MASTER THESIS

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Improving Subsurface Recharge through Breaking Restrictive Soil Layers by Mechanical Means

Bahir Dar University, Institute of Technology

Faculty of Civil and Water Resource Engineering

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A Thesis in partial Fulfillment of the requirements for the Degree of Master of Science in Hydraulics Engineering

Presented to the Faculty of Civil and Water Resource Engineering Institute of Technology, Bahir Dar University

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DECLARATION

I, Misba Abidela Hussen, declare that this thesis is my own original work. In compliance with internationally accepted practices, I have duly acknowledged and referenced all materials used in this work. I understand that non-adherence to principles of academic honesty and integrity, misrepresentation/fabrication of any idea/data/fact/source will constitute sufficient ground for disciplinary action by the university and can also evoke penal action from the sources which have not been properly cited or acknowledged.

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This thesis is dedicated to all my family for their love, care and support throughout my career.

ABSTRACT

The Ethiopian highlands receive high amounts of rainfall ranging between 1200 to 2200 mm per year. However, 50% and more of this rainwater is lost as surface runoff and subsurface flow as interflow resulting in moisture stress in crop production causing decrease in crop yields. The presence of restrictive soil layers commonly known as hardpans in the soil profile is one of the known reasons of more overland flow by saturation excess runoff mechanism. These layers are located 10 to 60 cm below the soil surface and restrict water and airflow in the soil profile.

In this study, the main objective was to assess the potential impact of mechanical breaking of restrictive soil layers on surface runoff, soil loss, crop performance, and soil water content (infiltration rate). Five experimental plots of size 12m by 30m were selected for this experiment, each of them were divided into three subplots of size 4m by 30m. The subplots were randomly assigned with no tillage (zero tillage), conventional tillage (ox driven Maresha plow, up to a depth of 15cm) and deep ripping of the soil restrictive layers (deep till, up to a depth of 60cm) tillage treatments. The same crop (maize) was planted, the same amounts of fertilizer applied, the same plant spacing and the same management practice (weeding by manually pulling and chopping) applied for all the subplots, repetitions and topographic locations. The performance of each tillage treatment was measured in terms of amounts of surface runoff and soil loss, soil moisture content and crop performance (maize plant height, maize yield and biomass).

The soil physical and chemical properties of the five plots were found to be different. During the growing season, the penetration resistance of the subplots treated with the three different measurements was measured and analyzed, and the results show that the cone index of the subplots treated with deep tillage were significantly less than that of subplots with no tillage and conventional tillage treatments. There was no significant difference in cone index between no till and conventional tillage subplots. Also the bulk density from deep tillage was significantly less from the rest of the two treatments. The post treatment steady state infiltration rate of the subplots treated with deep tillage was found to be significantly higher followed by conventional tillage and then no tillage.

Among the three tillage treatments, the event runoff response of deep tillage was significantly less, followed by conventional tillage and no tillage. However, the event runoff difference observed between conventional and no tillage treatment subplots were not significantly different. Event runoff between upslope and downslope subplots was significantly different. Higher event runoff was observed for downslope subplots than up slope subplots. Soil loss from the three tillage treatments was not significant; the deep tillage though gave less soil loss followed by conventional tillage and no tillage respectively. The soil loss was less by 42% for the deep tillage compared to conventional tillage and 64% compared to the no tillage, also the soil loss from the conventional tillage reduced by 15% compared to the no tillage.

Deep tillage gave a non- statistically significant 18% more maize yield than the conventional tillage and 42% more maize yield than the no tillage. Also the maize yield from the conventional tillage was 21% more than that from the no tillage. The maize yield from the downslope subplots was significantly higher than the upslope subplots. Deep tillage gave a non-statistically significant 22% more biomass than the conventional tillage and 46% more biomass than the no tillage. Also the biomass from the conventional tillage was 31% more than that from the no tillage. The biomass from the downslope subplots was significantly higher than the upslope subplots. The increase in maize yield and dry biomass for the deep tillage is attributed to the increase in water content and reduction of the cone index, so the plants were able to take water and nutrients from deeper portions of the soil horizon below the plow depth of the conventional tillage.

Key words: Restrictive soil layers, Event runoff, Sediment, Tillage.

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LIST OF ACRONYMS AND ABBREVIATIONS

AGP	Agricultural Growth Program
DAP	Day after planting

BD	Bulk Density
CT	Conventional Tillage
DT	Deep tillage
CEC	Cation exchange capacity
FAO	Food and Agricultural Organization
GPS	Global Positioning System
ha	Hectares
ILSSI	Innovation laboratory for small scale irrigation
IWMI	International Water Management Institute
IR	Infiltration Rate
Mpa	Mega Pascal
NGO	Non Governmental Organization
NT	No Tillage
PR	Penetration Resistance
PSI	Pounds per square inch
SSSA	Soil Science Society of America
SMPR	Soil moisture profiler reading
Y	Yield

1. INTRODUCTION

1.1. Background and justification

The Ethiopian highlands represent one of the most productive parts of the country, but have suffered from extensive resource degradation (Hurni, 1990; Hurni, 1993; Nyssen et al., 2007; Tewodros et al., 2009, Melesse et al., 2012). Land degradation in the form of soil erosion and declining soil quality is a serious challenge to agricultural productivity and economic growth in these highlands (Mulugeta et al., 2005). The northwestern highlands of the country suffer from such extreme land degradation due to repeated cross-plowing of the steep lands (Gete, 2000; Bezuayehu et al., 2002; Melesse et al., 2009). The traditional tillage adopted in the northern highland is by using oxen-driven Maresha plow, which can till the soil up to a depth of 15 cm. Before planting, tillage is conducted three to five times at ten to fifteen days interval, the same depth for all crops planted. Repeated traditional tillage damages the soil structure through excessive pulverization and increased rate of mineralization leading to reduction in soil organic matter content and aggregate stability (Mwendera and Mohamed, 1997; Melesse et al., 2009). This results in soil compaction over the plowed layer, surface crust and plow pan formation that reduce infiltration, increase both soil erosion and loss of soil moisture (Lal, 1997).

Hard pan also known as plow pan, is a state of soil formation where soil gets compacted due to external load and restricting aeration and water movement as well as plant root penetration resulting in poor top soil quality, soil crusting and soil erosion (Raper et al., 2001). Hardpans can form in two main ways: firstly, if the soil is ploughed or hoed at the same depth season after season and secondly, if the soil is clayey, hardpans can form naturally without any ploughing but by filling of the void spaces in the soil with fine particles of clay. As reported by Tibebeu et al., (2013), the formation of hardpan in the Ethiopian soils is related to the infiltration of sediment rich water after the soils are tilled and the soil cover is removed by plowing. The hard pans limits deep percolation of rainfall and produces local saturation excess runoff, resulting in sheet and rill erosion accelerating downslope water movement causing gully erosion in the saturated valley bottoms. Furthermore, the hard pan restricts root growth thus reducing the available root zone for water uptake by plants. The location of the hardpan within the soil layer is highly related to the plant root penetration restriction zone. Root penetration decreases linearly with penetration resistance, with no roots penetrating into soil for penetration resistance of 300 psi and above (Duiker, 2002). The occurrence and the extent of hardpan within the soil can be detected indirectly by (i) crop yields, (ii) runoff or infiltration rates, (iii) ease for soil management and tillage, (iv) bulk density variability between similar soil textures at different soil depths, and directly by (i) looking at the physical appearance of the plant root growth pattern in the soil, (ii) appearance of macrospores in the soil layer, and (iii) direct measurement using equipment like the soil penetrometer.

1.2. Statement of the Problem

The Ethiopian highlands receive a high amount of rainfall ranging between 1200 to 2200 mm per year. However, 50% and more of this rainwater is lost as surface runoff and subsurface inflow as interflow (FAO, 2003) resulting in moisture stress in crop production causing a decrease in crop yields. The presence of restrictive soil layers commonly known as hardpans in the soil profile is one of the known reasons of more overland flow by saturation excess runoff mechanism. These layers are located 10 to 60 cm below the soil surface and restrict water and air flow in the soil profile, impede root growth below the plough depth, thereby reducing plant's capacity to extract water and nutrients from deeper layer when soil moisture and nutrient reserves in the upper profile are depleted (Busscher and Bauer, 2003; Tekeste, 2006), resulting in reduced crop yields. This issue is of a particular concern in the Ethiopian highlands where soils have become eroded and degraded due to land use changes arising from increasing population pressure, leading to clogging of soil pores resulting in formation of restrictive soil layers. Preventing hardpans from forming or breaking existing hardpans will allow plants to develop a more extensive root zone, increase water infiltration and reduce runoff, resulting in higher water available for the crop (i.e. green water). Though hardpan breaking is believed to improve soil fertility, soil erosion and groundwater recharges, little information is known for the Ethiopian highlands. Due to the intensive agricultural practices in the area, the selected study area, Robit-Bata is one of those areas subjected to hardpans; a potential hardpan was identified using penetrometer. Therefore, in this study the main objective was assessing the potential impact of mechanical breaking of restrictive soil layers on surface runoff, soil loss, crop performance, and soil water content.

1.3. Research Question

Which method of ploughing/cultivating the land breaks or prohibits hard pan formation resulting in higher crop productivity and improved plant water availability?

1.4. Objective of the study

1.4.1. General objective

The general objective of this thesis research is to evaluate the potential impact of mechanical breaking of restrictive soil layers in improving crop productivity and sub-surface recharge on agricultural land.

1.4.2. Specific objectives

- ✓ To quantify the impact of various tillage practices on event runoff and soil loss from agricultural fields
- ✓ To evaluate changes in soil moisture due to the tillage practices throughout the cropping season
- ✓ To test the effect of the tillage practices on crop productivity

2. LITRATURE REVIEW

2.1. Formations of hard pans and factors responsible for its formation

A restrictive soil layer (hard pan) is a state of soil formation where the soil gets compacted due to external load restricting aeration and water movement as well as plant root penetration resulting in poor top soil quality, soil crusting and soil erosion (Raper et al., 2001). The hard pan's permeability is low; when the soil is compacted the natural porosity is markedly reduced so it prevents water from infiltrating and from draining off. Factors that are responsible for formation of restrictive soil layers include: field operations carried out when the soil is too wet, heavy equipment, reducing the number and extent of tillage operations, ploughing at the same depth season after season (Mohamed et al., 1997), livestock traffic or over grazing, and rainfall-droplet impact on soil surface (Hamza et al., 2005).

2.2. Some of the solutions to soil compaction

Among the major problems facing modern agriculture, soil compaction is one of them (Hamza et al., 2005). Solutions to soil compaction problems as mentioned by Hamza et al. (2005), include decreasing the bulk density of the soil (increasing the porosity), since the major effects of soil compaction is decreasing the porosity of the soil. Other solutions include: adding manure or increasing the organic matter content of the soil which reduces soil compaction by retaining water and thus helping the soil to rebound against compaction; mechanical loosening such as deep ripping or deep tillage, which breaks the compacted layers by loosening hence improve the soil porosity; crop rotation and using crops which have deeper roots and are able to break the compacted layers and hence creates more soil pores; and controlled traffic and reduced grazing, as both vehicle and animal traffic may cause the soils to compact.

2.3. Merits and demerits of Tillage

Tillage refers to mechanical manipulations of soil to keep it loose for plant growth and free from weeds during the growth of plant (FAO, 1993). Production of all types of crops involves use of some type of tillage system. The tillage system may be very simple, involving either digging or punching holes to sow seed or it may be a complex system comprised of primary tillage and several secondary tillage operations with different machines and equipment. Tillage operations and methods of land preparation vary from place to place and even in the same place, depending on the climate and crops cultivated.

Some of the fundamental purposes of tillage include: preparing suitable seed bed for plant growth (for better seed emergence and anchorage); destroying competitive weeds and destruction of pests (tillage exposes pests to predators and can also bring weeds to the surface, exposing them repeated action of sun and rain thereby killing them); improving the physical condition of soil (tillage can loosen the soil thereby reducing the bulk density and hence improving the porosity and infiltration rate of the soil); soil and water conservation (by loosening or improving the infiltration rate, tillage may reduce the surface runoff and hence reduces soil loss); improvement of soil structure, soil permeability, soil aeration, root penetration (due to loosening action, tillage can reduce the penetration resistance of the soil or cone index hence making it easier for plant roots to penetrate the soil) (Sadegh-Zadeh et al., 2011); and soil inversion (tillage causes partial or complete inversion of the soil and mixing up of crop residues with the soil).

There are some disadvantages of tillage too which include: modification of the soil environment (tillage can modify the soil physical and biological environment such as bringing soil biological organisms to the surface thus exposing them to predators and hence reducing the numbers of soil biological organisms); repeated tillage operation, especially at the same depth season after season over longer periods can cause plow pans at that depth; soil inversion due to tillage may hasten the oxidation of organic matter from the soil (hence reducing the organic matter content of the soil); heavy equipments used for tillage tend to break down the soil aggregates and a plow pan may form below the tilled layer, reducing deep percolation of water thus increasing runoff; tillage facilitates spread colonies of soil born pests and parasites; and also loosening of soil due to tillage practices makes the soil more prone to be carried away by agents of erosion.

2.4. Comparing effect of various tillage systems on soil properties

There are various types of tillage treatments adopted throughout the world, but in this thesis, specific emphasis is given to a few tillage types and their effects on soil physical and chemical properties. Zero tillage (or no till) is a method of crop production that involves no land cultivation other than opening the soil for the purpose of placing seed at the desired depth (SSSA, 1982). This tillage is an extreme form of minimum tillage, in which primary tillage is completely avoided and secondary tillage is restricted to seed planting in the row zone only. This type of tillage is resorted to where soils are subjected to wind and water erosion, timing of tillage operation is too difficult, and when time and labor requirements for tillage are too high (Sharma et al., 2008). In this type of tillage system, 50-100% of the soil surface has to be covered. Doing so will conserve soil moisture and the soil will remain stable. In the no till system weed control is accomplished by using herbicides, but the herbicides applied should not cause injury to the crops. In addition, weed control can be done by manual pulling or chopping especially in developing countries. When the weed control is done by manual pulling or by chopping, the weed cannot be completely removed as only the part of the weed that is above ground is removed thus the weed can develop again in a short time. The limitations of this type of tillage system include: huge population of weeds and build of pests, increase in soil density which causes reduction in infiltration rate and pore space. Advantages of zero tillage systems include: less soil disturbance, reduced cost of production such as saving time in seed bed preparation, less use of diesel fuel and animal draught power, and improved utilization of pastures.

Deep tillage is a practice that breaks up soil, usually 30-45 cm, to allow increased water movement, better aeration and access to minerals and nutrients required for the growth of the plant. The main aims of deep tillage is to reduce soil compaction, break hard pan, reduce the soil bulk density and soil strength thereby encouraging deeper rooting of plants, and improving soil infiltration rates, plant's access to water and minerals. While conventional tillage can break up the soil from 15 cm to 20 cm, in areas with soil compaction problem, this tillage practice may not be adequate (Mohamed et al., 1997).

2.4.1. Effect on bulk density and porosity

Tillage loosens the soil, thus changing particle to particle contact and porosity of the soil. Bulk density of the soil is affected by tillage. A decrease in bulk density results in an increase in porosity. When the soil is loosened, the soil volume increases without affecting the weight on the soil, hence the bulk density of tilled soil is less than that of untilled soil. Change in porosity of the soil in return affects the water and heat transmission characteristics of the soil directly. A change in porosity and particle to particle contact affects all the physical state variables of the soil (Gajri and Majumdar, 2002). Deep tillage system can improve soil physical properties such as decreased bulk density; improve infiltration rate and hydraulic conductivity; increases soil moisture and yield under dry land production (Busscher et al., 2000). A study conducted in western Iran to see the effect of tillage treatments and manure application to a coarse textured soil on corn root length density and soil physical properties showed that moldboard plow resulted into, higher root length density, lower bulk density and cone index. The tillage treatments compared were: no till (NT); chisel plow (CP), up to a depth of 15 cm, and moldboard plow(MP), up to a depth of 30 cm and involving complete inversion of soil and crop residue (Mosaddeghi et al., 2009). Other studies such as Sadegh-Zadeh et al., (2011) showed that deep tillage reduces the soil bulk density. According to the report by Burayu et al. (2006) the bulk densities of no tillage at 0-15 cm and 15 cm-30 cm were significantly higher than that of the conventional tillage for both soil depths.

2.4.2. Effect on soil cone index and root length density

Soil compaction is determined by measuring its resistance with a penetrometer and the value obtained is referred to as soil cone index. Since tillage operations loosen the soil, it facilitates root penetration and results in better anchorage, and better soil mineral and water exploitation by the plant. Mosaddeghi et al., (2009) showed that the cone index of moldboard plowed soil was smaller than that of chisel plow and no till systems. The same study shows that the plant root lengths and densities were higher for the moldboard tillage. A study by Sadegh-Zadeh et al., (2011) showed that deep tillage with mulch addition had resulted a lower cone index than other treatments.

2.4.3. Effect on soil moisture

Tillage affects the soil water status or moisture content and the capacity of the crop to utilize water from the soil. Tillage alters the surface and subsurface soil conditions that govern infiltration, evaporation of water, runoff, weed growth, crop establishment and growth of the roots of the crop. Loosening of the soil through tillage increases the porosity by decreasing the bulk density.

2.4.4. Effect on biological and chemical properties

Stirring of the soil and redistribution of residues at the surface or into the soil, influence the soil environment by modifying temperature, moisture, and aeration status of the soil. The effect of tillage on chemical and biological properties of the soil depends on climate, quantity of residue produced, soil type, soil management history, time of the year and time since the tillage system was initiated. Tillage affects the physical and chemical soil environment by which different organisms' live, thus affecting the soil microbial and other biological activities (Kladivko et al., 2001).

2.4.5. Effect on infiltration rate, hydraulic conductivity and groundwater recharge

Infiltration rate is the flux or volume of water entering the soil per unit area per unit time. Tillage can improve the infiltration rates of the soil by loosening or decreasing the bulk density or increasing the macro pores.

Scanlon et al. (2008) reported that low permeability soils are widespread in crop land areas globally, and deep plowing could greatly increase groundwater recharge in such areas. According to the report if deep plowing were applied to 10% of the Pullman soils, it could increase the regional volumetric recharge by 0.1km^3/ha, and which is similar to the existing volumetric recharge of the region. Also, the same report showed that deep tillage increased the yield by reducing water logging.

2.4.6. Effect of tillage on runoff and soil loss

Runoff is an important water balance component in rain fed agriculture. Runoff from a particular storm is a function of the infiltration rate of the soil, surface storage and rainfall intensity (Descheemaeker et al., 2006). As reported by Sadegh-Zadeh et al., (2011) the runoff and soil loss decreased with increase in depth of tillage. Also, the study showed that runoff and soil loss were reduced by application of mulching. The authors suggested that the reduction in runoff and soil loss were due to the improvement of the infiltration rates of the soils.

2.4.7. Effect of tillage on crop yield and biomass

Crop performance under different tillage treatments depends on site specific soil and climatic conditions as well as management practices. Tillage affects water and air dynamics in the soil-atmosphere system, which influences the growth and yield of crops. Coarse textured soils which are characterized by low water holding capacity and high permeability exhibit a sharp increase in soil strength when dry. On such types of soils because of the low availability of water storage and high potential of leaching of mobile nutrients, soil compaction would subject plants to water and nutrient stress thereby causing reduction in crop yield. On such types of soils, deep tillage would minimize the water and nutrient stress by encouraging deeper rooting which would enhance uptake of water and nutrients from the lower profiles of the soil horizon.

2.4.8. Effect of tillage on runoff water quality and nutrient leaching

Contaminants leave fields in the form of both water and sediment portions of runoff (Daniel et al., 2009). The greater the water loss from a field, the higher the loss of water born contaminants including nutrients, pesticides and sediment. The amount of nutrient runoff and leaching depends on the tillage practices. According to the report by Daniel et al. (2009), phosphorus exists in one of the following four forms in moist soils: (i) associated with soil particles; (ii) in mineral form as aluminum, iron or calcium compounds; (iii) soluble compounds dissolved in soil water; (iv) incorporated in organic matter.

Generally, soluble phosphorus losses are higher in no till treatments than tilled systems (Daniel et al., 2009).

3. MATERIALS AND METHODDS

3.1. Study Area

This study was conducted at an experimental watershed called Robit-Bata, which is located at the south-eastern edge of Lake Tana, Amhara Region, Bahirdar Zuria woreda, Robit-Bata Kebele administration. The watershed is located about 20km north of Bahirdar town, along the Bahirdar_Gonder asphalt road. The watershed area is about 1034ha. It has a sub-tropical ("WoinaDega") climate with average annual rainfall of 1500 mm, temperature ranges from 11.6 to 27.1^{0}C, and average sunshine hours of 8.0hrs. The area is one of Agricultural Growth Program (AGP) and Feed the Future Woredas in the region. The livelihood system is based on both crop and livestock production. Crop production mainly includes cereals (mainly maize, teff, millet, barley); fruits like mango and avocado, legumes like beans; and high value irrigated crop production like tomato, onion, potato, pepper and cabbage. Groundwater experience in smallholder irrigation with khat is relatively high. Motor pumps together with manual water lifting devices, mainly bucket mounted pulley system are widely used in the kebele. Shallow groundwater, river diversion and lake pumping are the main water sources used for irrigation. Land preparation and management in the area is by using ox driven Maresha plow, which can till up to a depth of 15 cm. Before planting, the tillage frequency ranges from three to five times depending on the type of crop sowed. This repeated tillage greatly contributes to the formation of restrictive soil layers as the dominant soil type in the area is clay. Since, for clay soils and with repeated tillage, fine clay particles infiltrate and can fill soil pores thus causing hardpan formations. Weed management is done manually by pulling, chopping, using ox driven Maresha plow between plant's row, and sometimes use of chemical herbicides. After harvest to the next planting, free animal grazing is a common practice. Thus this free grazing of animals would also contribute greatly for soil compaction.

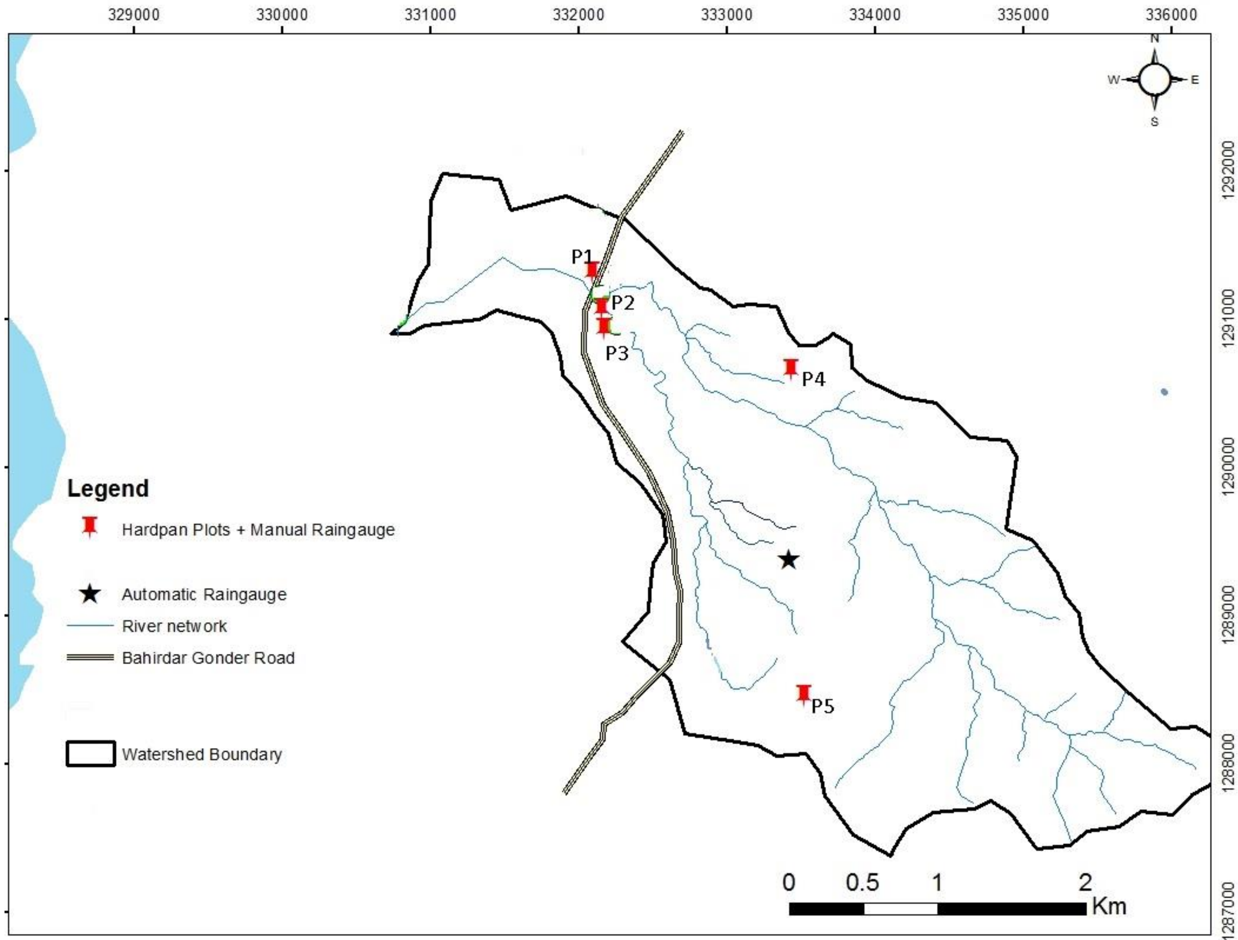

Figure 3.1 Location map of Robit and Yigashu watershed. Yigashu is the main river in the kebele.

3.2. Experimental design

3.2.1. Hardpan measurement and plot selection

Before the start of the tillage experiments, a pre-field study was performed to assess the presence of the hard pan using a cone penetrometer. A soil penetrometer consists of a 30° steel cone at the end of a steel shaft with a pressure gauge on the other end which reads in pounds per square inch (psi). The higher the reading, the more the soil is compacted (Raper et al., 2001). During the summer of 2014, 24 hours after a heavy rainfall (i.e. when the soil profile was considered to be at field capacity), the penetration resistance of various plots was measured to see the existence of restrictive soil layers (hardpans) using penetrometer. The penetrometer rod was driven in the soil at a rate of approximately 1 inch per second. Plots of penetration resistance greater than 300psi (2 Mpa) were selected for the experiment. The plot selection also considered similar plot slopes, topographic position, soil depth and uniform presence of boulders and rocks.

Table 3.1: Some of the plot characteristics considered for plot selection

Plot code	Topographic location	Soil depth	Average pre-treatment BD (g/cm^3)	Pre-treatment IR (mm/hr)	Average pre-treatment PR (Psi)	Average Slope (%)	Elevation (masl)
P1	Downslope	0.6m	1.24	171	310	6	1850
P2	Downslope	>3.5m	1.32	80	288	9.4	1958
P3	Downslope	>3.5m	1.12	192	326	10	1873
P4	Upslope	>3.5m	1.05	40	200	8.3	1871
P5	Upslope	0.8m	1.2	240	372	8	1976

3.2.2. Baseline survey, infiltration test and bulk density measurements

To support the measured penetration resistances of the plots, baseline surveys and infiltration tests were conducted on various plots to conform to the existence of hardpans. The baseline survey questions asked included for how long the farmer has been using the plot for agriculture, if they use the plot for only rainfed or irrigated agriculture too, how many cropping seasons do they have in a year, if they use the plot for grazing, what method of ploughing/ cultivating they use, how often they plough the land before cropping, and if they face any difficulty while ploughing the land. If so, what they think the problem might be. If the farmers use any organic or inorganic fertilizers on the plot, if there were any reduction of yield in the previous years. If so, why do they think it happened. Is it due to productivity of the soil? And how good is the productivity of their field compared to their neighbors' fields. After the baseline survey was conducted, the infiltration rates of the plots were also conducted using single ring infiltrometer. The infiltration rates were conducted by using a ring of 30 cm height and 30 cm diameter. The infiltrometer was driven up 15 cm into the soil. The sides of the infiltrometer were kept vertical with a level. Little disturbance was ensured to the soil inside and outside of the ring. An initial amount of water was poured into the ring and let to drain out. The ring was then filled with water and the depth measured and recorded. The water depth was measured with a float and a ruler. Subsequent water depths inside the ring with corresponding time lapses were recorded. The time interval varied from 1 minute to 10 minute depending on the infiltration rate of the soil. When the depth of water in the ring was low, additional water was poured into the ring and the depth recorded. The process continued until a constant rate of infiltration was obtained. The process of determination of plot's steady state infiltration rates was repeated at least three times in three different spots in each plot.

Undisturbed soil samples were taken from the plots at a depth of 20cm interval up to 1 m by using a core sampler in a 1 m dug pit. The ring was driven into the soil with a small mallet (plastic hammer) and block of wood. The ring was removed by cutting around the outside edge with a small, flat bladed knife. The excess soil from the bottom of the ring was removed with the knife. The sample was placed in a re sealable plastic bag and the bag was labeled. The sample including the bag was weighed and the weight recorded. The weight of the empty bag and the ring was also measured and recorded. The sample was oven dried for 24 hours at a temperature of 105^0C. Then the weight of the dry soil sample with ring measured. The dry weight of the soil sample was obtained by subtracting the dry sample plus core ring weight from the wet sample plus ring weight. Finally, the bulk density was obtained by dividing the dry soil sample weight by the volume of the core ring.

3.2.3. Experimental layout

This study was conducted using experimental farmer field plots in the Robit-Bata watershed. The size of each plot was fixed at 12 m by 30 m. Different tillage treatments were randomly assigned to subplots and their effects on water holding capacity, event runoff, sediment transport and crop yield responses evaluated. The experimental plots were classified based on topographic features and land use patterns. They were three replications of the 12 m * 30 m plot at lower slope and two replications of 12 m * 30 m plot at the upper slope. Each plot was divided into three subplots with dimensions of 4*30 m. The different treatments within the subplots were no tillage, conventional tillage (up to a depth of 15 cm) and 60 cm deep ripping of the impermeable layer.

The subplots was separated (demarcated) using sheet metals of 8 mm thickness and 50 cm width to protect surface and subsurface runoff and run-on between the subplots and also from the surrounding area as shown below in the figure 3.2. The metal sheets were driven up to 35 cm into the soil.

Figure 3.2 Subplot demarcation

3.3. Plot preparation and performing tillage

After the final selection of the plots, the subplots were randomly assigned with the different tillage treatments. Starting from May 14 2015, subplots subjected to conventional tillage were dug up to a depth of 15 cm, using ox driven Maresha plow, three times with fifteen days interval. The sub plots with treatment of deep tillage; the breaking of the restrictive soil layers was conducted by manually digging up to a depth of 60 cm using a mattock. For the no tillage treatment, only manually removing the weeds (pulling by hand) during planting was conducted. Finally after the plots were prepared, planting of the seeds took place on June 26, 2015.

Figure 3.3: Conducting tillage operations: left, deep tillage by manual digging using a mattock and right, conventional tillage by ox-driven Maresha plow.

GPS coordinates of the plots, slope of plots, size of experimental area; soil samples for physiochemical properties analysis were collected. Infiltration rates of the subplots were measured using single ring infiltrometer before and after the tillage treatments.

Important points about the experimental design are listed below:

- Five experimental plots, two in the upslope and three in the down slope of the watershed were selected.
- All the experimental plots were 12m x 30m.
- Hybrid maize seed was sowed in all subplots; this was based on the farmers' interest. Fertilizer was applied two times. First, at planting, di-ammonia phosphate (DAP) was applied at a rate of 200 kg/ha. At 60 days after planting UREA was applied at each subplot at a rate of 200kg/ha.
- The crop management systems (removing weeds by manual pulling and chopping) in all subplots were similar.
- The planting spacing of 20 by 50 cm for maize was used for all subplots.
- 15 Soil moisture profiler probe (SMPP) access tubes were installed in each subplot of tillage treatment to measure soil moisture two times a week up to 1 m soil depth.
- Manual rain gauge was installed at each plot to measure rainfall received at each rainfall event.

3.4. Installation of runoff barrels and access tubes

After planting, runoff collection barrels were installed at the outlet of each subplot. Two barrels were installed at the outlet of each subplot (Figure 3.4). One main barrel with diameter of 60 cm and height of 50 cm (140 liters) which directly collected runoff from a subplot through a PVC pipe. The main barrel had 10 outlets with 2.5 cm diameter pipes. When event runoff in the main barrel filled up to these outlets, any more incoming runoff would flow out through those 10 outlets. Event runoff from one of the outlets flowed into a second barrel of diameter 60 cm and height 40 cm (110 liters); implying that the second barrel receives one tenth of the water from the main barrel. The top of the barrels was covered with corrugated iron sheet roofs to prevent rainfall from falling into the runoff collection barrels (Figure 3.4).

One moisture access tube was installed at each subplot in the lower third of the subplots to measure the soil moisture contents two times a week; every Monday and Thursday up to a depth of one meter. Also, one manual rain gauge was installed at each plot to measure rainfall (Figure 3.4).

Figure 3.4: Runoff barrels (left) and manual rain gauge (right) installed to collect surface runoff and daily rainfall respectively

3.5. Data Collection and Methodology

3.5.1. Soil physiochemical properties

The soil samples were collected from each plot from 20 cm depth up to a depth of 1 m by manually digging a pit for those plots in which the parent rock was located at a depth below 1 m. For the plots where the parent rock was shallower, soil samples were taken up to 60 cm (depth up to which deep tillage was conducted). Soil samples from each plot were thoroughly mixed and 500-1000 gram of the composite analyzed for soil texture, electrical conductivity (EC), available organic matter (OM), and pH of soil sample, cation exchange capacity (CEC), total nitrogen (N), plant available phosphorus (P), potassium (K) and iron status. Soil texture of the field was determined in the laboratory using the hydrometer method. Electrometric method with the suspension of soil-water ratio of 1 to 2.5, stirred for 30 minute was used to determine the pH of soil. Kjeldahl method was used to determine total N. Plant available phosphorus was obtained from extraction of acid-soluble and adsorbed phosphorus with fluoride-containing solution according Bray I test (acid soil). Electrical conductivity bridge was used to determine the EC of the 60 min stirred suspended soil (1:5 soil:water ratio). Available organic matter was determined by using titration with ammonium sulphate. Potassium was determined by using Morgan's solution. Cation exchange capacity was determined by using flame photometer method.

