 6.4 Conclusions

1. Splash in the study area constitutes a serious erosion problem as the rate of splash is quite high - over 58 kg/m$^2$/yr. The state is ravaged by different forms of erosion including splash erosion.
2. Mulching not only improves the microclimate of the mulched area, it also controls splash rate and therefore nutrients loss from the soil and should be encouraged. The difference in quantity splashed between mulched and unmulched surfaces was quite high. For example, over 58 kg/m$^2$/yr of materials splashed at the surface not mulched as against the just over 12 kg/m$^2$/yr of materials splashed on one of the mulched surface.
3. The findings of this study agree with those of Kwaad (1977), Poesen and Savat (1978) and Eze (1996) that surfaces affected by splash are enriched by sand and stones. The present results also corroborate the findings of Poesen and Lavee (1990) that the effectiveness of mulch material is dependent on the size of the mulch. Bryan (1979) and Sutherland *et al*. (1996) drew similar conclusions with the current study that total splash increases with slope gradient to a point and then decreases with further increase in slope gradient. The findings that downslope splash is generally greater than upslope splash is in agreement with those of Wan *et al*. (1996) and Van dijk *et al*. (2003). The finding of the present study however differs from those of Morgan (1979) and McCarty (1980) who did not accept that there was any significant relationship between detachability and slope and Wan *et al*.'s (1996) conclusion that there was a linear relationship between total splash and slope.

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**Appendix 1: Monthly Rainfall Record for 2007 for Makurdi**

| Month | Rainfall (mm) |
|---|---|
| January | 00 |
| February | 00 |
| March | 00 |
| April | 187.0 |
| May | 189.1 |
| June | 238.5 |
| July | 94.4 |
| August | 283.1 |
| September | 314.4 |
| October | 226.0 |
| November | 00 |
| December | 00 |
| Total | 1532.5 |

Source: Collected at the experimental site by the Author, 2007.

**Appendix 2: Annual rainfall in Makurdi, 1973-2007**

| S/No | Year | Annual Rainfall (mm) |
|---|---|---|
| 1 | 1973 | 881.8 |
| 2 | 1974 | 1252.6 |
| 3 | 1975 | 1327.7 |
| 4 | 1976 | 1265.5 |
| 5 | 1977 | 1089.3 |
| 6 | 1978 | 1556.9 |
| 7 | 1979 | 1491 |
| 8 | 1980 | 1425.5 |
| 9 | 1981 | 1227.1 |
| 10 | 1982 | 951.5 |
| 11 | 1983 | 930.3 |
| 12 | 1984 | 1572 |
| 13 | 1985 | 891.2 |
| 14 | 1986 | 1207.7 |
| 15 | 1987 | 1207.7 |
| 16 | 1988 | 834.1 |
| 17 | 1989 | 1244.3 |
| 18 | 1990 | 1120.9 |
| 19 | 1991 | 1122.4 |
| 20 | 1992 | 972.7 |
| 21 | 1993 | 1217.1 |

| | | |
|---|---|---|
| 22 | 1994 | 973.2 |
| 23 | 1995 | 1192.1 |
| 24 | 1996 | 1323.9 |
| 25 | 1997 | 1335.9 |
| 26 | 1998 | 1556.9 |
| 27 | 1999 | 1618.0 |
| 28 | 2000 | 1173.7 |
| 29 | 2001 | 1076.0 |
| 30 | 2002 | 1281.5 |
| 31 | 2003 | 761.5 |
| 32 | 2004 | 964.8 |
| 33 | 2005 | 871.3 |
| 34 | 2006 | 1343.0 |
| 35 | 2007 | 1532.5 |
| | **Average** | 1193.4 |

Source: NIMET Weather Office, Nigerian Airforce Base, Makurdi, 2007.

**Appendix 3: Mean monthly rainfall in Makurdi (1973-2007)**

| Month | Rainfall (mm) | Percentage of the total rainfall |
|---|---|---|
| January | 3.4 | 0.29 |
| February | 1.6 | 0.13 |
| March | 14.3 | 1.20 |
| April | 83.9 | 7.03 |
| May | 143.3 | 12.01 |
| June | 185.1 | 15.51 |
| July | 194.0 | 16.26 |
| August | 225.2 | 18.87 |
| September | 227.3 | 19.05 |
| October | 109.9 | 9.21 |
| November | 4.7 | 0.39 |
| December | 0.7 | 0.06 |
| Average per year<br>Years of records | 1193.4<br>35yrs | 100 |

Source: NIMET Weather Office, Nigerian Airforce Base, Makurdi, 2007

**Appendix 4 Splash data – (in grammes) at the varied slope angles and mulch treatments and the amount of rainfall with dates**

| S/ N | DATE | RAIN-FALL (MM) | S/A | CONTROL (Without mulch) | | | | GROUNDNUT (Mulch) | | | | RICE (Mulch) | | | | GRASS (Mulch) | | | | SOYABEANS (Mulch) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | DS | US | LS | T | DS | US | LS | T | DS | US | LS | T | DS | US | LS | T | DS | US | LS | T |
| 1 | 07/04/07 | 23.3 | 5º | 29.5 | 41.2 | 103.6 | 174.3 | 2.4 | 6.1 | 10.8 | 19.3 | 3.7 | 3.4 | 11.1 | 18.2 | 3.7 | 8.4 | 15.3 | 27.4 | 2.1 | 9.4 | 14.0 | 25.5 |
| | | | 15º | 35.1 | 25.8 | 102.2 | 163.1 | 6.2 | 3.4 | 14.3 | 23.9 | 2.3 | 9.1 | 13.3 | 24.7 | 6.2 | 3.6 | 13.1 | 22.9 | 2.5 | 3.5 | 9.2 | 15.2 |
| | | | 25º | 53.4 | 17.2 | 114.9 | 185.5 | 8.3 | 4.1 | 15.5 | 27.9 | 4.8 | 3.7 | 12.5 | 21.0 | 9.3 | 5.0 | 14.3 | 28.6 | 8.2 | 3.3 | 18.1 | 29.6 |
| | | | 35º | 58.3 | 7.3 | 85.7 | 151.3 | 13.5 | 5.3 | 18.7 | 37.5 | 7.2 | 1.5 | 9.8 | 18.5 | 11.4 | 2.2 | 15.1 | 28.7 | 14.5 | 2.1 | 20.0 | 36.6 |
| 2 | 22/04/07 | 20.7 | 5º | 10.9 | 35.4 | 78.0 | 124.3 | 1.5 | 5.9 | 9.6 | 17.0 | 2.6 | 2.3 | 9.7 | 14.6 | 2.3 | 6.7 | 14.7 | 23.7 | 1.4 | 8.5 | 12.8 | 23.7 |
| | | | 15º | 22.1 | 24.9 | 86.6 | 133.6 | 4.6 | 2.7 | 13.1 | 20.4 | 1.4 | 7.0 | 11.3 | 19.7 | 4.5 | 2.4 | 11.2 | 18.1 | 1.6 | 2.5 | 8.4 | 12.5 |
| | | | 25º | 38.0 | 15.3 | 93.2 | 146.5 | 6.3 | 2.1 | 14.1 | 22.5 | 3.8 | 2.4 | 10.6 | 16.8 | 7.7 | 3.1 | 12.3 | 23.1 | 7.0 | 2.6 | 16.1 | 25.7 |
| | | | 35º | 56.6 | 9.8 | 88.2 | 154.6 | 11.5 | 3.5 | 16.7 | 31.7 | 5.8 | 0.3 | 8.4 | 14.5 | 9.6 | 1.6 | 13.2 | 24.4 | 13.4 | 1.4 | 18.0 | 32.8 |
| 3 | 23/04/07 | 20.7 | 5º | 73.0 | 58.9 | 116.6 | 248.5 | 2.5 | 7.7 | 16.2 | 26.4 | 12.8 | 4.7 | 21.9 | 39.4 | 3.6 | 13.5 | 36.7 | 53.8 | 2.5 | 8.5 | 18.7 | 29.7 |
| | | | 15º | 43.9 | 41.0 | 170.0 | 254.9 | 5.0 | 6.8 | 27.0 | 38.8 | 11.4 | 5.0 | 31.0 | 47.4 | 3.9 | 5.8 | 23.9 | 33.6 | 5.0 | 7.3 | 34.8 | 47.1 |
| | | | 25º | 62.4 | 32.1 | 186.1 | 280.6 | 4.6 | 7.5 | 31.6 | 43.7 | 4.4 | 4.8 | 14.5 | 23.7 | 6.6 | 6.4 | 23.1 | 36.1 | 9.0 | 4.5 | 25.9 | 39.4 |
| | | | 35º | 53.5 | 20.0 | 72.3 | 145.8 | 21.8 | 8.2 | 44.7 | 74.7 | 7.5 | 3.4 | 25.6 | 36.5 | 13.0 | 5.4 | 31.4 | 49.8 | 13.7 | 3.5 | 48.9 | 66.1 |
| 4 | 27/04/07 | 113.0 | 5º | 53.7 | 157.9 | 325.0 | 613.6 | 41.0 | 68.8 | 109.5 | 219.3 | 20.5 | 52.5 | 125.8 | 198.8 | 36.3 | 75.8 | 109.1 | 221.2 | 41.9 | 37.6 | 82.9 | 165.4 |
| | | | 15º | 152.9 | 142.5 | 825.9 | 1121.3 | 48.1 | 39.8 | 108.6 | 196.5 | 36.3 | 57.5 | 124.7 | 218.5 | 42.8 | 42.0 | 101.6 | 186.4 | 43.9 | 37.8 | 111.2 | 192.9 |
| | | | 25º | 285.2 | 115.8 | 514.3 | 915.3 | 69.8 | 33.6 | 150.0 | 253.4 | 48.6 | 27.9 | 109.0 | 183.5 | 90.2 | 44.3 | 125.9 | 260.4 | 58.1 | 24.7 | 98.8 | 181.6 |
| | | | 35º | 211.9 | 174.7 | 749.6 | 1136.2 | 89.0 | 49.6 | 160.1 | 298.7 | 54.0 | 14.0 | 112.5 | 180.5 | 77.7 | 25.3 | 134.4 | 237.4 | 65.5 | 27.7 | 141.3 | 234.5 |
| 5 | 29/04/07 | 8.8 | 5º | 6.1 | 5.5 | 21.1 | 32.7 | 1.7 | 2.0 | 5.6 | 9.3 | 2.3 | 1.7 | 5.4 | 9.4 | 1.0 | 2.7 | 4.6 | 8.3 | 0.8 | 1.1 | 4.3 | 6.2 |
| | | | 15º | 10.4 | 4.0 | 24.8 | 39.2 | 3.3 | 1.0 | 5.0 | 9.3 | 2.8 | 0.5 | 6.2 | 8.5 | 5.3 | 1.8 | 3.5 | 10.6 | 1.5 | 0.5 | 4.6 | 6.6 |
| | | | 25º | 14.6 | 1.4 | 22.5 | 38.5 | 4.0 | 0.3 | 4.7 | 9.0 | 2.5 | 0.5 | 5.2 | 8.2 | 3.6 | 0.4 | 3.4 | 7.4 | 3.7 | 0.3 | 4.3 | 8.3 |
| | | | 35º | 12.8 | 0.3 | 22.1 | 35.2 | 4.0 | 0.3 | 6.8 | 11.1 | 1.5 | 0.1 | 4.5 | 6.1 | 2.5 | 0.2 | 4.7 | 7.4 | 4.0 | 0.2 | 8.4 | 12.6 |
| 6 | 1/05/07 | 38.4 | 5º | 47.2 | 82.1 | 175.0 | 304.3 | 10.1 | 22.7 | 52.8 | 85.6 | 9.0 | 15.5 | 49.6 | 74.1 | 3.4 | 22.2 | 48.6 | 84.2 | 4.0 | 7.2 | 37.1 | 48.3 |
| | | | 15º | 87.2 | 58.1 | 219.2 | 364.5 | 21.4 | 8.6 | 58.1 | 88.1 | 14.3 | 18.7 | 54.7 | 87.7 | 22.1 | 8.1 | 59.4 | 89.6 | 12.7 | 27.1 | 57.1 | 96.9 |
| | | | 25º | 72.3 | 62.4 | 199.1 | 333.8 | 19.7 | 5.5 | 49.4 | 74.6 | 14.4 | 20.1 | 65.0 | 99.5 | 35.6 | 16.9 | 54.0 | 106.5 | 20.7 | 6.0 | 48.3 | 75.0 |
| | | | 35º | 128.1 | 14.0 | 183.6 | 325.7 | 40.9 | 6.3 | 58.3 | 105.5 | 31.7 | 11.3 | 57.6 | 100.6 | 26.9 | 12.1 | 60.0 | 99.2 | 28.8 | 8.8 | 57.9 | 95.5 |
| 7 | 3/05/07 | 35.7 | 5º | 37.0 | 61.0 | 124.6 | 222.6 | 4.4 | 17.0 | 38.4 | 59.8 | 10.3 | 9.8 | 39.3 | 59.4 | 8.0 | 15.3 | 29.5 | 53.3 | 9.6 | 6.1 | 22.0 | 37.7 |
| | | | 15º | 53.8 | 54.0 | 141.5 | 249.3 | 17.3 | 20.2 | 44.3 | 82.0 | 13.4 | 11.3 | 38.9 | 63.6 | 13.5 | 8.5 | 52.1 | 74.1 | 8.0 | 12.9 | 43.0 | 63.9 |
| | | | 25º | 78.1 | 31.2 | 166.3 | 275.6 | 14.7 | 6.3 | 33.9 | 54.9 | 19.7 | 13.8 | 23.6 | 57.1 | 28.1 | 9.3 | 42.8 | 80.2 | 6.7 | 4.8 | 41.3 | 52.8 |
| | | | 35º | 94.5 | 21.4 | 136.3 | 252.2 | 39.8 | 21.7 | 42.1 | 103.6 | 29.0 | 8.5 | 42.8 | 80.3 | 16.9 | 10.0 | 44.5 | 71.4 | 29.7 | 6.7 | 44.4 | 80.8 |
| 8 | 8/5/07 | 25.5 | 5º | 28.3 | 23.8 | 96.2 | 148.3 | 6.0 | 11.1 | 26.4 | 43.5 | 6.3 | 5.3 | 22.3 | 33.9 | 5.4 | 9.4 | 17.0 | 31.8 | 4.6 | 4.0 | 18.4 | 27.0 |
| | | | 15º | 34.7 | 21.4 | 88.9 | 145.0 | 13.1 | 7.7 | 21.3 | 42.1 | 8.3 | 6.3 | 29.7 | 44.3 | 9.5 | 3.0 | 20.0 | 32.7 | 4.3 | 4.5 | 18.1 | 26.9 |