3.5.2. Rainfall

The 24 hour cumulative rainfall data during the experimental period was collected from the manual rain gauges installed at each plot from July 1, 2015 to October 13, 2015.

3.5.3. Event runoff

The total event runoff from the different subplots was measured using the runoff collection barrels installed at the outlets of each subplot. The 24 hour cumulative event runoff was measured each day at 8:00am. The total event runoff depth in the barrels (depth of event runoff water in cm) was measured using ruler. The total event runoff depth is the sum of event runoff depth in the main barrel plus ten times the depth of event runoff in the overflow (second) barrel. This depth of event runoff in the barrels is converted to corresponding depth in subplots by dividing the volume of event runoff in the barrels by cross sectional area of the subplots. The event runoff coefficient which is the quotient of the total event runoff to the total rainfall was determined for each subplot for each runoff event. The runoff coefficient is a dimensionless coefficient relating the amount of runoff to the amount of precipitation received. It is a larger value for areas with low infiltration and high runoff. Also, the percent event runoff (i.e. the percentage of rainfall that turned into event runoff) for the various subplots and tillage treatments was determined to see how much of the received rainfall was lost as surface runoff.

3.5.4. Soil moisture change throughout the soil profile (SP)

The soil moisture profile probe (SMPP) measures soil moisture content at different depths within the soil profile. It consists of a sealed polycarbonate rod, 25 mm diameter, with electronic sensors attached at fixed intervals along its length. The tubes are specially constructed, thin-wall tubes which maximize the electromagnetic field into the surrounding soil. The probe is inserted into an access tube while taking a reading.

The installation of soil moisture profiler access tube took place for each subplot, treatment and topographic position up to a depth of 1m.

Measurements were taken regularly from planting to harvest two times in a week, every Monday and Thursday. The device records volumetric water content at the depth of 10, 20, 30, 40, 60, and 100 cm.

3.5.5. Agronomic performance and maize yield

The agronomic performance was collected from each subplot during the various growth stages i.e. initial, development, mid-stage, and final stage. Maize Plants heights were measured from the average of six randomly selected maize plants for subplot of each treatment. Maize plants were selected based on their relative growth: two smaller maize plants, two medium maize plants and two bigger maize plants. Finally at harvest the total maize yield from each subplot was measured. In addition the total dry biomass at harvest was also measured. After harvest the biomass was left for three weeks to dry before measuring. The biomass was harvested at some heights above the surface, on average 10 cm. During measuring: the biomass which was cut 10 cm above the surface and also the one remaining was uprooted and both measured.

3.5.6. Soil Loss

The soil loss from each treatment was measured by taking samples from the runoff water. One liter of runoff water samples were taken from runoff barrels of subplot treatment after stirring it well for at least for one minute. The frequency of taking samples was based on event runoff occurrences. Samples were taken every time runoff was collected in the barrels. The water samples were then filtered using filter paper of size 100µm of known weight. The filter paper and the sediment trapped on it were oven dried for 24 hours at 105^{o}C. After oven drying, the weight of sediment and filter paper was measured and the weight of sediment determined. The total sediment from the runoff water equals the sediment concentration (g/l) multiplied by the total runoff water.

3.5.7. Water Quality

The quality of the runoff water samples from each subplot were analyzed for K, P and N using Photometer method. Samples were taken once every week for analysis.

3.5.8. Infiltration rate

The infiltration rate of the plots selected for the experiment was measured two times by using single ring infiltrometer. First during plot selection, the infiltration rates of the plots were measured to confirm with the existence of restrictive soil layers. And again after harvest, the infiltration rate of the subplots was measured using the same method to see the effect of the tillage treatments on the infiltration rates of the subplots.

3.5.9. Bulk density and penetration resistance

During plot selection, the penetration resistance of the plots was measured to see if there were restrictive soil layers. Those plots which have an average penetration resistance of greater than 2 MPa, and which satisfies other selection criteria were selected for the experiment. After the tillage treatments were applied, at the planting, the penetration resistances of the subplots were measured to see the effect of the different tillage treatments on the penetration resistance. All the measurements were taken 24 hour after an intensive rainfall had occurred, when the subplots were assumed at field capacity.

Also, the bulk density of the plots was measured two times. The first time was before the tillage treatments were applied to the subplots; bulk density measurements were conducted at different soil depths up to 1m at 20 cm intervals. Undisturbed samples were taken by using core samplers ranging in diameter from 4.5 cm up to 5 cm and height ranging from 7 cm to 9 cm. The second bulk density measurement was done after harvest. Bulk density measurements were conducted to see the effect of the tillage treatments on the bulk density of the soil. Samples were taken from each subplot. Undisturbed soil samples up to a depth of 60 cm at 20 cm interval by using core samplers of diameter 5.08 cm (2 inch) and height 5 cm.

3.6. Data analysis

At the end of cropping season, the collected data such as event runoff, soil loss (sediment), crop yield and biomass was checked by Q-Q plot for normality test (Appendix J). Those data which were not normal were transformed into log normal by using Log (data+1). For those data which were normal, a one way analysis of variance (ANOVA) using the least significant differences (LSD) test at the 5% probability level ($p<0.05$) was performed for the original data. For those data which were normal after transformation, one way analysis of variance (ANOVA) using the least significant differences (LSD) test at the 5% probability level ($p<0.05$) was performed for the transformed data. For those data which were not normal even after transformation, a non-parametric test Kruskal- Wallis test was used. All statistical analyses performed in this study were done using SPSS 16.0 version software.

4. RESULT AND DISCUSSION

4.1. Soil physiochemical Properties

The averages and standard deviations of pH, EC, K,CEC, OM, plant available P, total N and Fe are shown in Table 4.1, and details can be found in appendix A. There were significant differences between the five plots in terms of the soil chemical properties as shown in the table 4.2. The various soil chemical properties generally did not differ significantly across the soil profile up to 1 m. The one way ANOVA, for the various parameters for the plots is shown in Appendix Table J. Generally, the organic matter contents of the plots are small, which may be an indication of the existence of hardpans. The relatively higher organic matter contents of plots P1 and P5 was due to the use of organic amendments in those plots before the application of the tillage treatments as obtained from the baseline survey information.

Table 4.1: Soil physio-chemical properties of all plots.

Plot code	Topographic location	Soil texture	pH	OM (%)	TN (%)	Plant available P (ppm)	Fe (ppm)	CEC (cmol(+)/kg)	K (ppm)	Ec (ds/m)
P1	Downslope	heavy clay	5.51	1.19	0.06	2.67	18.32	25.13	8.95	0.05
P2	Downslope	heavy clay	4.98	0.50	0.03	3.48	4.24	19.88	6.92	0.02
P3	Downslope	heavy clay	5.44	0.65	0.03	4.88	7.77	17.72	7.46	0.04
P4	Upslope	sandy clay loam	4.98	0.84	0.04	5.4	11.73	39.73	8.33	0.02
P5	Upslope	heavy clay	5.34	1.65	0.08	16.15	17.24	17.1	16.78	0.04

Average			5.25	0.97	0.05	6.52	11.86	23.91	9.69	0.03
StDev			0.25	0.46	0.02	5.49	6.03	9.39	4.04	0.01

Table 4.2: Soil chemical properties across plots and up to 1 m soil profile

	pH	EC	K	CEC	OM	TN	P	Fe
Plots								
P1	5.51 a*	0.05 a	8.95 a	25.13ab	1.19 ab	0.06 ab	2.67 a	18.32 a
P2	4.98 b	0.02a	6.92b	19.88ab	0.50 a	0.03a	3.48a	4.24b
P3	5.44a	0.04a	7.46ab	17.72a	0.65 a	0.03 a	4.88a	7.77b
P4	4.98bc	0.02 a	8.33ab	39.73b	0.84 a	0.04 a	5.40a	11.73ab
P5	5.34ac	0.04 a	16.78c	17.10a	1.65 a	0.08b	16.15b	17.24a
Soil layers								
0-20 cm	4.97 a	0.05 a	9.28 a	22.54 a	1.10 a	0.05 a	4.44 a	15.46 a
20-40 cm	5.30 b	0.03 b	8.89 a	23.16 a	0.91 a	0.05 a	6.11 a	11.97 a
40-60 cm	5.39 b	0.03 b	9.04 a	19.33 a	0.71 a	0.04 a	4.73 a	10.51 a
60-80 cm	5.34 b	0.03 b	8.73 a	21.22 a	0.83 a	0.04 a	4.27 a	10.25 a
80-100 cm	5.40 b	0.03 b	7.96 a	17.60 a	0.55 a	0.03 a	5.16 a	8.04 a

* Means that share a letter down a column are not significantly different at a probability level of 5%.

4.2. Infiltration rate

There were significant differences in infiltration rates of the plots before application of the tillage treatments. Before application of the tillage treatments, the infiltration rate of plot P5 was higher followed by plots P3 and P1. The lowest infiltration rate observed was for plot P4. The differences in infiltration rates of the plots were mainly because of the difference in the soil properties. On average the infiltration rates of the plots located in the downslope was slightly higher than that of the upslope plots (Table 4.3).

But the average infiltration values does not represent the actual infiltration rates of the two portions of the watershed, as only there were two upslope plots and the infiltration rate of plot P4 was very small compared to plot P5. There was a significant difference in the infiltration rates of the plots due to the three different tillage treatments (p=0.012), (Appendix K). The infiltration rate of the deep tillage subplots significantly improved due to the breakage of the restrictive soil layer or loosening of the compacted layer (more pores created). For the two topographic locations and after treatment applications, the average infiltration rate for the downslope subplots was again higher than that of the upslope subplots. Due to breakage of the restrictive soil layer in the deep tillage subplots, the infiltration rates for the downslope subplots improved from an average of 148 to about 172 mm/hr. The infiltration rates of the upslope subplots only improved slightly after treatments were applied; average before was 140 mm/hr to an average of 141 mm/hr after treatments were applied. The infiltration data sheet for the various plots and treatments is provided in appendix B.

Table 4.3: Pre- and post-treatment infiltration rate

Plot code	IR Before tillage application (mm/hr)	IR after harvest (mm/hr)	
		DT	240
		CT	210
P1	171	NT	120
		DT	270
		CT	120
P2	80	NT	108
		DT	240
		CT	60
P3	192	NT	180
		DT	150
		CT	120
P4	40	NT	60
		DT	216
		CT	180
P5	240	NT	120

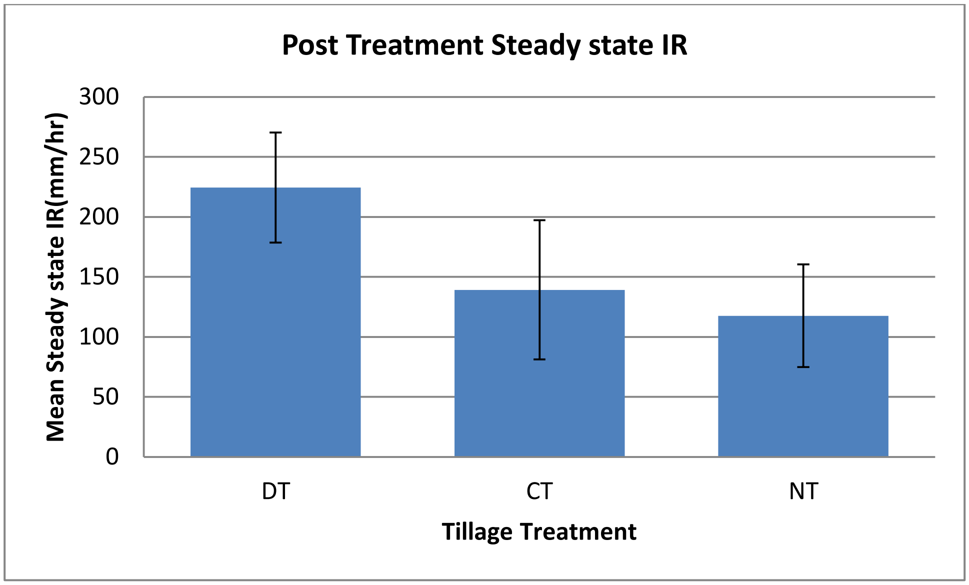

Figure 4.1: Post treatment mean steady state infiltration rate

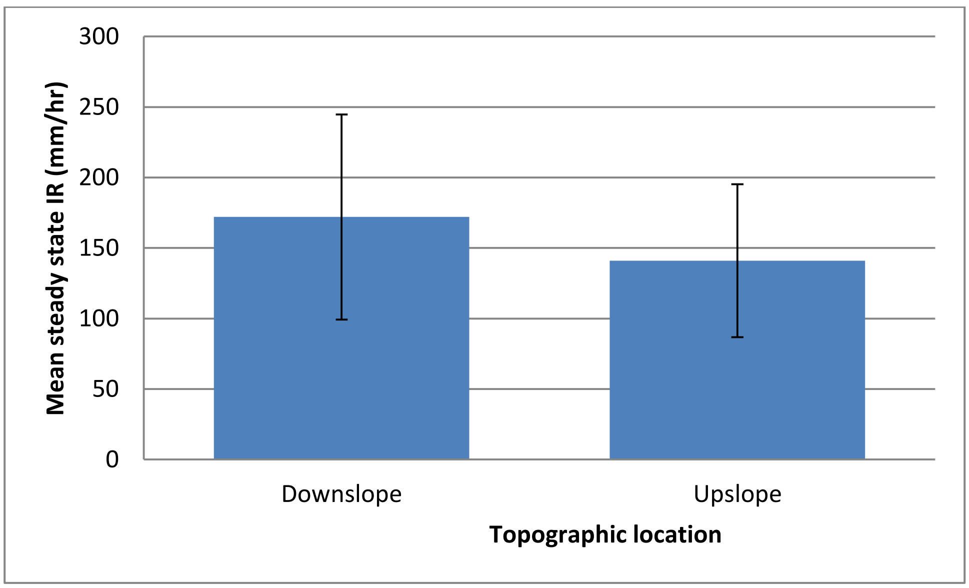

Figure 4.2: Post treatment mean steady state infiltration rates across topographic locations

4.3. Bulk density and penetration resistance

The pre-treatment bulk densities of the plots at different soil depths were not statistically significant (p=0.087). There were 1.21, 1.14, and 1.14 g/cm^3 at 0-20, 20-40 and 40-60 cm depths respectively. Pre-treatment bulk densities were highest for plot P2 at 1.32 g/cm^3 and lowest for P3 at 1.03 g/cm^3. Again the difference in bulk density was due to the differences in the soil properties. On average for topographic locations, the upper slope plots had lower bulk densities (1.11 g/cm^3) compared to 1.2 g/cm^3 of the downslope plots.

The bulk density of the subplots after harvest were not significantly different for the various soil depths ($p = 0.789$). There were 1.37, 1.36, and 1.40 g/cm^3 at depths 0-20, 20-40, and 40-60 cm respectively. Bulk density differences across tillage treatments after harvest were significantly different ($p<0.001$), (Appendix K). The bulk density of the subplots treated with deep tillage was significantly smaller compared to those sub plots treated with both conventional and no till (Figure 4.3). This was because the compacted soil layers have been broken during tillage or the soil becomes looser due to tillage. Bulk densities at harvest among plots were significantly different ($p=0.001$). Plot P1 had the highest bulk density of 1.47 g/cm^3, and plot P4 had the lowest average bulk density of 1.18 g/cm^3. The bulk densities of the plots located upslope were less than those plots located downslope (Figure 4.4).

Table 4.4: Bulk density before and after tillage treatment

Plot code	BD Before tillage application (g/cm^3)	BD after harvest (g/cm^3)	
		DT	1.31
		CT	1.5
P1	1.24	NT	1.6
		DT	1.25
		CT	1.49
P2	1.32	NT	1.62
		DT	1.2
		CT	1.46
P3	1.12	NT	1.43
		DT	1.03
		CT	1.21
P4	1.05	NT	1.29
		DT	1.17
		CT	1.46
P5	1.2	NT	1.55

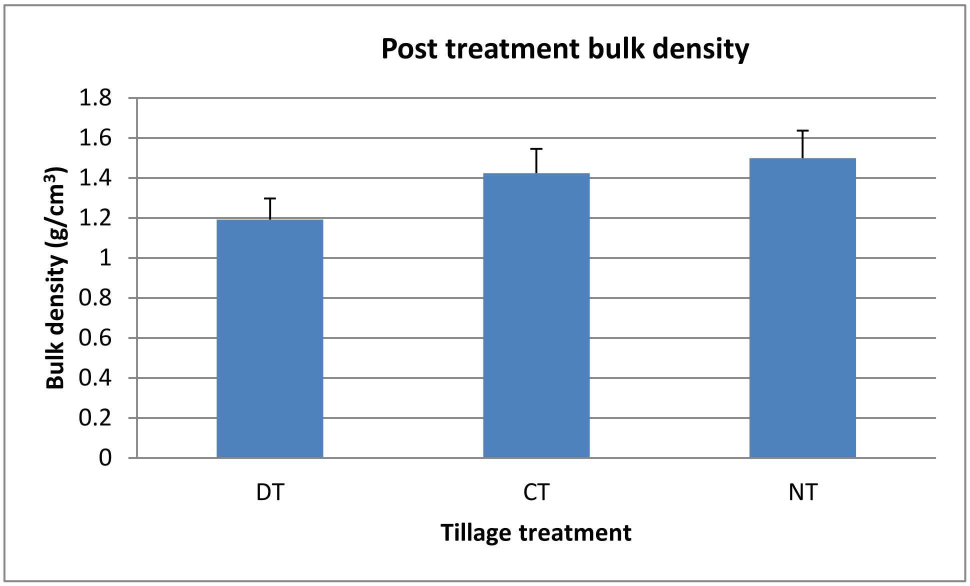

Figure 4.3: Post treatment bulk density for the different tillage treatments

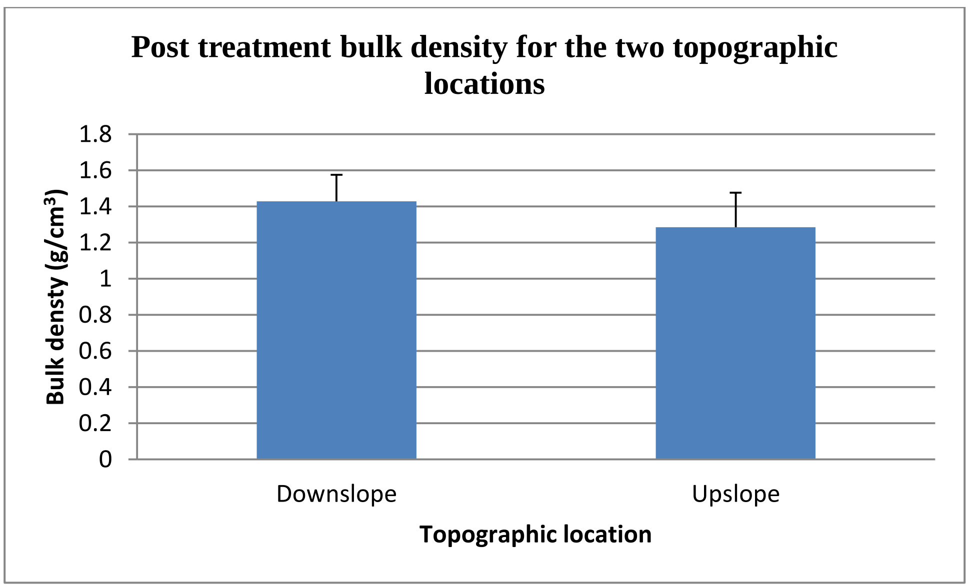

Figure 4.4: Post treatment bulk density for the different topographic locations

The penetration resistance (cone index) of the sub plots after the tillage treatments were applied was significantly different ($p<0.001$). The penetration resistance of the subplots treated with deep tillage was significantly smaller compared to those subplots treated with both conventional and no till (Figure 4.5). This was because the compacted layers were broken during tillage which makes the penetration by crop roots easier. The penetration resistance of the plots located upslope was less than those plots located downslope (Figure 4.6).

Table 4.5: Cone index before and after tillage treatment

Plot code	Cone index Before tillage application (Psi)	Cone index after harvest (Psi)	
P1	310	DT	124
		CT	226
		NT	306
P2	288	DT	118
		CT	282
		NT	334
P3	326	DT	104
		CT	227
		NT	287
P4	200	DT	46
		CT	148
		NT	229
P5	372	DT	112
		CT	287
		NT	326

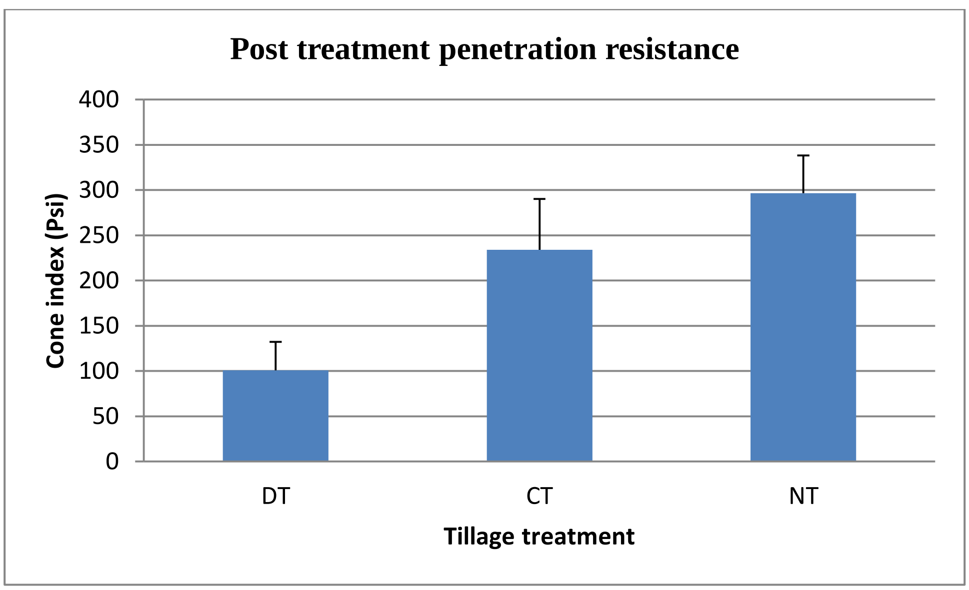

Figure 4.5: post treatment penetration resistance for the different tillage treatments

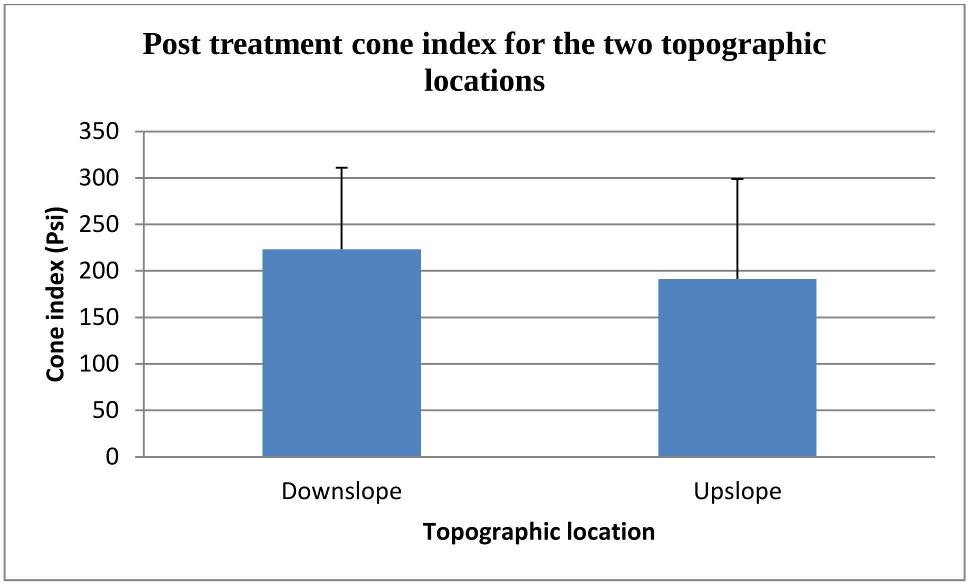

Figure 4.6: post treatment penetration resistance for the two topographic locations

4.4. Rainfall

The amount of rainfall received during the study period (1st July 2015-4th November 2015), at each plot were different. Among the five plots, the highest rainfall amount received was for plot P1 (1200mm), located at the downslope near the outlet of the watershed. And the lowest rainfall amount received was for plot P3 (877mm), located at the down slope but upstream of both plots P1 and P2. For the two topographic locations, a higher average amount of rainfall was received at the upslope of the watershed than the downslope.

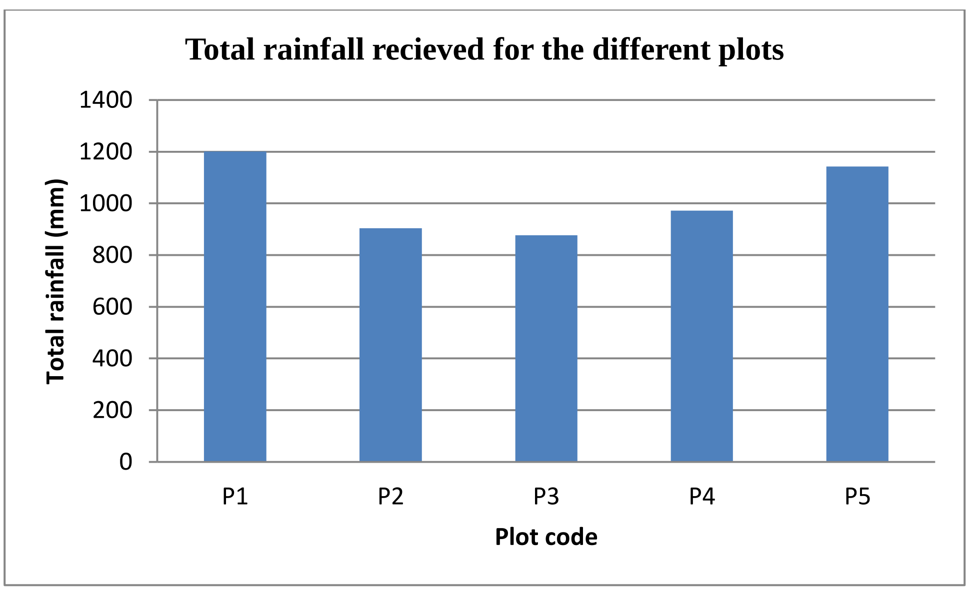

Figure 4.7: Total rainfall received for the different plots

4.5. Soil moisture

The soil volumetric moisture content at different soil depths for the different tillage treatments are plotted with the date of recording and corresponding rainfall (Appendix E). The results show that those subplots treated with deep tillage have higher soil water content as compared to subplots treated with conventional and no tillage (Table 4.6 and Figure 4.8). This is because in the deep tillage, the restrictive soil layers were broken so that the infiltration rates of the soil were improved, hence more rainfall was able to infiltrate into the ground. The soil moisture data for the different plots and treatments at the various depths is given in Appendix D and additional graphs (plot of soil moisture content versus recording dates) with the corresponding rainfall data are given in appendix E. Between the two topographic locations, the soil moisture for the downslope subplots was higher than that of the upslope subplots. The soil moisture content in deep tillage subplot of P1 was significantly higher than all the rest since the bedrock was shallower in plot 1 than any other plot; it caused the higher water content measured as the water is restricted on how deep it can flow due to the shallow bed rock.

Table 4.6: Average soil moisture content throughout the growing season for the three tillage treatments at various soil depths

Plot code	Tillage treatment	Soil depth (cm)					
		10	20	30	40	60	100
		Average soil moisture content (% volume)					
P1	DT	21.04	16.03	33.57	-	50.81	-
P2	DT	27.13	12.93	15.57	9.67	15.83	16.99
P3	DT	27.03	18.86	16.79	14.48	7.77	16.48
P4	DT	34.41	12.56	11.22	11.56	7.71	18.83
P5	DT	32.90	13.42	10.76	7.56	10.30	-
Average		28.50	14.76	17.58	10.83	18.50	17.43
P1	CT	13.50	9.62	3.40	-	19.42	-
P2	CT	18.25	14.99	11.96	6.62	14.12	14.20
P3	CT	18.10	16.43	12.10	9.70	8.80	15.43
P4	CT	31.04	18.78	7.05	9.13	8.50	14.65
P5	CT	22.50	12.15	10.78	9.56	9.72	-
Average		20.67	14.340	9.05	8.75	12.11	14.75
P1	NT	20.62	17.90	15.02	-	15.57	-
P2	NT	20.21	13.64	9.60	17.10	11.71	11.52
P3	NT	11.943	6.92	10.24	11.04	8.24	13.01
P4	NT	22.59	9.00	14.84	9.70	10.36	12.07

P5	NT	18.57	13.92	10.41	11.55	8.26	-
Average		18.80	12.27	12.02	12.35	10.83	12.20

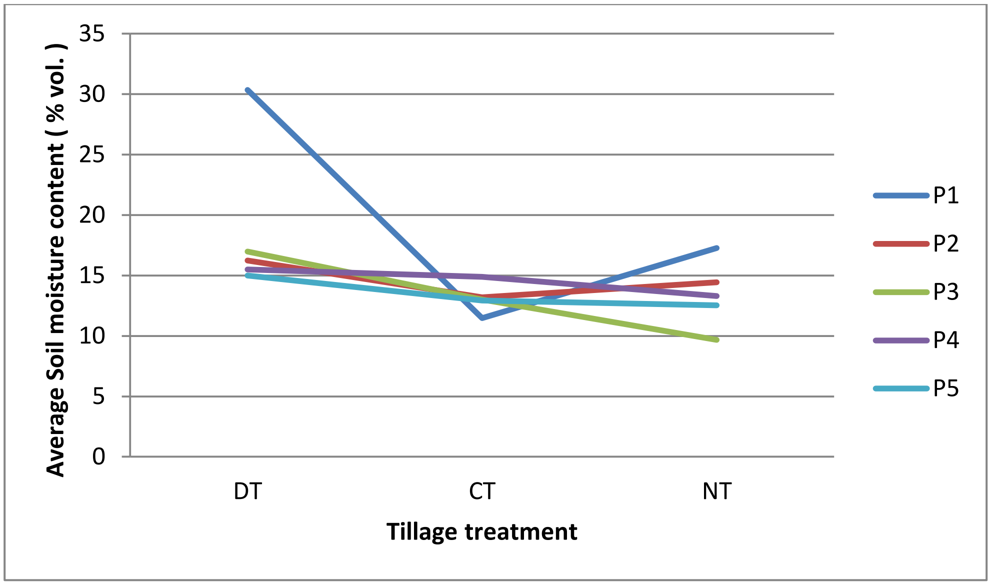

Figure 4.8: Average soil moisture content values for the different plots and tillage treatments

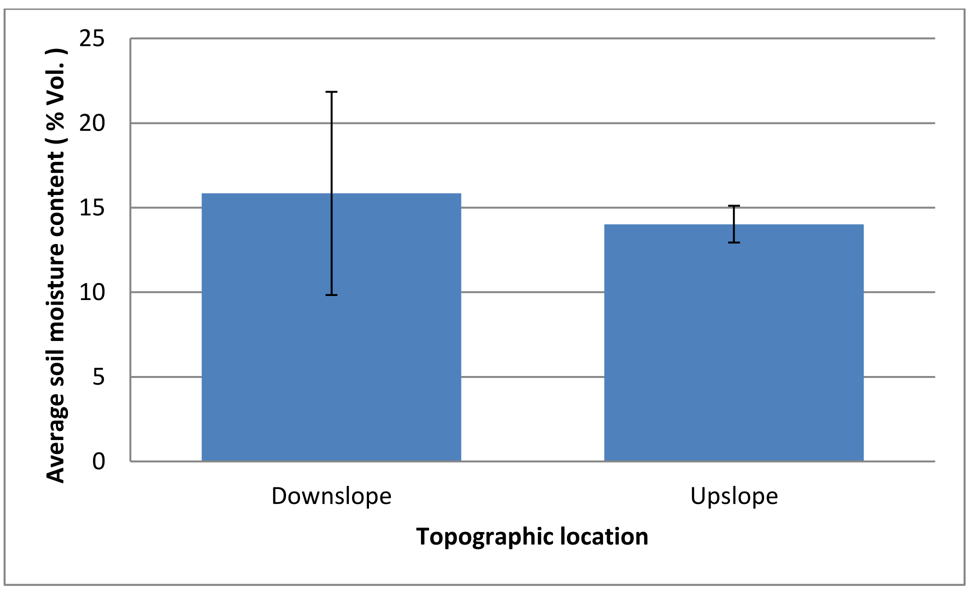

Figure 4.9: Average soil moisture content for the two topographic locations

4.6. Event runoff

Summary of all event runoff results for all the subplots is presented in Table 4.7. The data set was not normally distributed and didn’t satisfy homogeneity of variances (Appendix L). Even after transformation, the data set was neither normally distributed nor did it have equal variances. Hence a nonparametric Kruskal-Wallis test was used for the analysis.

Table 4.7: Summary of event runoff results

Plot code	Tillage treatment	Total event runoff (mm)
P1	DT	0.12
P2	DT	46.82
P3	DT	65.27
P4	DT	36.64
P5	DT	33.03
Average		36.38
P1	CT	1.04
P2	CT	207.35
P3	CT	99.76
P4	CT	54.45
P5	CT	64.98
Average		85.52
P1	NT	1.7
P2	NT	229.14
P3	NT	93.23
P4	NT	101.27
P5	NT	32.42
Average		91.55

4.6.1. Differences between the three treatments

The Kruskal-Wallis test was applied to see if there is a significant difference between the three different tillage treatments for all plots. The result shows that there was a significant difference (p=0.005) in event runoff between deep till, and the other treatments of conventional till and no till.

Table 4.8: p-values from post hoc analysis for comparison of event runoff among tillage treatments

Tillage treatments compared	Sample size(N)	Event runoff (P Value)
DT vs. CT	300	.002
CT vs NT	300	.703
DT vs. NT	300	.009

From the Mann Whitney test, event runoff from deep tillage subplots was significantly lower than that from both conventional and no till. There was no significant difference in event runoff from conventional and no till subplots. The event runoff from the deep tillage significantly reduced because the infiltrated water had room to move further down in the soil profile as in the changes in the soil moisture in the soil profile above (Figure 4.8).

4.6.2. Difference between topographic locations for the same tillage treatment

For the same tillage treatment, there was no significant difference in event runoff between the two topographic locations (upslope and downslope), i.e. the tillage treatments don’t behave differently between positions (Table 4.10). Overall, across the two topographic locations, the amount of event runoff observed in the downslope subplots was significantly higher than observed in the upslope subplots (p=0.022). This is because in the upper slopes, once rainfall infiltrates into the soil, it flows laterally under the soil surface to lower slope areas creating more room for more water to infiltrate, thus less event runoff is produced. On top of the rainfall that falls on the downslope subplots, they also receive interflow from the upper slopes making their moisture content levels high. As a result, subsequent rainfall turns to saturation excess overland flow in the downslope subplots when there is no room for more water to infiltrate in to the soil.

Table 4.9: Summary of event runoff results for the two topographic locations

Topographic location	Tillage treatment	Total event runoff (mm)
Downslope	DT	112.21
	CT	308.15
	NT	324.07
Average		248.14
Upslope	DT	69.67
	CT	119.43
	NT	133.69
Average		107.59

Table 4.10: p-values for comparison of effect of location

Tillage treatments compared	Sample size(N)	Run off (P Val
DT down slope vs. DT up slope	180	.077
CT down slope vs CT up slope	180	.350
NT down slope vs. NT up slope	180	.250

4.6.3. Difference in event runoff for each plots

The tillage treatments gave variable event runoff depths in the various plots (Figure 4.10). The reasons are explained as follows: for plot P1, there is a big *Ficus vasta* tree near the plot, which is assumed to extract from the soil significant amounts of water. For this plot (P1), event runoff was received from only four rainfall events in the no till and conventional tillage subplots, and from only one rainfall event for the deep tillage subplot throughout the cropping season. This also limited the magnitude of the impact of the different treatments on event runoff in this plot. This plot also had the lowest slope of 6%, which can also be the reason for the reduction of the surface runoff.

For plot P2, the three different tillage treatments gave significantly different event runoff response. In Figure 4.10 it can be seen that for this plot, the deep tillage gives significantly less event runoff compared to both conventional and no tillage subplots. And even though the conventional tillage subplot gave less event runoff than the no tillage subplot, the difference in event runoff response was not significant. This is because for the deep tillage, the restrictive soil layers were broken thereby reducing the bulk density and increasing the infiltration rate. For the conventional tillage subplot, the restrictive soil layers were not completely broken. Plot P2 gave the highest event runoff for conventional tillage and no till subplots because those subplots' penetration resistances after treatments were applied were generally higher than for those two treatments in the other plots. Also this plot had the highest slope.

For plot P3, the deep tillage subplot gave the least event runoff. No till treatments gave lower event runoff than that from conventional tillage because the subplot randomly selected for the conventional tillage had some portion of it used as a path for cattle before the study. Hence due to animal traffic, the soil was much more compacted which results a higher event runoff than the no tillage.

For plot P4, the event runoff response from the different tillage treatments was significantly different, with the deep tillage subplot giving the least event runoff, followed by conventional tillage and lastly, the no tillage subplot giving most event runoff as expected (Figure 4.10).

For plot P5, the event runoff responses were not significantly different across the tillage treatments. At this plot, the event runoff from the no tillage was relatively less than that for conventional and the deep tillage although the post treatment infiltration rate of the no till subplot was less than both conventional till and deep till subplot. Also the no tillage subplot had higher bulk density and penetration resistance as well as less soil moisture than the conventional tillage and deep tillage subplots as shown Figures 4.8. The reason for the less event runoff from the no till subplot is not clear.

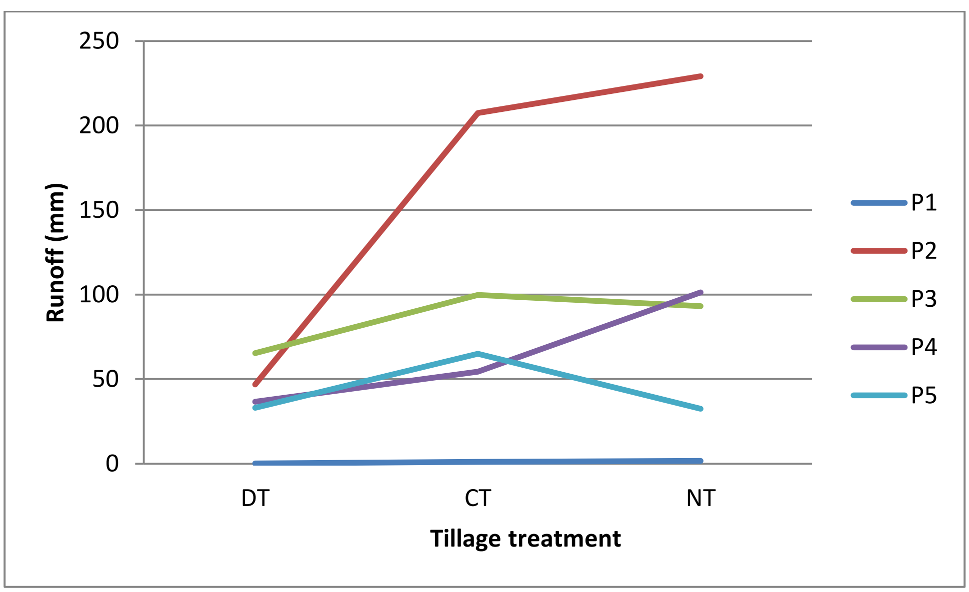

Figure 4.10: Event runoff values for the different plots and tillage treatments

Table 4.11: Comparison of effect tillage on event runoff all plots

Plot	All three treatments	DT –CT	DT-NT	CT-NT
1	.337	.163	.165	.981
2	.007	.014	.003	.850
3	.124	.043	.282	.319
4	.046	.078	.020	.357
5	.715	.565	.827	.430

4.6.4. Event runoff Coefficient and percent event runoff

The event runoff coefficient which is the quotient of the total event runoff to the total rainfall for the various tillage treatments is as shown in the table 4.14. Also, the percent event runoff (i.e. the percentage of rainfall that turned into event runoff) for the various subplots and tillage treatments is shown is shown in the table 4.12 and 4.14. Results show that, the no tillage treatment produced the most event runoff, 10% of the received rainfall followed by conventional tillage which produced 9.1% of the received rainfall. The deep tillage produced the least event runoff, 3.9% of the received rainfall. Among the two topographic locations, higher event runoff was observed from the down slope subplots, 9.2% of the total rainfall received while in the upslope subplots, the event runoff produced was 5.2% of the total rainfall received (Table 4.13).

Table 4.12: Event runoff coefficient and percent event runoff for the various tillage treatments

Tillage treatment	Average percent event runoff (%)
DT	3.9
CT	9.1
NT	9.9

Table 4.13: Average percentage event runoff values for the two topographic locations

Topographic location	Tillage treatment	Average Percent event runoff (%)

	DT	4.21
	CT	11.46
Downslope	NT	12.03
Average		9.2
	DT	3.32
	CT	5.64
Upslope	NT	6.62
Average		5.2

Table 4.14: Event runoff coefficient and percent event runoff for the various plots

Plot Code	Total RF(mm)	Tillage Treatment	Total event RO (mm)	Event runoff coefficient	Percent event runoff
		DT	0.12	1E-04	0.01
		CT	1.04	9E-04	0.09
P1	1200.9	NT	1.7	0.001	0.14
Average			0.95	8E-04	0.08
		DT	46.8	0.05	5.18
		CT	207.4	0.23	22.9
P2	904.5	NT	229.1	0.25	25.3
Average			161.1	0.2	17.8
		DT	65.27	0.07	7.44
		CT	99.8	0.12	11.4
P3	877.1	NT	93.2	0.11	10.6
Average			86.1	0.1	9.81
		DT	36.6	0.04	3.8
		CT	54.5	0.06	5.6
P4	972.45	NT	101.3	0.11	10.4
Average			64.1	0.07	6.59
		DT	33.0	0.03	2.89
		CT	65	0.06	5.68
P5	1143.24	NT	32.4	0.03	2.84
Average			43.5	0.04	3.8

4.7. Soil loss or sediment

4.7.1. Sediment due to tillage treatments and topographic position

The data set was not normal and didn't satisfy the assumption of homogeneity of variances. Hence the data was transformed by using the transformation function Log (data + 1). After transformation the data was normal and also satisfied the assumption of homogeneity of variances. Two-way analysis of variances was used on the transformed data.

There was no significant interaction between tillage treatments and topographic location for sediment from the subplots (p=0.824), appendix N. This implies that the tillage treatments and topographic positions had no combined effect on soil loss.

4.7.2. Effect of tillage on sediment

There was no significant difference among the three different tillage treatments (p=0.36) in sediment. Even though statistically non-significant, the soil loss was 42% higher for conventional tillage when compared to deep tillage, and 64% higher for no till when compared to compared to deep tillage. The reduction in soil loss for the deep tillage was due to the reduction in surface runoff which was responsible for the detachment and transport of the soil particles.

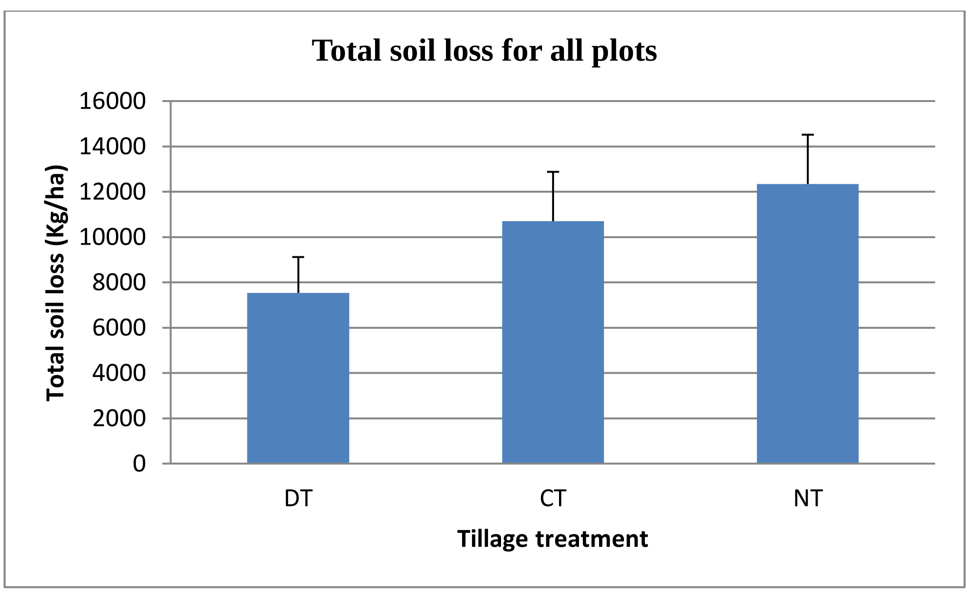

Figure 4.11: Sediment losses for the three different tillage treatments

4.7.3. Effect of location on sediment

The difference in the soil loss between the two topographic locations was not statistically significant (p=0.874). Even though statistically not significant, the soil loss from the upslope subplots was relatively lower than that from downslope subplots. This was due to the less surface runoff for the subplots located upslope.

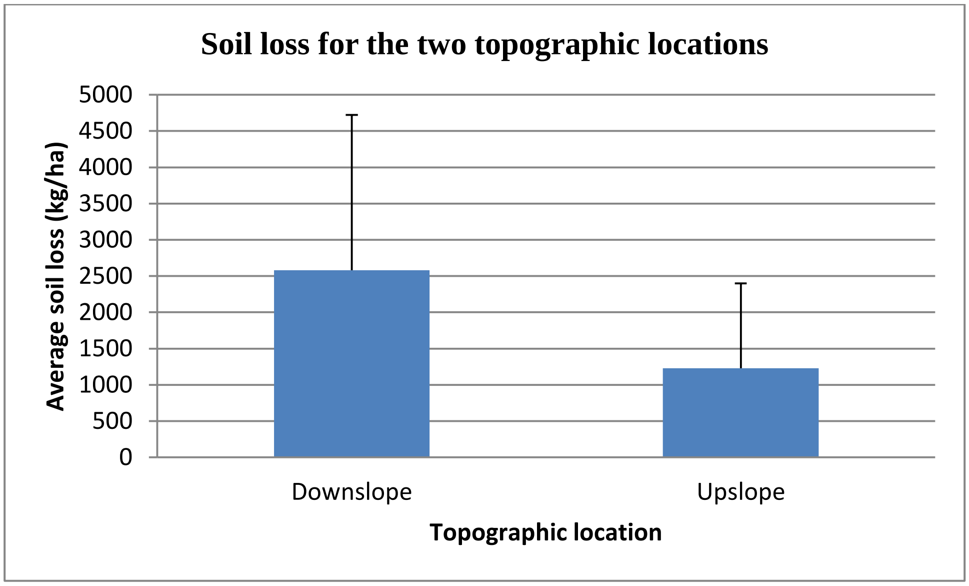

Figure 4.12: Average sediment losses for the two topographic locations

4.7.4. Sediment yield differences in plots

The average sediment yield from the different plots, for the three tillage treatments is as shown below (Figure 4.13). There was a significant difference in the soil loss between the five plots. Also plots P1 and P5 were significantly different from the other three plots. There was no significant difference between plots P2, P3 and P4. The soil loss from plots P1and P5 was significantly less than the rest of the three plots; this was because the event runoff from those plots was lower due to the reasons explained above. Plot P2 had the highest soil loss because it also gave the highest event runoff as seen in Figure 4.10.

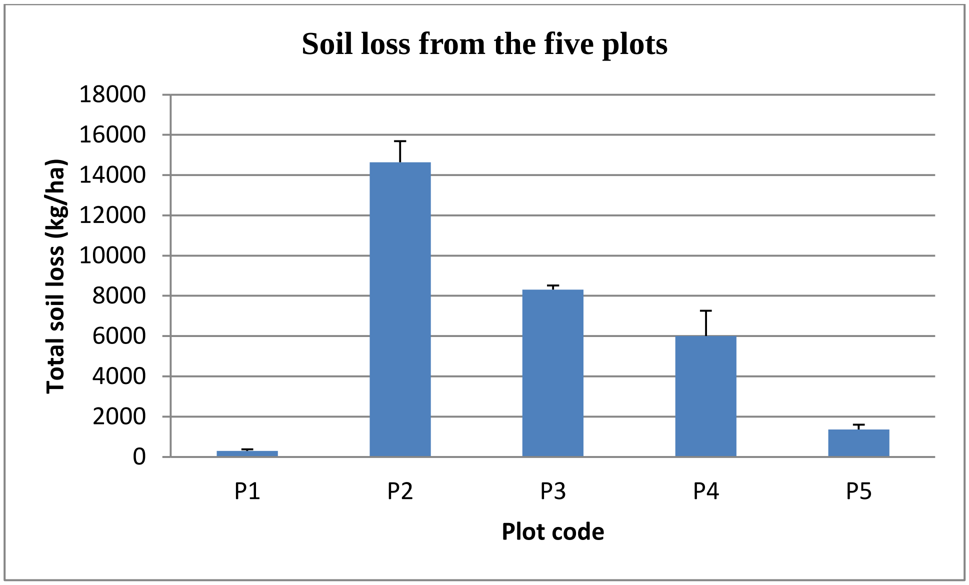

Figure 4.13: Total soil loss for the different plots (all treatments)

4.8. Runoff water quality

The runoff water quality was tested in terms of potassium, phosphorus and nitrogen. The data set was normally distributed and satisfied assumption of equality of variance. Hence two-way analysis of variance was used to test differences in water quality.

Among the three tillage treatments the concentration of potassium in the event runoff from the deep tillage treatment subplots was significantly less than that of the conventional and no tillage treatment subplots (p=0.034), Appendix O. But the differences in phosphorus and nitrogen concentrations between the tillage treatments were not significant, with p-values of 0.585 and 0.222 respectively. Even if statistically not significant, the concentrations of both phosphorus and nitrogen were higher for the no tillage treatment subplots followed by the conventional tillage treatment subplots. The higher concentration of nutrient loss from the no tillage treatment subplots was due to the fact that, as the fertilizer were placed near the surface it was exposed to be transported by the runoff water.

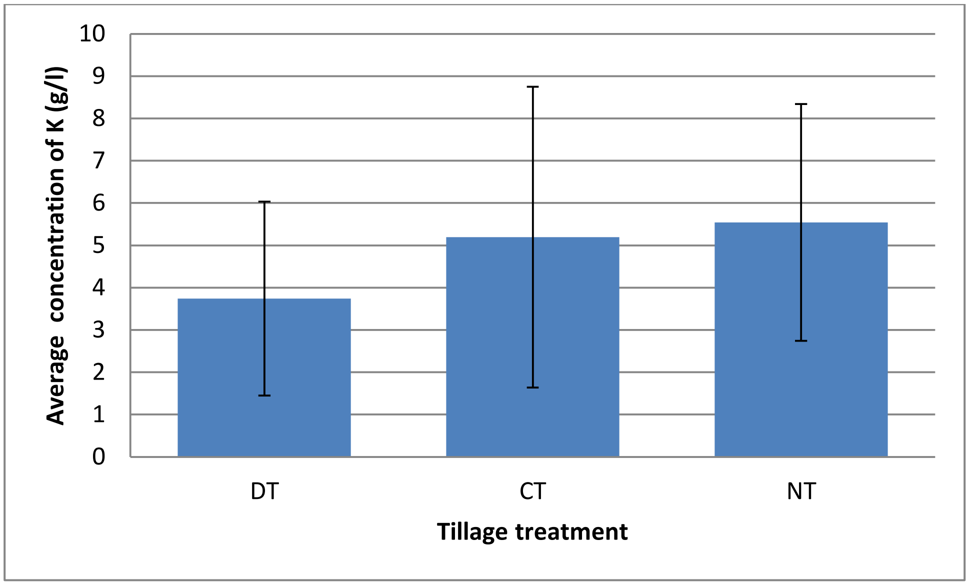

Figure 4.14: Average concentration of potassium for the three tillage treatments

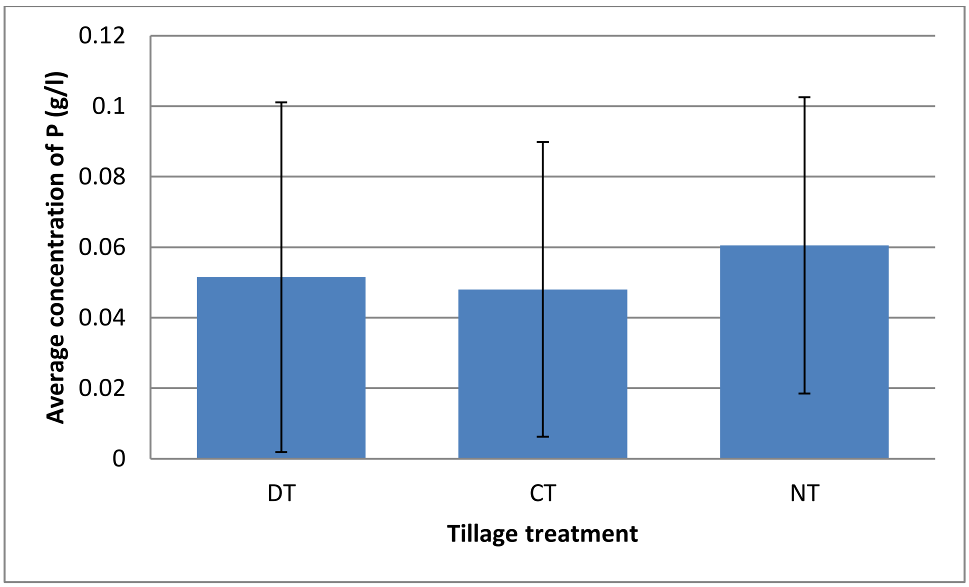

Figure 4.15: Average concentration of phosphorus for the three tillage treatments

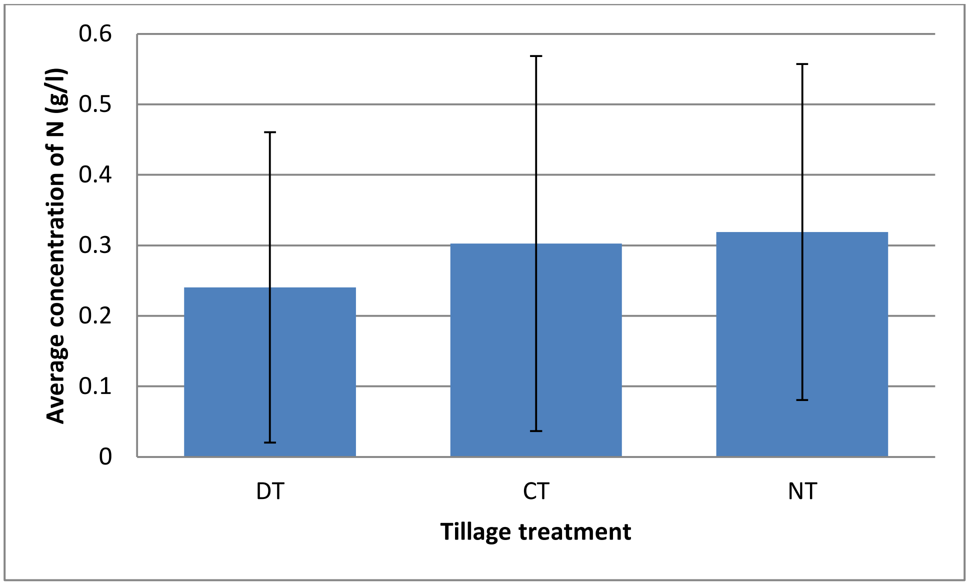

Figure 4.16: Average concentration of nitrogen for the three tillage treatments

4.9. Agronomic Performance

4.9.1. Plant height of maize

The height of maize at various days after planting (DAP) was measured and shown in Table 4.15. The tillage treatments significantly influenced plant heights in the various subplots as seen in Table 4.16. A more detailed statistical analysis can be seen in Appendix P.

Table 4.15: p-values at various development stages the three tillage treatments

Development Stage	DAP	p-value
Initial	30	0.001
Development	73	0.092
Mid	120	0.007
Late	150	0.000

Table 4.16: Average maize plant height for the three tillage treatments at various stages

Day After Planting	Tillage treatment		
	Deep Tillage	Conventional Tillage	No Tillage
	Plant height(cm)	Plant height(cm)	Plant height(cm)
30	35.37a	38.47 b	36.97 b
73	73.07 a	76.87 a	64.17 a
120	175.3 a	172.5 a	164.03 b
150	258.5 a	251.58 a	225.33 b

* Means across a row with the same letter are not statistically different at 5% confidence level.

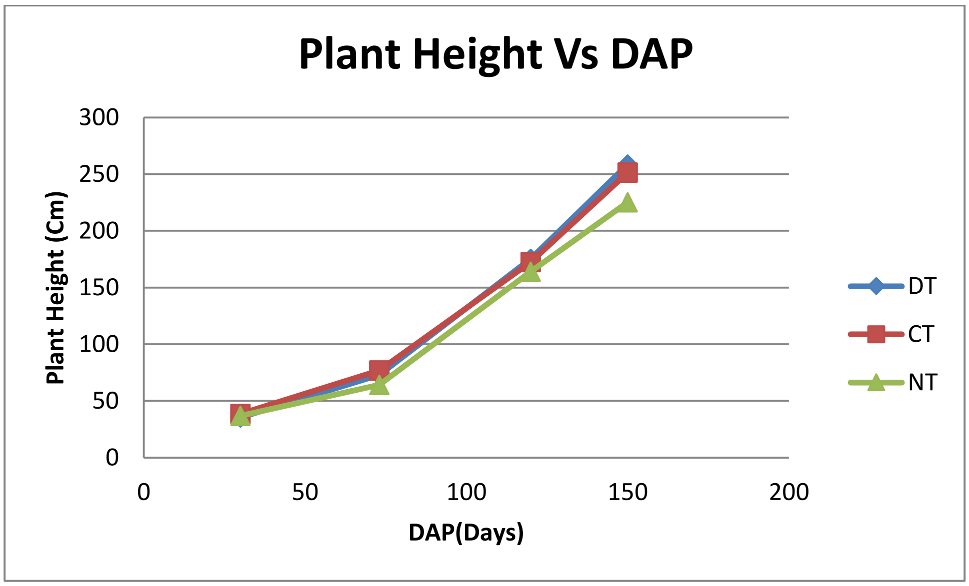

Figure 4.17: Day after planting versus maize height for the various treatments

4.9.2. Grain yield of maize

4.9.2.1. Combined effect of tillage and topographic position on maize grain yield

The data set was normal and the assumption of homogeneity of variances was satisfied. Hence a two-way analysis of variances was used, to see if there was a combined effect of tillage treatment and topographic location of the subplots on maize grain yield. From the analysis, the interaction between tillage and topographic location was not significant (P=0.849), i.e. there was no combined effect of tillage and topographic location on maize grain yield.

4.9.2.2. Effect of tillage on grain yield of maize

There was no significant difference in maize grain yield among the three different tillage treatments (p=0.521). Even though the difference in maize grain yield due to the three different tillage treatments was not statistically significant, the deep tillage gave a higher maize grain yield: 17.74% greater than for conventional tillage and 42.44% greater than for no tillage. Also, the conventional tillage gave 21% greater maize grain yield than the no tillage treatment. The increase in maize grain yield for the deep tillage was due the restrictive soil layers having been broken and the plants being able to take water and nutrients from a bigger portion of the soil profile. The ease for root penetration can be seen from the lower soil penetration resistance (cone index) values of the deep tillage subplots compared to conventional tillage or no tillage subplots. Also, the availability of more water for the deep tillage was due to the improved infiltration rate of the soil due to the breakage of the restrictive soil layers and the reduction in bulk density of the soil. The improvement of soil water availability for the deep tillage can be seen from the soil moisture results shown in the Table 4.6 and Figure 4.8. The full maize grain yield results are provided in appendix G.

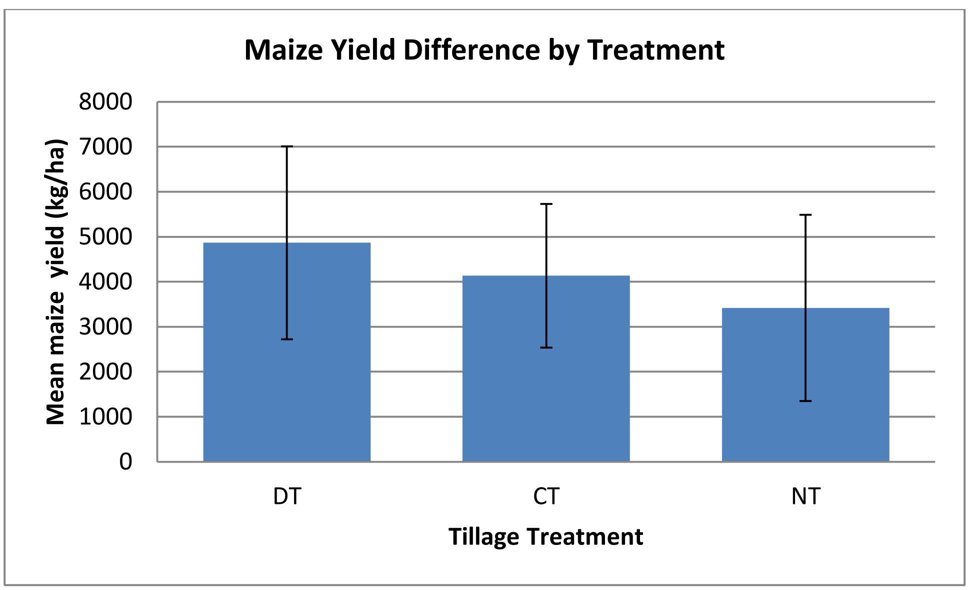

Figure 4.18: Mean maize grain yield in (kg/ha) from all plots for the three tillage treatments

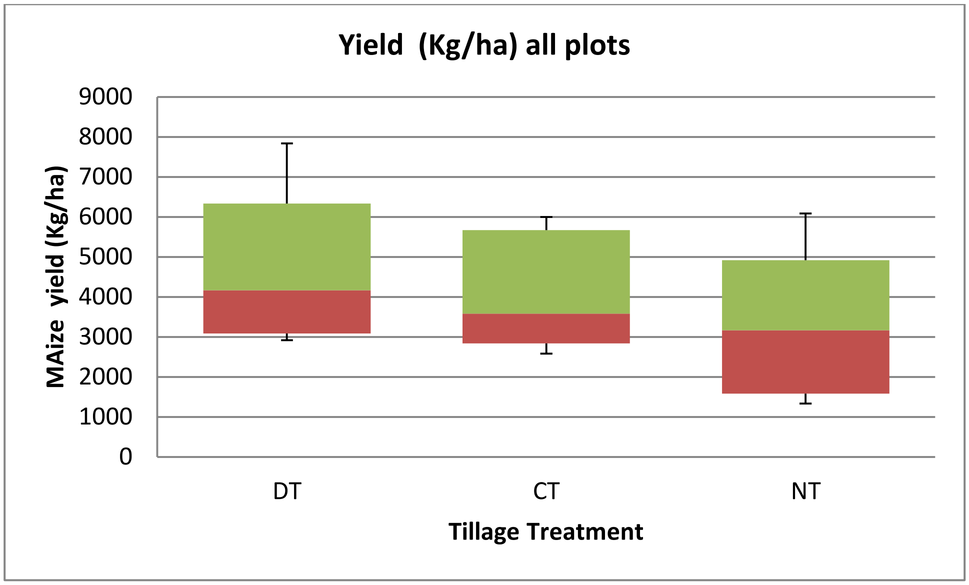

Figure 4.19: leaf plot of maize grain yield for the three tillage treatments

4.9.2.3. Effect of topographic location on maize grain yield

There was a significant difference between upslope and downslope subplots ($p<0.001$). This is due to the differences in climatic conditions; at the upslope plots at two different occasions there were a heavy rain with hailstones, so the plants were strongly damaged by the hailstones.

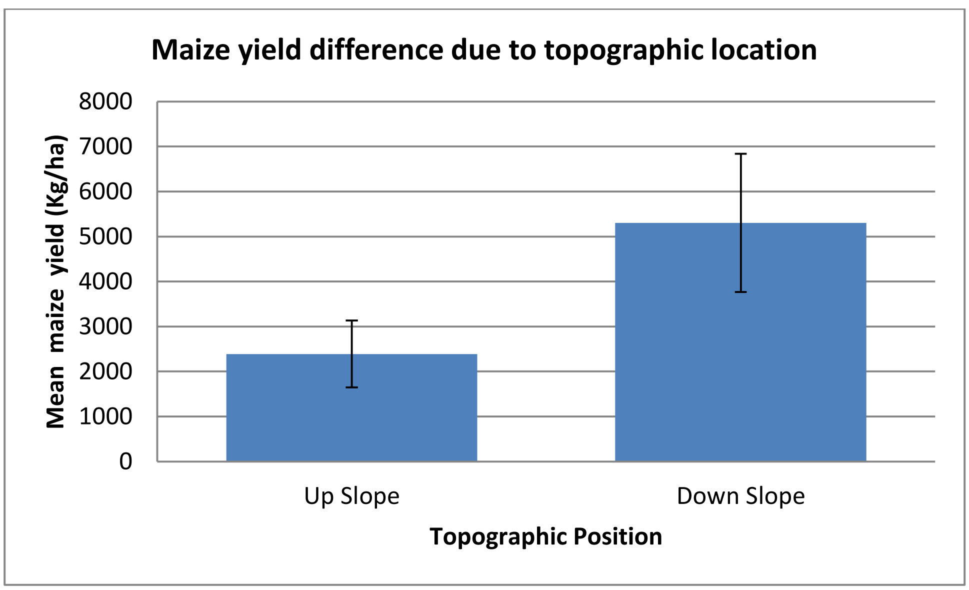

Figure 4.20: Average maize grain yield for all treatments, different topographic locations

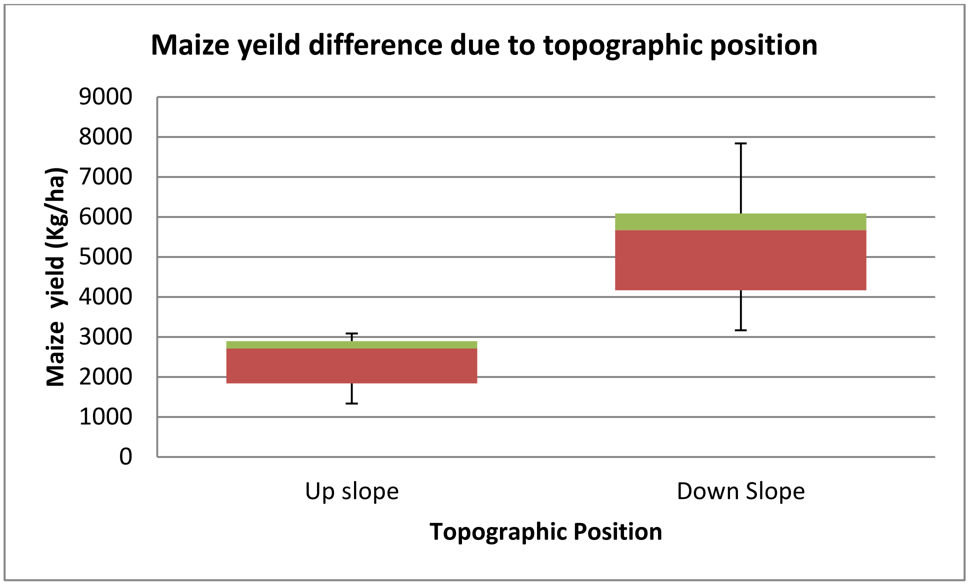

Figure 4.21: Grain yield difference due to topographic locations

4.9.2.4. Maize grain yield differences between plots

There was a statistically significant difference in maize grain yield between the five experimental plots ($p<0.001$).As can be seen from Figure 4.22, the high variability in maize grain yield at the various plots is largely attributed to the topographic locations of the plots as explained above. And the deviation of plot P1 from plots P2 and P3 located downslope is soil depth being shallower in plot P1 than in plots P2 and P3. The depth of the soil at plot P1 is less, i.e. there is a parent rock at a depth slightly greater than 60 cm. There is also a large *Ficus vasta* tree at plot P1 hindering the growth and production of the crops as it competes for the water and nutrients.