| S/N | DATE | RAIN-FALL (MM) | S/A | CONTROL (Without mulch) | | | | GROUNDNUT (Mulch) | | | | RICE (Mulch) | | | | GRASS (Mulch) | | | | SOYABEANS (Mulch) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | DS | US | LS | T | DS | US | LS | T | DS | US | LS | T | DS | US | LS | T | DS | US | LS | T |
| | | | 25º | 50.8 | 12.8 | 89.7 | 162.3 | 12.3 | 2.9 | 17.6 | 32.8 | 10.9 | 3.1 | 20.9 | 34.9 | 13.8 | 3.3 | 20.4 | 37.5 | 8.8 | 2.5 | 19.0 | 30.3 |
| | | | 35º | 60.8 | 4.7 | 81.8 | 147.3 | 11.8 | 3.7 | 23.8 | 39.3 | 12.2 | 2.5 | 18.6 | 33.3 | 15.2 | 2.2 | 18.9 | 36.3 | 8.1 | 2.5 | 18.4 | 29.0 |
| 9 | 11/5/07 | 8.2 | 5º | 4.8 | 5.3 | 49.0 | 59.1 | 1.2 | 1.9 | 5.8 | 8.9 | 1.2 | 1.2 | 5.6 | 8.0 | 1.1 | 1.8 | 4.4 | 7.3 | 1.1 | 1.0 | 5.7 | 7.8 |
| | | | 15º | 6.5 | 5.0 | 37.8 | 49.3 | 2.0 | 1.9 | 6.8 | 10.7 | 1.1 | 1.0 | 6.5 | 8.6 | 1.8 | 0.6 | 4.3 | 6.7 | 1.0 | 1.1 | 4.7 | 6.8 |
| | | | 25º | 10.5 | 4.9 | 45.0 | 60.4 | 1.4 | 0.2 | 3.1 | 4.7 | 2.2 | 1.2 | 6.5 | 9.9 | 2.1 | 0.5 | 3.9 | 6.5 | 1.5 | 0.4 | 6.1 | 8.0 |
| | | | 35º | 8.2 | 1.2 | 29.6 | 39.0 | 1.9 | 0.3 | 5.6 | 7.8 | 1.8 | 0.4 | 4.5 | 6.7 | 1.5 | 0.5 | 3.9 | 5.9 | 1.4 | 0.4 | 3.0 | 4.8 |
| 10 | 13/5/07 | 14.1 | 5º | 11.4 | 29.4 | 68.2 | 109.0 | 2.2 | 6.9 | 15.1 | 24.2 | 3.4 | 5.0 | 16.9 | 25.3 | 2.1 | 7.6 | 12.2 | 21.9 | 1.3 | 5.2 | 12.0 | 18.5 |
| | | | 15º | 24.0 | 16.7 | 67.3 | 108.0 | 4.0 | 5.8 | 13.6 | 23.4 | 3.4 | 6.9 | 19.4 | 29.7 | 4.6 | 5.4 | 15.8 | 25.8 | 3.1 | 5.9 | 16.3 | 25.3 |
| | | | 25º | 26.2 | 15.4 | 68.6 | 110.2 | 6.4 | 2.2 | 12.1 | 20.7 | 5.6 | 2.7 | 15.6 | 23.9 | 7.6 | 4.2 | 15.1 | 26.9 | 4.6 | 3.4 | 13.7 | 21.7 |
| | | | 35º | 42.8 | 6.7 | 67.4 | 116.9 | 7.0 | 1.5 | 16.4 | 24.9 | 7.1 | 2.3 | 13.7 | 23.1 | 8.9 | 2.3 | 14.6 | 25.8 | 6.2 | 3.7 | 21.8 | 31.7 |
| 11 | 21/5/07 | 21.8 | 5º | 17.5 | 55.2 | 97.8 | 170.5 | 7.0 | 17.8 | 27.6 | 52.4 | 2.3 | 5.8 | 15.3 | 23.4 | 7.6 | 13.1 | 13.5 | 34.3 | 9.2 | 5.6 | 13.0 | 27.8 |
| | | | 15º | 49.8 | 54.0 | 114.9 | 218.7 | 5.0 | 10.1 | 18.9 | 34.0 | 12.0 | 10.6 | 27.2 | 49.8 | 5.0 | 8.7 | 17.1 | 30.8 | 7.6 | 6.9 | 16.8 | 31.3 |
| | | | 25º | 49.7 | 34.7 | 118.7 | 203.1 | 9.0 | 4.0 | 18.5 | 31.7 | 7.3 | 5.8 | 24.7 | 37.8 | 12.9 | 5.6 | 19.8 | 38.3 | 6.0 | 5.2 | 18.7 | 29.9 |
| | | | 35º | 64.0 | 24.7 | 121.3 | 210.0 | 12.3 | 9.0 | 41.5 | 62.8 | 7.6 | 2.1 | 11.0 | 20.6 | 13.5 | 7.8 | 28.7 | 50.0 | 8.0 | 5.8 | 11.3 | 25.1 |
| 12 | 22/5/07 | 10.8 | 5º | 17.8 | 35.1 | 85.0 | 137.9 | 1.1 | 2.1 | 11.9 | 15.1 | 2.8 | 4.5 | 15.0 | 22.3 | 1.8 | 7.7 | 13.8 | 23.3 | 12.9 | 5.6 | 15.5 | 34.0 |
| | | | 15º | 28.1 | 33.4 | 90.8 | 152.3 | 5.3 | 5.2 | 19.7 | 30.2 | 4.5 | 7.1 | 24.6 | 36.2 | 4.2 | 5.2 | 17.7 | 27.1 | 3.8 | 5.1 | 19.7 | 29.6 |
| | | | 25º | 16.0 | 44.4 | 90.5 | 150.9 | 9.3 | 2.6 | 17.6 | 29.5 | 7.3 | 3.8 | 23.8 | 34.9 | 10.2 | 4.6 | 18.3 | 33.1 | 5.4 | 3.7 | 13.7 | 22.8 |
| | | | 35º | 44.9 | 7.8 | 83.8 | 136.5 | 8.4 | 1.2 | 19.0 | 28.6 | 9.0 | 3.6 | 19.6 | 32.2 | 6.2 | 2.6 | 15.4 | 24.2 | 8.5 | 3.0 | 18.3 | 26.8 |
| 13 | 27/5/07 | 26.9 | 5º | 37.0 | 47.3 | 112.3 | 196.6 | 1.9 | 13.4 | 19.4 | 34.7 | 7.6 | 5.0 | 11.4 | 24.0 | 1.9 | 8.6 | 12.1 | 22.6 | 2.8 | 3.6 | 11.9 | 18.3 |
| | | | 15º | 40.1 | 45.4 | 118.7 | 204.2 | 3.1 | 6.0 | 12.8 | 21.9 | 5.4 | 7.1 | 20.4 | 32.9 | 3.0 | 3.0 | 11.1 | 17.1 | 1.5 | 3.5 | 12.1 | 17.1 |
| | | | 25º | 47.1 | 33.1 | 121.4 | 201.6 | 7.0 | 3.5 | 16.5 | 27.0 | 4.0 | 6.2 | 24.7 | 34.9 | 7.3 | 4.7 | 16.8 | 28.8 | 4.0 | 3.3 | 16.4 | 23.7 |
| | | | 35º | 68.9 | 23.4 | 121.6 | 213.9 | 12.6 | 7.1 | 36.3 | 56.0 | 10.8 | 5.3 | 22.3 | 38.4 | 13.8 | 5.1 | 32.1 | 51.0 | 9.9 | 5.4 | 19.6 | 34.9 |
| 14 | 1/6/07 | 49.2 | 5º | 66.5 | 104.2 | 322.1 | 492.8 | 7.8 | 25.8 | 55.3 | 88.9 | 7.9 | 16.6 | 42.9 | 67.4 | 8.2 | 28.8 | 47.9 | 84.9 | 4.6 | 19.5 | 43.6 | 67.7 |
| | | | 15º | 91.7 | 111.4 | 353.0 | 556.1 | 15.5 | 12.6 | 38.6 | 66.7 | 12.6 | 21.4 | 61.1 | 95.1 | 13.7 | 14.0 | 49.1 | 76.8 | 11.0 | 12.9 | 54.0 | 77.9 |
| | | | 25º | 143.2 | 75.7 | 373.4 | 594.3 | 27.3 | 11.9 | 58.1 | 97.3 | 24.8 | 11.7 | 64.5 | 101.0 | 29.9 | 13.1 | 58.1 | 101.1 | 13.6 | 8.8 | 46.8 | 69.2 |
| | | | 35º | 245.2 | 49.2 | 333.3 | 627.7 | 38.3 | 7.7 | 64.4 | 110.4 | 46.3 | 13.4 | 68.5 | 128.2 | 43.1 | 11.8 | 69.9 | 124.8 | 31.7 | 15.1 | 59.4 | 106.2 |
| 15 | 3/6/07 | 45.1 | 5º | 89.6 | 89.4 | 399.9 | 578.9 | 18.2 | 24.7 | 72.5 | 115.4 | 15.7 | 21.0 | 69.0 | 105.7 | 17.0 | 31.8 | 71.6 | 120.4 | 53.1 | 24.7 | 58.0 | 135.8 |
| | | | 15º | 134.5 | 14.3 | 455.4 | 604.2 | 9.5 | 34.0 | 62.5 | 106.0 | 40.6 | 31.6 | 110.8 | 183.0 | 38.7 | 16.2 | 69.2 | 124.1 | 25.6 | 19.8 | 74.0 | 119.4 |
| | | | 25º | 184.2 | 96.7 | 395.6 | 676.5 | 16.9 | 17.0 | 78.3 | 112.2 | 54.3 | 17.2 | 104.9 | 176.4 | 53.1 | 17.5 | 69.6 | 140.2 | 32.8 | 54.6 | 61.6 | 149.0 |
| | | | 35º | 184.4 | 23.1 | 274.8 | 482.3 | 54.1 | 7.7 | 82.1 | 143.9 | 72.7 | 11.9 | 94.8 | 179.4 | 48.5 | 12.3 | 67.2 | 128.0 | 49.3 | 14.0 | 60.0 | 123.3 |
| 16 | 7/6/07 | 36.7 | 5º | 32.4 | 60.9 | 132.1 | 225.5 | 7.5 | 16.5 | 41.0 | 65.0 | 5.1 | 13.1 | 34.9 | 53.1 | 5.9 | 14.1 | 31.6 | 51.6 | 2.8 | 9.8 | 25.5 | 38.1 |
| | | | 15º | 59.4 | 57.3 | 157.1 | 273.8 | 12.1 | 9.5 | 39.0 | 60.6 | 13.3 | 15.2 | 60.1 | 68.6 | 14.8 | 7.7 | 44.8 | 67.3 | 10.9 | 9.5 | 46.3 | 66.7 |
| | | | 25º | 94.7 | 46.4 | 175.3 | 316.4 | 19.5 | 7.4 | 39.0 | 65.9 | 23.9 | 9.9 | 59.9 | 93.7 | 20.1 | 7.2 | 43.4 | 70.7 | 9.9 | 7.8 | 34.9 | 52.6 |
| | | | 35º | 121.7 | 25.4 | 161.1 | 308.2 | 50.7 | 6.3 | 53.6 | 110.6 | 37.1 | 9.1 | 58.1 | 104.3 | 45.0 | 9.1 | 59.2 | 113.3 | 20.0 | 9.2 | 40.4 | 69.6 |