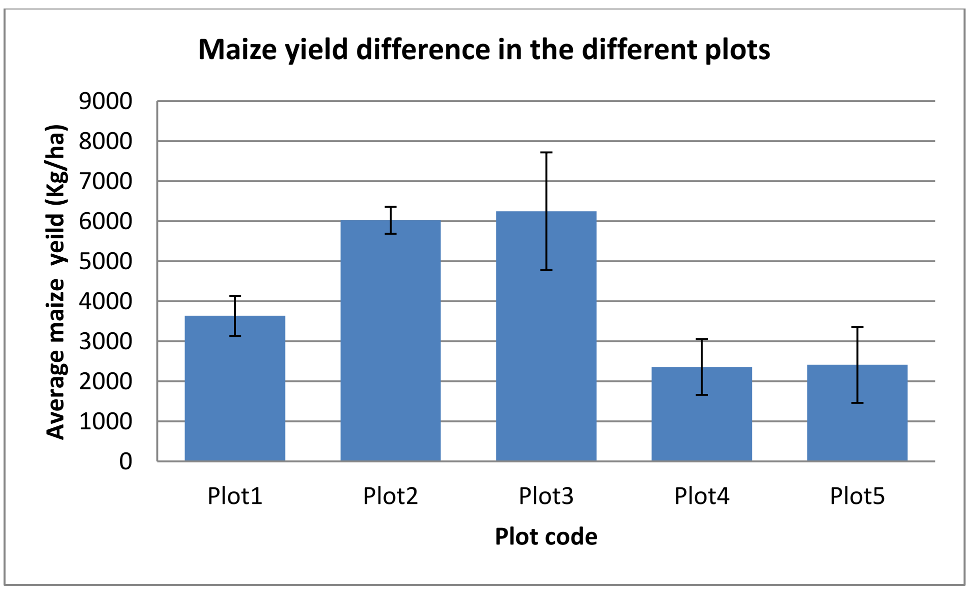

Figure 4.22: Average maize grain yield for the various plots

4.9.3. Biomass

4.9.3.1. Combined effect of tillage and topographic location on biomass

The data set was normal and the assumption of homogeneity of variances was satisfied. Hence a two-way analysis of variances was used.

The interaction between tillage treatments and topographic locations on biomass was not statistically significant (P=0.930), Appendix R.

4.9.3.2. Effect of tillage on biomass

The difference in biomass between the three different tillage treatments was statistically not significant (p=0.16). However, the deep tillage subplots gave a higher biomass, 22% greater than the conventional tillage subplots and 46% greater than the no tillage subplots. Also conventional tillage gave 31% greater biomass than the no tillage treatment. The increase in biomass for the deep tillage treatment is due to the restrictive soil layers having been broken and the plants were able to take water and nutrients from at bigger portion of the soil profile. The deep tillage subplots had less soil penetration resistance. Also the availability of more water for the deep tillage was due to the improved infiltration rate of the soil due to the breakage of the restrictive soil layers and the reduction in bulk density of the soil. The improvement of soil water availability for the deep tillage can be seen from the soil moisture results (Table 4.6 and Figure 4.8). The full biomass data sheet is provided in appendix G.

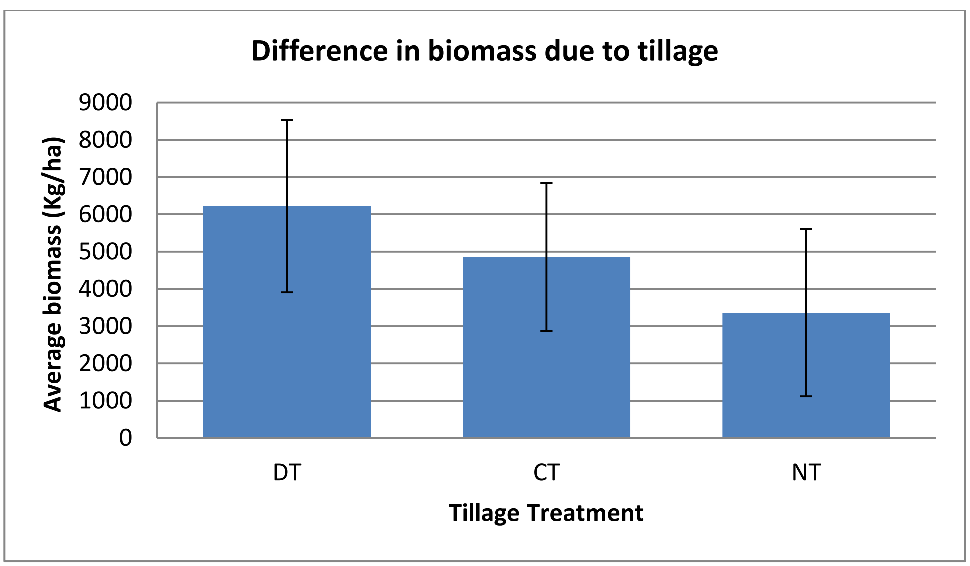

Figure 4.23: Average biomass for the three different tillage treatments

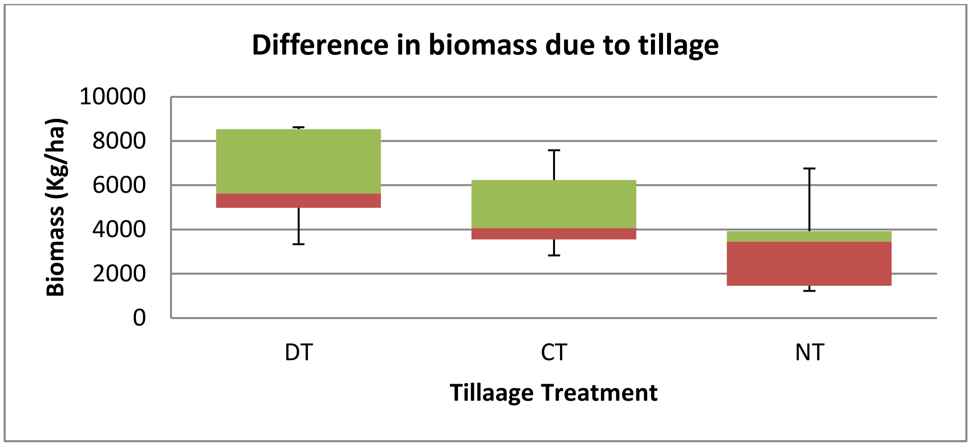

Figure 4.24: Difference in biomass for different tillage treatments

4.9.3.3. Effect of location on biomass

There was a statistically significant difference between upslope and downslope subplots (p=0.005). The analysis result is presented in Appendix N. The difference in biomass due to the topographic locations is as explained in maize grain yield section above.

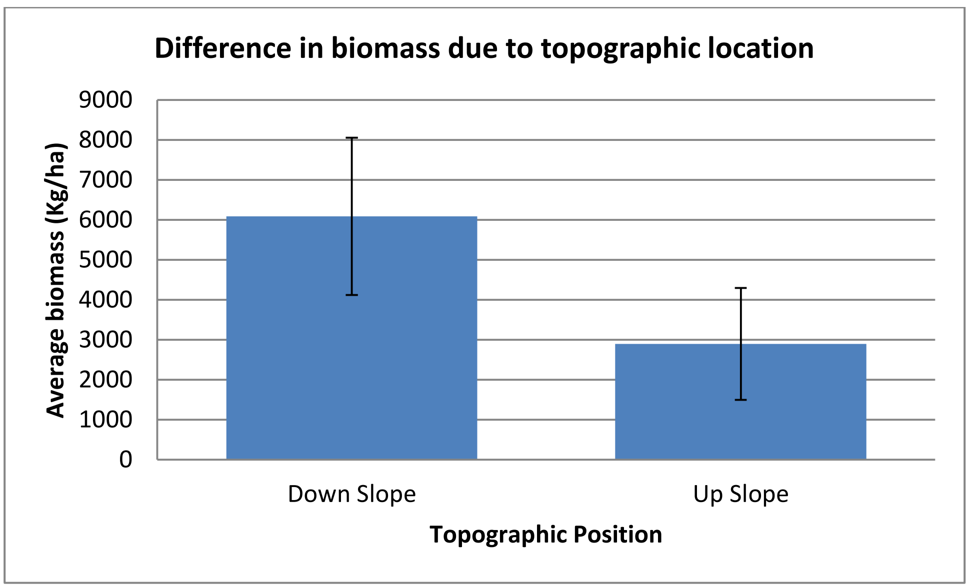

Figure 4.25: Average biomass for the two topographic locations

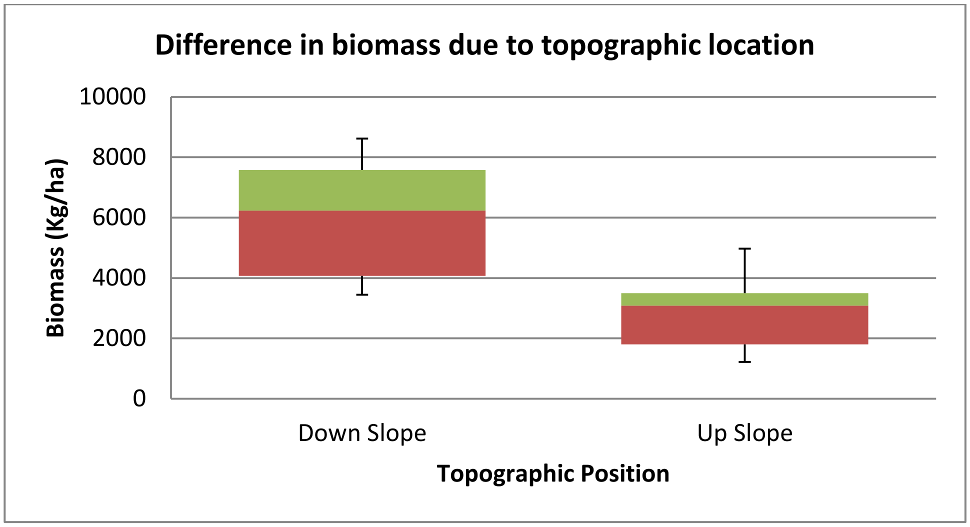

Figure 4.26: Effect of topographic location on biomass

4.9.3.4. Biomass differences in plots

The variability of biomass in the various plots was statistically significant (p=0.029). The reasons for the variation of biomass for the various plots are similar to what was as explained in portion 4.9.2.4 for maize grain yield.

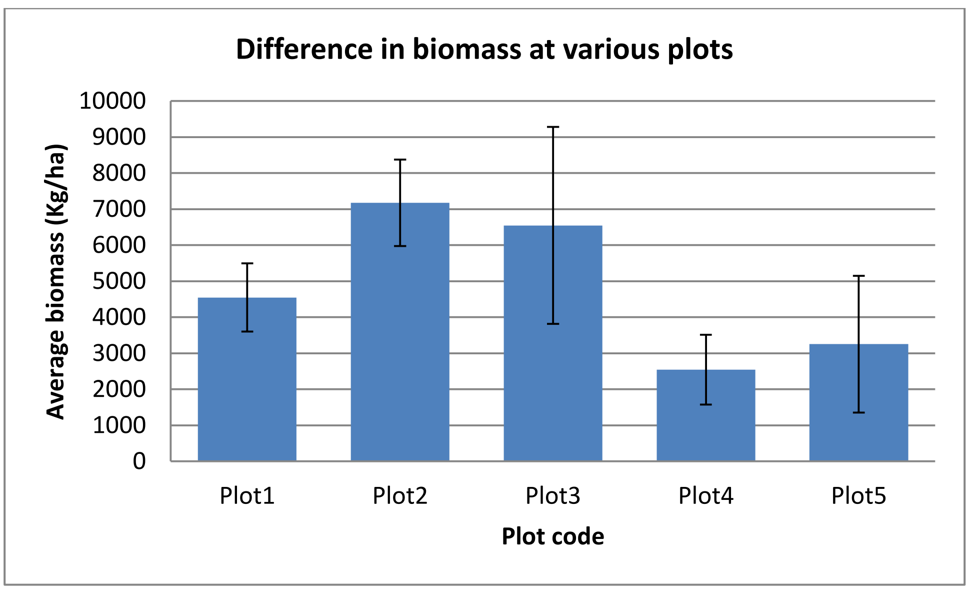

Figure 4.27: Average biomass values for the different plots (all treatments)

4.10. Discussion

Soil degradation is a major environmental problem worldwide and there is strong evidence that soil degradation has immediate impact or threat to biomass and economic yields as well as long term negative effects to future crop yield. So it is absolutely necessary that soil degradation must be put under control (Pagliai et al., 2004). Repeated traditional tillage damages the soil structure through excessive pulverization and increased rate of mineralization leading to reduction in soil organic matter content and aggregate stability (Mwendera and Mohamed, 1997; Melesse et al., 2009). This also results in soil compaction under the plowed depth causing plow pan formation that reduces infiltration, increase soil erosion and reducing ground water recharge (Lal, 1997).

The average organic matter content of the plots selected for this study was generally smaller (average value of 0.97%) than that was obtained by Ewnete 2015(average value of 3.58%), Mulugeta 2015 (average value of 5.2%) for the same watershed and that obtained by Corral-Nuñez, G., et al. (2014) in Tigray region which ranged between 2.1% to 2.9% and after 20 years of recovery the soil organic matter contents ranged from 2.6% to 5.6% which still was considered small. The lower organic matter content for the subplots may be due to the presence of hardpan, as the plots selected for this study were plots which showed signs of soil compaction, but the plots for the previously cited authors: both Ewnete (2015) and Mulugeta (2015), was selected without considering soil compaction as a selection criteria. The low organic matter content in the plots was due to reduced inputs of organic amendments and effect of high frequency tillage, which enhance soil organic matter decomposition (Corral-Nuñez, G., et al. 2014).

Results of this study show that generally the highest infiltration rates was measured at the upslope than those at the lower portions which is consistent with the findings of Bayabil et al. (2010) and Tilahun et al. (2015). Though, the average was lower for the upper portions. The average for the upper portion was lower as only there were two plots and the infiltration rate of plot P4 was small. The lower infiltration at P4 was not clear as this plot had the lowest bulk density and penetration resistance. Event runoff therefore was higher in the downslope subplots than that from the upslope subplots due to higher soil moisture contents in the lower subplots that limited infiltration. This is because in the upslope area, subsurface lateral flow is higher and the soil hardly saturated, thus there is room for more water to infiltrate in to the soil (steenhuis et al 2009). The downslope areas became saturated faster from rainfall and also subsurface flow from the upper or hill slopes (Tilahun, 2012), and thus will generate more runoff. The maximum event runoff coefficients observed for upslope subplots was 0.04 for deep tillage, 0.06 for conventional tillage and 0.1 for no tillage while for downslope, the maximum event runoff coefficient observed was 0.075 for deep tillage, 0.23 for conventional tillage and 0.25 for no tillage. Among the three tillage treatments, the event runoff coefficient was less for the deep tillage than for both the conventional and no tillage treatments. This is consistent with the findings in Iran (Sadegh-Zadeh et al., 2011).

The deep tillage treatment significantly reduced the surface runoff compared to the no tillage and conventional tillage treatments. The reduction in surface runoff was due to the breaking up of the restrictive soil layers, hence reducing the bulk density and improving the pores spaces so that more water were able to infiltrate and be stored in to the soil profile (Sadegh-Zadeh et al., 2011). The concentration of nutrient loss in the runoff water was lesser for the deep tillage treatment subplots followed by the conventional tillage treatments. The nutrient loss concentration in the no till subplots was higher. The higher nutrient loss in the no till subplots was because as the fertilizer was placed near the surface for the no till subplots it was exposed to be transported by the runoff water.

The soil loss or sediment concentration (g/l) was lower for the upper portion of the watershed than downslope of the watershed. This is because runoff which is mainly responsible for the transport of the soil particles other than wind was less in the upslope than the downslope. Studies that were conducted at watershed scale confirm the same findings Steenhuis et al. (2009); Bayabil et al. (2010) and Tilahun (2012). Among the three tillage treatments, the soil loss from deep tillage treatment was less than that for both the conventional and no tillage treatments, even though not statistically significant. The reduction in soil loss for deep tillage treatment was mainly due to the reduction in surface runoff due to improved infiltration. The trend of the soil loss was similar to the trend of the event runoff among tillage treatments. This result is in agreement with the findings of Sadegh-Zadeh et al. (2011).

The agronomic performance of the crops (maize plant height, maize grain yield and biomass), were higher for the downslope subplots than the upslope subplots. This was due to the difference in soil characteristics, climatic conditions and difference in elevations in the two parts of the watershed. This result is in agreement with the findings of Silva et al. (2008). The difference in climatic conditions at the two portions of the watershed can be explained as: at two occasions during the growing season, in the upslope of the watershed, a heavy storm with hailstones was observed, which highly damaged the crops thereby hindering or reducing the crop development and productivity. Also the difference in maize yield due to elevation can be explained as: as water tends to accumulate in lower landscape positions, and higher water availability leads to higher yields (Silva et al. 2008). Among the three tillage treatments, the deep tillage gave better crop performance (maize grain yield and biomass) than the conventional and no tillage treatments. The improvement was mainly due the breaking up of the restrictive soil layers, hence improved infiltration rates (more water availability to plants), reduction in bulk density and penetration resistance (ease for root penetration by crop roots) (Duiker, 2002), so that the crops were able to take more water and nutrients from bigger portions of the soil profile.

The finding from this study generally support the hypothesis of Tebebeu et al. (2013). Preventing hardpans to form or ameliorate existing hardpans will allow plants roots to grow more deeply, increase water infiltration and reduce runoff, all resulting in greater amounts of water availability for the crop. But this kind of study should be repeated in the different part of the Ethiopian highland for fir conclusion.

5. CONCLUSIONS AND RECOMMEMDATIONS

5.1. Conclusions

Among the three tillage treatments investigated in this study, deep tillage had better results than conventional and no tillage treatments by reducing surface runoff, reducing soil loss, and improving productivity (increasing maize grain yield and biomass). By breaking the restrictive soil layers (hardpans) through mechanical means (manually digging) up to a depth of 60cm, the event runoff from all the plots was significantly reduced. The event runoff from the deep tillage treatment subplots was significantly less than that from conventional and no tillage treatment subplots. Also not statistically significant, the conventional tillage treatment subplots gave a lesser surface runoff than the no tillage treatment subplots. The reduction in surface runoff in the deep tillage treatment was largely attributed to the loosening of the compacted soil layers (or formation of more macro pores) by reducing the bulk density and hence improved infiltration rate. Even though statistically not significant, the deep tillage treatment subplots gave a lesser soil loss compared to conventional tillage and no tillage treatment subplots, followed by conventional tillage treatment subplots. The reduction in soil loss for the deep tillage treatment was due to the reduction in surface runoff, which is mainly responsible for the detachment and transport of the soil particles. By breaking the restrictive soil layers through mechanical means, the bulk density and penetration resistance of the soil were reduced significantly, which resulted in improved infiltration rate, more soil water storage and reduced event runoff.

The maize grain yield and the total dry biomass from the deep tillage treatment subplots were higher than that from conventional and no tillage treatment subplots, followed by conventional tillage treatment subplots. The improved maize grain yield from the deep tillage treatment subplots was due to the loosening of the compacted soil layers during tillage, which resulted: reduction in bulk density, penetration resistance and improved infiltration rate, so more water were available for the crops and, the crops were able to take water and nutrients from a bigger portion of the soil profile. Also as deep tillage reduced the cone index the plants were able to penetrate the soil well, which helps to withstand well and resist wind and runoff forces which sometimes causes the plants to fall.

5.2. Recommendation

As found in this study, deep tillage can be the solution to alleviate problems of soils associated with compaction or soils with hard pans.

- ❖ By adapting deep tillage farmers will benefit, by reducing the surface runoff and soil loss from their plots, which will enable more nutrients and water availability for crops and improve both grain yield and dry biomass.
- ❖ As is seen from this study, the productivity of maize is highly affected by topographic location; significantly less maize grain yield was obtained in the upslope subplots than the downslope subplots of the watershed. Therefore the upper parts of the watershed must be given more attention by Kebele officials as well as the regional government to ensure food sustainability and self-sufficiency of the farmers.
- ❖ Even if deep tillage can reduce surface runoff, soil loss and improve water infiltration and grain yield (for soils which are affected by soil compaction), it is more costly than the other tillage treatments. It requires more labor and time to plow to a deeper depth. Some farmers who are poor and don’t have the required labor will have difficulty adopting deep tillage. So the government and NGOs will need to collaborate to solve the problem by for example by providing a credit system for tillage equipment such as small tillage tractors which can be accessed and operated by the less skilled farmers.
- ❖ Even if the breaking of the restrictive soil layers reduced surface runoff and soil loss and improved crop yield, the long term effect of tillage on soil physical and chemical properties needs continuous and further investigation. Also as repeated tillage is one of the causes of the formation of hardpans, the long term effect of deep tillage as a measure to alleviate problem of soil compaction needs further investigation and research.

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APPENDIXES

Appendix-A: Physical and chemical property of soil (pre-treatment).

Sr. No	plot code	depth Cm	pH	EC ds/m	Texture % sand	% Clay	% Silt	Class	Av. K PPm	CEC cmol(+)/Kg	OC %	TN	Av. P PPm	Fe
		0-20	4.64	0.042	10	78	12	heavy clay	7.62	19	0.35	0.03	2.8	5.9
		20-40	5.21	0.02	4	82	14	heavy clay	6.91	20	0.31	0.03	3.6	4.02
		40-60	5.01	0.02	4	80	16	heavy clay	6.75	19.8	0.31	0.03	3	3.66
		60-80	4.94	0.019	10	74	16	heavy clay	6.92	19.6	0.27	0.02	3.8	3.88
1	P2	80-100	5.08	0.018	10	72	18	heavy clay	6.41	21	0.23	0.02	4.2	3.74
		0-20	4.75	0.031	44	34	22	clay loam	7.82	47.8	0.59	0.05	5	11.9
		20-40	4.91	0.025	56	30	14	sandy clay loam	8.35	49	0.55	0.05	6.4	10.2
2	P4	40-60	5.28	0.017	48	32	20	sandy clay loam	8.82	22.4	0.35	0.03	4.8	13.1
		0-20	4.95	0.064	8	72	20	heavy clay	8.61	20	0.74	0.06	4	14.5
		20-40	5.44	0.032	4	80	16	heavy clay	7.36	19.6	0.23	0.02	5.2	7.62
		40-60	5.58	0.028	2	82	16	heavy clay	7.87	18.4	0.31	0.03	5.8	5.98
		60-80	5.66	0.023	2	82	16	heavy clay	6.74	17.6	0.43	0.04	5	4.5
3	P3	80-100	5.58	0.03	4	78	18	heavy clay	6.7	13	0.2	0.02	4.4	6.28
		0-20	5.21	0.084	12	68	20	heavy clay	9.22	23.4	0.55	0.05	1.2	18.3
		20-40	5.62	0.026	12	66	22	heavy clay	8.71	23	1.01	0.09	5	19.3
4	P1	40-60	5.71	0.032	22	64	14	heavy clay	8.92	29	0.51	0.04	1.8	17.3
		0-20	5.3	0.052	16	50	34	Clay	15.8	18	1.29	0.11	25.8	26.7
		20-40	5.34	0.042	10	68	22	heavy clay	16.9	19.6	1.01	0.09	14.2	18.7
		40-60	5.35	0.039	4	78	18	heavy clay	16	13.4	0.7	0.06	15.8	12.5
5	P5	60-80	5.38	0.04	2	78	20	heavy clay	18.4	17.4	0.82	0.07	8.8	11

Appendix B: Pre and post infiltration rate

Plot Code	Pre-treatment IR. (mm/hr)	Post-treatment IR. (mm/hr)		
		Tillage Treatment		
		DT	CT	NT
P1	171	240	210	120
P2	80	270	120	108
P3	192	240	60	180
P4	40	150	120	60
P5	240	216	180	120

Appendix C: Bulk density and Penetration resistance data

Plot Code	Depth(Cm)	Pre Treatment BD (g/cm^3)	Pre Treatment Penetration (PSI)	Tillage treatment (Post Treatment)					
				DT		CT		NT	
				BD(g/cm3)	PR(PSI)	BD(g/cm3)	PR(PSI)	BD(g/cm^3)	PR(PSI)
	0-20	1.08	200	1.27	44	1.45	110	1.53	204
	20-40	1.34	350	1.32	130	1.52	234	1.63	352
P1	40-60	1.31	380	1.33	200	1.54	334	1.66	362.5
	0-20	1.58	200	1.23	34	1.57	204	1.55	304
	20-40	1.16	280	1.26	116	1.38	300	1.67	352
P2	40-60	1.23	320	1.27	206	1.54	342	1.64	348
	0-20	1.03	200	1.15	30	1.45	110	1.45	180
	20-40	1.07	300	1.19	72	1.44	240	1.42	316
P3	40-60	0.99	350	1.27	210	1.5	332	1.44	366
	0-20	1.08	100	1.05	12	1.22	32	1.33	174
	20-40	1.07	200	1.01	50	1.23	156	1.23	214
P4	40-60	0.99	300	1.02	76	1.19	256	1.3	300
	0-20	1.28	320	1.28	70	1.46	220	1.5	300
	20-40	1.07	380	1.15	106	1.41	284	1.58	310
P5	40-60	1.17	390	1.22	160	1.52	356	1.56	368

Appendix D: Soil moisture data

D1: Soil moisture data for plot code P1

Date	Treatment											
	Conventional Till				No Till				Deep Till			
	Depth (Cm)											
	10	20	30	60	10	20	30	60	10	20	30	60

9-Jul-15	20.1	4.4	-	2.7	25.7	40	19.5	11.9	25.3	40	10.1	9.1
13-Jul-15	16.9	7.7	-	2.8	12.8	13.8	19.5	12.1	10.3	13	5	47.8
16-Jul-15	14	3.5	-	2.5	10.8	17.2	21.2	10.2	-	9.6	34.1	47.2
20-Jul-15	11.1	10.7	-	8.2	13.1	17.6	24.6	10.7	15	11.7	56.9	-
23-Jul-15	12	-	-	8.8	13.6	12.5	22.4	13.8	2	5.4	24.7	48.9
27-Jul-15	7.7	2.4	-	13.2	11	-	18.5	12.5	-	5.3	20.4	45.6
30-Jul-15	7.2	4.5	-	21.7	-	12.2	-	-	-	17.8	33.9	74.6
3-Aug-15	14.6	18.9	6.2	13	12	1.8	11.5	10.3	46.6	5.2	-	-
10-Aug-15	33.6	2.9	-	16.8	30.6	13.2	20.8	14.6	54	22.4	35	20.1
13-Aug-15	30.4	1.2	-	17.8	29	15.9	18.7	16.2	-	25	33.5	84.9
20-Aug-15	17.3	2.2	1	16.1	-	15.5	-	10.1	-	42.1	33	78.8
24-Aug-15	17.4	5.1	0.9	11	10.1	59.9	-	-	-	31.3	34.6	93.1
27-Aug-15	23	7.2	0.9	12.7	29.4	68.4	10.6	-	-	32.2	35.5	82.4
7-Sep-15	24.8	5.2	-	80.3	86.8	29.3	-	-	-	27.9	58.2	69.6
10-Sep-15	15.2	6	0.8	12.2	67.2	83.9	-	75.4	27.4	10.4	86	10.3
14-Sep-15	-	29.1	-	27.7	23.3	-	2.2	-	-	32.2	53	99.6
17-Sep-15	12.5	27.4	24.3	-	20.1	14	2.5	1.7	13.4	15.3	24	92.4
21-Sep-15	19	-	1.5	13.6	0.9	13.2	-	5.1	1.7	17.3	9.6	34.8
24-Sep-15	15.9	12.4	-	25.2	-	6.2	4.2	-	-	16.4	-	14.9
28-Sep-15	11.1	0.1	-	26.1	53.3	23.7	-	-	-	12.6	-	-
5-Oct-15	10.9	11.8	-	26.7	-	25	25.8	24.4	-	9.5	-	-
8-Oct-15	8.8	16.6	0.2	20.4	32	7.6	-	-	-	9.6	21.1	13.2
12-Oct-15	15.1	12	0.6	32.1	6.9	22.8	-	-	-	4.8	26.4	-
16-Oct-15	13.4	12.3	1.6	21.7	7.2	22.2	3.3	-	-	24.4	12	10.4
19-Oct-15	4	16.5	6.6	4.9	20.1	2.6	-	4.6	-	15.6	49.6	46.9
22-Oct-15	10.4	9.3	0.8	35.4	38.3	3.8	-	-	25.6	4.3	24.2	42.4
30-Oct-15	9.4	10.9	-	13	2.1	12.2	-	-	10.1	17.3	-	-
2-Nov-15	9.9	9.8	-	-	12.8	4.2	-	-	-	8.1	-	-
5-Nov-15	8.9	11.4	1.6	35.7	4.8	2.3	-	-	-	-	-	-
8-Nov-15	7.1	10.1	-	35.1	12.8	3.6	-	-	-	11.2	-	-
11-Nov-15	8.3	6.7	0.4	9.1	11.5	3.8	-	-	-	-	-	-
15-Nov-15	6.6	10.9	-	14.7	8.6	1.8	-	-	-	7.8	-	-
18-Nov-15	5.4	10.6	-	4.22	5.9	1.4	-	-	-	4	-	-
22-Nov-15	3.6	8.1	-	36.1	6	0.8	-	-	-	3.1	51.3	-

D2: Soil moisture data for plot code P2

Date	Treatment																	
	Conventional Till						No Till						Deep Till					
	Depth(cm)																	
	10	20	30	40	60	100	10	20	30	40	60	100	10	20	30	40	60	100
9-Jul-15	16.8	14.7	12.9	12.8	13.3	10.5	19.8	13.9	10.8	16.3	18.1	17.9	31.2	12.6	13.4	-	17	18.1

13-Jul-15	18.4	12.4	12.2	4.5	15.1	12.2	14.2	12.7	10.9	17	17.4	18.6	29.5	12.8	12.9	-	18	18.2
16-Jul-15	16.2	19.9	14.8	5.2	14.3	11	14.5	9.5	10	10.4	18.1	17.4	30.4	11.9	16.7	-	21	19.5
20-Jul-15	20.6	8	16.4	4.7	13.9	11.9	15.8	7.8	7.5	7.8	9.3	17.4	30.8	11.2	19.2	-	14.6	19.7
23-Jul-15	23.4	9.6	9.6	4.6	12.1	9.7	6.8	-	11.7	25.9	12.3	11	30	11.4	14.3	-	15	20.4
27-Jul-15	11.9	18.3	7.7	12.1	10.5	11.3	3.2	9.9	5.5	12.5	9.2	9.7	28.2	15.3	9.2	-	16.3	18.6
30-Jul-15	26	18.9	19.7	11.17	14.6	16.2	19.7	13.3	9	15.2	10.8	9.7	30.7	12.9	22.3	-	11	17.2
3-Aug-15	-	-	-	1.5	2.1	19.3	-	-	9.9	-	4.6	-	7.9	23.8	9.8	-	5.6	-
10-Aug-15	22.9	13.4	13	5.2	19.3	19.1	33.4	15.3	8.8	19.7	12.9	10.4	28.4	8.1	16.1	-	25.1	18.3
13-Aug-15	20.5	13.2	12.7	4.5	18.5	19.8	31.3	15.1	9	21.8	13.5	10.7	-	22.4	22.4	5.3	-	-
20-Aug-15	-	20.7	13	7	20.3	21.9	36	17.6	12.9	19.4	10.6	13.3	-	12.9	17	7	10.6	13.3
24-Aug-15	19.3	13.2	13.3	5.5	20.4	18.2	30.5	16.3	9.5	20.3	12	11	26.8	11	14.1	-	24	16.7
27-Aug-15	20.9	13.8	12.7	5.6	19.3	19.6	35.9	16.3	9	19.2	13.5	11.5	27.9	8.6	16.6	-	26	19.4
7-Sep-15	19.4	12.5	9.8	5.3	17.4	22.9	30.3	14.9	7.8	21.3	9.2	8.9	29.9	11.8	10.2	-	22.3	17.4
10-Sep-15	-	13.4	13.7	5.7	17.7	17	32.6	16.4	8.7	20.2	10.8	10.9	33.6	8.9	14.9	-	19.2	20.3
14-Sep-15	22.1	13.9	13.5	6.3	18.3	16.5	29.4	17.5	8.3	18.5	9.9	9.5	30.1	19.7	18.3	-	5.6	21.5
17-Sep-15	38.5	24.6	-	-	3.5	9.9	14.8	-	5.8	-	4.3	15.7	40.1	5.6	10.1	9.7	7.4	20.9
21-Sep-15	19.4	18.2	13.7	5.5	15.8	15.3	28.2	15.3	9.5	21	9.1	7.9	-	-	29	11.1	17	16.7
24-Sep-15	-	-	14.1	12.6	15.8	15.3	28	15.7	25.2	20.9	11	8.4	30.3	11.6	-	-	16.8	16.4
28-Sep-15	16.8	15.4	12	5.9	16.6	16.6	23	13.7	9.3	17.1	10.8	9.4	26.3	7.5	18	-	19.5	18.9
5-Oct-15	14.8	15.2	12.1	4.9	15.5	15.7	21.5	13	8.8	16.3	8.7	7.6	15.6	15.4	8.9	5.5	9	7.7
8-Oct-15	12.4	15	4	4.6	-	12.3	11.7	19.4	6.6	-	8.4	7.3	25.5	7.7	7.3	-	-	16.6
12-Oct-15	21.8	3.5	14	5.7	15.1	-	23.9	13.4	10.2	16	13.3	9.5	32	8.6	19	-	15.9	16.6
16-Oct-15	20.3	17.3	7	6.4	9.2	15.2	21.7	14.3	10	14	13.3	10.4	31.3	19.9	22.3	19	10.3	17
19-Oct-15	17.1	17	12.4	7.5	18.2	14.3	10.1	14.7	9.6	18.7	11.6	9	24	9.1	20.7	-	21.4	14.3
22-Oct-15	-	13.7	13.1	6.3	15.8	13.9	13.3	14.4	6.6	15.7	9.6	9.1	26.3	17	16.5	-	16.2	16

30-Oct-15	19.3	18.2	12.2	6.2	15.6	14.3	22.1	12.4	8.8	17.5	12.9	10.5	26.4	19.3	-	-	16.8	17
2-Nov-15	11.4	16.4	13.1	6.7	15.8	13.5	17.5	13.4	10.5	16.3	11.2	12.3	25.4	11.1	18.3	-	19	15.1
5-Nov-15	16.7	16.7	12.9	7.5	5.4	5.2	22.7	13.9	10.3	16.9	11.1	11.5	26.9	18.8	18.1	10.2	6.3	16.6
8-Nov-15	-	12.5	12.5	10	15.7	12.5	7.4	7.4	12	14.8	13.7	11	29	8	15.4	-	18.4	16.1
11-Nov-15	6.1	-	10.8	-	12.4	10.8	2.4	-	9.5	-	14.8	14.7	26.7	-	11.3	-	15.9	16.9
15-Nov-15	1.6	15.1	9.8	7.1	11.1	9.2	-	4.3	6.5	8.2	13.6	13.1	23.3	13.1	13.6	-	15.3	15.9
18-Nov-15	-	-	10	-	9.6	10.1	4.7	-	8.4	-	14.4	12.7	25.4	-	12	-	14.8	15.3
22-Nov-15	-	-	3.9	-	7.9	6.6	-	-	9.6	-	14.1	12.3	11	-	10.3	-	15.1	11.1

D3: Soil moisture data for plot code P3

	Treatment																	
	Conventional Till						No Till						Deep Till					
	Depth(cm)																	
Date	10	20	30	40	60	100	10	20	30	40	60	100	10	20	30	40	60	100
9-Jul-15	32.3	21.1	14.6	8	12.2	12.3	21.1	17.5	10.7	12.6	4.9	10.2	32	17.7	14.3	12.3	6.7	8.8
13-Jul-15	32.1	21.9	13.4	6.5	11.9	12.5	14.4	15.7	9.9	14	4.6	9.9	30.9	17.6	13.8	12	14.3	12.3
16-Jul-15	36.5	19.2	13.7	6.7	11.8	11.9	17.1	16.4	10.5	15	5	9	31.9	18.8	15.2	13.4	4.9	13.8
20-Jul-15	39.4	20.6	14	6.8	12.1	12.4	16	12.4	10.4	16.9	7.9	13	32.4	20.2	16.5	14.4	5	15.3
23-Jul-15	37.1	19.3	15.8	8.8	12.7	12.9	12.9	9.8	9.7	10.3	6.1	10.6	33.1	21.4	18	15.1	7.1	15.1
27-Jul-15	34	16.4	12.3	7.5	9.8	5.8	14.8	10.3	10.3	9.8	6.8	9.6	30.1	18.6	15.6	14.2	7.6	14.1
30-Jul-15	37.6	22.3	10.7	8.4	13.3	18.4	15.1	9.5	8.6	10.2	5.7	9.8	17.3	-	14.5	15.7	3	16.9
3-Aug-15	33.4	21	12.7	9.4	15.2	24.5	17.2	10.5	9.9	11.2	6.7	9.6	-	15	17.1	13	9	8.5
10-Aug-15	3.9	15.7	8.1	5.7	11.6	11.8	11	6.4	11	17.9	12.1	17	30.8	20.9	17.6	16.2	7.2	15.4
13-Aug-15	13.1	16.1	7.9	5.6	11	11.6	9.1	6.6	13.4	17.1	11.5	19	30.3	19.3	17.8	16	7.7	15
20-Aug-15	34.2	20.4	8.6	8.6	11.1	13	9.6	6.8	14.2	11.1	13.5	16.3	24.2	18.5	15.7	8	13.2	10.6
24-Aug-15	3.8	18.1	11.3	5.7	10.9	11.3	8.5	7	13.8	19.3	16.1	20.2	31.4	20.8	19.1	16.8	8.6	15.3

27-Aug-15	5.7	18.4	10.6	5.3	10.2	11.5	13.4	4.7	16.5	26.7	17.5	21.3	32	21.1	19.8	17.5	8.6	15.6
7-Sep-15	18.6	15	11.5	3.4	7.4	58.6	8.5	8.8	11.1	16.5	13.7	19	24.3	15.6	16.9	13.4	4.5	15.5
10-Sep-15	2	18.1	6.4	6.4	10.9	12.2	-	5.3	10.3	10.3	7.2	17.3	32.7	23.1	20.7	16.9	3.4	17.4
14-Sep-15	2.5	18.3	10.1	6.7	10.9	32.1	-	5.8	11.6	12.5	6.4	18.7	32	22.2	18.4	15.3	7.9	27.3
17-Sep-15	0.3	17	10.8	5.6	9.5	13.7	2.3	6.3	5.3	4.2	4.2	-	30.1	22.4	19.9	16.3	1.9	16.7
21-Sep-15	-	31.7	12.3	12.3	13.5	19.3	-	-	6.1	7.7	7.2	7	23.2	21.1	18	17.9	5.2	-
24-Sep-15	5.9	19.1	18.9	13.9	4.3	9	0.1	7.8	7.5	4.7	-	8.3	29.3	21.6	19.9	16.7	3.7	16.5
28-Sep-15	21.2	-	18.7	13	9.4	-	-	1	8.2	5.7	4	9.2	-	21	32.3	32.3	46.4	52.6
5-Oct-15	19.3	-	9.2	8.6	4.7	15.2	-	1.1	8.2	7	4.5	10.1	15.8	19.2	16.8	13.4	1	17.2
8-Oct-15	18.3	7.2	12	11.9	-	15.6	-	-	5.6	5.2	6.7	8.2	26.2	18.5	15.6	14.3	1.5	16.9
12-Oct-15	21.4	9.6	13.6	13.3	5.3	12.8	-	5.7	13.1	8.1	6.8	13.1	29.6	18.5	15.1	13.3	3	17.2
16-Oct-15	25.9	8.9	13.8	12	2.3	14.4	-	3.9	13.6	11.3	7.4	12.5	29.3	18	14.5	12.2	3.7	17.6
19-Oct-15	22.5	15.4	13.7	19.7	4.3	15.7	-	1	9	10.6	6.6	11.1	24.8	19.8	17.8	15.9	12.8	16.7
22-Oct-15	6.2	4.5	9.5	5.2	3.9	6.2	-	-	5.7	6.4	7.5	8.4	26.6	14	15.7	11.3	4.1	16.6
30-Oct-15	14.5	9.5	13.4	12.4	8.3	15.2	-	5.1	11.4	10	10.8	13.2	27.3	18	15.5	14.4	14	16.8
2-Nov-15	2	17.4	13.6	8.2	4.2	14	-	9.7	9.7	10	12.2	13.1	5.4	18.8	14.5	12.7	9	16.4
5-Nov-15	3.8	9.8	15.1	13.2	8.5	16.5	-	4.5	12.6	7.4	7	15.5	29.2	21	16.8	13.6	-	15.7
8-Nov-15	-	15.3	12.2	12.2	10.2	15.2	-	2.9	11.4	9	8.6	15.3	27.6	18.9	15.3	13	12	16.6
11-Nov-15	1.5	17.3	13.5	19.3	4.5	14.9	-	4.1	11.7	9	8.8	15.7	26	18.6	15.7	13.7	6	15.9
15-Nov-15	30.2	9.8	1.7	7.4	5	13.5	-	-	-	-	8.9	11.7	32	6.5	7.9	7.8	8.3	19
18-Nov-15	0.5	13.1	11.2	15.9	4.7	9.9	-	0.6	8.7	8.1	7.1	13.3	12.9	18.5	15.9	11.2	2	2.7
22-Nov-15	-	18.4	15.6	15.6	4.2	15.4	-	0.4	8.2	8.4	7.8	13.2	24.2	17.3	12.7	12.1	3	15.8

D4: Soil moisture data for plot code P4

Date	Treatment																	
	Conventional Till						No Till						Deep Till					

	Depth(cm)																	
	10	20	30	40	60	100	10	20	30	40	60	100	10	20	30	40	60	100
9-Jul-15	27.9	16.6	7.5	9.8	10.4	-	40.7	-	-	-	7.9	10.5	32.1	6.6	13	11.9	3.8	19
13-Jul-15	47.5	23.3	13.9	10.6	16.5	-	36	-	-	-	6.2	11	39.7	15.7	12.6	13.6	14.1	21.5
16-Jul-15	43.8	21.3	11.8	7.9	13.7	-	36.6	1.1	-	10.5	7	11.1	39.9	9.6	13.6	13.9	5	20.1
20-Jul-15	42	21.3	13	7.2	14.8	10.8	35	-	-	-	8.5	13.3	42.2	8.5	13.6	13.3	7.7	21.2
23-Jul-15	39.9	34.8	6.9	-	16.1	15.3	-	0.9	-	-	10.5	12.9	44.2	9	16.3	13.1	8	20.3
27-Jul-15	42.8	15.6	8.3	14.2	16.1	18.2	34.1	-	-	-	3.7	13.7	43	6.1	12.4	7.7	8.3	20.2
30-Jul-15	25.4	22.8	11.2	13.6	10.6	14.9	33.8	-	-	-	8.4	12.1	46.2	14.5	13.1	18.3	8.5	20.4
3-Aug-15	-	-	0.8	27.4	12.3	13.5	36.4	0.8	-	-	8.6	13.5	40	8.4	11.2	13.3	8.3	20
10-Aug-15	39.5	23.8	6.8	4.8	4.6	16.9	-	12.8	-	-	16.5	11.5	42.3	14.9	9.6	10.3	6.9	20.4
13-Aug-15	8.4	0.3	4.2	-	14.6	-	30	10.2	-	-	24.6	6.8	36.2	20.2	4.8	6.4	-	-
20-Aug-15	36.3	27.1	6.1	-	5.4	16.5	37.5	-	-	-	9.6	15.8	44.7	9.6	13.2	10.9	10.9	21.5
24-Aug-15	50	24.2	8.4	-	1.8	15.4	37.7	-	-	-	6.5	13.3	40.1	9	13.8	15	9.4	22.4
27-Aug-15	2.7	17.4	10.2	-	9.8	10.8	5.8	10.5	15.4	-	-	20.4	31.2	21.9	20.5	17	6.5	16.3
7-Sep-15	35.5	25.5	10.2	-	2.7	17.1	25.8	-	-	-	3.1	11.9	44.4	6	9	10.9	4.1	20.7
10-Sep-15	13.1	8.6	5.2	10.4	7.3	-	27.4	9.2	-	14.6	12.9	15.5	26.3	9.4	-	-	20.4	23.1
14-Sep-15	9.3	11.2	-	13	11.4	26.6	5.6	13.1	12.7	-	6.4	17.3	32.4	20.2	16.5	13.5	2.7	17.8
17-Sep-15	39.6	24.7	5.2	-	4.9	16.6	20.2	-	-	-	9.9	13.3	41	25.9	10.4	9.4	8.6	21.3
21-Sep-15	36.5	20.4	8.8	-	4.8	18.7	12.5	4.6	-	7.6	-	11.2	35.2	22.1	6	9.4	-	17.2
24-Sep-15	39.4	23.3	4.6	-	4.7	15.7	16.9	-	-	-	20.8	12.7	38.5	7.1	11.2	13.4	4.8	20.8
28-Sep-15	-	21	10.5	8.3	12.9	10.8	22.6	13.5	45.3	-	22.2	16.2	5.6	23.7	1.6	-	-	11.7
5-Oct-15	-	20.2	8.1	12.7	17.1	-	1.2	8.7	6.1	-	5	10	26	17.9	18.6	12.4	-	-
8-Oct-15	-	18.4	6.2	10.7	14.2	12	5.3	8.9	7.6	-	-	13.2	24.2	15	12.3	-	4.9	-
12-Oct-15	1.4	23.4	10.6	0.3	6.9	6.7	-	-	5.8	-	9.3	10	21.1	12.9	18.6	12.8	3.6	3.6

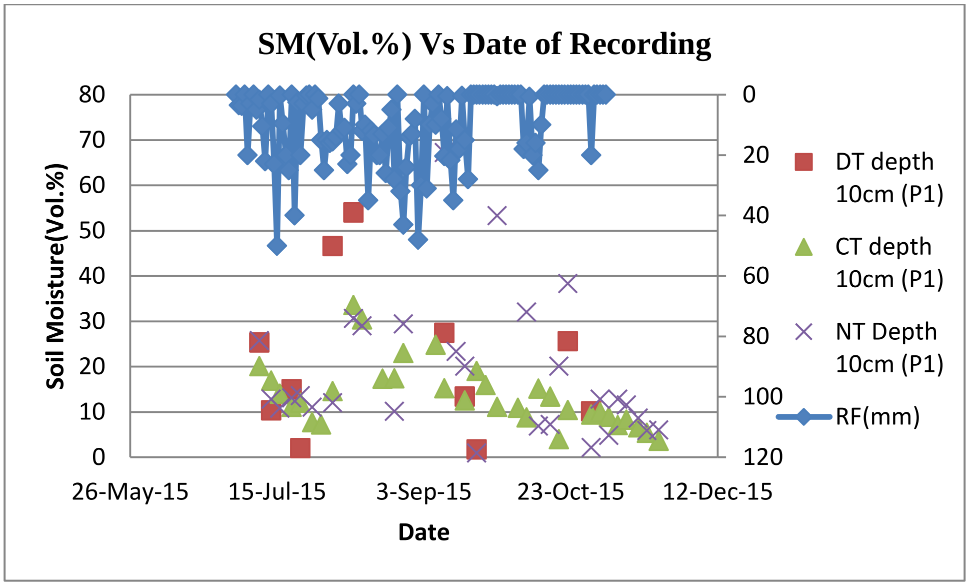
16-Oct-15	21.3	27.7	13.4	15.2	10.1	7.3	-	-	12	10.2	8.8	13.4	18.3	21.7	10	13.8	6.6	9.3
19-Oct-15	34.4	7.6	5.1	9.2	1.6	15.5	16	4.8	-	7.2	15.2	10.3	31.4	14.2	9.3	12.5	8.8	19.1
22-Oct-15	30.2	26.5	4.4	-	2.7		14.4	-	-	-	9.6	12.5	30.3	7.3	10.7	8.6	19.4	31.8
30-Oct-15	41.8	22.3	2.5	5.8	3.5	20	21	-	-	-	7	11.3	41.2	16.2	8.1	8.1	7.8	21.2
2-Nov-15	38.5	3.5	2.1	0.6	0.7	17	15.9	-	-	-	8.4	10.3	37.5	6.5	8.3	7.6	8.4	19.8
5-Nov-15	32.9	2.5	1.6	6.9	1.5	16.7	19.6	-	-	-	1.6	9	37.7	6.9	9.4	11.4	3.8	20.6
8-Nov-15	38.1	20.4	1	6	-	15.7	17.2	-	-	-	16.6	11.1	36.1	5.1	6.9	7.8	6.8	19.9
11-Nov-15	40.2	21.7	0.4	6.9	-	14.6	18.7	-	-	-	16.7	9.7	35.6	16.9	9.9	12.2	14.1	19.9
15-Nov-15	14.9	3.5	9.6	5.8	-	4.3	-	26.8	13.8	8.1	6.5	5.6	30.3	6.9	10.1	-	2.8	6.4
18-Nov-15	25.8	21.9	-	7.3	-	12.9	15.1	-	-	-	6.4	10.2	28.9	5.7	8.2	10.1	3.6	18.7
22-Nov-15	32.1	17	-	4.5	0.6	15.1	16.2	-	-	-	16.9	9.8	26.2	5.4	7.3	8.7	2.7	17.4

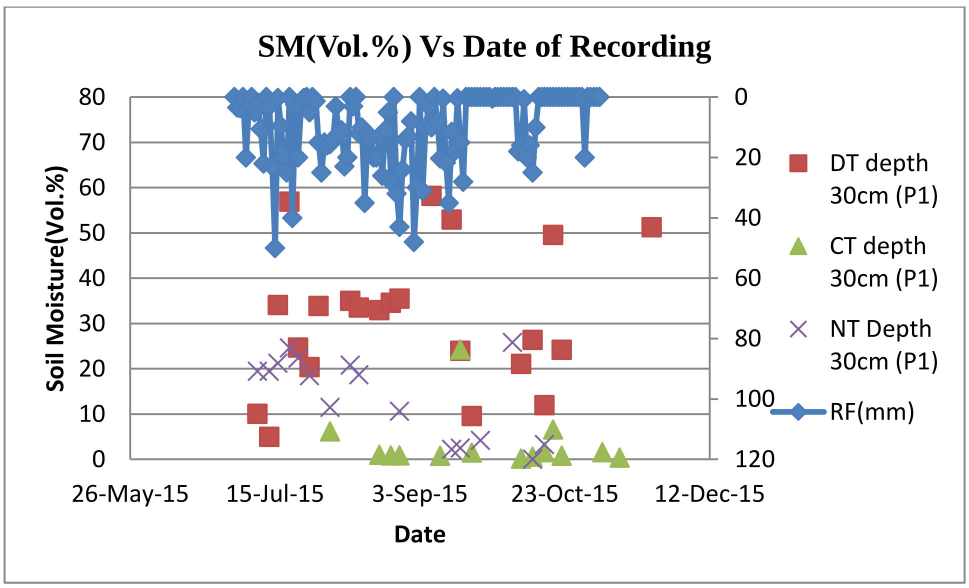
D5: Soil moisture data for plot code P5

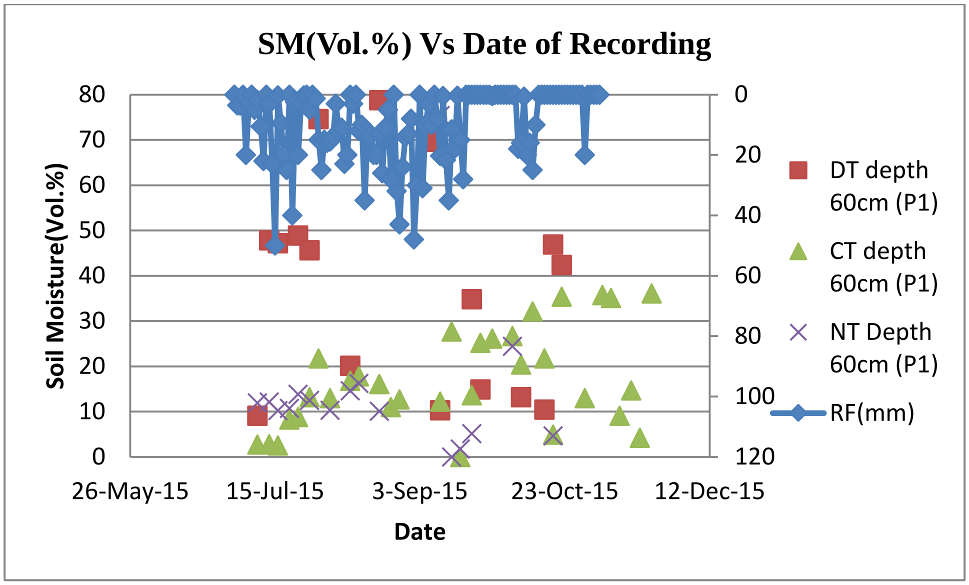
Date	Treatment															
	Conventional Till						No Till					Deep Till				
	Depth(cm)															
	10	20	30	40	60	100	10	20	30	40	60	10	20	30	40	60
9-Jul-15	33.7	6.9	14.2	-	1	8.8	47.2	21.1	4.1	12	2.8	45.1	13.1	5.3	-	3.5
13-Jul-15	21.6	8.4	9.7	-	-	11.3	4.4	23.3	3.1	11.7	4.9	42.7	12.4	2	4	5.4
16-Jul-15	21.7	9.9	9.4	1	-	2.3	46.5	22.8	25	9.4	5.1	46	10.6	18	-	5.7
20-Jul-15	22.9	9.6	8.9	-	-	9.9	19.7	23.5	5	13	2.7	44.4	14.2	1.8	-	4.5
23-Jul-15	18.1	-	8.1	9.6	-	-	45.6	36.4	7.6	3.9	4.7	46.5	-	8	8.6	9.9
27-Jul-15	21.8	11.9	8	-	-	12.8	45.2	22.2	8.6	11.7	2.9	46	16	5.3	-	5.5
30-Jul-15	36.7	5.1	0.4	-	5	9.6	0.3	21.1	14.3	11.6	-	-	13.9	-	-	11.7
3-Aug-15	18.5	21.8	6.4	-	-	5.5	4.6	21.2	6	12.6	-	10.3	10.5	6.6	14	12
10-Aug-15	33.8	10.5	13.9	6	-	4.5	49.4	22.9	6.8	10	3.2	40.3	10.4	3.9	11.3	6.4

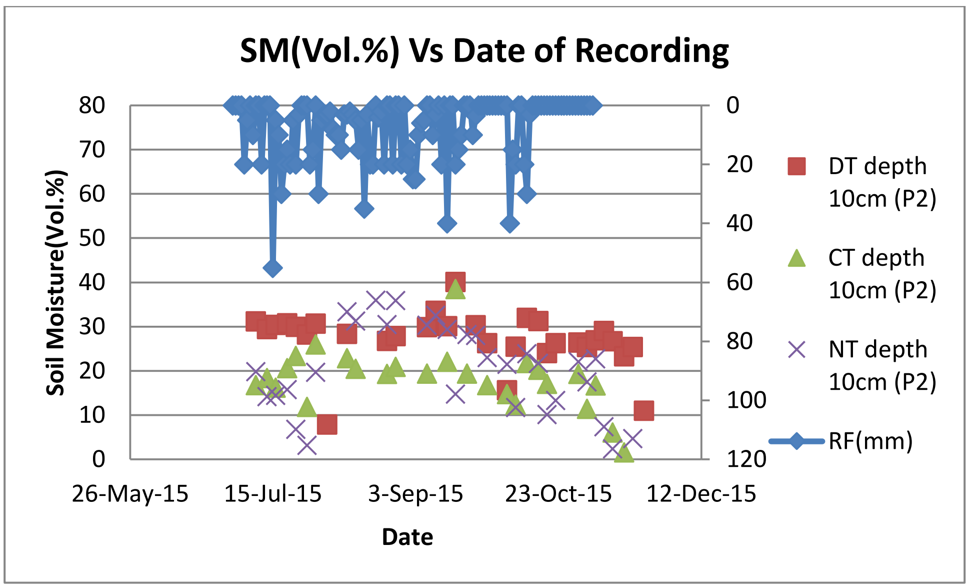
13-Aug-15	38.3	8.5	14.6	7	5.5	-	5.2	6.7	10.2	3.5	2	-	8.2	3.6	11	6.6
20-Aug-15	27.4	-	16.2	-	-	-	46.1	-	8.6	-	2.4	33		4.6	1.9	7.7
24-Aug-15	3	7	9.9	10.5	-	-	10.3	14.2	-	11.3	21.5	31	9.9	20.2	0.8	15.2
27-Aug-15	2.8	17.1	10.8	4.7	-	11.5	5.8	14.9	10.5	15.9	16.5	30.7	21.3	14.6	8.3	22.7
7-Sep-15	23.5	-	8.3	-	6.6	-	17.6	-	18.7	-	16.2	28.5		24.3	4.3	-
10-Sep-15	32.6	18.4	10.6	6.9	-	18.2	49.4	11.8	3	7.7	4.3	44.9	20.1	-	8.4	8.3
14-Sep-15	30.4	13.6	10.1	-	-	9.9	15.6	13.4	13.7	19	3.8	42.3	29.2	8.2	1.4	9
17-Sep-15	27.4	8.7	9.9	8.5	7.5	3.8	13.2	15.9	11.6	13.9	5.4	38.2	8.9	12.1	1.1	6
21-Sep-15	36.7	10.1	30.9	6.6	-	3.2	10	3.4	-	-	-	27.1	8.2	15	-	16.2
24-Sep-15	-	6.2	11.8	-	12.1	8.4	15	8.7	16.4	-	15	24.8	7.4	-	-	16.8
28-Sep-15	-	35.6	10.6	55.5	13.4	54.2	-	7	15.2	-	16.2	20.2	17.6	-	2.4	12.1
5-Oct-15	-	21.1	12.5	8	13.2	9	-	13.4	18.7	17.8	15.2	32.8	7.1	19	-	16.4
8-Oct-15	5.3	19.2	10.6	7	12.4	6	-	9.9	15.3	8.4	13	30.4	19.4	2.7	15.6	11.1
12-Oct-15	25.8	18.4	17.1	13.1	6.3	-	26.3	9.2	13.1	16.4	15.2	24.3	-	17.3	17	16.6
16-Oct-15	-	18.8	16.2	7.9	24.5	11.2	-	14.6	0.8	19.2	7.3	-	22	27.3	14.3	11.5
19-Oct-15	20.5	16.9	10	7.7	-	9.2	3.9	-	9.2	17.6	6.3	37	20.1	9	-	8.3
22-Oct-15	19.3	18.2	8.2	14	-	14.9	2.6	13.2	2.4	15.7	3.7	29.8	18.9	12	13.6	5.9
30-Oct-15	21.6	7.1	7.4	2.9	-	2	4.4	12.9	-	2.5	2.9	-	8.3	7.4	3.8	5.4
2-Nov-15	19.3	7.8	7.5	4.8	-	6	8.8	5.4	8.1	6.6	3.7	32.3	5.3	-	2.5	8.2
5-Nov-15	20.6	7.1	8.9	2.7	-	2.2	9.6	0.9	8.3	3.1	4.5	32.8	30.7	10.1	11.1	8.3
8-Nov-15	1.6	4.8	9.8	6	11.1	3.9	4.3	2.6	7.1	7.9	13.1	23.3	6.4	-	9	15.9
11-Nov-15	-	2.8	10	6	9.6	4.2	4.7	14.4	15	10.4	12.7	25.4	5.1	-	2	15.3
15-Nov-15	-	12.9	3.9	8.2	7.9	9.2	4.4	6.5	15.6	13.6	12.3	11	14.4	-	-	11.1
18-Nov-15	-	6.1	-	12.2	-	10.1	-	8.4	-	14.4	-	-	7.1	-	-	-
22-Nov-15	-	6.3	-	12.7	-	6.6	-	9.6	-	14.1	-	-	5.8	-	-	-

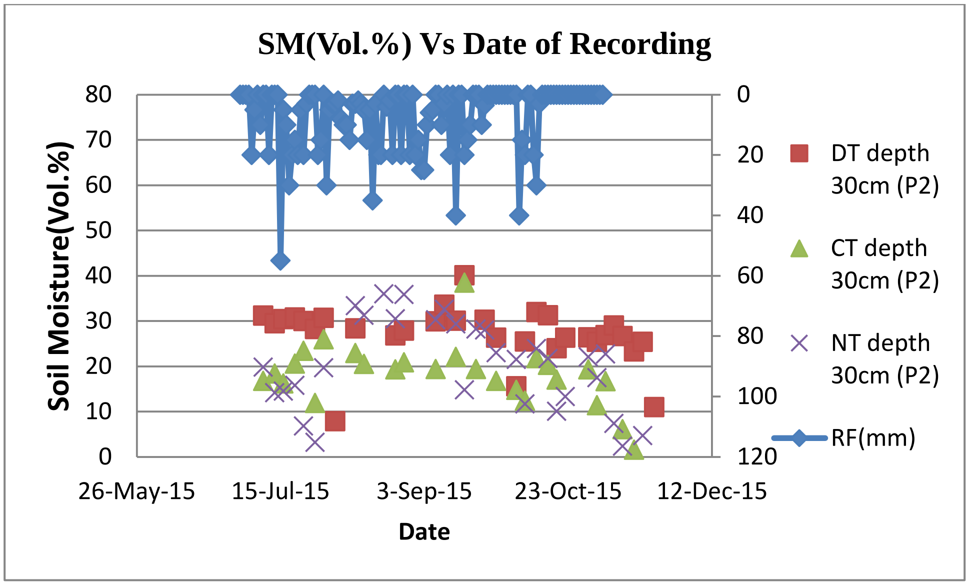
Appendix E: Soil moisture Vs Date of recording with RF at various depths

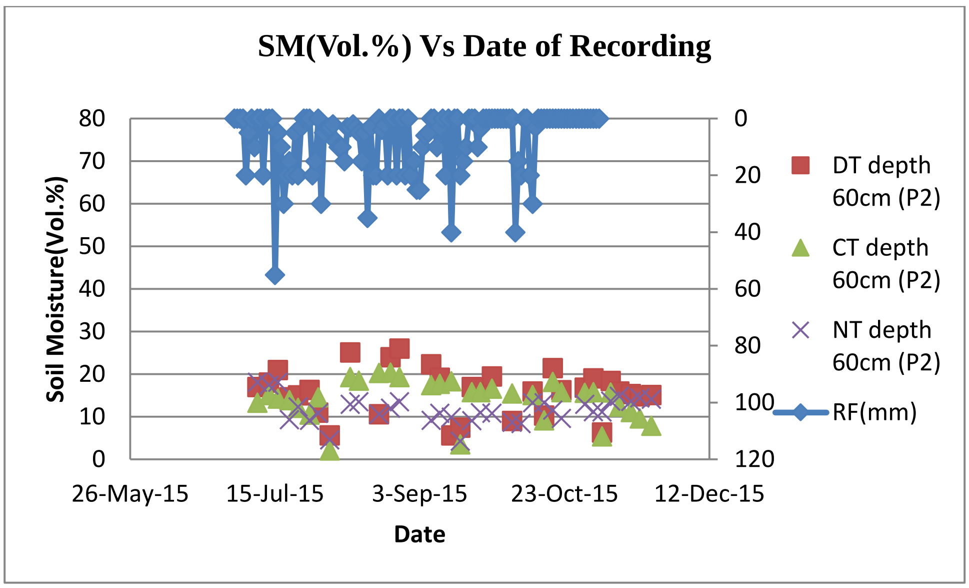


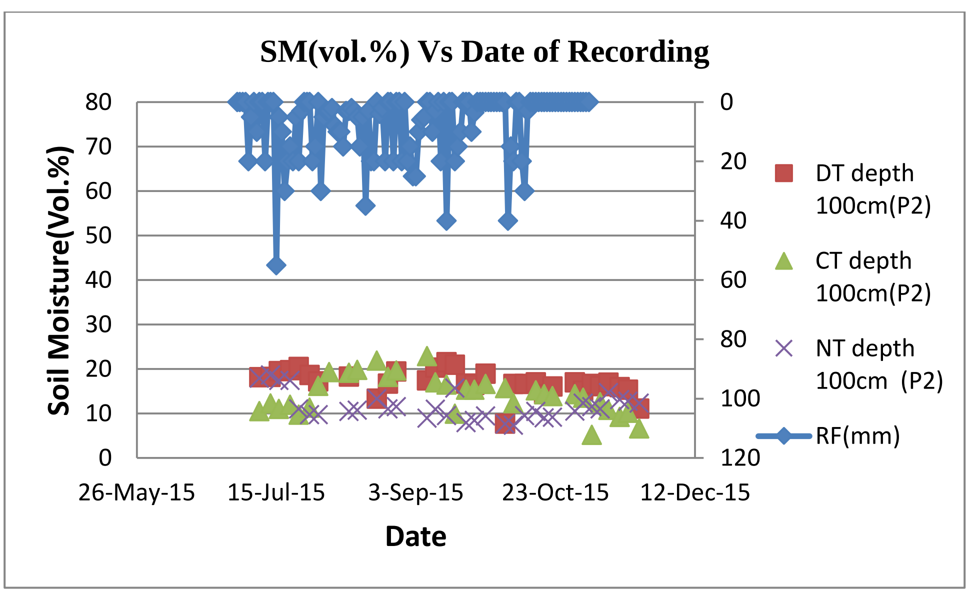


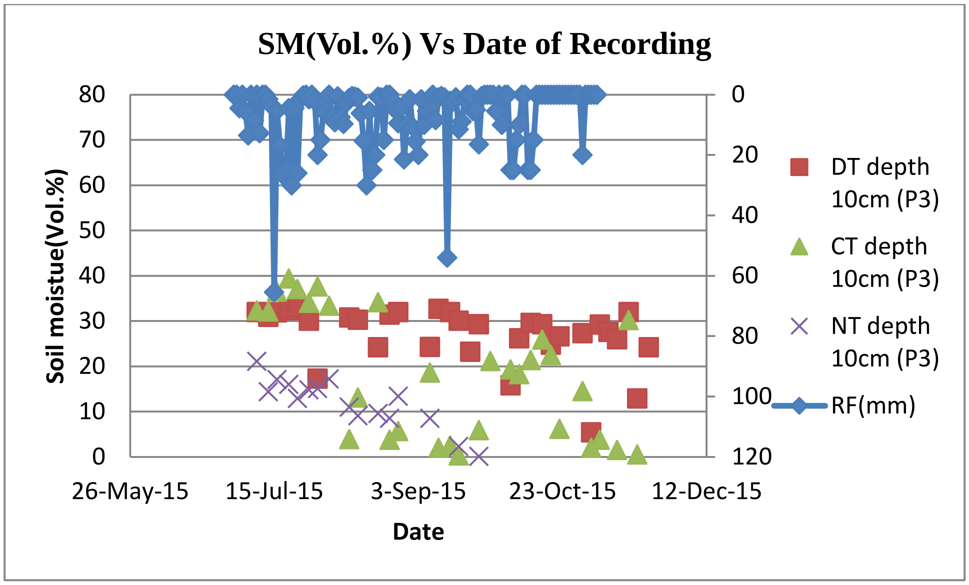

SM(Vol.%) Vs Date of Recording
Soil Moisture(Vol.%)
80
70
60
50
40
30
20
10
0
0
20
40
60
80
100
120
26-May-15
15-Jul-15
3-Sep-15
23-Oct-15
12-Dec-15
Date
DT depth 60cm (P1)
CT depth 60cm (P1)
NT Depth 60cm (P1)
RF(mm)