| S/ N | DATE | RAIN-FALL (MM) | S/A | CONTROL (Without mulch) | | | | GROUNDNUT (Mulch) | | | | RICE (Mulch) | | | | GRASS (Mulch) | | | | SOYABEANS (Mulch) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | DS | US | LS | T | DS | US | LS | T | DS | US | LS | T | DS | US | LS | T | DS | US | LS | T |
| 17 | 10/6/07 | 51.3 | 5º | 49.1 | 63.3 | 160.5 | 273.2 | 9.2 | 26.7 | 58.4 | 94.3 | 3.6 | 13.2 | 35.6 | 52.4 | 5.1 | 16.4 | 34.8 | 56.3 | 2.5 | 8.8 | 21.6 | 32.9 |
| | | | 15º | 79.8 | 68.1 | 228.2 | 376.1 | 17.7 | 10.6 | 41.8 | 70.1 | 22.9 | 16.5 | 72.2 | 111.6 | 12.3 | 8.8 | 52.5 | 73.6 | 11.8 | 11.3 | 50.5 | 73.1 |
| | | | 25º | 113.4 | 9.1 | 223.6 | 246.6 | 26.2 | 7.4 | 47.1 | 80.7 | 28.7 | 12.6 | 70.8 | 112.1 | 29.0 | 8.6 | 53.4 | 91.0 | 18.8 | 7.8 | 44.1 | 70.7 |
| | | | 35º | 159.5 | 24.3 | 203.7 | 387.5 | 55.3 | 8.2 | 60.3 | 124.8 | 50.8 | 9.2 | 67.1 | 127.1 | 57.1 | 10.1 | 67.1 | 134.3 | 26.5 | 6.6 | 43.9 | 77.0 |
| 18 | 13/6/07 | 8.9 | 5º | 13.5 | 35.5 | 83.4 | 132.4 | 2.6 | 7.9 | 20.7 | 31.2 | 3.0 | 7.5 | 17.2 | 27.7 | 3.6 | 6.3 | 14.5 | 24.4 | 3.9 | 0.6 | 11.9 | 16.5 |
| | | | 15º | 31.7 | 41.2 | 91.1 | 164.0 | 6.6 | 3.9 | 16.6 | 27.1 | 7.4 | 4.9 | 28.3 | 40.6 | 5.5 | 3.1 | 20.5 | 29.1 | 4.5 | 4.3 | 21.5 | 31.3 |
| | | | 25º | 51.2 | 11.6 | 85.2 | 148.0 | 7.0 | 3.3 | 19.1 | 29.4 | 11.4 | 3.6 | 28.9 | 43.8 | 11.1 | 3.8 | 19.3 | 34.2 | 7.5 | 2.1 | 15.8 | 25.4 |
| | | | 35º | 56.1 | 7.7 | 86.5 | 150.3 | 16.2 | 2.4 | 28.3 | 46.9 | 18.2 | 3.0 | 28.8 | 50.0 | 15.8 | 3.9 | 26.8 | 46.5 | 7.7 | 2.8 | 15.7 | 26.2 |
| 19 | 16/6/07 | 12.2 | 5º | 34.1 | 28.5 | 101.7 | 164.3 | 3.9 | 6.8 | 18.2 | 28.9 | 4.4 | 6.8 | 17.3 | 28.5 | 3.1 | 4.7 | 13.2 | 21.0 | 2.6 | 4.7 | 14.5 | 21.8 |
| | | | 15º | 42.0 | 21.7 | 99.9 | 163.6 | 8.7 | 3.5 | 14.2 | 26.4 | 10.4 | 4.7 | 28.2 | 43.3 | 8.8 | 3.8 | 16.6 | 29.2 | 5.7 | 5.1 | 15.8 | 26.6 |
| | | | 25º | 57.8 | 12.7 | 95.5 | 166.0 | 6.8 | 2.5 | 12.1 | 21.4 | 16.7 | 4.1 | 23.5 | 44.8 | 10.3 | 3.0 | 15.3 | 28.6 | 8.5 | 2.9 | 12.8 | 24.2 |
| | | | 35º | 63.5 | 3.7 | 61.8 | 129.0 | 16.6 | 3.6 | 17.8 | 38.0 | 19.8 | 3.7 | 23.3 | 46.8 | 16.5 | 2.0 | 14.7 | 33.2 | 7.0 | 2.0 | 10.2 | 19.4 |
| 20 | 29/6/07 | 9.3 | 5º | 21.1 | 8.6 | 55.2 | 84.7 | 1.6 | 4.3 | 3.9 | 9.8 | 1.5 | 3.0 | 5.9 | 14.4 | 4.6 | 1.3 | 7.7 | 13.6 | 1.8 | 2.2 | 5.4 | 9.4 |
| | | | 15º | 33.0 | 4.5 | 54.7 | 92.5 | 4.2 | 1.3 | 6.1 | 11.6 | 2.1 | 1.0 | 3.9 | 7.0 | 1.9 | 0.6 | 5.0 | 7.5 | 2.2 | 0.5 | 5.8 | 8.5 |
| | | | 25º | 38.1 | 1.3 | 53.9 | 93.3 | 2.6 | 1.5 | 4.7 | 8.2 | 4.3 | 2.0 | 6.9 | 13.2 | 3.4 | 1.4 | 6.2 | 11.0 | 2.2 | 2.9 | 6.0 | 11.1 |
| | | | 35º | 51.0 | 0.5 | 35.7 | 85.2 | 6.1 | 1.4 | 5.0 | 12.5 | 6.4 | 1.9 | 3.4 | 11.7 | 3.4 | 0.8 | 13.7 | 17.9 | 3.7 | 1.9 | 3.6 | 9.2 |
| 21 | 30/6/07 | 11.9 | 5º | 14.2 | 16.3 | 64.5 | 95.0 | Ns | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | | | 15º | 22.7 | 13.9 | 64.1 | 100.7 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | | | 25º | 29.5 | 2.7 | 57.6 | 99.8 | - | - | - | - | 1.3 | 0.5 | 3.7 | 5.5 | - | - | - | - | - | - | - | - |
| | | | 35º | 36.5 | - | 47.3 | 83.8 | - | - | - | - | - | - | - | - | - | - | - | - | 2.2 | - | 5.1 | 7.3 |
| 22 | 13/7/07 | 15.5 | 5º | 30.2 | 36.0 | 94.1 | 160.3 | 3.2 | 4.8 | 16.9 | 23.9 | 2.0 | 2.0 | 6.6 | 10.6 | 4.4 | 5.2 | 10.1 | 19.7 | 4.4 | 5.8 | 9.9 | 20.1 |
| | | | 15º | 34.3 | 21.9 | 89.4 | 145.6 | 5.7 | 5.2 | 8.8 | 21.7 | 1.8 | 2.8 | 5.7 | 10.3 | 3.5 | 4.0 | 9.3 | 16.8 | 2.9 | 1.7 | 10.7 | 15.3 |
| | | | 25º | 58.3 | 9.1 | 92.6 | 160.0 | 2.9 | 1.7 | 9.9 | 13.0 | 4.2 | 2.6 | 11.6 | 18.4 | 4.1 | 4.3 | 8.3 | 16.7 | 1.5 | 4.2 | 8.1 | 13.8 |
| | | | 35º | 65.5 | 4.3 | 77.0 | 146.8 | 9.0 | 1.0 | 10.1 | 20.1 | 5.2 | 0.9 | 8.4 | 14.5 | 4.2 | 1.4 | 13.8 | 19.4 | 8.4 | 1.8 | 13.4 | 23.6 |
| 23 | 14/7/07 | 9.3 | 5º | 15.2 | 9.3 | 50.9 | 75.5 | - | - | - | | - | - | - | | - | - | - | | - | - | - | |
| | | | 15º | 16.6 | 6.8 | 48.3 | 75.7 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | | | 25º | 28.7 | 1.6 | 39.9 | 70.2 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | | | 35º | 31.9 | - | 29.7 | 61.6 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 24 | 20/7/07 | 16.0 | 5º | 30.2 | 16.6 | 75.4 | 122.2 | 3.1 | 2.8 | 9.0 | 14.9 | 2.6 | 1.6 | 3.3 | 7.5 | 6.0 | 2.0 | 8.1 | 16.1 | 1.2 | 2.3 | 4.9 | 8.4 |
| | | | 15º | 30.1 | 8.4 | 63.1 | 101.6 | 2.8 | 5.0 | 5.7 | 13.5 | 1.3 | 1.1 | 5.3 | 7.7 | 1.5 | 2.8 | 5.6 | 9.9 | 0.9 | - | 3.4 | 4.3 |
| | | | 25º | 44.9 | 3.6 | 64.6 | 113.1 | 3.1 | 1.0 | 7.9 | 12.0 | 1.7 | 0.5 | 8.4 | 10.6 | 3.4 | 2.4 | 7.2 | 13.0 | 2.0 | 0.5 | 6.6 | 9.2 |
| | | | 35º | 53.8 | 0.4 | 54.0 | 107.8 | 4.0 | - | 4.1 | 8.1 | 5.1 | - | 8.0 | 13.1 | 2.3 | - | 5.2 | 7.5 | 3.5 | - | 3.2 | 5.7 |
| 25 | 22/7/07 | 5.1 | 5º | 10.0 | 5.3 | 32.2 | 47.5 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | | | 15º | 12.3 | 3.9 | 23.1 | 39.3 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |

| S/N | DATE | RAIN-FALL (MM) | S/A | CONTROL (Without mulch) | | | | GROUNDNUT (Mulch) | | | | RICE (Mulch) | | | | GRASS (Mulch) | | | | SOYABEANS (Mulch) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | DS | US | LS | T | DS | US | LS | T | DS | US | LS | T | DS | US | LS | T | DS | US | LS | T |
| | | | 25º | 15.5 | 1.9 | 20.9 | 38.3 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | | | 35º | 20.6 | - | 18.6 | 39.2 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 26 | 27/7/07 | 6.2 | 5º | 5.9 | 4.9 | 26.3 | 37.1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | | | 15º | 7.4 | 2.5 | 22.7 | 32.6 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | | | 25º | 9.1 | 0.8 | 19.6 | 29.5 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | | | 35º | 8.3 | - | 13.0 | 21.3 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 27 | 28/7/07 | 17.6 | 5º | 51.9 | 16.3 | 93.4 | 161.6 | 2.1 | 2.6 | 10.3 | 15.0 | 1.5 | 2.3 | 8.5 | 11.3 | 6.1 | 2.2 | 11.7 | 20.0 | 2.8 | 4.6 | 9.2 | 16.6 |
| | | | 15º | 53.2 | 10.7 | 80.3 | 144.0 | 3.3 | 0.9 | 5.1 | 9.3 | 1.0 | 1.3 | 4.6 | 6.9 | 1.8 | 1.7 | 9.5 | 13.0 | 2.0 | 0.5 | 5.0 | 7.7 |
| | | | 25º | 63.7 | 3.9 | 73.0 | 139.6 | 2.3 | - | 5.2 | 7.5 | 3.0 | - | 7.0 | 10.0 | 4.7 | - | 6.9 | 11.6 | 3.0 | - | 7.0 | 10.0 |
| | | | 35º | 73.0 | - | 58.1 | 131.1 | 2.1 | - | 4.5 | 6.6 | 4.2 | - | 8.9 | 12.6 | 5.3 | - | 7.6 | 12.9 | 3.5 | - | 3.1 | 6.6 |
| 28 | 29/7/07 | 23.7 | 5º | 30.6 | 12.9 | 84.9 | 128.4 | 1.1 | 1.3 | 5.5 | 7.9 | 2.5 | 1.8 | 4.5 | 8.8 | 3.7 | 1.4 | 8.7 | 13.8 | 1.2 | 1.5 | 5.1 | 7.8 |
| | | | 15º | 46.8 | 9.5 | 71.4 | 126.7 | 1.8 | 0.7 | 3.1 | 5.6 | .6 | 1.1 | 4.7 | 6.4 | 1.3 | 3.1 | 6.2 | 10.6 | 3.1 | - | 6.7 | 9.8 |
| | | | 25º | 55.3 | 2.2 | 61.3 | 118.8 | 1.8 | 0.5 | 5.2 | 7.5 | 1.7 | 0.6 | 4.2 | 6.5 | 2.0 | 1.0 | 6.6 | 9.6 | 1.8 | 0.7 | 3.7 | 6.2 |
| | | | 35º | 44.8 | - | 47.4 | 92.2 | - | - | - | - | 2.9 | - | 5.1 | 8.0 | 1.2 | - | 3.8 | 5.0 | - | - | - | - |
| 29 | 1/8/07 | 4.6 | 5º | 6.5 | 3.3 | 18.2 | 28.0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | | | 15º | 8.0 | - | 19.8 | 27.8 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | | | 25º | 8.9 | - | 18.2 | 27.1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | | | 35º | 3.6 | - | 10.3 | 13.9 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 30 | 4/8/07 | 52.8 | 5º | 79.1 | 41.1 | 168.7 | 288.9 | 3.2 | 8.1 | 32.9 | 44.2 | 8.0 | 11.3 | 26.6 | 48.9 | 15.2 | 8.6 | 40.7 | 64.5 | 5.5 | 9.8 | 22.0 | 37.3 |
| | | | 15º | 173.4 | 29.2 | 108.9 | 311.5 | 13.5 | 4.3 | 20.6 | 38.3 | 4.3 | 4.3 | 19.5 | 28.1 | 6.3 | 9.7 | 25.2 | 41.2 | 8.8 | 6.9 | 4.9 | 17.6 |
| | | | 25º | 132.6 | 11.6 | 159.5 | 303.7 | 6.9 | 2.3 | 18.8 | 28.0 | 10.4 | 5.7 | 32.5 | 48.6 | 12.4 | 5.7 | 24.6 | 42.7 | - | 3.8 | 20.8 | 24.6 |
| | | | 35º | 126.1 | 3.6 | 114.7 | 244.4 | 9.8 | 7.0 | 22.8 | 39.6 | 10.5 | 0.9 | 20.8 | 32.2 | 16.0 | - | 23.5 | 39.5 | 7.8 | - | 3.7 | 11.5 |
| 31 | 5/8/07 | 15.4 | 5º | 16.8 | 8.1 | 48.3 | 73.2 | 0.7 | - | 5.2 | 5.9 | 1.8 | - | 5.4 | 7.2 | 3.5 | - | 5.7 | 9.2 | 0.7 | - | 4.9 | 5.6 |
| | | | 15º | 19.1 | 4.9 | 49.1 | 73.1 | - | - | 5.7 | 5.7 | - | - | 4.6 | 4.6 | 2.6 | 1.6 | 4.8 | 8.5 | 2.2 | - | 6.8 | 9.0 |
| | | | 25º | 32.4 | 1.4 | 39.0 | 72.8 | - | - | 4.5 | 4.5 | 3.3 | - | 4.1 | 7.4 | 2.5 | 0.7 | 2.2 | 5.4 | - | - | 4.3 | 4.3 |
| | | | 35º | 35.5 | - | 30.7 | 66.2 | - | - | 2.9 | 2.9 | 2.7 | - | 5.2 | 7.9 | - | - | - | - | - | - | - | - |
| 32 | 9/8/07 | 10.8 | 5º | 12.6 | 9.8 | 50.3 | 72.7 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | | | 15º | 18.9 | 8.7 | 50.5 | 78.1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | | | 25º | 28.5 | 3.1 | 39.5 | 71.1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | | | 35º | 25.3 | - | 28.5 | 53.8 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 33 | 13/8/07 | 78.7 | 5º | 60.6 | 42.9 | 148.7 | 252.2 | 7.2 | 10.4 | 27.6 | 45.2 | 14.3 | 14.8 | 49.3 | 77.9 | 17.6 | 12.9 | 42.9 | 73.4 | 6.5 | 11.7 | 31.2 | 43.4 |
| | | | 15º | 112.1 | 43.5 | 171.5 | 327.4 | 17.4 | 6.3 | 29.0 | 52.7 | 5.5 | 6.3 | 21.5 | 33.3 | 6.6 | 14.4 | 22.6 | 43.6 | 12.9 | 4.6 | 24.6 | 42.1 |
| | | | 25º | 129.4 | 16.4 | 154.0 | 299.8 | 8.3 | 3.3 | 22.9 | 34.5 | 12.4 | 9.9 | 47.4 | 69.7 | 14.1 | 10.9 | 37.6 | 62.6 | 8.7 | 6.2 | 25.0 | 39.9 |
| | | | 35º | 126.0 | 9.0 | 126.5 | 261.5 | 12.0 | 1.7 | 30.8 | 44.5 | 20.4 | - | 35.2 | 55.6 | 19.9 | - | 30.0 | 49.9 | 15.0 | - | 24.3 | 39.3 |