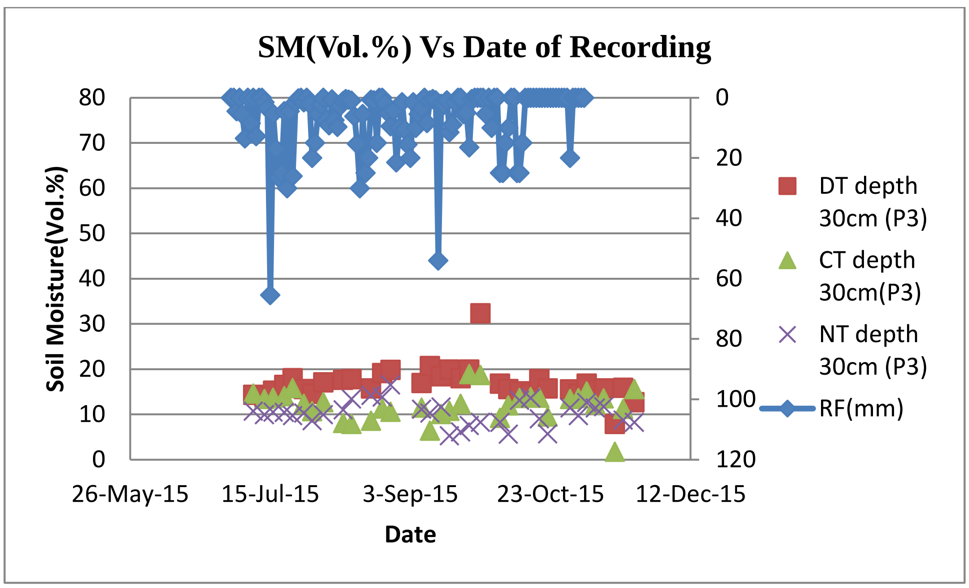

SM(Vol.%) Vs Date of Recording
Soil Moisture(Vol.%)
80
70
60
50
40
30
20
10
0
0
20
40
60
80
100
120
26-May-15
15-Jul-15
3-Sep-15
23-Oct-15
12-Dec-15
Date
DT depth 10cm (P2)
CT depth 10cm (P2)
NT depth 10cm (P2)
RF(mm)

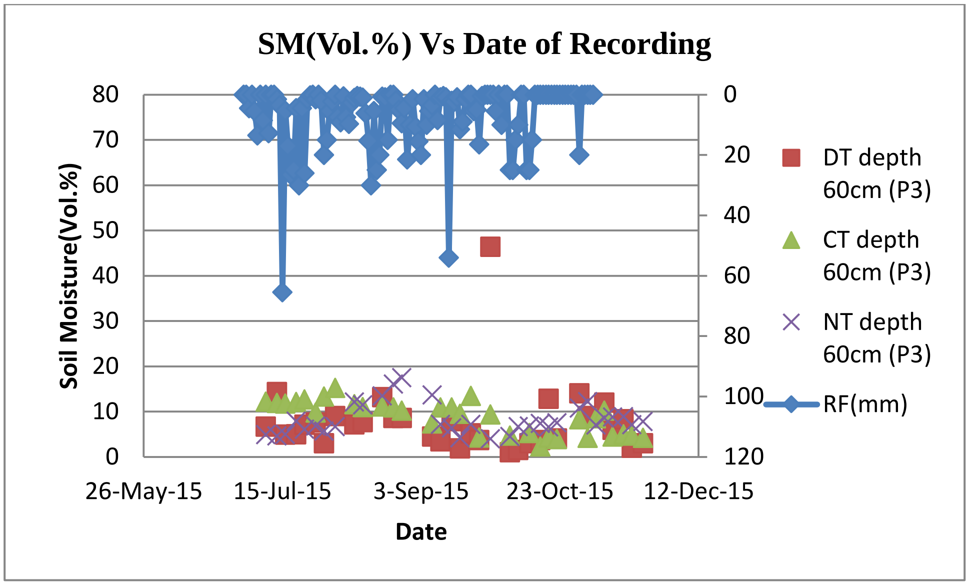

SM(Vol.%) Vs Date of Recording
Soil Moisture(Vol.%)
80
70
60
50
40
30
20
10
0
26-May-15
15-Jul-15
3-Sep-15
23-Oct-15
12-Dec-15
Date
0
20
40
60
80
100
120
DT depth 30cm (P2)
CT depth 30cm (P2)
NT depth 30cm (P2)
RF(mm)

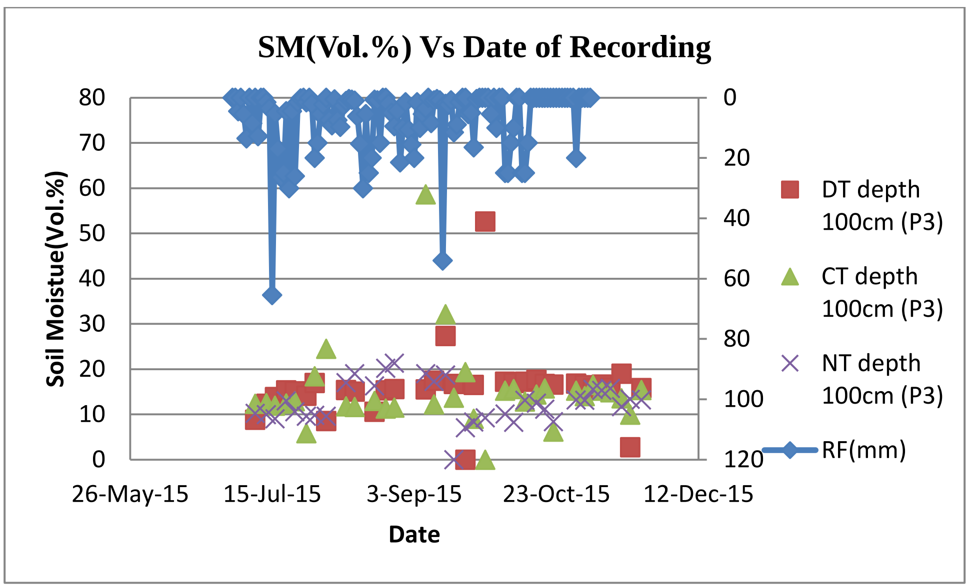

SM(Vol.%) Vs Date of Recording
Soil Moisture(Vol.%)
80
70
60
50
40
30
20
10
0
26-May-15
15-Jul-15
3-Sep-15
23-Oct-15
12-Dec-15
Date
0
20
40
60
80
100
120
DT depth 60cm (P2)
CT depth 60cm (P2)
NT depth 60cm (P2)
RF(mm)

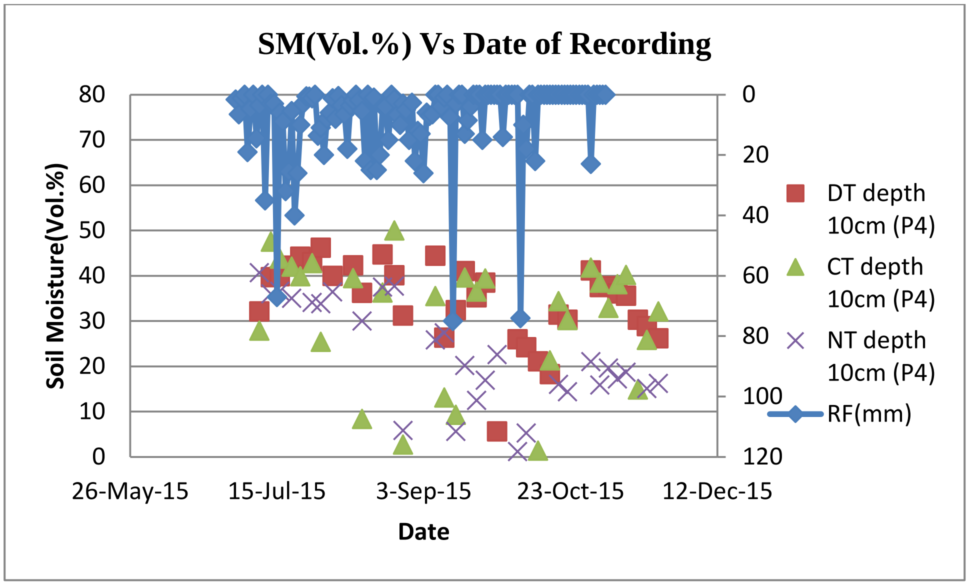

SM(vol.%) Vs Date of Recording
Soil Moisture(Vol.%)
80
70
60
50
40
30
20
10
0
26-May-15
15-Jul-15
3-Sep-15
23-Oct-15
12-Dec-15
Date
0
20
40
60
80
100
120
DT depth 100cm(P2)
CT depth 100cm(P2)
NT depth 100cm (P2)
RF(mm)

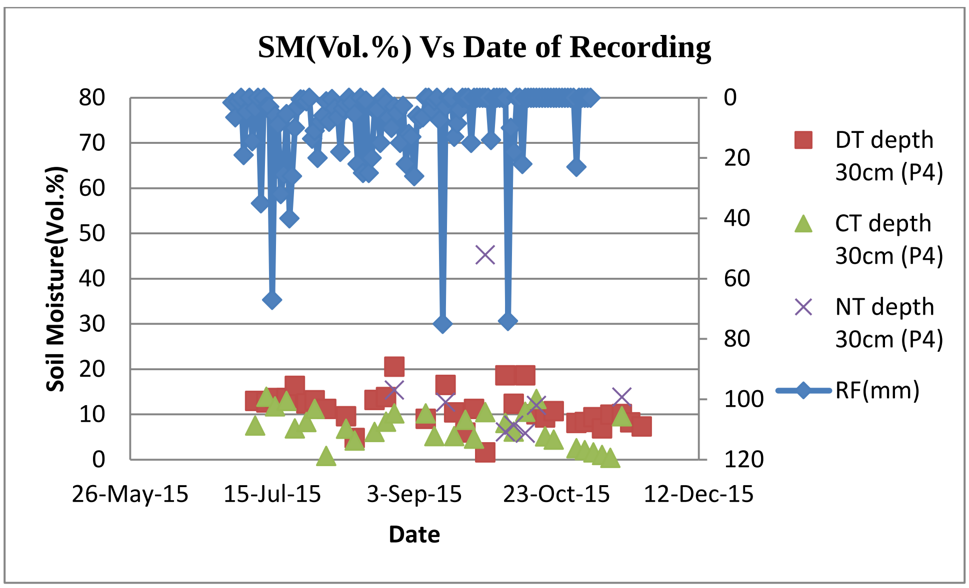

SM(Vol.%) Vs Date of Recording
Soil moistue(Vol.%)
80
70
60
50
40
30
20
10
0
0
20
40
60
80
100
120
26-May-15
15-Jul-15
3-Sep-15
23-Oct-15
12-Dec-15
Date
DT depth 10cm (P3)
CT depth 10cm (P3)
NT depth 10cm (P3)
RF(mm)

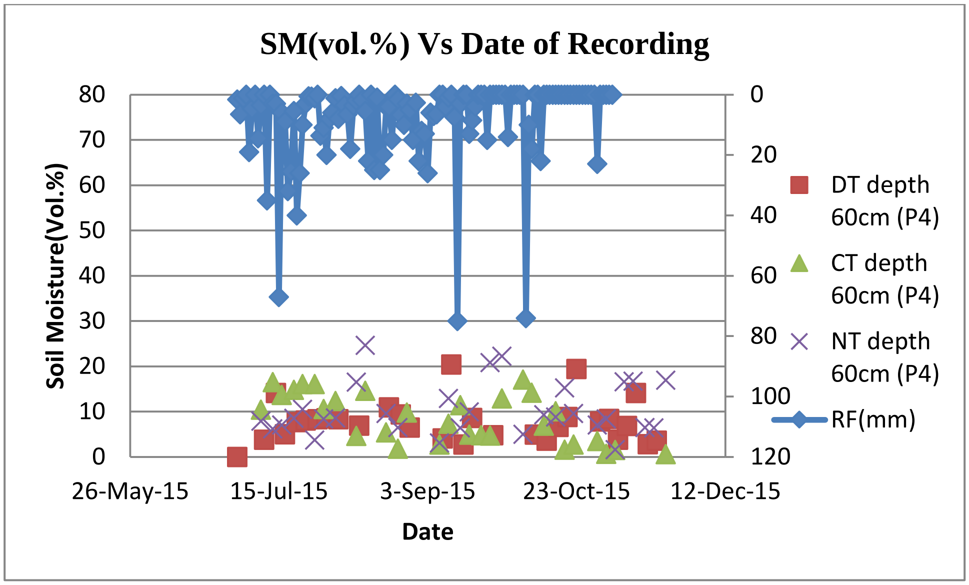

SM(Vol.%) Vs Date of Recording
Soil Moisture(Vol.%)
80
70
60
50
40
30
20
10
0
0
20
40
60
80
100
120
26-May-15
15-Jul-15
3-Sep-15
23-Oct-15
12-Dec-15
Date
DT depth 30cm (P3)
CT depth 30cm(P3)
NT depth 30cm (P3)
RF(mm)

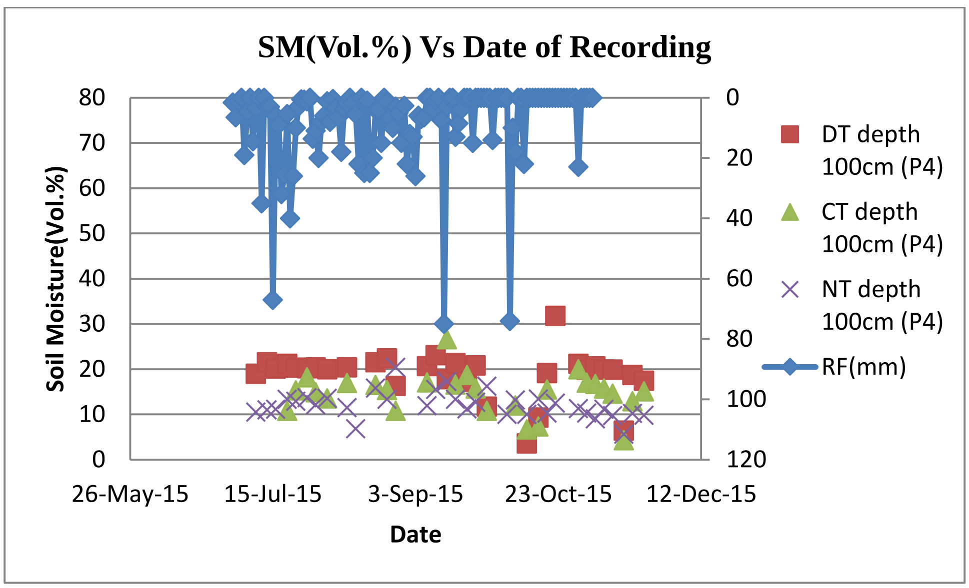

SM(Vol.%) Vs Date of Recording
Soil Moisture(Vol.%)
80
70
60
50
40
30
20
10
0
0
20
40
60
80
100
120
26-May-15
15-Jul-15
3-Sep-15
23-Oct-15
12-Dec-15
Date
DT depth 60cm (P3)
CT depth 60cm (P3)
NT depth 60cm (P3)
RF(mm)

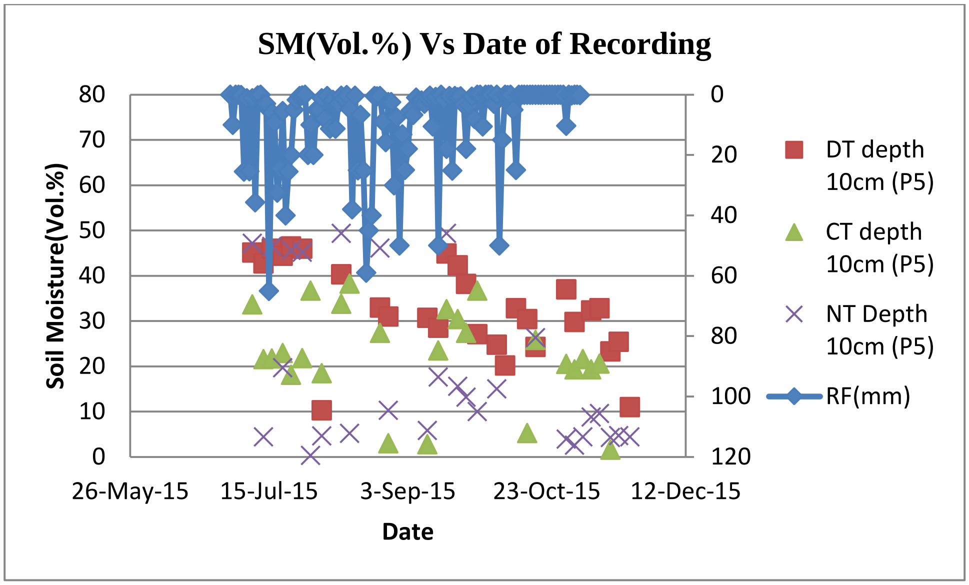

SM(Vol.%) Vs Date of Recording
Soil Moistue(Vol.%)
80
70
60
50
40
30
20
10
0
0
20
40
60
80
100
120
26-May-15
15-Jul-15
3-Sep-15
23-Oct-15
12-Dec-15
Date
DT depth 100cm (P3)
CT depth 100cm (P3)
NT depth 100cm (P3)
RF(mm)

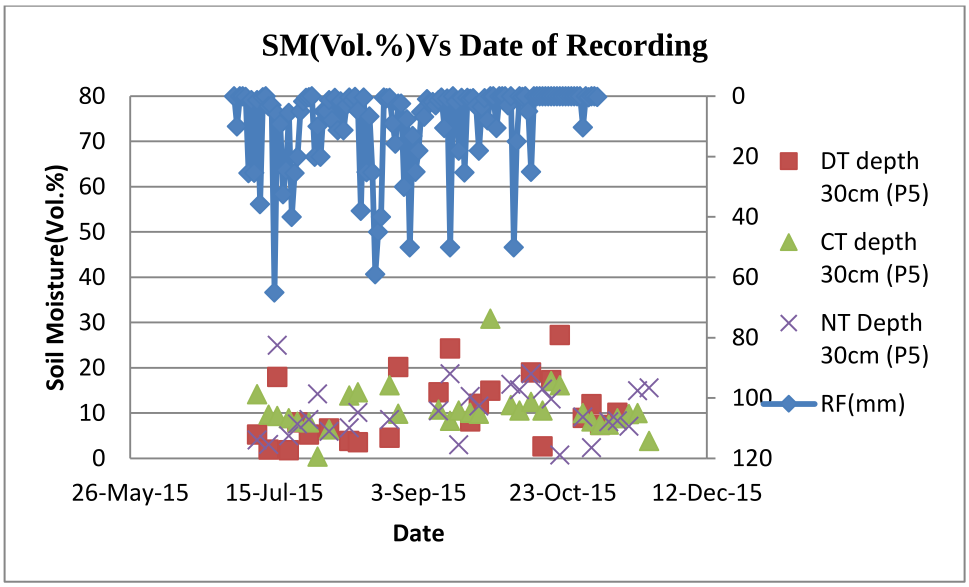

SM(Vol.%) Vs Date of Recording
Soil Moisture(Vol.%)
80
70
60
50
40
30
20
10
0
0
20
40
60
80
100
120
26-May-15
15-Jul-15
3-Sep-15
23-Oct-15
12-Dec-15
Date
DT depth 10cm (P4)
CT depth 10cm (P4)
NT depth 10cm (P4)
RF(mm)

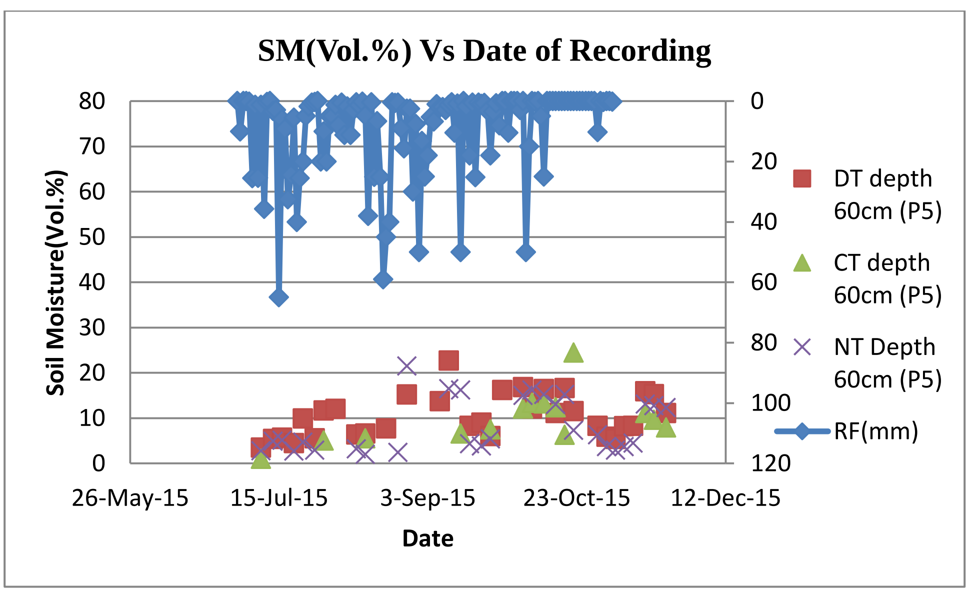

SM(Vol.%) Vs Date of Recording
Soil Moisture(Vol.%)
80
70
60
50
40
30
20
10
0
0
20
40
60
80
100
120
26-May-15
15-Jul-15
3-Sep-15
23-Oct-15
12-Dec-15
Date
DT depth 30cm (P4)
CT depth 30cm (P4)
NT depth 30cm (P4)
RF(mm)


SM(vol.%) Vs Date of Recording
Soil Moisture(Vol.%)
80
70
60
50
40
30
20
10
0
0
20
40
60
80
100
120
26-May-15
15-Jul-15
3-Sep-15
23-Oct-15
12-Dec-15
Date
DT depth 60cm (P4)
CT depth 60cm (P4)
NT depth 60cm (P4)
RF(mm)


SM(Vol.%) Vs Date of Recording
Soil Moisture(Vol.%)
80
70
60
50
40
30
20
10
0
0
20
40
60
80
100
120
26-May-15
15-Jul-15
3-Sep-15
23-Oct-15
12-Dec-15
Date
DT depth 100cm (P4)
CT depth 100cm (P4)
NT depth 100cm (P4)
RF(mm)


SM(Vol.%) Vs Date of Recording
Soil Moisture(Vol.%)
80
70
60
50
40
30
20
10
0
0
20
40
60
80
100
120
26-May-15
15-Jul-15
3-Sep-15
23-Oct-15
12-Dec-15
Date
DT depth 10cm (P5)
CT depth 10cm (P5)
NT Depth 10cm (P5)
RF(mm)


SM(Vol.%)Vs Date of Recording
Soil Moisture(Vol.%)
80
70
60
50
40
30
20
10
0
0
20
40
60
80
100
120
26-May-15
15-Jul-15
3-Sep-15
23-Oct-15
12-Dec-15
Date
DT depth 30cm (P5)
CT depth 30cm (P5)
NT Depth 30cm (P5)
RF(mm)


SM(Vol.%) Vs Date of Recording
Soil Moisture(Vol.%)
80
70
60
50
40
30
20
10
0
0
20
40
60
80
100
120
26-May-15
15-Jul-15
3-Sep-15
23-Oct-15
12-Dec-15
Date
DT depth 60cm (P5)
CT depth 60cm (P5)
NT Depth 60cm (P5)
RF(mm)

Appendix F: Event runoff and Rainfall data

F1: Event runoff and rainfall data for plot coded P1

Date of Recording	RF (mm)	Tillage treatment		
		DT	CT	NT
		Event runoff (mm)		
1-Jul-15	0	0	0	0
2-Jul-15	3.5	0	0	0
3-Jul-15	3.7	0	0	0
4-Jul-15	0	0	0	0
5-Jul-15	20	0	0	0
6-Jul-15	3	0	0	0
7-Jul-15	0	0	0	0
8-Jul-15	5	0	0	0
9-Jul-15	1.7	0	0	0
10-Jul-15	10.5	0	0	0
11-Jul-15	22	0	0	0
12-Jul-15	0	0	0	0
13-Jul-15	3	0	0	0
14-Jul-15	23	0	0	0
15-Jul-15	50	0	0	0
16-Jul-15	0.3	0	0	0
17-Jul-15	9.5	0	0	0
18-Jul-15	20	0	0	0
19-Jul-15	25	0	0	0
20-Jul-15	0	0	0	0
21-Jul-15	40	0	0.165	0.8
22-Jul-15	2.5	0	0	0
23-Jul-15	20	0	0	0
24-Jul-15	3	0	0	0
25-Jul-15	0.3	0	0	0
26-Jul-15	0	0	0	0
27-Jul-15	5	0	0	0
28-Jul-15	0	0	0	0
29-Jul-15	1.3	0	0	0
30-Jul-15	15	0	0	0
31-Jul-15	25	0	0	0
1-Aug-15	15	0	0	0
2-Aug-15	16	0	0	0
3-Aug-15	15.5	0	0	0
4-Aug-15	14	0	0	0
5-Aug-15	3	0	0	0
6-Aug-15	12	0	0	0

7-Aug-15	11	0	0	0
8-Aug-15	23	0	0	0
9-Aug-15	20	0	0.21	0.12
10-Aug-15	0	0	0	0
11-Aug-15	3	0	0	0
12-Aug-15	0	0	0	0
13-Aug-15	12	0	0	0
14-Aug-15	10	0	0	0
15-Aug-15	35	0.12	0.52	0.6
16-Aug-15	12	0	0	0
17-Aug-15	13.5	0	0	0
18-Aug-15	20	0	0	0
19-Aug-15	20	0	0.14	0.2
20-Aug-15	13	0	0	0
21-Aug-15	26	0	0	0
22-Aug-15	11	0	0	0
23-Aug-15	5	0	0	0
24-Aug-15	28	0	0	0
25-Aug-15	0	0	0	0
26-Aug-15	32	0	0	0
27-Aug-15	43	0	0	0
28-Aug-15	24	0	0	0
29-Aug-15	14	0	0	0
30-Aug-15	13	0	0	0
31-Aug-15	8	0	0	0
1-Sep-15	48	0	0	0
2-Sep-15	30	0	0	0
3-Sep-15	0	0	0	0
4-Sep-15	31	0	0	0
5-Sep-15	10	0	0	0
6-Sep-15	3	0	0	0
7-Sep-15	10	0	0	0
8-Sep-15	0	0	0	0
9-Sep-15	8	0	0	0
10-Sep-15	20.3	0	0	0
11-Sep-15	0.5	0	0	0
12-Sep-15	21.7	0	0	0
13-Sep-15	35	0	0	0
14-Sep-15	11.5	0	0	0
15-Sep-15	18	0	0	0
16-Sep-15	0.4	0	0	0
17-Sep-15	15	0	0	0
18-Sep-15	28	0	0	0
19-Sep-15	0	0	0	0

20-Sep-15	0	0	0	0
21-Sep-15	0	0	0	0
22-Sep-15	0	0	0	0
23-Sep-15	0	0	0	0
24-Sep-15	0	0	0	0
25-Sep-15	0	0	0	0
26-Sep-15	0	0	0	0
27-Sep-15	0	0	0	0
28-Sep-15	0.5	0	0	0
29-Sep-15	0	0	0	0
30-Sep-15	0	0	0	0
1-Oct-15	0	0	0	0
2-Oct-15	0	0	0	0
3-Oct-15	0	0	0	0
4-Oct-15	0	0	0	0
5-Oct-15	0	0	0	0
6-Oct-15	0	0	0	0
7-Oct-15	18	0	0	0
8-Oct-15	16	0	0	0
9-Oct-15	0.7	0	0	0
10-Oct-15	20	0	0	0
11-Oct-15	16	0	0	0
12-Oct-15	25	0	0	0
13-Oct-15	10	0	0	0
14-Oct-15	0	0	0	0
15-Oct-15	0	0	0	0
16-Oct-15	0	0	0	0
17-Oct-15	0	0	0	0
18-Oct-15	0	0	0	0
19-Oct-15	0	0	0	0
20-Oct-15	0	0	0	0
21-Oct-15	0	0	0	0
22-Oct-15	0	0	0	0
23-Oct-15	0	0	0	0
24-Oct-15	0	0	0	0
25-Oct-15	0	0	0	0
26-Oct-15	0	0	0	0
27-Oct-15	0	0	0	0
28-Oct-15	0	0	0	0
29-Oct-15	0	0	0	0
30-Oct-15	20	0	0	0
31-Oct-15	0	0	0	0
1-Nov-15	0	0	0	0
2-Nov-15	0	0	0	0

3-Nov-15	0	0	0	0
4-Nov-15	0	0	0	0

F2: Event runoff and rainfall data for plot coded P2

Date of Recording	RF (mm)	Tillage treatment		
		DT	CT	NT
		Event runoff (mm)		
1-Jul-15	0	0	0	0
2-Jul-15	0	0	0	0
3-Jul-15	0	0	0	0
4-Jul-15	0	0.659734	0.706858	7.539822
5-Jul-15	20	0	0	0
6-Jul-15	5	0	0	0
7-Jul-15	0	0	0	0
8-Jul-15	10	0	0	0
9-Jul-15	0	0	0	0
10-Jul-15	0	0	0	0
11-Jul-15	20	0.777544	6.361725	8.011061
12-Jul-15	0	0	0	0
13-Jul-15	0	0	0	0
14-Jul-15	0	0	0	0
15-Jul-15	55	0.683296	0.942478	5.654867
16-Jul-15	5	0.047124	0.11781	0.070686
17-Jul-15	10	0	0	0
18-Jul-15	30	2.827433	9.424778	8.011061
19-Jul-15	20	6.126106	8.953539	9.189159
20-Jul-15	15	0.235619	0.259181	9.660397
21-Jul-15	20	3.063053	9.424778	0.73042
22-Jul-15	5	0	0	0
23-Jul-15	20	0.235619	10.36726	10.36726
24-Jul-15	3	0.11781	0.141372	0.188496
25-Jul-15	0	0	0	0
26-Jul-15	0	0	0	0
27-Jul-15	0	0	0	0
28-Jul-15	20	0	0	0
29-Jul-15	15	0	0.11781	0.353429
30-Jul-15	0	0	8.835729	8.4823
31-Jul-15	30	0.918916	8.953539	8.71792
1-Aug-15	5	0.141372	0.141372	0.070686
2-Aug-15	3	0	0	0
3-Aug-15	3	0	0	0
4-Aug-15	2	0	0	0

5-Aug-15	8	0	0	0
6-Aug-15	10	0	0	0
7-Aug-15	10	0	0.164934	0.801106
8-Aug-15	15	2.356194	2.356194	8.011061
9-Aug-15	3	0	0	0
10-Aug-15	3	0	0	0
11-Aug-15	2	0	0	0
12-Aug-15	3	0	0	0
13-Aug-15	5	0	0	0
14-Aug-15	15	0.282743	0.84823	3.769911
15-Aug-15	5	0.11781	0.070686	0.188496
16-Aug-15	35	0.942478	8.71792	8.71792
17-Aug-15	3	0	0	0
18-Aug-15	20	2.120575	8.71792	8.71792
19-Aug-15	20	2.120575	8.011061	6.832964
20-Aug-15	0	0	0	0
21-Aug-15	4	0	0	0
22-Aug-15	2	0	0	0
23-Aug-15	20	0.942478	8.011061	5.654867
24-Aug-15	0	0	0	0
25-Aug-15	0	0	0	0
26-Aug-15	20	0.871792	8.71792	6.126106
27-Aug-15	0	0	0	0
28-Aug-15	0	0	0	0
29-Aug-15	20	0.801106	8.71792	8.71792
30-Aug-15	0	0	0	0
31-Aug-15	20	0.918916	3.298672	5.654867
1-Sep-15	15	0.918916	0.84823	0.918916
2-Sep-15	25	0.918916	2.591814	5.654867
3-Sep-15	25	0.918916	6.361725	7.068583
4-Sep-15	10	0.518363	0.84823	0.801106
5-Sep-15	6	0	0	0
6-Sep-15	5	0.801106	0.895354	2.120575
7-Sep-15	0	0	0	0
8-Sep-15	0	0	0	0
9-Sep-15	10	4.005531	3.534292	0.895354
10-Sep-15	3	0	0	0
11-Sep-15	0	0	0	0
12-Sep-15	20	0.895354	6.832964	5.654867
13-Sep-15	0	0		
14-Sep-15	40	0.918916	8.953539	8.953539
15-Sep-15	0	0	0	0
16-Sep-15	0	0	0	0
17-Sep-15	20	0.871792	8.71792	8.71792

18-Sep-15	15	0.895354	0.895354	0.895354
19-Sep-15	10	0.942478	5.183628	6.126106
20-Sep-15	0	0	0	0
21-Sep-15	0	0	0	0
22-Sep-15	0	0	0	0
23-Sep-15	10	0.942478	8.71792	6.597345
24-Sep-15	3.5	0.659734	0.612611	0.706858
25-Sep-15	0	0	0	0
26-Sep-15	0	0	0	0
27-Sep-15	0	0	0	0
28-Sep-15	0	0	0	0
29-Sep-15	0	0	0	0
30-Sep-15	0	0	0	0
1-Oct-15	0	0	0	0
2-Oct-15	0	0	0	0
3-Oct-15	0	0	0	0
4-Oct-15	0	0	0	0
5-Oct-15	0	0	0	0
6-Oct-15	40	0.871792	8.71792	8.71792
7-Oct-15	15	0.518363	0.518363	0.801106
8-Oct-15	20	2.120575	4.948008	6.832964
9-Oct-15	0	0	0	0
10-Oct-15	0	0	0	0
11-Oct-15	20	0.871792	8.011061	8.71792
12-Oct-15	30	0.918916	7.775442	8.71792
13-Oct-15	3	0	0	0
14-Oct-15	0	0	0	0
15-Oct-15	0	0	0	0
16-Oct-15	0	0	0	0
17-Oct-15	0	0	0	0
18-Oct-15	0	0	0	0
19-Oct-15	0	0	0	0
20-Oct-15	0	0	0	0
21-Oct-15	0	0	0	0
22-Oct-15	0	0	0	0
23-Oct-15	0	0	0	0
24-Oct-15	0	0	0	0
25-Oct-15	0	0	0	0
26-Oct-15	0	0	0	0
27-Oct-15	0	0	0	0
28-Oct-15	0	0	0	0
29-Oct-15	0	0	0	0
30-Oct-15	0	0	0	0
31-Oct-15	0	0	0	0

1-Nov-15	0	0	0	0
2-Nov-15	0	0	0	0
3-Nov-15	0	0	0	0
4-Nov-15	0	0	0	0

F3: Event runoff and rainfall data for plot coded P3

Date of Recording	RF (mm)	Tillage treatment		
		DT	CT	NT
		Event runoff (mm)		
1-Jul-15	0	0	0	0
2-Jul-15	0	0	0	0
3-Jul-15	4.5	0	0	0
4-Jul-15	0	0	0	0
5-Jul-15	5.5	0	0	0
6-Jul-15	13.5	0	0	0
7-Jul-15	0	0	0	0
8-Jul-15	8.5	0	0	0
9-Jul-15	0	0	0	0
10-Jul-15	12.8	6.126106	8.71792	7.304203
11-Jul-15	0	0	0	0
12-Jul-15	0	0	0	0
13-Jul-15	1.5	0	0	0
14-Jul-15	3.5	0	0	0
15-Jul-15	65.5	0.942478	8.71792	0.942478
16-Jul-15	5.3	0	0	0
17-Jul-15	17	0	0	0
18-Jul-15	26.5	6.597345	0.824668	0.706858
19-Jul-15	25	0.141372	0.824668	0.918916
20-Jul-15	4.5	0	0.376991	0.235619
21-Jul-15	30	0.494801	0.824668	0.706858
22-Jul-15	4.5	0	0	0
23-Jul-15	26	0.683296	4.712389	2.827433
24-Jul-15	1.5	0	0	0
25-Jul-15	0.3	0	0	0
26-Jul-15	0	0	0	0
27-Jul-15	1.5	0	0	0
28-Jul-15	0	0	0	0
29-Jul-15	2.1	0	0	0
30-Jul-15	20	0	0.636173	0
31-Jul-15	15	0	0.824668	0.683296
1-Aug-15	5.5	0	0	0
2-Aug-15	2.3	0	0	0

3-Aug-15	0	0	0	0
4-Aug-15	7.5	0	0	0
5-Aug-15	9.2	0	0	0
6-Aug-15	0.6	0	0	0
7-Aug-15	7.5	0	0	0
8-Aug-15	9.7	0	4.005531	0.871792
9-Aug-15	2.7	0	0	0
10-Aug-15	1.1	0	0	0
11-Aug-15	0.5	0	0	0
12-Aug-15	0.7	0	0	0
13-Aug-15	1	0	0	0
14-Aug-15	6.2	0	0	0
15-Aug-15	15.3	0	0	0
16-Aug-15	30	2.356194	6.832964	6.832964
17-Aug-15	5.5	0	0	0
18-Aug-15	25	0.871792	3.769911	9.424778
19-Aug-15	20	0	0	0
20-Aug-15	0.7	0	0	0
21-Aug-15	0.9	0	0	0
22-Aug-15	15	0	0.942478	0.353429
23-Aug-15	0	0	0	0
24-Aug-15	0	0	0	0
25-Aug-15	2	0	0	0
26-Aug-15	5	0	0	0
27-Aug-15	9.5	0	0	0
28-Aug-15	4.4	0	0.871792	0.84823
29-Aug-15	21.5	2.120575	4.47677	5.890486
30-Aug-15	10	0.259181	0.895354	0.824668

31-Aug-15	1.5	0	0	0
1-Sep-15	10.7	0	0	0
2-Sep-15	15.5	0	0.84823	0
3-Sep-15	20	9.189159	8.953539	9.424778
4-Sep-15	1.5	0	0	0
5-Sep-15	10	0	0.376991	0
6-Sep-15	5.5	0	0	0
7-Sep-15	3.5	0	0	0
8-Sep-15	0	0	0	0
9-Sep-15	8.4	0	0.942478	0.424115
10-Sep-15	0.9	0	0	0
11-Sep-15	0.5	0	0	0
12-Sep-15	0.9	0	0	0
13-Sep-15	54	9.189159	3.298672	8.011061
14-Sep-15	2.1	0	0	0
15-Sep-15	2.4	0	0	0
16-Sep-15	0.9	0	0	0
17-Sep-15	11.5	0.659734	0.918916	0.895354
18-Sep-15	9	0.871792	0.871792	5.419247
19-Sep-15	1.5	0	0	0
20-Sep-15	0	0	0	0
21-Sep-15	0	0	0	0
22-Sep-15	5.5	0	0	0
23-Sep-15	5	0	0.918916	0
24-Sep-15	16.5	0.164934	1.979203	0
25-Sep-15	0.5	0	0	0
26-Sep-15	0	0	0	0
27-Sep-15	0	0	0	0

28-Sep-15	0	0	0	0
29-Sep-15	0	0	0	0
30-Sep-15	5.5	0	0	0
1-Oct-15	0	0	0	0
2-Oct-15	10	0	0.824668	0
3-Oct-15	0	0	0	0
4-Oct-15	0	0	0	0
5-Oct-15	25	0	0	0
6-Oct-15	25	7.068583	8.246681	8.71792
7-Oct-15	15	6.832964	7.068583	6.126106
8-Oct-15	10	0	0	0
9-Oct-15	0	0	0	0
10-Oct-15	0	0	0	0
11-Oct-15	25	0	0	0
12-Oct-15	25	5.277876	8.246681	8.71792
13-Oct-15	15	5.419247	8.011061	6.126106
14-Oct-15	0	0	0	0
15-Oct-15	0	0	0	0
16-Oct-15	0	0	0	0
17-Oct-15	0	0	0	0
18-Oct-15	0	0	0	0
19-Oct-15	0	0	0	0
20-Oct-15	0	0	0	0
21-Oct-15	0	0	0	0
22-Oct-15	0	0	0	0
23-Oct-15	0	0	0	0
24-Oct-15	0	0	0	0
25-Oct-15	0	0	0	0
26-Oct-15	0	0	0	0
27-Oct-15	0	0	0	0
28-Oct-15	0	0	0	0
29-Oct-15	0	0	0	0
30-Oct-15	20	0	0	0
31-Oct-15	0	0	0	0
1-Nov-15	0	0	0	0
2-Nov-15	0	0	0	0
3-Nov-15	0	0	0	0
4-Nov-15	0	0	0	0

F4: Event runoff and rainfall data for plot coded P4

Date of Recording	RF (mm)	Tillage treatment		
		DT	CT	NT
		Event runoff (mm)		
1-Jul-15	1.6	0	0	0
2-Jul-15	6.5	0	0	0
3-Jul-15	1.25	0	0	0
4-Jul-15	0	0	0	0
5-Jul-15	19	0.04712389	0.447677	3.298672
6-Jul-15	4.75	0	0	0
7-Jul-15	0	0	0	0
8-Jul-15	14.5	0	0	0
9-Jul-15	3.5	0	0.447677	0.942478
10-Jul-15	0	0	0	0
11-Jul-15	35	0.447676953	4.47677	8.71792
12-Jul-15	0	0	0	0
13-Jul-15	3	0	0	0
14-Jul-15	3	0	0	0
15-Jul-15	67	0.04712389	0.942478	9.660397
16-Jul-15	6	0	0	0
17-Jul-15	9	0	0	0
18-Jul-15	32	1.649336143	2.120575	7.304203
19-Jul-15	25.5	0.09424778	0.942478	4.47677
20-Jul-15	5.5	0	0.400553	0.471239
21-Jul-15	40	0.117809725	2.591814	5.419247
22-Jul-15	26	0	0	0
23-Jul-15	10	0	2.591814	5.654867
24-Jul-15	3	0	0	0
25-Jul-15	0.6	0	0	0
26-Jul-15	0.7	0	0	0
27-Jul-15	1.25	0	0	0
28-Jul-15	0	0	0	0
29-Jul-15	13.6	0	0	0
30-Jul-15	11	0	0	0
31-Jul-15	20	4.476769531	0.942478	5.654867
1-Aug-15	8	0.447676953	0.376991	0.942478
2-Aug-15	6	0	0	0
3-Aug-15	1.25	0	0	0
4-Aug-15	8	0	0	0
5-Aug-15	0.5	0	0	0
6-Aug-15	3.5	0	0	0

7-Aug-15	6.5	0	0	0.188496
8-Aug-15	18	0.565486678	0.942478	0.942478
9-Aug-15	3.7	0	0	0
10-Aug-15	2	0	0	0
11-Aug-15	0	0	0	0
12-Aug-15	1.8	0	0	0
13-Aug-15	5.5	0	0	0
14-Aug-15	22	0.942477796	0.942478	3.769911
15-Aug-15	0	0	0	0
16-Aug-15	25	0	0.942478	0.942478
17-Aug-15	1	0	0	0
18-Aug-15	25	0	3.298672	3.298672
19-Aug-15	20	0	0.942478	0.942478
20-Aug-15	4	0	0	0
21-Aug-15	4	0	0	0
22-Aug-15	15	0	0	0
23-Aug-15	0	0	0.942478	0.942478
24-Aug-15	1.5	0	0	0
25-Aug-15	6.75	0	0	0
26-Aug-15	10	0	0	0
27-Aug-15	3	0	0	0
28-Aug-15	5	0	0	0
29-Aug-15	15	1.884955592	2.356194	4.47677
30-Aug-15	2.7	0	0	0
31-Aug-15	22	0.942477796	0.942478	0.942478
1-Sep-15	12	0	0.942478	0.942478
2-Sep-15	13	0.942477796	0.942478	4.005531
3-Sep-15	26	0.942477796	0.942478	0.942478
4-Sep-15	6	0	0	0
5-Sep-15	7	0	0	0
6-Sep-15	6.5	0	0	0
7-Sep-15	0	0	0	0
8-Sep-15	0	0	0	0
9-Sep-15	4	0	0	0
10-Sep-15	1	0	0	0
11-Sep-15	0	0	0	0
12-Sep-15	7.5	0	0	0
13-Sep-15	75	0	0	0
14-Sep-15	3	8.717919614	9.660397	9.660397
15-Sep-15	0	0	0	0
16-Sep-15	0	0	0	0
17-Sep-15	13	0.942477796	0.942478	0.942478
18-Sep-15	8.5	0.942477796	0.942478	0.942478
19-Sep-15	4	0.942477796	0.942478	0.942478

20-Sep-15	0	0	0	0
21-Sep-15	0	0	0	0
22-Sep-15	0	0	0	0
23-Sep-15	15	0	0	0
24-Sep-15	0	0	0	0
25-Sep-15	0	0	0	0
26-Sep-15	0	0	0	0
27-Sep-15	0	0	0	0
28-Sep-15	0	0	0	0
29-Sep-15	0	0	0	0
30-Sep-15	14	0	0	0
1-Oct-15	0	0	0	0
2-Oct-15	0	0	0	0
3-Oct-15	0	0	0	0
4-Oct-15	0	0	0	0
5-Oct-15	0	0	0	0
6-Oct-15	74	9.66039741	9.660397	9.660397
7-Oct-15	10	0	0	0
8-Oct-15	18	0.942477796	0.942478	3.298672
9-Oct-15	0	0	0	0
10-Oct-15	0	0	0	0
11-Oct-15	22	0.942477796	0.942478	0.942478
12-Oct-15	0	0	0	0
13-Oct-15	0	0	0	0
14-Oct-15	0	0	0	0
15-Oct-15	0	0	0	0
16-Oct-15	0	0	0	0
17-Oct-15	0	0	0	0
18-Oct-15	0	0	0	0
19-Oct-15	0	0	0	0
20-Oct-15	0	0	0	0
21-Oct-15	0	0	0	0
22-Oct-15	0	0	0	0
23-Oct-15	0	0	0	0
24-Oct-15	0	0	0	0
25-Oct-15	0	0	0	0
26-Oct-15	0	0	0	0
27-Oct-15	0	0	0	0
28-Oct-15	0	0	0	0
29-Oct-15	0	0	0	0
30-Oct-15	23	0	0	0
31-Oct-15	0	0	0	0
1-Nov-15	0	0	0	0
2-Nov-15	0	0	0	0

3-Nov-15	0	0	0	0
4-Nov-15	0	0	0	0

F5: Event runoff and rainfall data for plot coded P5

Date of Recording	RF (mm)	Tillage treatment		
		DT	CT	NT
		Event runoff (mm)		
1-Jul-15	0	0	0	0
2-Jul-15	10	0.065973	0.091892	0
3-Jul-15	0	0	0	0
4-Jul-15	0	0	0	0
5-Jul-15	0.2	0	0	0
6-Jul-15	25.5	0.424115	0.612611	0.37699112
7-Jul-15	1.25	0	0	0
8-Jul-15	25.4	1.484403	5.183628	0.77754418
9-Jul-15	1.25	0	0	0
10-Jul-15	35.7	2.120575	2.827433	2.59181394
11-Jul-15	0.3	0	0	0
12-Jul-15	0	0	0	0
13-Jul-15	3.25	0	0	0
14-Jul-15	3	0	0	0
15-Jul-15	65	1.413717	1.767146	5.41924733
16-Jul-15	6	0	0	0
17-Jul-15	9.25	0	0	0
18-Jul-15	32.5	0.824668	0.895354	3.76991118
19-Jul-15	24.5	0	0	0
20-Jul-15	5.5	0	0	0
21-Jul-15	40	0.84823	0.918916	6.59734457
22-Jul-15	25.5	0	0	0
23-Jul-15	20	0.11781	0.471239	0.63617251
24-Jul-15	5	0	0	0.02356194
25-Jul-15	1.75	0	0	0
26-Jul-15	0.5	0	0	0
27-Jul-15	0.3	0	0	0
28-Jul-15	0	0	0	0
29-Jul-15	20	0.035343	0.023562	0.53014376
30-Jul-15	10	0	0	0
31-Jul-15	20	0.824668	0.541925	0.25918139
1-Aug-15	5	0.141372	0.259181	0.63617251
2-Aug-15	5	0	0	0
3-Aug-15	1.25	0	0	0
4-Aug-15	8	0	0	0

5-Aug-15	0.5	0	0	0
6-Aug-15	11.25	0.141372	0.235619	0.65973446
7-Aug-15	1.75	0	0	0
8-Aug-15	11.25	0.824668	0.824668	0.42411501
9-Aug-15	3	0.235619	0.141372	0.35342917
10-Aug-15	0.4	0	0	0
11-Aug-15	1.35	0	0	0
12-Aug-15	0.2	0	0	0
13-Aug-15	4.75	0	0	0
14-Aug-15	38	1.295907	9.424778	0.35342917
15-Aug-15	0.4	0.058905	0.047124	0.07068583
16-Aug-15	25.1	1.767146	5.183628	0.75398224
17-Aug-15	6.7	0.11781	0.353429	0.14137167
18-Aug-15	25.2	2.120575	9.189159	0.64795348
19-Aug-15	59	0.471239	0.589049	0.40055306
20-Aug-15	45	0	0	0
21-Aug-15	40	3.298672	8.36449	2.37975644
22-Aug-15	0.45	0	0	0
23-Aug-15	0.6	0	0	0
24-Aug-15	0.5	0	0	0
25-Aug-15	9	0.023562	0.023562	0.02356194
26-Aug-15	15.7	1.743584	1.720022	0.70685835
27-Aug-15	2.5	0.094248	0.047124	0.23561945
28-Aug-15	2.5	0	0	0
29-Aug-15	30	1.531526	1.130973	0.4712389
30-Aug-15	7.6	0.164934	0.094248	0.07068583
31-Aug-15	50	2.120575	4.005531	0.07068583
1-Sep-15	13.2	2.356194	2.356194	0.09424778
2-Sep-15	25	1.178097	2.120575	0.11780972
3-Sep-15	18	0.094248	0.094248	0.11780972
4-Sep-15	5.25	0	0	0
5-Sep-15	6.75	0	0	0
6-Sep-15	1	0	0	0
7-Sep-15	2.15	0	0	0
8-Sep-15	1.95	0	0	0
9-Sep-15	3	0	0	0
10-Sep-15	1.25	0	0	0
11-Sep-15	0.4	0	0	0
12-Sep-15	10.5	0	0	0
13-Sep-15	0.8	0	0	0
14-Sep-15	50	1.178097	1.178097	0.40055306
15-Sep-15	0	0	0	0
16-Sep-15	1.79	0	0	0
17-Sep-15	18	0	0.11781	0.16493361

18-Sep-15	0.5	0	0	0
19-Sep-15	25.2	2.356194	2.356194	0.89535391
20-Sep-15	0.5	0	0	0
21-Sep-15	0.9	0	0	0
22-Sep-15	0.6	0	0	0
23-Sep-15	3.2	0	0	0
24-Sep-15	18	0.494801	0.824668	0.42411501
25-Sep-15	3.5	0	0	0
26-Sep-15	0.7	0	0	0
27-Sep-15	8	0	0	0
28-Sep-15	0	0	0	0
29-Sep-15	0	0	0	0
30-Sep-15	10.5	0	0	0
1-Oct-15	0	0	0	0
2-Oct-15	0	0	0	0
3-Oct-15	0	0	0	0
4-Oct-15	3	0	0	0
5-Oct-15	0	0	0	0
6-Oct-15	50	0.541925	0.353429	0.25918139
7-Oct-15	15	0.259181	0.306305	0.25918139
8-Oct-15	0	0	0	0
9-Oct-15	0.2	0	0	0
10-Oct-15	0	0	0	0
11-Oct-15	5	0	0	0
12-Oct-15	25	0	0	0
13-Oct-15	0	0.259181	0.306305	0.30630528
14-Oct-15	0	0	0	0
15-Oct-15	0	0	0	0
16-Oct-15	0	0	0	0
17-Oct-15	0	0	0	0
18-Oct-15	0	0	0	0
19-Oct-15	0	0	0	0
20-Oct-15	0	0	0	0
21-Oct-15	0	0	0	0
22-Oct-15	0	0	0	0
23-Oct-15	0	0	0	0
24-Oct-15	0	0	0	0
25-Oct-15	0	0	0	0
26-Oct-15	0	0	0	0
27-Oct-15	0	0	0	0
28-Oct-15	0	0	0	0
29-Oct-15	0	0	0	0
30-Oct-15	10.3	0	0	0
31-Oct-15	0	0	0	0

1-Nov-15	0.3	0	0	0
2-Nov-15	0	0	0	0
3-Nov-15	0	0	0	0
4-Nov-15	0.2	0	0	0

Appendix G: Plant height, Yield and Biomass data

G1: Plant height data

Date	Plot code	Tillage treatment																	
		Deep Till						Conventional Till						No Till					
		Plant height (cm)																	
		Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6
9-Jul-15	P1	26	20	25	19	27	23	17	21	23	17	22	26	24	26	18	15	21	29
24-Jul-15	P1	42	41	36	34	35	26	46	48	42	34	33	29	47	40	37	36	31	24
5-Sep-15	P1	110	93	77	67	59	74	115	90	94	47	84	68	114	115	84	54	51	66
22-Oct-15	P1	186	185	180	176	169	160	184	176	174	169	160	159	174	170	166	174	179	164
21-Nov-15	P1	269	259	275	264	256	249	262	265	253	250	264	257	253	245	230	242	254	192
9-Jul-15	P2	17	23	15	24	16	28	27	29	19	19	18	24	20	21	22	22	20	20
24-Jul-15	P2	42	38	36	32	29	28	51	46	41	36	30	25	44	44	44	32	35	28
5-Sep-15	P2	86	84	76	65	56	60	60	76	65	65	56	64	74	66	64	67	58	49
22-Oct-15	P2	198	196	185	180	174	167	180	182	173	174	164	154	163	166	183	168	173	160
21-Nov-15	P2	273	260	227	235	267	263	194	207	256	253	267	276	237	228	197	188	242	247
9-Jul-15	P3	27	24	21	26	28	19	25	21	28	27	23	24	22	18	30	20	26	22

24-Jul-15	P3	53	36	43	26	28	30	47	44	43	42	37	25	45	47	49	34	33	23
5-Sep-15	P3	65	64	69	66	62	53	85	73	78	54	75	73	46	78	58	46	63	46
22-Oct-15	P3	184	178	172	174	163	157	186	192	174	173	164	160	175	169	162	165	155	149
21-Nov-15	P3	268	256	223	236	269	265	197	200	255	264	271		228	225	186	179	238	245
9-Jul-15	P4	10	13	14	17	25	30	14	15	11	17	26	30	14	15	11	17	26	30
24-Jul-15	P4	42	39	35	35	38	30	40	46	42	46	33	24	35	47	36	44	28	27
5-Sep-15	P4	97	78	84	74	63	58	110	100	87	80	75	63	48	52	62	73	52	46
22-Oct-15	P4	178	175	185	173	165	156	186	179	176	170	163	161	162	158	150	152	154	152
21-Nov-15	P4	276	263	274	264	253	243	264	257	273	268	244	252	238	229	219	187	255	235
9-Jul-15	P5	15	13	7	17	14	8	18	15	13	13	12	16	16	13	17	19	15	12
24-Jul-15	P5	43	33	49	30	27	25	42	46	40	39	31	26	45	42	52	28	32	20
5-Sep-15	P5	100	76	85	76	66	49	99	95	86	73	63	53	77	72	73	65	54	52
22-Oct-15	P5	187	185	173	172	161	165	187	180	176	171	166	162	175	170	164	160	156	153
21-Nov-15	P5	269	287	260	260	250	242	250	254	274	272	259	252	189	196	210	254	249	243

G2: Yield and biomass data

Plot code	Tillage Treatment		
	DT	CT	NT

	Yield(Kg/ha)	Biomass(Kg/ha)	Yield(Kg/ha)	Biomass(Kg/ha)	Yield(Kg/ha)	Biomass(Kg/ha)
P1	4166.67	5633.33	3583.33	4070	3166.67	3930
P2	6333.33	8529.166667	5666.67	6233.333333	6083.33	6763.33
P3	7833.33	8616.67	6000	7580	4916.67	3443.333333
P4	2916.67	3333.333	2583.33	2833.33	1583.33	1458.33
P5	3083.33	4975	2833.33	3554.17	1333.33	1219.17

G3: Average biomass for the various plots (kg/ha), all three treatments

Plot Code	Topographic Location	Average Yield(Kg/ha)	Average Biomass(Kg/ha)
P1	Down Slope	3638.89	4544.44
P2	Down Slope	6027.78	7175.28
P3	Down Slope	6250	6546.67
P4	Up Slope	2361.11	2541.67
P5	Up Slope	2416.67	3249.44

Appendix H: Sediment data

Date	Plot code	Tillage treatment		
		Deep till	Conventional till	No till
		Sediment concentration (g/l)		
21.07.2015	P1	0	0.4	0.9
08.08.2015	P1	0	3.2	7.7
15.08.2015	P1	11.4	20.4	25.7
11.07.2015	P2	3.4	4.2	6.2
18.07.2015	P2	6.2	5	6.1
19.07.2015	P2	25.9	7	5
31.07.2015	P2	3.1	13.4	6.1
08.08.2015	P2	50.1	2.1	6.3
14.08.2015	P2	0	3.3	5.2

16.08.2015	P2	4.7	1.8	3.7
18.08.2015	P2	4.1	5	7
19.08.2015	P2	9.5	9.6	9.9
23.08.2015	P2	0.4	3.6	1.2
26.08.2015	P2	18.4	3.3	0.7
29.08.2015	P2	0.6	0.8	1
02.09.2015	P2	1	1.3	1.2
17.09.2015	P2	0.9	1.9	1.3
18.09.2015	P2	2.8	3.3	1.5
23.09.2015	P2	0.7	0.2	1.1
06.10.2015	P2	0.7	1.2	1.5
08.10.2015	P2	0.1	0.7	2.6
11.10.2015	P2	0.9	0.4	0.2
12.10.2015	P2	0.2	6.8	1.6
10.07.2015	P3	12.6	4.1	0.5
15.07.2015	P3	3.1	2.3	1.5
18.07.2015	P3	11.6	8.6	3.1
19.07.2015	P3	0	5.7	14.9
21.07.2015	P3	8.9	22.8	25.7
23.07.2015	P3	4.9	7.3	10
16.08.2015	P3	9.5	4.9	1.2
18.08.2015	P3	1.1	4.3	0.6
29.08.2015	P3	1.5	7.8	10.6
03.09.2015	P3	5.7	1	10.7
13.09.2015	P3	0.4	1.1	1.2
17.09.2015	P3	5.7	0.3	13.4
18.09.2015	P3	0.6	7.3	0.7
06.10.2015	P3	0.1	1.6	0.1
12.10.2015	P3	0.6	0.5	0.2
13.10.2015	P3	0.3	0.5	1.3
11.07.2015	P4	6.9	4.3	3.9
18.07.2015	P4	9.9	4.6	7.9
19.07.2015	P4	0	3.5	1.2
21.07.2015	P4	0	0.9	3.6
23.07.2015	P4	0	1.7	7.8
31.07.2015	P4	4	3	0.8
01.08.2015	P4	1.7	0.6	0.8
08.08.2015	P4	3.8	1.5	1
14.08.2015	P4	0.9	1.1	1.5
16.08.2015	P4	0	1.4	2.9
18.08.2015	P4	0	3	4.3
19.08.2015	P4	0	2.9	1.7
23.08.2015	P4	0	0.8	3

29.08.2015	P4	0.6	1.2	3.7
31.08.2015	P4	0.8	1.7	2
01.09.2015	P4	0	0.2	3.8
02.09.2015	P4	1.2	2.3	2.3
03.09.2015	P4	1.1	1.4	1.4
14.09.2015	P4	1.5	1.7	1.6
17.09.2015	P4	3	2.2	1.5
18.09.2015	P4	1.2	1.1	3.8
19.08.2015	P4	1.6	1.2	2.1
06.10.2015	P4	3.7	6.1	7.5
08.10.2015	P4	1.1	2.4	3.2
11.10.2015	P4	2.6	1.7	5.1
08.07.2015	P5	0.1	0.8	1.9
10.07.2015	P5	0.5	0.9	1.1
15.07.2015	P5	0.3	0.2	0.7
18.07.2015	P5	0.4	0.7	1.2
21.07.2015	P5	0.6	0.4	1.4
14.08.2015	P5	0.7	1.2	1.2
16.08.2015	P5	1.2	1.4	2.5
18.08.2015	P5	0.2	0.2	0.7
21.08.2015	P5	1	1.8	2.2
26.08.2015	P5	0.3	0.9	3.5
29.08.2015	P5	0.3	1.8	4.2
03.09.2015	P5	0.9	1.7	0.9
14.09.2015	P5	0.8	0.9	2
19.09.2015	P5	0.3	1.5	3.6
24.09.2015	P5	6.7	0.4	0.2
06.10.2015	P5	0.3	0.1	0.3

Appendix I: Runoff water quality data

Date	Plot code	Treatment treatment	K (g/l)			P (g/l)			N (g/l)		
			Trial 1	Trial 2	Trial 3	Trial 1	Trial 2	Trial 3	Trial 1	Trial 2	Trial 3
21-Jul-15	P1	Conventional Till	5.5	5.5	5.3	0.08	0.09	0.08	0.093	0.095	0.094
21-Jul-15	P1	Deep Till	0	0	0	0	0	0	0	0	0
21-Jul-15	P1	No Till	6.2	6.2	6.2	0.11	0.11	0.11	0.205	0.206	0.209
15-Aug-15	P1	Conventional Till	6.5	6.2	6.4	0.14	0.07	0.06	0.695	0.695	0.695

15-Aug-15	P1	Deep Till	3.6	3.5	3.6	0.15	0.11	0.12	0.11	0.112	0.11
15-Aug-15	P1	No Till	7.2	7.2	7.2	0.05	0.07	0.06	0.101	0.098	0.1
19-Jul-15	P2	Conventional Till	11	11.5	11.5	0.15	0.15	0.15	0.241	0.244	0.254
19-Jul-15	P2	Deep Till	3.6	3.5	3.5	0.03	0.02	0.02	0.07	0.065	0.06
19-Jul-15	P2	No Till	4.3	4.34	4.3	0.03	0.02	0.02	0.123	0.12	0.122
31-Jul-15	P2	Conventional Till	5.3	5.3	5.3	0.01	0.02	0.02	0.07	0.073	0.073
31-Jul-15	P2	Deep Till	5.8	5.6	5.7	0.02	0.022	0.02	0.05	0.07	0.07
31-Jul-15	P2	No Till	8.4	8.6	8.6	0.08	0.08	0.08	0.424	0.416	0.407
8-Aug-15	P2	Conventional Till	12	12	12	0.14	0.16	0.16	0.134	0.135	0.129
8-Aug-15	P2	Deep Till	8.5	8.5	8.5	0.04	0.06		0.312	0.314	0.311
8-Aug-15	P2	No Till	7.8	7.7	7.8	0.02	0.03	0.01	0.595	0.6	0.6
16-Aug-15	P2	Conventional Till	3.4	3.5	3.5	0.05	0.05	0.05	0.465	0.455	0.43
16-Aug-15	P2	Deep Till	3.9	3.8	3.8	0.07	0.07	0.07	0.585	0.588	0.587
16-Aug-15	P2	No Till	3.7	3.7	3.7	0.06	0.06	0.06	0.565	0.564	0.565
23-Aug-15	P2	Conventional Till	8.8	8.8	8.8	0.05	0.05	0.05	0.07	0.086	0.075
23-Aug-15	P2	Deep Till	2.3	2.3	2.3	0.03	0.03	0.04	0.299	0.317	0.321
23-Aug-15	P2	No Till	4.4	4.4	4.4	0.03	0.02	0.02	0.55	0.545	0.545
2-Sep-15	P2	Conventional Till	12	12	12	0.07	0.05	0.06	0.263	0.275	0.273
2-Sep-15	P2	Deep Till	7.8	7.9	8	0.05	0.05	0.05	0.075	0.074	0.074
2-Sep-15	P2	No Till	10.5	10.2	10.4	0.06	0.05	0.06	0.365	0.368	0.632
18-Sep-15	P2	Conventional Till	7.3	7.3	7.3	0.02	0.02	0.02	0.16	0.168	0.165
18-Sep-15	P2	Deep Till	4	4	4	0.04	0.04	0.05	0.218	0.221	0.217
18-Sep-15	P2	No Till	6.2	6.2	6.2	0.02	0.02	0.23	0.151	0.146	0.148
23-Sep-15	P2	Conventional Till	3	3	3	0.06	0.06	0.06	0.447	0.455	0.446
23-Sep-15	P2	Deep Till	8.4	8.4	8.4	0.16	0.15	0.15	0.045	0.049	0.049

23-Sep-15	P2	No Till	4.9	4.9	4.9	0.16	0.21	0.17	0	0.001	0.001
6-Oct-15	P2	Conventional Till	5	5	5	0.03	0.03	0.03	0.035	0.037	0.034
6-Oct-15	P2	Deep Till	4	4	4	0.04	0.06	0.05	0.076	0.074	0.074
6-Oct-15	P2	No Till	4.3	4.3	4.3	0.11	0.06	0.06	0.525	0.53	0.525
12-Oct-15	P2	Conventional Till	2	2.1	2	0	0.01	0.02	0.052	0.05	0.049
12-Oct-15	P2	Deep Till	4.7	4.7	4.7	0.02	0.12	0.07	0.038	0.044	0.036
12-Oct-15	P2	No Till	4.2	4.3	4.3	0.07	0.08	0.08	0.83	0.845	
15-Jul-15	P3	Conventional Till	4	4	4	0.01	0.02	0.01	0.069	0.069	0.068
15-Jul-15	P3	Deep Till	3.7	3.7	3.7	0.03	0.03	0.03	0.352	0.352	0.342
15-Jul-15	P3	No Till	9.6	9.4	9.4	0.01	0.02	0.02	0.449	0.448	0.448
23-Jul-15	P3	Conventional Till	4.4	4.4	4.7	0.05	0.06	0.05	0.443	0.447	0.445
23-Jul-15	P3	Deep Till	4.8	4.8	4.8	0.03	0.02	0.02	0.232	0.24	0.244
23-Jul-15	P3	No Till	2.5	2.5	2.5	0.19	0.2	0.2	0.112	0.116	0.117
16-Aug-15	P3	Conventional Till	3.4	3.4	3.4	0.01	0.02	0.01	0.171	0.169	0.185
16-Aug-15	P3	Deep Till	1.7	1.7	1.8	0.08	0.08	0.07	0.12	0.12	0.11
16-Aug-15	P3	No Till	6	6	6	0.02	0.02	0.03	0.358	0.357	0.355
29-Aug-15	P3	Conventional Till	3.3	3.3	3.3	0.02	0.03	0.03	0.286	0.285	0.284
29-Aug-15	P3	Deep Till	3.9	3.7	3.9	0.01	0.01	0.01	0.456	0.458	0.457
29-Aug-15	P3	No Till	4.6	4.6	4.6	0.02	0.03	0.03	0.575	0.6	0.605
3-Sep-15	P3	Conventional Till	2.8	2.8	2.5	0.02	0.02	0.02	0.157	0.157	0.156
3-Sep-15	P3	Deep Till	5.6	5.2	5.4	0.02	0.03	0.02	0.234	0.31	0.235
3-Sep-15	P3	No Till	7.8	7.8	7.6	0.02	0.02	0.03	0.156	0.158	0.157
18-Sep-15	P3	Conventional Till	1.6	1.6	1.5	0.1	0.1	0.1	0.605	0.59	0.59
18-Sep-15	P3	Deep Till	6.2	6.2	6.2	0.12	0.12	0.07	0.362	0.363	0.365
18-Sep-15	P3	No Till	9.5	9.5	9.5	0.09	0.1	0.11	0.232	0.23	0.229

6-Oct-15	P3	Conventional Till	8.8	8.8	8.8	0.18	0.19	0.18	0.134	0.131	0.134
6-Oct-15	P3	Deep Till	5.8	5.4	5.6	0.01	0.01	0.01	0.74	0.745	0.745
6-Oct-15	P3	No Till	8.4	8.4	8.4	0.01	0.01	0.01	0.296	0.295	0.295
12-Oct-15	P3	Conventional Till	7.4	7.5	7.5	0.06	0.07	0.08	1.02	0.92	0.91
12-Oct-15	P3	Deep Till	6.8	6.9	6.9	0.01	0.02	0.02	0.915	0.9	0.895
12-Oct-15	P3	No Till	8.2	8.2	8.2	0.05	0.06	0.06	1.01	1.01	1.01
15-Jul-15	P4	Conventional Till	2.3	2.3	2.3	0.04	0.05	0.04	0.288	0.287	0.289
15-Jul-15	P4	Deep Till	1.6	1.8	1.8	0.03	0.03	0.05	0.074	0.081	0.088
15-Jul-15	P4	No Till	2.3	2.4	2.3	0.08	0.08	0.1	0.312	0.318	0.319
31-Jul-15	P4	Conventional Till	1.8	1.8	1.8	0.07	0.08	0.08	0.238	0.24	0.233
31-Jul-15	P4	Deep Till	2.4	2.2	2.2	0.03	0.03	0.03	0.18	0.181	0.181
31-Jul-15	P4	No Till	0.6	0.6	0.6	0.02	0.03	0.02	0.17	0.17	0.14
8-Aug-15	P4	Conventional Till	2.1	2.1	2.2	0.05	0.06	0.06	0.237	0.235	0.235
8-Aug-15	P4	Deep Till	1.6	1.3	1.4	0.03	0.03	0.03	0.042	0.044	0.041
8-Aug-15	P4	No Till	6.1	6.1	6.1	0.07	0.06	0.06	0.352	0.355	0.35
14-Aug-15	P4	Conventional Till	1.2	1.2	1.3	0.05	0.04	0.05	0.84	0.835	0.835
14-Aug-15	P4	Deep Till	1.4	1.5	1.5	0.07	0.07	0.07	0.705	0.73	0.425
14-Aug-15	P4	No Till	3.8	3.8	3.8	0	0.01	0.08	0.087	0.073	0.076
29-Aug-15	P4	Conventional Till	12	12	12	0.08	0.08	0.08	0.312	0.321	0.322
29-Aug-15	P4	Deep Till	0.4	0.5	0.4	0.05	0.05	0.05	0.114	0.115	0.115
29-Aug-15	P4	No Till	0.1	0.5	0.9	0.05	0.05	0.04	0.293	0.294	0.298
3-Sep-15	P4	Conventional Till	0.8	0.6	0.9	0.05	0.05	0.05	0.155	0.16	0.158
3-Sep-15	P4	Deep Till	0.6	0.5	0.3	0.08	0.08	0.08	0.194	0.201	0.2
3-Sep-15	P4	No Till	1.2	1.4	1.2	0.08	0.07	0.07	0.437	0.453	0.458
18-Sep-15	P4	Conventional Till	7.5	7.5	7.6	0.035	0.034	0.034	0.09	0.086	0.087
18-Sep-15	P4	Deep Till	6.5	6.5	6.5	0.02	0.01	0.01	0.013	0.018	0.02

18-Sep-15	P4	No Till	8.8	8.8	8.8	0.05	0.04	0.05	0.162	0.159	0.158
6-Oct-15	P4	Conventional Till	2.8	2.8	2.9	0.03	0.03	0.03	0.075	0.0751	0.075
6-Oct-15	P4	Deep Till	2.2	2.2	2.2	0.01	0.01	0.01	0.046	0.049	0.044
6-Oct-15	P4	No Till	3.7	3.7	3.8	0.04	0.04	0.04	0.202	0.201	0.199
11-Oct-15	P4	Conventional Till	2.6	2.5	2.4	0	0	0	0.04	0.041	0.039
11-Oct-15	P4	Deep Till	1.9	2.2	2	0.25	0.26	0.24	0.171	0.17	0.174
11-Oct-15	P4	No Till	3.2	3.1	3	0.05	0.05	0.05	0.072	0.063	0.06
15-Jul-15	P5	Conventional Till	4	4	4.1	0.04	0.03	0.04	0.138	0.138	0.142
15-Jul-15	P5	Deep Till	3.4	3.4	3.5	0.01	0.02	0.02	0.113	0.114	0.109
15-Jul-15	P5	No Till	7.1	7.17	7.1	0.07	0.06	0.05	0.045	0.046	0.03
16-Aug-15	P5	Conventional Till	1.7	1.7	1.8	0.03	0.03	0.04	0.9	0.895	0.965
16-Aug-15	P5	Deep Till	2.5	2.5	2.5	0.02	0.01	0.03	0.132	0.129	0.134
16-Aug-15	P5	No Till	2.7	2.8	2.8	0.05	0.06	0.16	0.062	0.063	0.072
19-Sep-15	P5	Conventional Till	3.8	3.8	3.8	0.05	0.06	0.05	0.218	0.215	0.219
19-Sep-15	P5	Deep Till	1.6	1.6	1.7	0.04	0.06	0.05	0.097	0.097	0.097
19-Sep-15	P5	No Till	3.5	3.5	3.5	0.03	0.04	0.04	0.183	0.176	0.175
6-Oct-15	P5	Conventional Till	4.2	4.2	4.2	0.02	0.01	0.03	0.79	0.795	0.795
6-Oct-15	P5	Deep Till	2.8	2.8	2.8	0.05	0.03	0.05	0.319	0.318	0.323
6-Oct-15	P5	No Till	4.6	4.6	4.6	0.07	0.07	0.07	0.58	0.62	0.59

Appendix J: Soil Physiochemical property Analysis

ANOVA

Av.k

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	271.237	4	67.809	123.519	.000
Within Groups	8.235	15	.549		
Total	279.471	19			

ANOVA

CEC

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1176.921	4	294.230	8.353	.001
Within Groups	528.349	15	35.223		
Total	1705.270	19			

ANOVA

OC

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1.190	4	.298	7.577	.002
Within Groups	.589	15	.039		
Total	1.779	19			

ANOVA

TN

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.009	4	.002	7.393	.002
Within Groups	.004	15	.000		
Total	.013	19			

ANOVA

Av.P

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	478.909	4	119.727	10.935	.000
Within Groups	164.233	15	10.949		
Total	643.142	19			

ANOVA

Fe

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	598.634	4	149.659	9.996	.000
Within Groups	224.583	15	14.972		
Total	823.218	19			

Appendix K: Analysis of Bulk density and Penetration resistance and infiltration rate

Analysis of variance of infiltration rate.