| S/N | DATE | RAIN-FALL (MM) | S/A | CONTROL (Without mulch) | | | | GROUNDNUT (Mulch) | | | | RICE (Mulch) | | | | GRASS (Mulch) | | | | SOYABEANS (Mulch) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | DS | US | LS | T | DS | US | LS | T | DS | US | LS | T | DS | US | LS | T | DS | US | LS | T |
| 34 | 16/8/07 | 41.6 | 5º | 44.2 | 49.9 | 114.0 | 208.1 | 10.9 | 13.0 | 48.6 | 72.5 | 22.9 | 26.7 | 65.6 | 115.2 | 17.3 | 19.6 | 53.1 | 90.0 | 6.9 | 12.9 | 34.3 | 54.1 |
| | | | 15º | 59.6 | 40.5 | 137.0 | 232.1 | 25.2 | 17.2 | 49.1 | 91.5 | 20.0 | 12.7 | 58.4 | 91.1 | 12.9 | 11.7 | 31.0 | 55.6 | 22.4 | 8.0 | 47.7 | 78.1 |
| | | | 25º | 76.8 | 23.7 | 127.7 | 228.2 | 14.0 | 6.2 | 32.9 | 53.1 | 19.9 | 13.8 | 50.5 | 84.2 | 15.3 | 10.2 | 36.4 | 61.9 | 11.2 | 4.4 | 36.0 | 51.6 |
| | | | 35º | 100.3 | 14.9 | 124.6 | 239.8 | 36.1 | 6.3 | 56.6 | 99.0 | 48.0 | 10.9 | 70.1 | 129.0 | 37.6 | 7.2 | 56.7 | 101.5 | 34.9 | 8.3 | 33.8 | 77.0 |
| 35 | 20/8/07 | 18.1 | 5º | 22.9 | 10.8 | 56.2 | 89.9 | 3.4 | 6.6 | 16.1 | 26.1 | 9.0 | 7.8 | 26.6 | 43.4 | 5.7 | 4.4 | 14.5 | 24.6 | 3.2 | 1.6 | 9.7 | 14.5 |
| | | | 15º | 24.3 | 4.0 | 50.2 | 78.5 | 8.0 | 2.7 | 9.8 | 20.5 | 7.1 | 3.2 | 18.3 | 28.6 | 3.9 | 0.8 | 8.1 | 12.8 | 3.9 | 2.5 | 8.1 | 14.5 |
| | | | 25º | 34.5 | 3.9 | 54.0 | 92.4 | 5.9 | 1.0 | 9.9 | 16.8 | 1.1 | 7.7 | 9.5 | 18.3 | 6.3 | 1.9 | 12.7 | 20.9 | 4.7 | 1.2 | 4.0 | 9.9 |
| | | | 35º | 50.9 | - | 38.5 | 89.4 | 7.9 | - | 11.8 | 19.7 | 27.5 | 3.1 | 14.9 | 45.5 | 10.9 | 0.8 | 9.7 | 21.4 | 4.6 | 0.7 | 5.6 | 10.9 |
| 36 | 24/8/07 | 47.1 | 5º | 41.6 | 27.8 | 90.0 | 159.4 | 9.0 | 9.9 | 38.6 | 57.5 | 26.8 | 13.2 | 52.8 | 92.6 | 15.2 | 20.7 | 44.6 | 80.5 | 7.9 | 5.8 | 27.0 | 40.7 |
| | | | 15º | 60.7 | 26.5 | 121.0 | 208.2 | 20.4 | 5.2 | 26.8 | 52.4 | 18.0 | 7.3 | 50.5 | 75.8 | 8.5 | 10.4 | 28.3 | 47.2 | 14.9 | 6.7 | 27.5 | 49.1 |
| | | | 25º | 83.9 | 12.0 | 92.8 | 188.7 | 7.1 | .8 | 18.9 | 26.8 | 17.7 | 4.6 | 29.4 | 51.7 | 11.6 | - | 20.5 | 32.1 | 11.6 | 2.6 | 11.0 | 25.2 |
| | | | 35º | 82.5 | 3.8 | 82.8 | 169.1 | 21.3 | 1.7 | 37.1 | 60.1 | 43.8 | - | 51.4 | 95.2 | 26.7 | 1.1 | 31.0 | 58.8 | 5.7 | - | 3.1 | 8.8 |
| 37 | 25/8/07 | 8.3 | 5º | 4.9 | 4.2 | 18.8 | 27.9 | 1.2 | 2.0 | 3.2 | 6.4 | 3.1 | 2.4 | 7.3 | 12.8 | 1.5 | 1.7 | 4.7 | 7.9 | - | - | - | - |
| | | | 15º | 7.5 | 3.8 | 22.1 | 33.4 | 3.8 | 1.1 | 5.5 | 10.4 | 2.8 | 1.5 | 5.6 | 9.9 | 0.7 | 1.2 | 2.8 | 4.7 | 2.8 | 1.1 | 4.4 | 8.3 |
| | | | 25º | 6.9 | - | 14.1 | 21.0 | 1.6 | 0.7 | 3.5 | 5.8 | 3.4 | - | 5.1 | 8.4 | 1.9 | 1.1 | 4.2 | 7.2 | 2.0 | 0.7 | 3.0 | 5.7 |
| | | | 35º | 7.7 | 1.2 | 8.5 | 17.4 | - | - | - | - | 3.9 | - | 4.8 | 8.7 | - | - | - | - | - | - | - | - |
| 38 | 29/8/07 | 5.7 | 5º | 17.6 | 9.3 | 44.5 | 71.4 | 5.2 | 2.8 | 14.0 | 22.0 | 4.4 | 3.1 | 6.3 | 13.7 | 9.1 | 3.5 | 19.1 | 31.7 | 3.5 | 2.7 | 11.0 | 17.2 |
| | | | 15º | 30.1 | 4.9 | 49.9 | 84.9 | 9.7 | 2.3 | 9.7 | 21.7 | 4.2 | 1.3 | 8.3 | 13.8 | 3.8 | 2.5 | 12.5 | 18.8 | 5.5 | 1.7 | 9.9 | 17.1 |
| | | | 25º | 25.0 | 1.6 | 32.4 | 59.0 | 3.9 | 0.8 | 8.1 | 12.8 | 5.4 | - | 6.4 | 11.8 | 5.6 | 1.5 | 8.5 | 15.6 | 6.6 | 1.0 | 4.2 | 11.8 |
| | | | 35º | 28.1 | 1.0 | 21.2 | 50.3 | 7.5 | - | 9.8 | 17.3 | - | - | 2.8 | 2.8 | 9.7 | - | 7.0 | 16.7 | - | - | 5.6 | 5.6 |
| 39 | 3/9/07 | 14.4 | 5º | 2.6 | 1.2 | 8.0 | 11.8 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | | | 15º | 4.4 | 1.2 | 8.2 | 13.8 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | | | 25º | 4.8 | 1.9 | 6.9 | 13.6 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | | | 35º | 5.8 | - | 4.8 | 10.6 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 40 | 4/9/07 | 20.2 | 5º | 22.6 | 14.2 | 68.5 | 105.3 | 7.9 | 4.9 | 18.8 | 31.6 | 3.5 | 4.0 | 9.9 | 17.4 | 8.1 | 4.6 | 21.9 | 34.6 | 3.1 | 4.9 | 10.0 | 18.0 |
| | | | 15º | 40.2 | 14.4 | 71.9 | 126.5 | 11.0 | 2.7 | 15.3 | 29.0 | 4.0 | 2.0 | 9.5 | 15.5 | 2.5 | 2.3 | 9.6 | 14.4 | 4.9 | 3.3 | 11.1 | 19.3 |
| | | | 25º | 52.7 | 4.4 | 61.9 | 119.0 | 8.1 | 1.3 | 14.1 | 23.5 | 6.8 | - | 12.2 | 19.0 | 8.4 | 1.6 | 8.5 | 18.5 | 8.8 | 1.5 | 7.9 | 18.2 |
| | | | 35º | 45.6 | - | 38.3 | 83.9 | 11.2 | - | 16.8 | 28.0 | 5.5 | 1.8 | 4.7 | 12.0 | 10.0 | - | 11.6 | 21.6 | 3.8 | 1.3 | 6.2 | 11.3 |
| 41 | 5/9/07 | 13.5 | 5º | 4.9 | 2.7 | 18.8 | 26.4 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | | | 15º | 5.3 | 1.7 | 17.1 | 22.1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | | | 25º | 8.3 | .5 | 12.1 | 20.9 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | | | 35º | 5.0 | .6 | 7.1 | 12.6 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 42 | 6/9/07 | 33.7 | 5º | 50.4 | 17.7 | 73.8 | 141.9 | 13.5 | 7.7 | 49.2 | 70.4 | 7.0 | 6.2 | 21.1 | 34.3 | 16.0 | 7.0 | 26.2 | 49.2 | 7.3 | 4.9 | 18.8 | 31.0 |
| | | | 15º | 45.8 | 7.9 | 73.3 | 127.0 | 22.2 | 2.7 | 26.8 | 51.7 | 5.7 | 2.0 | 15.7 | 23.4 | 6.8 | 3.9 | 39.1 | 49.8 | 9.2 | 2.7 | 21.8 | 33.7 |

| S/N | DATE | RAIN-FALL (MM) | S/A | CONTROL (Without mulch) | | | | GROUNDNUT (Mulch) | | | | RICE (Mulch) | | | | GRASS (Mulch) | | | | SOYABEANS (Mulch) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | DS | US | LS | T | DS | US | LS | T | DS | US | LS | T | DS | US | LS | T | DS | US | LS | T |
| | | | 25º | 58.1 | 3.0 | 64.7 | 125.8 | 16.8 | 1.4 | 20.1 | 38.3 | 12.2 | 1.1 | 20.1 | 33.4 | 14.6 | 1.9 | 20.8 | 37.3 | 9.6 | 1.2 | 9.2 | 20.0 |
| | | | 35º | 56.5 | - | 42.0 | 98.5 | 17.7 | 0.9 | 30.9 | 49.5 | 5.1 | 1.0 | 5.6 | 11.8 | 14.5 | - | 12.5 | 27.0 | 3.2 | - | 5.8 | 9.0 |
| 43 | 8/9/07 | 27.9 | 5º | 18.8 | 13.1 | 69.0 | 100.9 | 5.4 | 10.1 | 23.4 | 38.9 | 3.5 | 3.8 | 16.6 | 23.9 | 5.4 | 10.0 | 26.9 | 42.3 | 3.9 | 6.0 | 15.8 | 25.7 |
| | | | 15º | 29.1 | 23.9 | 76.1 | 129.1 | 7.2 | 1.5 | 13.8 | 22.5 | 4.1 | 11.0 | 10.3 | 25.4 | 3.7 | 4.5 | 16.5 | 24.7 | 6.3 | 3.3 | 14.6 | 24.2 |
| | | | 25º | 11.6 | 38.6 | 61.6 | 111.8 | 8.9 | 4.9 | 24.3 | 38.1 | 5.4 | 3.0 | 18.2 | 26.6 | 4.8 | 3.3 | 15.8 | 23.9 | 6.2 | 1,8 | 6.8 | 14.8 |
| | | | 35º | 48.5 | 6.8 | 62.4 | 117.7 | 12.4 | 5.8 | 43.7 | 51.9 | 7.2 | 3.5 | 14.0 | 24.7 | 14.8 | 3.8 | 24.8 | 43.4 | 4.2 | 6.5 | 15.9 | 25.6 |
| 44 | 9/9/07 | 18.2 | 5º | 8.3 | 5.8 | 32.9 | 47.0 | 2.4 | 2.9 | 10.3 | 15.6 | 2.1 | 4.4 | 9.1 | 15.6 | 5.0 | 4.0 | 13.5 | 22.5 | 1.3 | 3.0 | 9.0 | 13.3 |
| | | | 15º | 12.6 | 6.8 | 45.5 | 64.9 | 2.0 | 2.0 | 8.3 | 12.3 | 3.6 | 2.7 | 6.7 | 13.0 | 2.4 | 2.8 | 8.4 | 13.6 | 3.2 | 1.4 | 6.6 | 11.2 |
| | | | 25º | 21.0 | 2.9 | 29.7 | 53.6 | 1.1 | 1.1 | 9.6 | 11.8 | 1.8 | 1.4 | 7.0 | 10.2 | 3.3 | 0.9 | 8.3 | 12.5 | 3.4 | 0.5 | 3.2 | 7.1 |
| | | | 35º | 22.4 | 1.1 | 22.9 | 46.4 | 4.3 | 1.1 | 13.7 | 19.1 | 3.8 | 0.7 | 5.6 | 8.1 | 5.8 | 0.5 | 8.7 | 15.0 | 6.4 | 0.9 | 1.9 | 9.2 |
| 45 | 16/9/07 | 51.8 | 5º | 71.4 | 69.3 | 198.6 | 339.3 | 27.0 | 14.8 | 88.5 | 130.3 | 18.4 | 18.0 | 52.7 | 89.1 | 22.5 | 35.7 | 73.4 | 131.6 | 10.7 | 20.3 | 47.8 | 78.8 |
| | | | 15º | 106.8 | 58.4 | 226.6 | 391.5 | 42.6 | 15.7 | 65.8 | 124.1 | 28.7 | 12.0 | 51.5 | 92.9 | 18.1 | 24.9 | 60.4 | 103.4 | 27.6 | 11.4 | 52.9 | 91.9 |
| | | | 25º | 127.7 | 31.0 | 176.9 | 335.6 | 31.2 | 13.0 | 69.2 | 113.4 | 31.0 | 10.0 | 56.8 | 96.8 | 27.9 | 14.2 | 64.8 | 106.9 | 44.6 | 13.5 | 60.3 | 118.4 |
| | | | 35º | 133.3 | 11.0 | 142.9 | 287.2 | 50.3 | 11.5 | 76.6 | 138.4 | 6.4 | - | 38.0 | 44.4 | 53.1 | 5.7 | 24.3 | 83.1 | 17.4 | - | 35.1 | 52.5 |
| 46 | 19/9/07 | 27.0 | 5º | 24.8 | 55.6 | 118.4 | 198.8 | 8.9 | 21.0 | 50.6 | 80.5 | 4.7 | 9.6 | 31.1 | 45.4 | 7.7 | 27.9 | 53.1 | 88.7 | 2.7 | 10.5 | 23.1 | 36.3 |
| | | | 15º | 51.6 | 54.8 | 145.5 | 251.9 | 20.2 | 14.7 | 54.2 | 89.1 | 10.5 | 15.7 | 35.8 | 62.0 | 8.6 | 5.8 | 39.1 | 53.5 | 13.3 | 8.6 | 33.5 | 55.4 |
| | | | 25º | 74.1 | 28.6 | 129.5 | 232.2 | 17.6 | 10.8 | 56.7 | 85.1 | 9.6 | 12.2 | 33.0 | 54.8 | 17.9 | 8.8 | 49.4 | 76.1 | 12.8 | 11.4 | 50.8 | 75.0 |
| | | | 35º | 88.8 | 13.8 | 109.9 | 212.5 | 28.4 | 10.8 | 66.0 | 105.2 | 7.8 | 6.0 | 28.9 | 42.7 | 35.1 | 11.7 | 52.1 | 98.9 | 12.2 | 6.3 | 24.2 | 42.7 |
| 47 | 20/9/07 | 80.3 | 5º | 54.8 | 84.1 | 215.2 | 354.4 | 27.2 | 49.6 | 115.4 | 192.2 | 14.0 | 18.7 | 58.5 | 91.2 | 22.5 | 54.5 | 106.8 | 183.8 | 10.5 | 22.4 | 54.4 | 87.3 |
| | | | 15º | 101.0 | 76.1 | 336.8 | 513.9 | 58.3 | 32.8 | 107.8 | 198.9 | 24.5 | 50.0 | 85.9 | 160.4 | 24.5 | 37.2 | 84.5 | 146.2 | 36.5 | 23.7 | 76.4 | 136.6 |
| | | | 25º | 141.3 | 50.6 | 276.1 | 468.0 | 59.1 | 28.4 | 107.7 | 195.2 | 41.1 | 18.6 | 96.7 | 156.4 | 56.9 | 25.5 | 93.8 | 176.2 | 50.0 | 20.1 | 91.5 | 161.5 |
| | | | 35º | 187.4 | 25.5 | 218.0 | 424.9 | 80.8 | 18.1 | 124.2 | 223.1 | 43.9 | 13.8 | 69.5 | 127.2 | 64.0 | 1.2 | 107.2 | 182.4 | 47.0 | 13.1 | 75.4 | 135.5 |
| 48 | 29/9/07 | 8.3 | 5º | 6.0 | 12.3 | 35.0 | 53.9 | 6.5 | 3.5 | 8.2 | 18.2 | 0.5 | 2.9 | 5.7 | 9.1 | 1.1 | 5.3 | 8.7 | 15.1 | 0.8 | 1.5 | 3.1 | 5.4 |
| | | | 15º | 9.2 | 12.4 | 39.3 | 60.9 | 5.6 | 2.0 | 7.4 | 15.0 | 2.3 | 1.6 | 7.3 | 11.2 | 1.5 | 2.5 | 5.3 | 9.3 | 3.3 | - | 4.8 | 8.1 |
| | | | 25º | 17.0 | 5.7 | 22.5 | 45.2 | 2.6 | 1.5 | 6.9 | 11.0 | 2.9 | 1.1 | 7.4 | 11.4 | 5.1 | 1.5 | 7.4 | 14.0 | 4.5 | 1.3 | 8.9 | 14.7 |
| | | | 35º | 12.2 | 2.7 | 32.0 | 46.9 | 5.3 | 1.5 | 12.5 | 19.3 | 4.2 | 1.7 | 22.0 | 27.9 | 6.7 | 0.2 | 6.2 | 13.1 | 3.9 | 1.1 | 5.9 | 10.9 |
| 49 | 30/9/07 | 7.7 | 5º | 6.7 | 4.1 | 19.6 | 30.4 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | | | 15º | 4.5 | 1.1 | 7.7 | 13.3 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | | | 25º | 8.8 | 1.1 | 12.0 | 21.9 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | | | 35º | 8.3 | - | 6.8 | 15.1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 50 | 2/10/07 | 13.5 | 5º | 4.4 | 6.5 | 21.8 | 32.7 | 1.0 | 1.3 | 3.0 | 5.3 | 0.8 | 1.7 | 3.2 | 5.7 | 1.3 | 0.9 | 4.0 | 6.2 | 0.3 | 1.2 | 2.9 | 4.4 |
| | | | 15º | 6.7 | 5.3 | 28.6 | 40.6 | 2.0 | 0.9 | 2.8 | 5.7 | 8.3 | - | 2.2 | 10.5 | 1.6 | 0.4 | 2.2 | 4.2 | 1.3 | 0.1 | 2.3 | 3.7 |
| | | | 25º | 7.6 | 2.9 | 20.6 | 31.1 | 2.4 | 0.2 | 3.1 | 5.7 | 2.3 | 0.2 | 3.5 | 6.0 | 0.2 | 2.9 | 2.9 | 6.0 | 2.7 | 0.1 | 3.4 | 6.2 |
| | | | 35º | 18.7 | 1.3 | 28.6 | 48.6 | 4.0 | 0.1 | 4.9 | 9.0 | 2.4 | 0.5 | 6.3 | 9.2 | 3.6 | 0.1 | 2.3 | 6.0 | 3.1 | - | 2.2 | 5.3 |

| S/N | DATE | RAIN-FALL (MM) | S/A | CONTROL (Without mulch) | | | | GROUNDNUT (Mulch) | | | | RICE (Mulch) | | | | GRASS (Mulch) | | | | SOYABEANS (Mulch) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | DS | US | LS | T | DS | US | LS | T | DS | US | LS | T | DS | US | LS | T | DS | US | LS | T |
| 51 | 7/10/07 | 21.8 | 5º | 3.8 | 8.8 | 25.9 | 38.6 | 0.8 | 2.2 | 5.6 | 8.6 | 0.8 | 2.3 | 4.8 | 7.9 | 1.8 | 2.5 | 7.0 | 11.3 | 0.4 | 1.5 | 4.1 | 6.0 |
| | | | 15º | 13.4 | 14.5 | 78.8 | 106.7 | 2.1 | 2.0 | 4.4 | 8.5 | 1.8 | - | 4.2 | 6.0 | 1.3 | 1.5 | 5.4 | 8.2 | 2.4 | - | 4.9 | 7.3 |
| | | | 25º | 19.3 | 5.3 | 39.2 | 63.8 | 2.4 | 0.2 | 4.9 | 7.5 | 2.8 | 0.3 | 5.0 | 8.1 | 2.8 | 0.6 | 4.1 | 7.5 | 3.6 | 0.5 | 6.7 | 10.8 |
| | | | 35º | 38.6 | 4.2 | 74.5 | 117.3 | 2.9 | 0.5 | 7.7 | 11.1 | 4.5 | 1.0 | 9.4 | 14.9 | 1.7 | 0.8 | 4.8 | 7.3 | 3.4 | - | 4.1 | 7.5 |
| 52 | 9/10/07 | 14.0 | 5º | 1.2 | 5.1 | 10.3 | 16.6 | 0.6 | 3.1 | 6.2 | 9.9 | 0.1 | 1.5 | 3.7 | 5.3 | 1.2 | 2.5 | 6.1 | 9.8 | 0.3 | 1.5 | 4.2 | 6.3 |
| | | | 15º | 8.5 | 12.5 | 52.1 | 73.1 | 0.9 | 2.4 | 6.3 | 9.6 | 1.0 | 0.7 | 3.3 | 5.0 | 0.4 | 1.1 | 4.1 | 5.6 | 1.2 | 0.2 | 4.4 | 5.8 |
| | | | 25º | 11.2 | 3.2 | 24.0 | 38.4 | 2.8 | 0.7 | 5.3 | 8.8 | 2.1 | 0.2 | 4.7 | 7.0 | 2.0 | - | 4.2 | 6.2 | 4.4 | 0.5 | 6.9 | 11.8 |
| | | | 35º | 29.6 | 4.5 | 60.3 | 94.4 | 4.0 | 0.3 | 8.9 | 13.2 | 3.1 | 0.6 | 8.9 | 12.3 | 1.5 | 0.4 | 3.2 | 5.1 | 2.9 | 0.5 | 3.6 | 7.0 |
| 53 | 19/10/07 | 10.3 | 5º | 1.7 | 5.0 | 12.8 | 19.5 | 2.1 | 1.7 | 2.9 | 6.7 | 0.4 | 1.6 | 2.9 | 4.9 | 1.1 | 1.8 | 4.7 | 7.6 | 0.2 | 1.2 | 2.3 | 3.7 |
| | | | 15º | 8.3 | 7.0 | 36.8 | 52.1 | 1.3 | 0.9 | 3.7 | 5.9 | 1.1 | 1.2 | 2.2 | 4.5 | 0.8 | 1.3 | 4.3 | 6.4 | 1.4 | 0.4 | 2.7 | 4.5 |
| | | | 25º | 13.0 | 4.4 | 24.7 | 42.1 | 1.8 | 0.3 | 5.3 | 7.4 | 0.4 | 0.4 | 7.7 | 8.5 | 1.7 | 0.8 | 4.3 | 6.8 | 2.2 | 0.4 | 4.5 | 7.1 |
| | | | 35º | 19.7 | 2.0 | 33.6 | 55.3 | 1.3 | 0.4 | 3.6 | 5.3 | 2.5 | 0.8 | 6.2 | 9.5 | 1.3 | 0.5 | 2.4 | 4.2 | 2.4 | 0.3 | 3.8 | 6.5 |
| 54 | 20/10/07 | 70.5 | 5º | 13.4 | 20.8 | 121.4 | 155.6 | 5.7 | 22.5 | 51.1 | 79.3 | 5.8 | 12.2 | 36.8 | 54.8 | 11.3 | 12.2 | 48.7 | 72.2 | 4.8 | 11.0 | 35.6 | 51.4 |
| | | | 15º | 116.3 | 46.9 | 263.6 | 426.8 | 16.3 | 15.6 | 49.6 | 81.5 | 13.3 | 3.8 | 23.5 | 40.6 | 1.6 | 11.1 | 39.1 | 51.8 | 13.8 | 2.4 | 29.7 | 45.9 |
| | | | 25º | 177.0 | 24.1 | 229.5 | 430.6 | 20.5 | 6.6 | 56.8 | 83.9 | 18.9 | 2.4 | 35.1 | 56.4 | 44.2 | 4.1 | 30.4 | 78.7 | 31.5 | 4.1 | 49.0 | 84.6 |
| | | | 35º | 169.7 | 12.2 | 218.8 | 400.7 | 38.3 | 5.9 | 135.8 | 180.0 | 54.7 | 5.9 | 22.9 | 83.5 | 15.1 | 2.5 | 22.0 | 39.6 | 14.0 | 4.1 | 32.6 | 50.7 |
| 55 | 21/10/07 | 27.9 | 5º | 4.0 | 10.5 | 33.2 | 47.7 | 3.1 | 8.3 | 19.4 | 30.8 | 1.8 | 4.7 | 11.4 | 17.9 | 5.0 | 2.9 | 18.2 | 26.1 | 3.1 | 4.9 | 11.7 | 19.7 |
| | | | 15º | 26.7 | 14.9 | 172.9 | 214.5 | 6.4 | 6.5 | 15.8 | 28.7 | 5.8 | 2.2 | 11.4 | 17.4 | 4.7 | 4.2 | 24.1 | 33.0 | 7.8 | 1.3 | 12.4 | 21.5 |
| | | | 25º | 9.9 | 34.4 | 105.9 | 150.2 | 6.7 | 2.2 | 19.1 | 28.0 | 8.0 | 1.5 | 14.0 | 23.5 | 10.4 | 5.2 | 16.0 | 31.6 | 11.4 | 1.8 | 16.8 | 30.0 |
| | | | 35º | 79.0 | 6.3 | 117.7 | 203.0 | 10.3 | 3.9 | 34.6 | 48.8 | 9.4 | 2.4 | 8.9 | 20.7 | 6.6 | 0.8 | 19.5 | 26.9 | 7.2 | 1.4 | 13.4 | 22.0 |
| 56 | 24/10/07 | 10.9 | 5º | 1.5 | 2.9 | 7.6 | 12.0 | 0.4 | 2.2 | 4.0 | 6.6 | 2.0 | 0.8 | 4.2 | 7.0 | 1.3 | 1.6 | 4.7 | 7.6 | 0.2 | 1.0 | 2.9 | 4.1 |
| | | | 15º | 6.6 | 4.6 | 28.0 | 39.2 | 1.0 | 1.2 | 3.4 | 5.6 | 1.3 | 0.6 | 2.4 | 4.3 | 1.7 | 0.9 | 3.8 | 6.4 | 1.2 | 0.1 | 2.3 | 3.6 |
| | | | 25º | 8.4 | 2.1 | 20.8 | 31.3 | 2.4 | 0.7 | 3.9 | 7.0 | 1.9 | 0.2 | 4.1 | 6.2 | 1.9 | - | 3.8 | 5.7 | 4.0 | - | 4.6 | 8.6 |
| | | | 35º | 14.3 | 1.3 | 20.0 | 35.6 | 1.3 | - | 5.8 | 6.1 | 2.9 | - | 2.2 | 5.1 | 1.4 | - | 2.2 | 3.6 | 1.7 | - | 8.6 | 10.3 |
| 57 | 25/10/07 | 14.5 | 5º | 0.4 | 2.6 | 6.3 | 9.3 | 1.8 | 0.3 | 5.1 | 7.2 | 1.5 | 0.8 | 3.1 | 5.4 | 0.4 | 1.4 | 4.5 | 6.3 | 3.0 | 0.5 | 0.4 | 3.9 |
| | | | 15º | 8.7 | 7.5 | 32.6 | 48.8 | 1.6 | 1.7 | 4.9 | 8.2 | 1.8 | 0.8 | 4.4 | 7.0 | 1.3 | 1.1 | 6.6 | 9.0 | 1.5 | 0.2 | 4.9 | 6.6 |
| | | | 25º | 10.8 | 2.3 | 18.9 | 32.0 | 2.4 | 1.1 | 5.8 | 9.3 | 2.2 | .6 | 4.8 | 7.6 | 2.0 | 2.3 | 4.6 | 8.9 | 2.8 | 0.5 | 6.2 | 9.5 |
| | | | 35º | 18.7 | 1.7 | 27.3 | 47.7 | 2.0 | 0.5 | 9.4 | 11.9 | 2.8 | 0.7 | 6.7 | 10.2 | 1.3 | - | 2.3 | 3.6 | 2.7 | 0.8 | 9.0 | 12.5 |
| 58 | 26/10/07 | 32.6 | 5º | 1.6 | 6.6 | 16.8 | 25.0 | 0.6 | 5.3 | 13.8 | 19.7 | 2.2 | 0.8 | 6.2 | 9.2 | 2.6 | 4.4 | 15.1 | 22.1 | 0.6 | 4.0 | 9.7 | 14.3 |
| | | | 15º | 22.8 | 27.1 | 117.2 | 167.1 | 4.7 | 4.8 | 16.5 | 26.0 | 4.2 | 2.5 | 11.6 | 18.3 | 3.9 | 4.5 | 38.5 | 46.9 | 3.0 | 1.7 | 20.0 | 24.7 |
| | | | 25º | 28.4 | 11.9 | 105.0 | 145.3 | 10.6 | 2.1 | 35.4 | 48.1 | 7.4 | 2.2 | 18.6 | 28.2 | 7.9 | 1.5 | 16.0 | 25.4 | 4.4 | 2.2 | 21.9 | 29.0 |
| | | | 35º | 63.6 | 7.5 | 164.3 | 240.4 | 11.2 | 3.3 | 39.8 | 54.3 | 8.8 | 2.8 | 19.8 | 31.4 | 3.0 | 1.5 | 8.7 | 13.2 | 13.2 | 2.7 | 25.4 | 41.3 |
| 59 | 27/10/07 | 8.2 | 5º | 0.6 | 1.5 | 5.1 | 7.3 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | | | 15º | 4.7 | 2.6 | 15.9 | 23.2 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |

| S/N | DATE | RAIN-FALL (MM) | S/A | CONTROL (Without mulch) | | | | GROUNDNUT (Mulch) | | | | RICE (Mulch) | | | | GRASS (Mulch) | | | | SOYABEANS (Mulch) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | DS | US | LS | T | DS | US | LS | T | DS | US | LS | T | DS | US | LS | T | DS | US | LS | T |
| | | | 25º | 5.6 | 0.7 | 11.4 | 17.7 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | | | 35º | 8.9 | 0.2 | 10.5 | 19.6 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |

**Key: DS = Downslope; US = Upslope; LS = Lateral side; T = Total; and - = No splash; S/A = Slope Angle; mm = Millimetre**

**Appendix 5: Mean monthly splash per mean storm/mulch/slope in grams**

| | | | Control (without mulch) | | | | Groundnut mulch | | | | Rice mulch | | | | Grass mulch | | | | Soyabeans mulch | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **M** | **N/S** | **SA** | **DS** | **US** | **LS** | **TOT** | **DS** | **US** | **LS** | **TOT** | **DS** | **US** | **LS** | **TOT** | **DS** | **US** | **LS** | **TOT** | **DS** | **US** | **LS** | **TOT** |
| A | 5 | **5º** | 34.64 | 59.78 | 128.86 | 238.68 | 9.82 | 18.10 | 30.34 | 58.26 | 8.38 | 12.92 | 34.78 | 56.08 | 9.38 | 21.42 | 36.08 | 66.88 | 9.74 | 13.02 | 26.54 | 50.10 |
| A | 5 | **15º** | 52.88 | 47.64 | 241.90 | 342.42 | 13.44 | 10.74 | 33.60 | 57.78 | 10.84 | 15.82 | 37.30 | 63.76 | 12.54 | 11.12 | 30.66 | 54.32 | 10.90 | 10.32 | 33.64 | 54.86 |
| A | 5 | **25º** | 90.72 | 36.36 | 186.20 | 313.28 | 18.60 | 9.52 | 43.18 | 71.30 | 12.82 | 7.86 | 30.36 | 50.64 | 23.48 | 11.84 | 35.80 | 71.12 | 17.20 | 7.08 | 32.64 | 56.92 |
| A | 5 | **35º** | 78.62 | 42.42 | 203.58 | 324.62 | 27.96 | 13.38 | 49.40 | 90.74 | 15.20 | 3.86 | 32.16 | 51.22 | 22.84 | 6.94 | 39.76 | 69.54 | 22.22 | 6.98 | 47.32 | 76.52 |
| M | 9 | **5º** | 25.13 | 42.40 | 101.01 | 168.54 | 4.24 | 11.61 | 24.68 | 40.53 | 5.36 | 6.51 | 21.93 | 33.80 | 3.91 | 10.71 | 18.89 | 34.84 | 5.69 | 4.79 | 16.95 | 27.43 |
| M | 9 | **15º** | 41.74 | 37.08 | 109.41 | 188.23 | 9.14 | 8.70 | 25.20 | 43.06 | 8.63 | 9.06 | 28.53 | 46.21 | 8.21 | 6.03 | 25.44 | 39.70 | 6.01 | 8.80 | 24.06 | 39.00 |
| M | 9 | **25º** | 43.84 | 29.86 | 112.41 | 187.24 | 9.98 | 3.40 | 21.09 | 34.49 | 8.93 | 7.09 | 25.60 | 41.61 | 14.70 | 6.14 | 23.89 | 44.73 | 7.21 | 3.66 | 22.15 | 33.03 |
| M | 9 | **35º** | 64.03 | 12.99 | 103.18 | 180.19 | 16.84 | 6.35 | 30.38 | 53.56 | 13.65 | 4.50 | 23.76 | 41.90 | 12.86 | 5.33 | 27.26 | 45.48 | 12.58 | 4.54 | 24.34 | 41.08 |
| J | 8 | **5º** | 40.06 | 50.84 | 164.93 | 255.85 | 7.26 | 16.10 | 38.57 | 61.93 | 5.89 | 11.60 | 31.83 | 49.89 | 6.79 | 14.77 | 31.61 | 53.17 | 10.19 | 10.04 | 25.79 | 46.03 |
| J | 8 | **15º** | 56.50 | 53.69 | 175.14 | 285.36 | 11.47 | 7.71 | 27.84 | 47.03 | 11.61 | 12.16 | 44.99 | 65.90 | 10.10 | 7.43 | 33.94 | 51.47 | 8.16 | 8.07 | 35.41 | 51.71 |
| J | 8 | **25º** | 89.01 | 32.03 | 182.51 | 292.61 | 15.19 | 7.29 | 36.91 | 59.30 | 20.68 | 7.70 | 45.39 | 73.81 | 22.41 | 7.80 | 37.90 | 68.11 | 13.33 | 12.41 | 31.71 | 57.46 |
| J | 8 | **35º** | 114.74 | 19.13 | 150.53 | 281.75 | 33.90 | 5.33 | 44.50 | 83.87 | 35.90 | 7.46 | 49.14 | 92.50 | 32.77 | 7.14 | 45.51 | 85.43 | 18.51 | 7.37 | 29.79 | 54.78 |
| JL | 7 | **5º** | 24.86 | 14.47 | 65.31 | 104.66 | 2.38 | 2.88 | 10.43 | 15.43 | 2.15 | 1.93 | 5.73 | 9.55 | 5.05 | 2.70 | 9.65 | 17.40 | 2.40 | 3.55 | 7.28 | 13.23 |
| JL | 7 | **15º** | 28.67 | 9.10 | 56.90 | 95.07 | 3.40 | 2.95 | 5.68 | 12.53 | 1.18 | 1.58 | 5.08 | 7.83 | 2.03 | 2.90 | 7.65 | 12.58 | 2.23 | 1.10 | 6.45 | 9.28 |
| JL | 7 | **25º** | 39.36 | 3.30 | 53.13 | 95.64 | 2.53 | 1.07 | 7.05 | 10.00 | 2.65 | 1.23 | 7.80 | 11.38 | 3.55 | 2.57 | 7.25 | 12.73 | 2.08 | 1.80 | 6.35 | 9.80 |

| | | | Control (without mulch) | | | | Groundnut mulch | | | | Rice mulch | | | | Grass mulch | | | | Soyabeans mulch | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **M** | **N/S** | **SA** | **DS** | **US** | **LS** | **TOT** | **DS** | **US** | **LS** | **TOT** | **DS** | **US** | **LS** | **TOT** | **DS** | **US** | **LS** | **TOT** | **DS** | **US** | **LS** | **TOT** |
| JL | 7 | **35º** | 42.56 | 2.35 | 42.54 | 85.71 | 5.03 | 1.00 | 6.23 | 11.60 | 4.35 | 0.90 | 7.60 | 12.05 | 3.25 | 1.40 | 7.60 | 11.20 | 5.13 | 1.80 | 6.57 | 11.97 |
| AU | 10 | **5º** | 30.68 | 20.72 | 75.77 | 127.17 | 5.10 | 7.54 | 23.28 | 34.98 | 11.29 | 11.33 | 29.99 | 51.46 | 10.64 | 10.20 | 28.16 | 47.73 | 4.89 | 7.42 | 20.01 | 30.40 |
| AU | 10 | **15º** | 51.37 | 18.44 | 78.00 | 145.50 | 14.00 | 5.59 | 19.53 | 36.65 | 8.84 | 5.23 | 23.34 | 35.65 | 5.66 | 6.54 | 16.91 | 29.05 | 9.18 | 4.50 | 16.74 | 29.48 |
| AU | 10 | **25º** | 56.28 | 9.00 | 73.07 | 136.55 | 6.81 | 2.16 | 13.78 | 20.76 | 8.54 | 8.34 | 21.00 | 34.17 | 8.02 | 4.09 | 16.54 | 28.20 | 7.47 | 2.84 | 12.51 | 19.70 |
| AU | 10 | **35º** | 58.60 | 5.58 | 58.63 | 120.58 | 15.77 | 4.18 | 24.54 | 40.44 | 22.40 | 4.97 | 25.65 | 47.11 | 20.13 | 3.03 | 26.32 | 47.97 | 13.60 | 4.50 | 12.68 | 25.52 |
| S | 11 | **5º** | 24.66 | 25.46 | 77.98 | 128.19 | 12.35 | 14.31 | 45.55 | 72.21 | 6.71 | 8.45 | 25.59 | 40.75 | 11.04 | 18.63 | 41.31 | 70.98 | 5.04 | 9.19 | 22.75 | 36.98 |
| S | 11 | **15º** | 37.32 | 23.52 | 95.27 | 155.90 | 21.14 | 9.26 | 37.43 | 67.83 | 10.43 | 12.13 | 27.84 | 50.48 | 8.51 | 10.49 | 32.86 | 51.86 | 13.04 | 7.77 | 27.71 | 47.55 |
| S | 11 | **25º** | 47.76 | 15.30 | 77.63 | 140.69 | 18.18 | 7.80 | 38.58 | 64.55 | 13.85 | 6.77 | 31.43 | 51.08 | 17.36 | 7.21 | 33.60 | 58.18 | 17.49 | 7.07 | 29.83 | 53.71 |
| S | 11 | **35º** | 55.80 | 8.79 | 62.46 | 123.30 | 26.30 | 7.10 | 48.05 | 79.31 | 10.49 | 4.07 | 23.54 | 37.35 | 25.50 | 3.85 | 30.93 | 60.56 | 12.26 | 4.87 | 21.30 | 37.09 |
| O | 10 | **5º** | 3.26 | 7.03 | 26.12 | 36.43 | 1.79 | 5.21 | 12.34 | 19.34 | 1.71 | 2.93 | 8.48 | 13.12 | 2.89 | 3.36 | 12.56 | 18.80 | 1.43 | 2.98 | 8.20 | 12.64 |
| O | 10 | **15º** | 22.27 | 14.29 | 82.65 | 119.21 | 4.03 | 4.00 | 11.93 | 19.97 | 4.29 | 1.69 | 7.24 | 12.62 | 1.92 | 2.90 | 14.23 | 19.06 | 3.73 | 0.80 | 9.29 | 13.73 |
| O | 10 | **25º** | 29.12 | 9.13 | 60.00 | 98.25 | 5.78 | 1.57 | 15.51 | 22.86 | 5.11 | 0.89 | 10.83 | 16.83 | 8.12 | 2.49 | 9.59 | 19.64 | 7.44 | 1.26 | 13.33 | 21.96 |
| O | 10 | **35º** | 46.08 | 4.12 | 75.56 | 126.26 | 8.37 | 1.86 | 27.83 | 37.74 | 10.12 | 1.84 | 10.14 | 21.87 | 3.94 | 0.94 | 7.49 | 12.17 | 5.62 | 1.63 | 11.41 | 18.12 |

**Source: Computed from raw data, 2007**
**Key: M = Month; N/S = Number of storm per month; SA = Slope Angle; TOT = Total;**
**A = April; M = May; J = June; JL = July; AU = August; S = September; O = October**

## Appendix 6: Physical and Chemical Analysis of Splashed Soil for selected Months

| S/no | Month/ Slope Angle | H20 1:1 | Kcl 1:2 | Org Carbon % | Org Matter % | Sand % | Site % | Clay % | Texture class | Bulk density g/cm$^3$ | Porosity g/cm$^3$ | Permeability Cm/s | Water Content (W%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | APRIL 35$^0$DS | 6.50 | 4.60 | 0.80 | 1.38 | 83.6 | 11.2 | 5.2 | LS | 0.78 | 0.35 | 2.55x10$^{-3}$ | 33.1 |
| 2 | 35$^0$ US | 6.35 | 4.20 | 0.60 | 1.04 | 77.6 | 15.2 | 7.2 | " | 0.89 | 0.38 | 2.73x10$^{-3}$ | 21.7 |
| 3 | 25$^0$ DS | 6.30 | 4.30 | 0.70 | 1.20 | 75.6 | 17.2 | 7.2 | " | 0.85 | 0.41 | 2.90X10$^{-3}$ | 21.7 |
| 4 | 25US | 6.25 | 4.19 | 0.61 | 1.05 | 73.6 | 17.2 | 9.2 | " | 0.97 | 0.46 | 2.98X10$^{-3}$ | 20.9 |
| 5 | 15DS | 6.40 | 4.86 | 0.60 | 1.04 | 85.6 | 11.2 | 3.2 | " | 0.73 | 0.37 | 2.33X10$^{-3}$ | 18.0 |
| 6 | 15US | 6.35 | 4.11 | 0.52 | 0.90 | 79.6 | 15.2 | 5.2 | " | 0.68 | 0.39 | 2.46X10$^{-3}$ | 15.61 |
| 7 | 5DS | 6.30 | 4.50 | 0.63 | 1.09 | 83.6 | 11.2 | 5.2 | " | 0.70 | 0.40 | 2.60X10$^{-3}$ | 14.0 |
| 8 | 5US | 6.30 | 4.43 | 0.57 | 0.99 | 81.6 | 13.2 | 5.2 | " | 0.66 | 0.44 | 2.41X10$^{-3}$ | 12.5 |
| 9 | JUNE 35DS | 6.45 | 5.30 | 0.88 | 1.52 | 73.6 | 17.2 | 9.2 | " | 1.28 | 0.48 | 3.24X10$^{-3}$ | 39.5 |
| 10 | 35US | 6.40 | 5.20 | 0.82 | 1.42 | 69.6 | 19.2 | 11.2 | SL | 1.37 | 0.52 | 3.32X10$^{-3}$ | 25.4 |
| 11 | 25US | 6.85 | 5.06 | 0.77 | 1.33 | 71.4 | 17.2 | 11.4 | LS | 1.26 | 0.36 | 3.45X10$^{-3}$ | 30.2 |
| 12 | 25US | 6.40 | 4.89 | 0.70 | 1.20 | 67.4 | 19.2 | 13.4 | SL | 1.30 | 0.40 | 3.47X10$^{-3}$ | 17.6 |
| 13 | 15DS | 6.50 | 4.70 | 0.73 | 1.26 | 69.4 | 19.2 | 11.4 | " | 1.44 | 0.33 | 2.86X10$^{-3}$ | 16.5 |
| 14 | 15US | 6.45 | 4.94 | 0.68 | 1.18 | 65.4 | 17.2 | 17.4 | " | 1.40 | 0.37 | 2.90X10$^{-3}$ | 15.7 |
| 15 | 5DS | 6.35 | 4.88 | 0.66 | 1.14 | 67.4 | 19.2 | 13.4 | " | 1.37 | 0.31 | 2.75X10$^{-3}$ | 13.6 |
| 16 | 5US | 6.40 | 4.75 | 0.61 | 1.05 | 61.4 | 19.2 | 19.4 | SL | 1.51 | 0.35 | 2.86X10$^{-3}$ | 10.1 |
| 17 | AUGUST 35DS | 6.45 | 5.15 | 0.69 | 1.19 | 77.4 | 15.2 | 7.4 | LS | 1.11 | 0.43 | 2.57X10$^{-3}$ | 30.9 |
| 18 | 35US | 6.40 | 4.90 | 0.63 | 1.09 | 71.4 | 19.2 | 9.4 | " | 1.25 | 0.47 | 2.66X10$^{-3}$ | 26.8 |
| 19 | 25DS | 6.35 | 4.77 | 0.76 | 1.31 | 73.4 | 17.2 | 9.4 | " | 1.20 | 0.55 | 2.80X10$^{-3}$ | 22.8 |
| 20 | 25US | 6.35 | 4.64 | 0.71 | 1.22 | 67.4 | 19.2 | 13.4 | SL | 1.30 | 0.58 | 2.88X10$^{-3}$ | 20.1 |
| 21 | 15DS | 6.51 | 5.28 | 0.82 | 1.42 | 74.6 | 17.0 | 7.5 | LS | 1.09 | 0.36 | 3.10X10$^{-3}$ | 17.4 |
| 22 | 15US | 6.48 | 5.14 | 0.70 | 1.20 | 61.6 | 19.0 | 19.4 | SL | 1.28 | 0.39 | 3.02X10$^{-3}$ | 14.0 |
| 23 | 5DS | 6.35 | 4.80 | 0.67 | 1.16 | 73.6 | 19.0 | 9.4 | LS | 1.25 | 0.32 | 2.77X10$^{-3}$ | 15.3 |
| 24 | 5US | 6.30 | 4.60 | 0.64 | 1.11 | 61.6 | 19.0 | 19.4 | SL | 1.43 | 0.37 | 2.90X10$^{-3}$ | 11.7 |
| 25 | OCT 35DS | 6.38 | 4.74 | 0.75 | 1.30 | 73.6 | 19.0 | 9.4 | LS | 1.37 | 0.39 | 2.65X10$^{-3}$ | 36.0 |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 26 | 35US | 6.30 | 4.55 | 0.71 | 1.22 | 65.6 | 17.0 | 17.4 | SL | 1.48 | 0.43 | $2.70X10^{-3}$ | 30.9 |
| 27 | 25DS | 6.40 | 4.60 | 0.69 | 1.19 | 69.6 | 17.0 | 13.4 | SL | 1.19 | 0.31 | $2.55X10^{-3}$ | 33.1 |
| 28 | 25US | 6.35 | 4.45 | 0.65 | 1.14 | 63.6 | 21.0 | 15.4 | “ | 1.26 | 0.38 | $2.71X10^{-3}$ | 29.5 |
| 29 | 15DS | 6.35 | 4.30 | 0.70 | 1.20 | 67.6 | 19.0 | 13.4 | “ | 1.11 | 0.30 | $2.83X10^{-3}$ | 25.1 |
| 30 | 15US | 6.35 | 4.30 | 0.66 | 1.14 | 61.4 | 19.4 | 9.2 | SL | 1.28 | 0.34 | $2.87X10^{-3}$ | 20.0 |
| 31 | 5DS | 6.30 | 4.50 | 0.57 | 0.99 | 75.4 | 17.4 | 7.2 | LS | 1.36 | 0.36 | $2.46X10^{-3}$ | 18.9 |
| 32 | 5US | 6.25 | 4.45 | 0.53 | 0.92 | 67.4 | 19.4 | 13.2 | SL | 1.40 | 0.39 | $2.52X10^{-3}$ | 16.4 |

**Appendix 7: Multiple Comparisons of the significant differences between pairs of mulch treatments**

| Dependent Variable | (I) Type of Mulch | (J) Type of Mulch | Mean Difference (I-J) | Std. Error | Sig. | 95% Confidence Interval Lower Bound | Upper Bound |
|---|---|---|---|---|---|---|---|
| Down Slope | Without mulch | Groundnut mulch | 34.1290 | 2.5025 | .000 | 27.3028 | 40.9552 |
| | | Rice mulch | 35.5733 | 2.4883 | .000 | 28.7859 | 42.3607 |
| | | Grass mulch | 34.6035 | 2.4918 | .000 | 27.8065 | 41.4005 |
| | | Soyabeans mulch | 36.8580 | 2.5061 | .000 | 30.0219 | 43.6941 |
| | Groundnut mulch | Without mulch | -34.1290 | 2.5025 | .000 | -40.9552 | -27.3028 |
| | | Rice mulch | 1.4443 | 2.6175 | .982 | -5.6957 | 8.5843 |
| | | Grass mulch | .4745 | 2.6208 | 1.000 | -6.6746 | 7.6236 |
| | | Soyabeans mulch | 2.7290 | 2.6345 | .839 | -4.4573 | 9.9154 |
| | Rice mulch | Without mulch | -35.5733 | 2.4883 | .000 | -42.3607 | -28.7859 |
| | | Groundnut mulch | -1.4443 | 2.6175 | .982 | -8.5843 | 5.6957 |
| | | Grass mulch | -.9698 | 2.6073 | .996 | -8.0819 | 6.1422 |
| | | Soyabeans mulch | 1.2847 | 2.6210 | .988 | -5.8648 | 8.4342 |
| | Grass mulch | Without mulch | -34.6035 | 2.4918 | .000 | -41.4005 | -27.8065 |
| | | Groundnut mulch | -.4745 | 2.6208 | 1.000 | -7.6236 | 6.6746 |
| | | Rice mulch | .9698 | 2.6073 | .996 | -6.1422 | 8.0819 |
| | | Soyabeans mulch | 2.2545 | 2.6243 | .912 | -4.9041 | 9.4131 |
| | Soyabeans mulch | Without mulch | -36.8580 | 2.5061 | .000 | -43.6941 | -30.0219 |
| | | Groundnut mulch | -2.7290 | 2.6345 | .839 | -9.9154 | 4.4573 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | Rice mulch | -1.2847 | 2.6210 | .988 | -8.4342 | 5.8648 |
| | | Grass mulch | -2.2545 | 2.6243 | .912 | -9.4131 | 4.9041 |
| Upper Slope | Without mulch | Groundnut mulch | 14.7019 | 1.5773 | .000 | 10.3995 | 19.0043 |
| | | Rice mulch | 15.2632 | 1.5893 | .000 | 10.9281 | 19.5984 |
| | | Grass mulch | 14.5740 | 1.5868 | .000 | 10.2456 | 18.9025 |
| | | Soyabeans mulch | 15.9736 | 1.6045 | .000 | 11.5969 | 20.3503 |
| | Groundnut mulch | Without mulch | -14.7019 | 1.5773 | .000 | -19.0043 | -10.3995 |
| | | Rice mulch | .5613 | 1.6579 | .997 | -3.9610 | 5.0837 |
| | | Grass mulch | -.1279 | 1.6555 | 1.000 | -4.6438 | 4.3881 |
| | | Soyabeans mulch | 1.2717 | 1.6725 | .942 | -3.2904 | 5.8339 |
| | Rice mulch | Without mulch | -15.2632 | 1.5893 | .000 | -19.5984 | -10.9281 |
| | | Groundnut mulch | -.5613 | 1.6579 | .997 | -5.0837 | 3.9610 |
| | | Grass mulch | -.6892 | 1.6670 | .994 | -5.2364 | 3.8580 |
| | | Soyabeans mulch | .7104 | 1.6838 | .993 | -3.8827 | 5.3035 |
| | Grass mulch | Without mulch | -14.5740 | 1.5868 | .000 | -18.9025 | -10.2456 |
| | | Groundnut mulch | .1279 | 1.6555 | 1.000 | -4.3881 | 4.6438 |
| | | Rice mulch | .6892 | 1.6670 | .994 | -3.8580 | 5.2364 |
| | | Soyabeans mulch | 1.3996 | 1.6815 | .921 | -3.1872 | 5.9864 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Soyabeans mulch | Without mulch | -15.9736 | 1.6045 | .000 | -20.3503 | -11.5969 |
| | | Groundnut mulch | -1.2717 | 1.6725 | .942 | -5.8339 | 3.2904 |
| | | Rice mulch | -.7104 | 1.6838 | .993 | -5.3035 | 3.8827 |
| | | Grass mulch | -1.3996 | 1.6815 | .921 | -5.9864 | 3.1872 |
| Lateral Sides | Without mulch | Groundnut mulch | 69.7305 | 5.4525 | .000 | 54.8573 | 84.6036 |
| | | Rice mulch | 72.5783 | 5.4296 | .000 | 57.7674 | 87.3892 |
| | | Grass mulch | 72.4413 | 5.4525 | .000 | 57.5681 | 87.3144 |
| | | Soyabeans mulch | 76.3252 | 5.4602 | .000 | 61.4309 | 91.2195 |
| | Groundnut mulch | Without mulch | -69.7305 | 5.4525 | .000 | -84.6036 | -54.8573 |
| | | Rice mulch | 2.8479 | 5.6908 | .987 | -12.6753 | 18.3710 |
| | | Grass mulch | 2.7108 | 5.7126 | .990 | -12.8718 | 18.2934 |
| | | Soyabeans mulch | 6.5948 | 5.7200 | .778 | -9.0080 | 22.1975 |
| | Rice mulch | Without mulch | -72.5783 | 5.4296 | .000 | -87.3892 | -57.7674 |
| | | Groundnut mulch | -2.8479 | 5.6908 | .987 | -18.3710 | 12.6753 |
| | | Grass mulch | -.1370 | 5.6908 | 1.000 | -15.6602 | 15.3861 |
| | | Soyabeans mulch | 3.7469 | 5.6982 | .965 | -11.7965 | 19.2903 |
| | Grass mulch | Without mulch | -72.4413 | 5.4525 | .000 | -87.3144 | -57.5681 |
| | | Groundnut mulch | -2.7108 | 5.7126 | .990 | -18.2934 | 12.8718 |
| | | Rice mulch | .1370 | 5.6908 | 1.000 | -15.3861 | 15.6602 |
| | | Soyabeans mulch | 3.8839 | 5.7200 | .961 | -11.7188 | 19.4867 |
| | Soyabeans mulch | Without mulch | -76.3252 | 5.4602 | .000 | -91.2195 | -61.4309 |
| | | Groundnut mulch | -6.5948 | 5.7200 | .778 | -22.1975 | 9.0080 |
| | | Rice mulch | -3.7469 | 5.6982 | .965 | -19.2903 | 11.7965 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | Grass mulch | -3.8839 | 5.7200 | .961 | -19.4867 | 11.7188 |
| Total | Without mulch | Groundnut mulch | 117.5939 | 8.7791 | .000 | 93.6465 | 141.5413 |
| | | Rice mulch | 122.6645 | 8.7423 | .000 | 98.8174 | 146.5116 |
| | | Grass mulch | 120.4666 | 8.7791 | .000 | 96.5192 | 144.4140 |
| | | Soyabeans mulch | 128.4553 | 8.7916 | .000 | 104.4739 | 152.4368 |
| | Groundnut mulch | Without mulch | -117.5939 | 8.7791 | .000 | -141.5413 | -93.6465 |
| | | Rice mulch | 5.0706 | 9.1628 | .982 | -19.9233 | 30.0646 |
| | | Grass mulch | 2.8727 | 9.1978 | .998 | -22.2170 | 27.9624 |
| | | Soyabeans mulch | 10.8615 | 9.2098 | .763 | -14.2607 | 35.9836 |
| | Rice mulch | Without mulch | -122.6645 | 8.7423 | .000 | -146.5116 | -98.8174 |
| | | Groundnut mulch | -5.0706 | 9.1628 | .982 | -30.0646 | 19.9233 |
| | | Grass mulch | -2.1980 | 9.1628 | .999 | -27.1919 | 22.7960 |
| | | Soyabeans mulch | 5.7908 | 9.1747 | .970 | -19.2358 | 30.8174 |
| | Grass mulch | Without mulch | -120.4666 | 8.7791 | .000 | -144.4140 | -96.5192 |
| | | Groundnut mulch | -2.8727 | 9.1978 | .998 | -27.9624 | 22.2170 |
| | | Rice mulch | 2.1980 | 9.1628 | .999 | -22.7960 | 27.1919 |
| | | Soyabeans mulch | 7.9888 | 9.2098 | .909 | -17.1334 | 33.1109 |
| | Soyabeans mulch | Without mulch | -128.4553 | 8.7916 | .000 | -152.4368 | -104.4739 |
| | | Groundnut mulch | -10.8615 | 9.2098 | .763 | -35.9836 | 14.2607 |
| | | Rice mulch | -5.7908 | 9.1747 | .970 | -30.8174 | 19.2358 |
| | | Grass mulch | -7.9888 | 9.2098 | .909 | -33.1109 | 17.1334 |

* The mean difference is significant at the .05 level.

**Appendix 8: Multiple paired comparisons of components of splash during the months**

| Dependent Variable (1) Month | | (J) Mouths | Mean Difference (1-J) | Std. Error | Sig. | 95% confidence Interval lower Bound | Upper Bound |
|---|---|---|---|---|---|---|---|
| Down Slope | April | May | 9.1429 | 3.7002 | .170 | -17.7666 | 20.0523 |
| | | June | -4.9924 | 3.7678 | .840 | -16.1012 | 6.1164 |
| | | July | 12.4954* | 4.2175 | .048 | 6.086E-02 | 24.9300 |
| | | August | 4.5240 | 3.7278 | .889 | -6.4669 | 15.5149 |
| | | September | 3.8412 | 3.6502 | .942 | -6.9208 | 14.6033 |
| | | October | 15.9039* | 3.6062 | .000 | 5.2717 | 26.5362 |
| | May | April | -9.1429 | 3.7002 | .170 | -20.0523 | 1.7666 |
| | | June | -14.1353* | 3.3222 | .000 | -23.9302 | -4.3404 |
| | | July | 3.3526 | 3.8246 | .976 | 7.9237 | -14.6288 |
| | | August | -4.6189 | 3.2768 | .797 | -14.2798 | 5.0421 |
| | | September | -5.3016 | 3.1882 | .641 | 14.7015 | 4.0982 |
| | | October | 6.7611 | 3.1377 | .321 | -2.4899 | 16.0120 |
| | June | April | 4.9924 | 3.7678 | .840 | -6.1164 | 16.1012 |
| | | June | 14.1353* | 3.3222 | .000 | 4.3404 | 23.9302 |
| | | July | 17.4879* | 3.8901 | .000 | 6.0186 | 28.9571 |
| | | August | 9.5164 | 3.3529 | .068 | -.3691 | 19.4019 |
| | | September | 8.8337 | 3.2664 | .097 | -.7968 | 18.4642 |
| | | October | 20.8964* | 3.2172 | .000 | 11.4111 | 30.3816 |
| | July | April | -12.4954* | 4.2175 | .048 | -24.9300 | -6.0862E-02 |
| | | June | -3.3526 | 3.8246 | .979 | -14.6288 | 7.9237 |
| | | July | -17.4879* | 3.8901 | .000 | -28.9571 | -6.0186 |
| | | August | -7.9715 | 3.8514 | .371 | -19.3265 | 3.3836 |
| | | September | -8.6542 | 3.7763 | .248 | -19.7879 | 2.4795 |
| | | October | 3.4085 | 3.7338 | .971 | -7.598 | 14.4168 |

| | | | | | | |
|---|---|---|---|---|---|---|
| August | April | -4.5240 | 3.7278 | .9889 | -15.5149 | 6.4669 |
| | May | 4.6189 | 3.2768 | .797 | -5.0421 | 14.2798 |
| | June | -9.5164 | 3.3529 | .068 | -19.4019 | .3691 |
| | July | 7.9725 | 3.8514 | .371 | -3.3836 | 19.3265 |
| | September | -.6828 | 3.2202 | 1.000 | -10.1770 | 8.8115 |
| | October | 11.3799* | 3.1702 | .006 | 2.0331 | 20.7268 |
| September | April | -3.8412 | 3.6502 | .942 | -14.6033 | 6.9208 |
| | May | 5.3016 | 3.1882 | .641 | -4.0982 | 14.7015 |
| | June | -8.8337 | 3.2664 | .097 | -18.4642 | .7968 |
| | July | 8.6542 | 3.7763 | .248 | -2.4795 | 19.7879 |
| | August | .6828 | 3.2202 | 1.000 | -8.8115 | 10.1770 |
| | October | 12.0627* | 3.0786 | .002 | 2.9860 | s21.1394 |
| October | April | -15.9039* | 3.6062 | .000 | -26.5362 | -5.2717 |
| | May | -6.7611 | 3.1377 | .321 | -16.0103 | 2.4899 |
| | June | -20.8964* | 3.2172 | .000 | -30.3816 | -11.4111 |
| | July | -3.4085 | 3.7338 | .971 | -14.4168 | 7.5998 |
| | August | -11.3799* | 3.1702 | .006 | -20.7268 | -2.0331 |
| | September | -12.0627* | 3.0786 | .002 | -21.1394 | -2.9860 |
| Upper slope April | May | 7.0373* | 2.0847 | .013 | .8907 | 13.1838 |
| | June | 2.8678 | 2.1288 | .830 | -3.4087 | 9.1443 |
| | July | 14.0951* | 2.5594 | .000 | 6.5491 | 21.6412 |
| | August | 10.1174* | 2.1864 | .000 | 3.6711 | 16.5637 |
| | September | 6.8054* | 2.0847 | .019 | .6589 | 12.9519 |
| | October | 14.5437* | 2.0588 | .000 | 8.4737 | 20.6137 |
| May | April | -7.0373* | 2.0847 | .013 | -13.1838 | -.8907 |
| | June | -4.1694 | 1.8785 | .285 | -9.7080 | 1.3691 |
| | July | 7.0579* | 2.3554 | .043 | .1135 | 14-0023 |
| | August | 3.0802 | 1.9436 | .692 | -2.6502 | 8.8105 |
| | September | -.2319 | 1.8284 | 1.000 | -5.6227 | 5.1590 |
| | October | 7.5065* | 1.7988 | .001 | 2.2030 | 12.8099 |
| June | April | -2.8678 | 2.1288 | .830 | -9.1443 | 3.4087 |
| | May | 4.1694 | 1.8785 | .285 | -1.3691 | 9.7080 |
| | July | 11.2273* | 2.3945 | .000 | 4.1676 | 18.270 |
| | August | 7.2496* | 1.9908 | .005 | 1.3801 | 13.1191 |
| | September | 3.9376 | 1.8785 | .355 | -1.6010 | 9.4761 |
| | October | 11.6759* | 1.8497 | .000 | 6.2224 | 17.1294 |

| | | | | | | |
|---|---|---|---|---|---|---|
| July | April | -14.0951* | 2.5594 | .000 | -21.6412 | -6.5491 |
| | May | -7.0579* | 2.3554 | .043 | -14.0023 | -.1135 |
| | June | -11.2273* | 2.3945 | .000 | -18.2870 | -4.1676 |
| | August | -3.9777 | 2.4458 | .665 | -11.1888 | 3.2334 |
| | September | -7.2898* | 2.3554 | .032 | -14.2342 | -.3454 |
| | October | .4486 | 2.3324 | 1.000 | -6.4282 | 7.3254 |
| August | April | -10.1174* | 2.1864 | .000 | -16.5637 | -3.6711 |
| | May | -3.0802 | 1.9436 | .692 | -8.8105 | 2.6502 |
| | June | -7.2496* | 1.9908 | .005 | -13.1191 | -1.3801 |
| | July | 3.9777 | 2.4458 | .665 | -3.2334 | 11.1888 |
| | September | -3.3120 | 1.9436 | .613 | -9.0424 | 2.4183 |
| | October | 4.4263 | 1.9157 | .239 | -1.2219 | 10.0745 |
| September | April | -6.8054 | 2.0847 | .019 | -12.9519 | -.6589 |
| | May | .2319 | 1.8284 | 1.000 | -5.1590 | 5.6227 |
| | June | -3.9376 | 1.8785 | .355 | -9.4761 | 1.6010 |
| | July | 7.2898* | 2.3554 | .032 | .3454 | 14.2342 |
| | August | 3.3120 | 1.9436 | .613 | -2.4183 | 9.0424 |
| | October | 7.7383* | 1.7988 | .000 | 2.4349 | 13.0418 |
| October | April | -14.5437* | 2.0588 | .000 | -20.6137 | -8.4737 |
| | May | -7.5065* | 1.7988 | .001 | -12.8099 | -2.2030 |
| | June | -11.6759* | 1.8497 | .000 | -17.1294 | -6.2224 |
| | July | -4486 | 2.3324 | 1.000 | -7.3254 | 6.4282 |
| | August | -4.4263 | 1.9157 | .239 | -10..0745 | 1.2219 |

*. The mean different is significant at the .05 level

Appendix 9: Wet rainfall years in Makurdi

| Annual Rainfall (mm) | Year |
|---|---|
| **1252.6** | **1974** |
| **1327.7** | **1975** |
| **1265.5** | **1976** |
| **1556.9** | **1978** |
| **1491** | **1979** |
| **1425.5** | **1980** |
| **1227.1** | **1981** |
| **1572** | **1984** |
| **1207.7** | **1986** |
| **1207.7** | **1987** |
| **1244.3** | **1989** |
| **1217.1** | **1993** |
| **1323.9** | **1996** |
| **1335.9** | **1997** |
| **1556.9** | **1998** |
| **1618.0** | **1999** |
| **1281.5** | **2002** |

| | |
|---|---|
| **1343.0** | **2006** |
| **1532.5** | **2007** |

**Appendix 10: Rainfall Erosivity Parameters of the storms studied**

| S/NO | Date | Rainfall Amount(mm) | Total Intensity ($mmh^{-1}$) | Total Kinetic Energy ($Jm^{-2}\ mm^{-1}$) |
|---|---|---|---|---|
| 1 | 7/4/07 | 23.3 | 19.97 | 23.42 |
| 2 | 22/4/07 | 20.7 | 8.45 | 14.72 |
| 3 | 23/4/07 | 20.7 | 23.43 | 24.36 |
| 4 | 27/4/07 | 113 | 32.29 | 25.85 |
| 5 | 29/4/07 | 8.8 | 1.76 | 00 |
| 6 | 1/5/07 | 38.4 | 6.98 | 11.53 |
| 7 | 3/5/07 | 35.7 | 8.08 | 14.02 |
| 8 | 8/5/07 | 25.5 | 7.29 | 12.31 |
| 9 | 11/5/07 | 8.2 | 5.47 | 6.49 |
| 10 | 13/5/07 | 14.1 | 3.87 | 00 |
| 11 | 21/5/07 | 21.8 | 15.13 | 4.95 |
| 12 | 22/5/07 | 10.8 | 21.6 | 23.9 |
| 13 | 27/5/07 | 26.9 | 10.09 | 17.16 |
| 14 | 1/6/07 | 49.2 | 49.2 | 27.21 |
| 15 | 3/6/07 | 45.1 | 11.28 | 18.5 |
| 16 | 7/6/07 | 36.7 | 36.7 | 26.33 |

| S/NO | Date | Rainfall Amount(mm) | Total Intensity ($mmh^{-1}$) | Total Kinetic Energy ($Jm^{-2} mm^{-1}$) |
|---|---|---|---|---|
| 17 | 10/6/07 | 51.3 | 25.65 | 24.83 |
| 18 | 13/6/07 | 8.9 | 2.22 | 00 |
| 19 | 16/6/07 | 12.2 | 5.23 | 3.22 |
| 20 | 29/6/07 | 9.3 | 4.65 | 2.38 |
| 21 | 30/6/07 | 11.9 | 4.76 | 3.01 |
| 22 | 13/7/07 | 15.5 | 6.41 | 9.91 |
| 23 | 14/7/07 | 9.3 | 5.26 | 5.56 |
| 24 | 20/7/07 | 16 | 17.45 | 22.49 |
| 25 | 22/7/07 | 5.1 | 2.43 | 00 |
| 26 | 27/7/07 | 6.2 | 7.44 | 12.66 |
| 27 | 28/7/07 | 17.6 | 5.15 | 5.02 |
| 28 | 29/7/07 | 23.7 | 16.73 | 22.18 |
| 29 | 1/8/07 | 4.6 | 3.63 | 00 |
| 30 | 4/8/07 | 52.8 | 26.34 | 24.96 |
| 31 | 5/8/07 | 15.4 | 13.20 | 20.14 |
| 32 | 9/8/07 | 10.8 | 18.0 | 22.72 |
| 33 | 13/8/07 | 78.7 | 25.52 | 24.80 |
| 34 | 16/8/07 | 41.6 | 33.28 | 25.97 |
| 35 | 20/8/07 | 18.1 | 12.78 | 19.8 |
| 36 | 24/8/07 | 47.1 | 22.60 | 24.16 |
| 37 | 25/8/07 | 8.3 | 4.60 | 2.08 |
| 38 | 29/8/07 | 5.7 | 5.26 | 5.56 |

| S/NO | Date | Rainfall Amount(mm) | Total Intensity ($mmh^{-1}$ ) | Total Kinetic Energy ($Jm^{-2}$ $mm^{-1}$) |
|---|---|---|---|---|
| 39 | 3/9/07 | 14.4 | 9.6 | 16.52 |
| 40 | 4/9/07 | 20.2 | 14.9 | 20.75 |
| 41 | 5/9/07 | 13.5 | 11.57 | 18.80 |
| 42 | 6/9/07 | 33.7 | 9.54 | 16.44 |
| 43 | 8/9/07 | 27.9 | 11.16 | 18.38 |
| 44 | 9/9/07 | 18.2 | 8.4 | 14.62 |
| 45 | 16/9/07 | 51.8 | 14.46 | 20.98 |
| 46 | 19/9/07 | 27 | 12.76 | 19.81 |
| 47 | 20/9/07 | 80.3 | 20.50 | 23.58 |
| 48 | 29/9/07 | 8.3 | 5.41 | 6.23 |
| 49 | 30/9/07 | 7.7 | 6.42 | 9.94 |
| 50 | 2/10/07 | 13.5 | 9.52 | 16.41 |
| 51 | 7/10/07 | 21.8 | 12.46 | 19.57 |
| 52 | 9/10/07 | 14.0 | 7.00 | 11.59 |
| 53 | 19/10/07 | 10.3 | 6.18 | 9.17 |
| 54 | 2010/10/07 | 70.5 | 18.80 | 23.02 |
| 55 | 21/10/07 | 27.9 | 8.86 | 15.41 |
| 56 | 24/10/07 | 10.9 | 5.45 | 6.41 |
| 57 | 25/10/07 | 14.5 | 6.30 | 9.56 |
| 58 | 26/10/07 | 32.6 | 9.18 | 15.91 |
| 59 | 27/10/07 | 8.2 | 3.81 | 00 |

Source: Field work, 2007