Tests of Between-Subjects Effects

Dependent Variable: Infiltration Rate

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	31377.600a	2	15688.800	6.456	.012
Intercept	382082.400	1	382082.400	157.236	.000
Tillage	31377.600	2	15688.800	6.456	.012
Error	29160.000	12	2430.000		
Total	442620.000	15			
Corrected Total	60537.600	14			

a. R Squared = .518 (Adjusted R Squared = .438)

Between-Subjects Factors

		Value Label	N
Tillage	1	Deep Till	15
	2	Conventional Till	15
	3	No Till	15

Tests of Between-Subjects Effects

Dependent Variable: Penetration Resistance

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	299374.811a	2	149687.406	23.908	.000
Intercept	1995645.606	1	1995645.606	318.738	.000
Tillage	299374.811	2	149687.406	23.908	.000
Error	262965.833	42	6261.091		
Total	2557986.250	45			
Corrected Total	562340.644	44			

a. R Squared = .532 (Adjusted R Squared = .510)

Multiple Comparisons

Penetration Resistance

LSD

(I) Tillage	(J) Tillage	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Deep Till	Conventional Till	-132.9333*	28.89312	.000	-191.2420	-74.6247
	No Till	-195.6333*	28.89312	.000	-253.9420	-137.3247
Conventional Till	Deep Till	132.9333*	28.89312	.000	74.6247	191.2420
	No Till	-62.7000*	28.89312	.036	-121.0087	-4.3913
No Till	Deep Till	195.6333*	28.89312	.000	137.3247	253.9420
	Conventional Till	62.7000*	28.89312	.036	4.3913	121.0087

Based on observed means.

The error term is Mean Square(Error) = 6261.091.

*. The mean difference is significant at the 0.05 level.

Between-Subjects Factors

		Value Label	N
Tillage	1	Deep Till	15
	2	Conventional Till	15
	3	No Till	15

Tests of Between-Subjects Effects

Dependent Variable: Bulk Density

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	.726[a]	2	.363	24.472	.000
Intercept	85.229	1	85.229	5742.978	.000
Tillage	.726	2	.363	24.472	.000
Error	.623	42	.015		
Total	86.579	45			
Corrected Total	1.350	44			

a. R Squared = .538 (Adjusted R Squared = .516)

Multiple Comparisons

Bulk Density

LSD

(I) Tillage	(J) Tillage	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Deep Till	Conventional Till	-.2267*	.04448	.000	-.3164	-.1369
	No Till	-.2980*	.04448	.000	-.3878	-.2082
Conventional Till	Deep Till	.2267*	.04448	.000	.1369	.3164
	No Till	-.0713	.04448	.116	-.1611	.0184
No Till	Deep Till	.2980*	.04448	.000	.2082	.3878
	Conventional Till	.0713	.04448	.116	-.0184	.1611

Based on observed means.

The error term is Mean Square(Error) = .015.

*. The mean difference is significant at the 0.05 level.

Between-Subjects Factors

		N
Plot	1	9
	2	9
	3	9
	4	9
	5	9

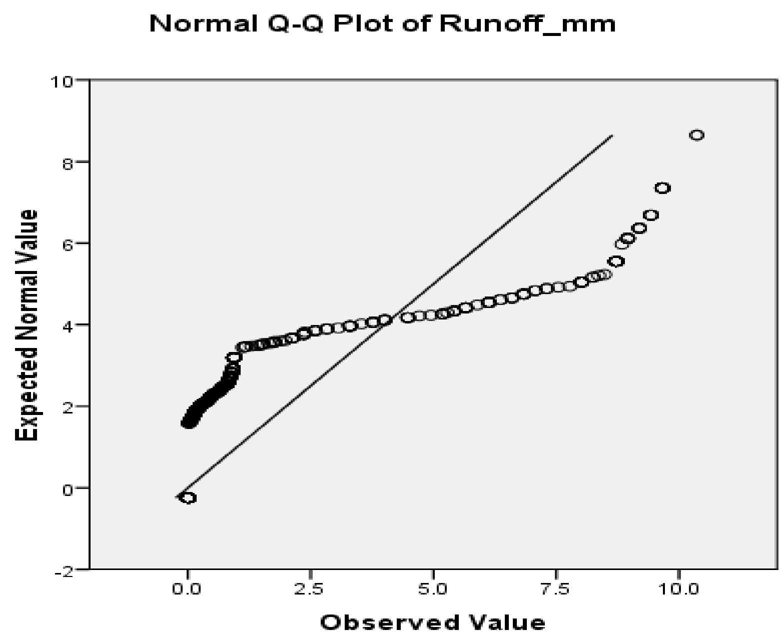
Tests of Between-Subjects Effects

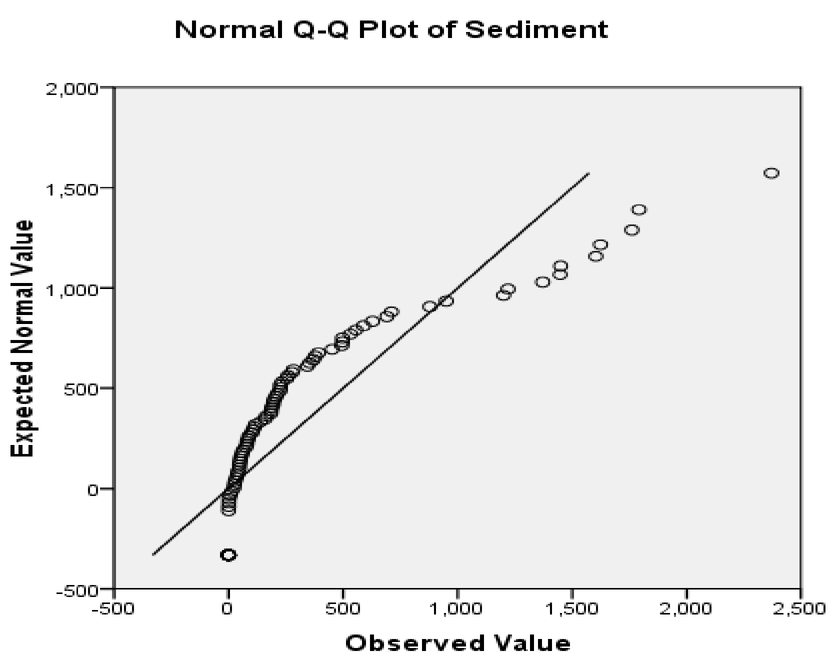
Dependent Variable: Bulk Density

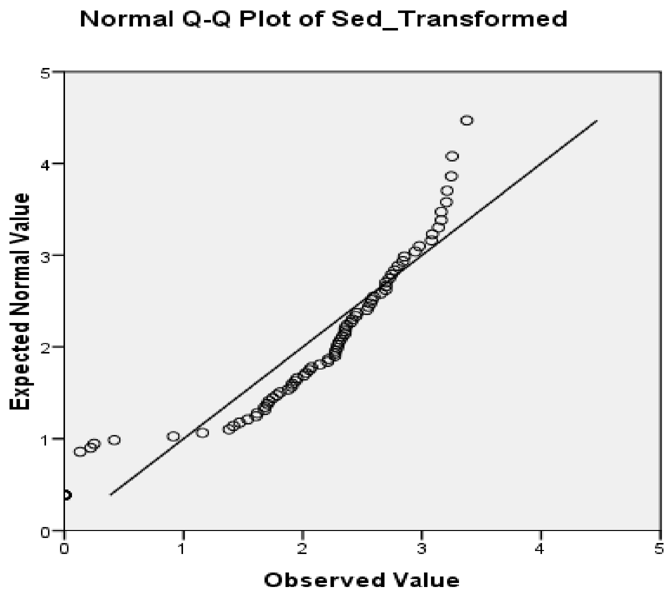
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	.514[a]	4	.128	6.148	.001
Intercept	85.229	1	85.229	4078.831	.000
Plot	.514	4	.128	6.148	.001
Error	.836	40	.021		
Total	86.579	45			
Corrected Total	1.350	44			

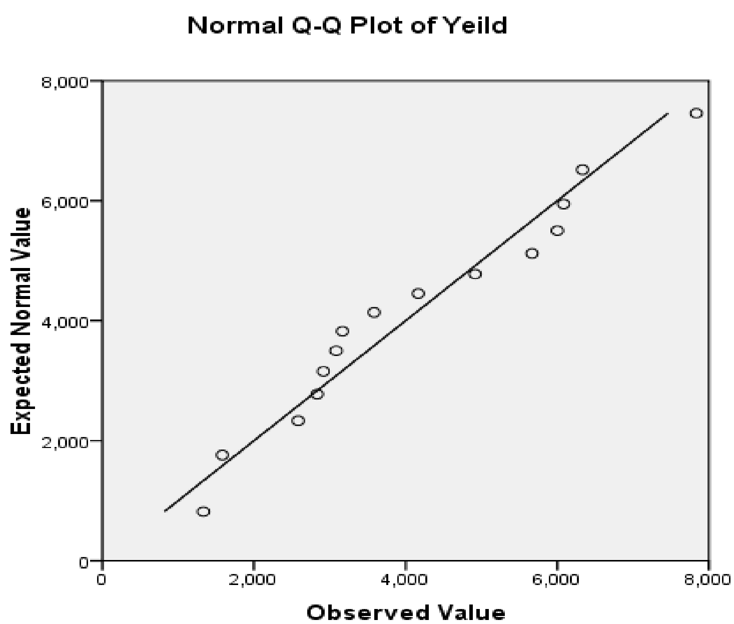
a. R Squared = .381 (Adjusted R Squared = .319)

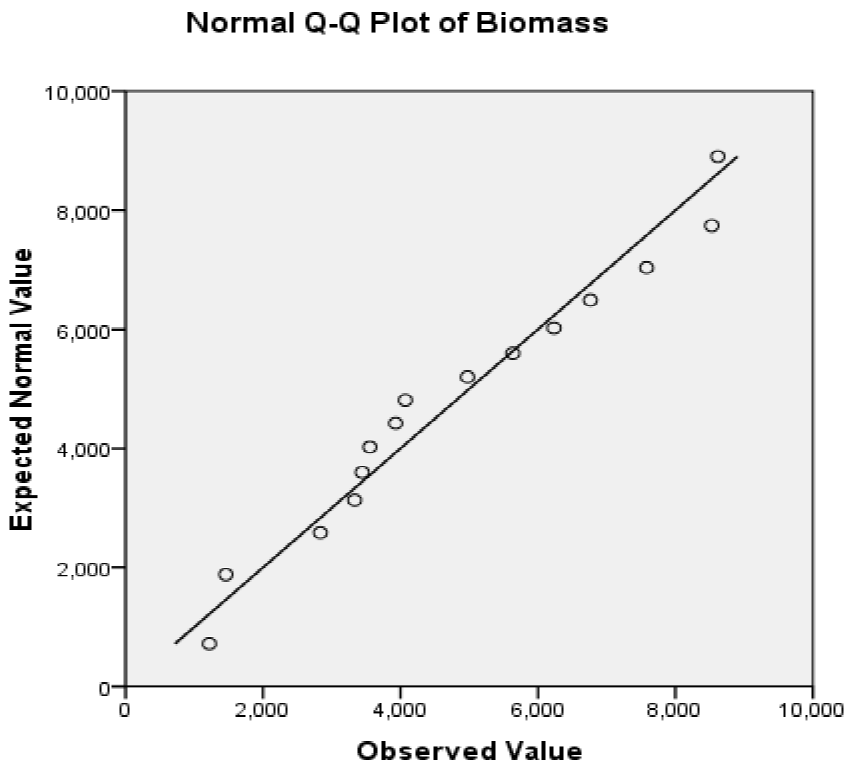
Appendix L: Q-Q plot for normality test






Normal Q-Q Plot of Sed_Transformed
Expected Normal Value
Observed Value
0
1
2
3
4
5


Normal Q-Q Plot of Yeild
Expected Normal Value
Observed Value
0
2,000
4,000
6,000
8,000


Normal Q-Q Plot of Biomass
Expected Normal Value
Observed Value
0
2,000
4,000
6,000
8,000
10,000

Appendix M: Analysis of Event runoff

M1: Analysis of Event runoff due to tillage

Kruskal_wallis Test for event runoff between the three different treatments

Ranks

	Tillage	N	Mean Rank
Event runoff	Deep Till	300	414.29
	Conventional Till	300	472.49
	No Till	300	464.72
	Total	900	

Test Statistics

	Event runoff
Chi-Square	10.785
df	2
Asymp. Sig.	.005

a. Kruskal Wallis Test

b. Grouping Variable: Tillage

Post_Hoc Analysis the mann_Whitney test

Ranks

	Tillage	N	Mean Rank	Sum of Ranks
Event runoff	DeepTill	300	280.99	84297.00
	ConventionalTill	300	320.01	96003.00
	Total	600		

Test Statistics

	Event runoff
Mann-Whitney U	39147.000
Wilcoxon W	84297.000
Z	-3.058
Asymp. Sig. (2-tailed)	.002

Grouping Variable: Tillage

Ranks

	Tillage	N	Mean Rank	Sum of Ranks
Event runoff	Deep Till	300	283.80	85139.50
	No Till	300	317.20	95160.50
	Total	600		

Test Statistics

	Event runoff
Mann-Whitney U	39989.500
Wilcoxon W	85139.500
Z	-2.631
Asymp. Sig. (2-tailed)	.009

a. Grouping Variable: Tillage

Ranks

	Tillage	N	Mean Rank	Sum of Ranks
Event runoff	Conventional Till	300	302.98	90895.00
	No Till	300	298.02	89405.00
	Total	600		

Test Statistics

	Event runoff
Mann-Whitney U	44255.000
Wilcoxon W	89405.000
Z	-.381
Asymp. Sig. (2-tailed)	.703

a. Grouping Variable: Tillage

M2: Analysis of event runoff difference between locations in one treatment

Ranks

	Location	N	Mean Rank
Event runoff_DeepTillage	Down Slope	180	144.18
	Up slope	120	159.99
	Total	300	

Test Statistics

	Event runoff_DeepTillage
Chi-Square	3.126
df	1
Asymp. Sig.	.077

a. Kruskal Wallis Test

b. Grouping Variable: Location

Ranks

	Location	N	Mean Rank
Event runoff_Conventional Tillage	DownSlope	180	146.97
	Upslope	120	155.79
	Total	300	

Test Statistics

	Event runoff_ConventionalTillage
Chi-Square	.872
df	1
Asymp. Sig.	.350

a. Kruskal Wallis Test

b. Grouping Variable: Location

Ranks

		Location	N	Mean Rank
Event Tillage	runoff_No	DownSlope	180	146.19
		Upslope	120	156.97
		Total	300	

Test Statistics

	Event runoff_NoTillage
Chi-Square	1.326
df	1
Asymp. Sig.	.250

a. Kruskal Wallis Test

b. Grouping Variable: Location

M3: Effect of tillage and position on event runoff

Ranks

	TillPos	N	Mean Rank
Event runoff	11	180	396.84
	12	120	440.45
	21	180	460.78
	22	120	490.07
	31	180	449.92
	32	120	486.91
	Total	900	

Test Statistics

	Event runoff
Chi-Square	16.135
df	5
Asymp. Sig.	.006

a. Kruskal Wallis Test

b. Grouping Variable: TillPos

Pair wise comparisons of tillage types at each topographic location

Ranks

	Tillage	N	Mean Rank	Sum of Ranks
Event runoff	Deep Till	180	168.52	30334.00
	Conventional Till	180	192.48	34646.00
	Total	360		

Test Statistics

	Event runoff
Mann-Whitney U	14044.000
Wilcoxon W	30334.000
Z	-2.501
Asymp. Sig. (2-tailed)	.012

a. Grouping Variable: Tillage

Ranks

	Tillage	N	Mean Rank	Sum of Ranks
Event runoff	Deep Till	180	170.86	30754.50
	No Till	180	190.14	34225.50
	Total	360		

Test Statistics

	Event runoff
Mann-Whitney U	14464.500
Wilcoxon W	30754.500
Z	-2.040
Asymp. Sig. (2-tailed)	.041

a. Grouping Variable: Tillage

Ranks

	Tillage	N	Mean Rank	Sum of Ranks
Event runoff	Conventional Till	180	182.71	32888.00
	No Till	180	178.29	32092.00
	Total	360		

Test Statistics

	Event runoff
Mann-Whitney U	15802.000
Wilcoxon W	32092.000
Z	-.452
Asymp. Sig. (2-tailed)	.651

a. Grouping Variable: Tillage

Ranks

	Tillage	N	Mean Rank
Event runoff	Deep Till	120	113.50
	Conventional Till	120	127.50
	Total	240	

Test Statistics

	Event runoff
Chi-Square	2.789
df	1
Asymp. Sig.	.095

a. Kruskal Wallis Test

b. Grouping Variable: Tillage

Ranks

	Tillage	N	Mean Rank	Sum of Ranks
Event runoff	Deep Till	120	113.65	13637.50
	No Till	120	127.35	15282.50
	Total	240		

Test Statistics

	Event runoff
Mann-Whitney U	6377.500
Wilcoxon W	13637.500
Z	-1.633
Asymp. Sig. (2-tailed)	.102

a. Grouping Variable: Tillage

Ranks

	Tillage	N	Mean Rank	Sum of Ranks
Event runoff	Conventional Till	120	120.97	14516.00
	No Till	120	120.03	14404.00
	Total	240		

Test Statistics

	Event runoff
Mann-Whitney U	7144.000
Wilcoxon W	14404.000
Z	-.110
Asymp. Sig. (2-tailed)	.913

a. Grouping Variable: Tillage

M4: Analysis of difference between position within one treatment

Down slope

Deep till down slope

Ranks

	Repetition	N	Mean Rank
Event runoff	1	60	61.54
	2	60	118.92
	3	60	91.03
	Total	180	

Test Statistics

	Event runoff
Chi-Square	51.728
df	2
Asymp. Sig.	.000

a. Kruskal Wallis Test

b. Grouping Variable: Repetition

Conventional till down slope

Ranks

	Repetition	N	Mean Rank
Event runoff	1	60	55.98
	2	60	119.32
	3	60	96.19
	Total	180	

Test Statistics

	Event runoff
Chi-Square	55.890
df	2
Asymp. Sig.	.000

a. Kruskal Wallis Test

b. Grouping Variable: Repetition

No till down slope

Ranks

	Repetition	N	Mean Rank
Event runoff	1	60	59.22
	2	60	122.27
	3	60	90.01
	Total	180	

Test Statistics

	Event runoff
Chi-Square	56.476
df	2
Asymp. Sig.	.000

a. Kruskal Wallis Test

b. Grouping Variable: Repetition

Up slope

Deep till up slope

Ranks

	Repetition	N	Mean Rank
Event runoff	1	60	54.61
	2	60	66.39
	Total	120	

Test Statistics

	Event runoff
Chi-Square	4.095
df	1
Asymp. Sig.	.043

a. Kruskal Wallis Test

b. Grouping Variable: Repetition

Conventional till up slope

Ranks

	Repetition	N	Mean Rank
Event runoff	1	60	59.22
	2	60	61.78
	Total	120	

Test Statistics

	Event runoff
Chi-Square	.181
df	1
Asymp. Sig.	.670

a. Kruskal Wallis Test

b. Grouping Variable: Repetition

No till up slope

Ranks

	Repetition	N	Mean Rank
Event runoff	1	60	64.37
	2	60	56.63
	Total	120	

Test Statistics

	Event runoff
Chi-Square	1.634
df	1
Asymp. Sig.	.201

a. Kruskal Wallis Test

b.Grouping Variable: Repetition

M5: Difference in event runoff response for the same treatment for all fields

Ranks

	Plot	N	Mean Rank
Event runoff_Deep Tillage	1	60	94.75
	2	60	192.02
	3	60	145.76
	4	60	146.42
	5	60	173.55
	Total	300	

Test Statistics

	Event runoff_Deep Tillage
Chi-Square	56.279
df	4
Asymp. Sig.	.000

a. Kruskal Wallis Test

b. Grouping Variable: Plot

Ranks

	Plot	N	Mean Rank
Event runoff_Conventional Tillage	1	60	86.02
	2	60	197.78
	3	60	157.12
	4	60	152.63
	5	60	158.95
	Total	300	

Test Statistics

	Event runoff Conventional Tillage
Chi-Square	60.839
df	4
Asymp. Sig.	.000

a. Kruskal Wallis Test

b. Grouping Variable: Plot

Ranks

	Plot	N	Mean Rank
Event runoff_No Tillage	1	60	89.24
	2	60	203.92
	3	60	145.40
	4	60	163.22
	5	60	150.72
	Total	300	

Test Statistics

	Event runoff_NoTillage
Chi-Square	64.532
df	4
Asymp. Sig.	.000

a. Kruskal Wallis Test

b. Grouping Variable: Plot

M6: Difference in event runoff due to treatments for each plot

Plot 1

Ranks

	Tillage	N	Mean Rank
Event runoff	Deep Till	60	87.44
	Conventional Till	60	92.00
	No Till	60	92.06
	Total	180	

Test Statistics

	Event runoff
Chi-Square	2.174
df	2
Asymp. Sig.	.337

a. Kruskal Wallis Test

b. Grouping Variable: Tillage

Ranks

	Tillage	N	Mean Rank	Sum of Ranks
Event runoff	Deep Till	60	58.97	3538.00
	Conventional Till	60	62.03	3722.00
	Total	120		

Test Statistics

	Event runoff
Mann-Whitney U	1708.000
Wilcoxon W	3538.000
Z	-1.395
Asymp. Sig. (2-tailed)	.163

a. Grouping Variable: Tillage

Ranks

	Tillage	N	Mean Rank	Sum of Ranks
Event runoff	Deep Till	60	58.98	3538.50
	No Till	60	62.02	3721.50
	Total	120		

Test Statistics

	Event runoff
Mann-Whitney U	1708.500
Wilcoxon W	3538.500
Z	-1.387
Asymp. Sig. (2-tailed)	.165

a. Grouping Variable: Tillage

Ranks

	Tillage	N	Mean Rank	Sum of Ranks
Event runoff	Conventional Till	60	60.47	3628.00
	No Till	60	60.53	3632.00
	Total	120		

Test Statistics

	Event runoff
Mann-Whitney U	1798.000
Wilcoxon W	3628.000
Z	-.024
Asymp. Sig. (2-tailed)	.981

a. Grouping Variable: Tillage

Plot 2

Ranks

	Tillage	N	Mean Rank
Event runoff	Deep Till	60	73.42
	Conventional Till	60	97.60
	No Till	60	100.48
	Total	180	

Test Statistics

	Event runoff
Chi-Square	10.036
df	2
Asymp. Sig.	.007

a. Kruskal Wallis Test

b. Grouping Variable: Tillage

Ranks

	Tillage	N	Mean Rank	Sum of Ranks
Event runoff	Deep Till	60	52.81	3168.50
	Conventional Till	60	68.19	4091.50
	Total	120		

Test Statistics

	Event runoff
Mann-Whitney U	1338.500
Wilcoxon W	3168.500
Z	-2.459
Asymp. Sig. (2-tailed)	.014

a. Grouping Variable: Tillage

Ranks

	Tillage	N	Mean Rank	Sum of Ranks
Event runoff	Deep Till	60	51.12	3067.00
	No Till	60	69.88	4193.00
	Total	120		

Test Statistics

	Event runoff
Mann-Whitney U	1237.000
Wilcoxon W	3067.000
Z	-3.001
Asymp. Sig. (2-tailed)	.003

a. Grouping Variable: Tillage

Ranks

	Tillage	N	Mean Rank	Sum of Ranks
Event runoff	Conventional Till	60	59.91	3594.50
	No Till	60	61.09	3665.50
	Total	120		

Test Statistics

	Event runoff
Mann-Whitney U	1764.500
Wilcoxon W	3594.500
Z	-.189
Asymp. Sig. (2-tailed)	.850

a. Grouping Variable: Tillage

Plot 3

Ranks

	Tillage	N	Mean Rank
Event runoff	Deep Till	60	81.83
	Conventional Till	60	99.12
	No Till	60	90.54
	Total	180	

Test Statistics

	Event runoff
Chi-Square	4.183
df	2
Asymp. Sig.	.124

a. Kruskal Wallis Test

b. Grouping Variable: Tillage

Ranks

	Tillage	N	Mean Rank	Sum of Ranks
Event runoff	Deep Till	60	54.77	3286.00
	Conventional Till	60	66.23	3974.00
	Total	120		

Test Statistics

	Event runoff
Mann-Whitney U	1456.000
Wilcoxon W	3286.000
Z	-2.028
Asymp. Sig. (2-tailed)	.043

a. Grouping Variable: Tillage

Ranks

	Tillage	N	Mean Rank	Sum of Ranks
Event runoff	Deep Till	60	57.57	3454.00
	No Till	60	63.43	3806.00
	Total	120		

Test Statistics

	Event runoff
Mann-Whitney U	1624.000
Wilcoxon W	3454.000
Z	-1.077
Asymp. Sig. (2-tailed)	.282

a. Grouping Variable: Tillage

Ranks

	Tillage	N	Mean Rank	Sum of Ranks
Event runoff	Conventional Till	60	63.39	3803.50
	No Till	60	57.61	3456.50
	Total	120		

Test Statistics

	Event runoff
Mann-Whitney U	1626.500
Wilcoxon W	3456.500
Z	-.998
Asymp. Sig. (2-tailed)	.319

a. Grouping Variable: Tillage

Plot 4

Ranks

	Tillage	N	Mean Rank
Event runoff	Deep Till	60	78.88
	Conventional Till	60	92.78
	No Till	60	99.84
	Total	180	

Test Statistics

	Event runoff
Chi-Square	6.141
df	2
Asymp. Sig.	.046

a. Kruskal Wallis Test

b. Grouping Variable: Tillage

Test Statistics

	Event runoff
Mann-Whitney U	1501.500
Wilcoxon W	3331.500
Z	-1.761
Asymp. Sig. (2-tailed)	.078

a. Grouping Variable: Tillage

	Tillage	N	Mean Rank	Sum of Ranks
Event runoff	Deep Till	60	55.52	3331.50
	Conventional Till	60	65.48	3928.50
	Total	120		

Ranks

	Tillage	N	Mean Rank	Sum of Ranks
Event runoff	DeepTill	60	53.86	3231.50
	NoTill	60	67.14	4028.50
	Total	120		

Test Statistics

	Event runoff
Mann-Whitney U	1401.500
Wilcoxon W	3231.500
Z	-2.333
Asymp. Sig. (2-tailed)	.020

a. Grouping Variable: Tillage

Ranks

	Tillage	N	Mean Rank	Sum of Ranks
Event runoff	Conventional Till	60	57.80	3468.00
	No Till	60	63.20	3792.00
	Total	120		

Test Statistics

	Event runoff
Mann-Whitney U	1638.000
Wilcoxon W	3468.000
Z	-.921
Asymp. Sig. (2-tailed)	.357

a. Grouping Variable: Tillage

Plot 5

Ranks

	Tillage	N	Mean Rank
Event runoff	Deep Till	60	89.41
	Conventional Till	60	94.68
	No Till	60	87.41
	Total	180	

Test Statistics

	Event runoff
Chi-Square	.671
df	2
Asymp. Sig.	.715

a. Kruskal Wallis Test

b. Grouping Variable: Tillage

Ranks

	Tillage	N	Mean Rank	Sum of Ranks
Event runoff	Deep Till	60	58.74	3524.50
	Conventional Till	60	62.26	3735.50
	Total	120		

Test Statistics

	Event runoff
Mann-Whitney U	1694.500
Wilcoxon W	3524.500
Z	-.575
Asymp. Sig. (2-tailed)	.565

a. Grouping Variable: Tillage

Ranks

	Tillage	N	Mean Rank	Sum of Ranks
Event runoff	Deep Till	60	61.17	3670.00
	No Till	60	59.83	3590.00
	Total	120		

Test Statistics

	Event runoff
Mann-Whitney U	1760.000
Wilcoxon W	3590.000
Z	-.218
Asymp. Sig. (2-tailed)	.827

a. Grouping Variable: Tillage

Ranks

	Tillage	N	Mean Rank	Sum of Ranks
Event runoff	Conventional Till	60	62.92	3775.50
	No Till	60	58.08	3484.50
	Total	120		

Test Statistics

	Event runoff
Mann-Whitney U	1654.500
Wilcoxon W	3484.500
Z	-.789
Asymp. Sig. (2-tailed)	.430

a. Grouping Variable: Tillage

Appendix N: Analysis of sediment loss

N1: Analysis of sediment loss due to tillage and topographic location

Between-Subjects Factors

		N
TillPos	11	18
	12	12
	21	18
	22	12
	31	18
	32	12

Tests of Between-Subjects Effects

Dependent Variable: Sed_Transformed

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	2.584a	5	.517	.433	.824
Intercept	288.815	1	288.815	242.014	.000
TillPos	2.584	5	.517	.433	.824
Error	100.244	84	1.193		
Total	402.458	90			
Corrected Total	102.828	89			

a. R Squared = .025 (Adjusted R Squared = -.033)

N2: ANOVA Analysis of effect of tillage on sediment

Between-Subjects Factors

		Value Label	N
Tillage	1	Deep Tillage	30
	2	Conventional Tillage	30
	3	No Tillage	30

Tests of Between-Subjects Effects

Dependent Variable: Sed_Transformed

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	2.386a	2	1.193	1.033	.360
Intercept	299.630	1	299.630	259.531	.000
Tillage	2.386	2	1.193	1.033	.360
Error	100.442	87	1.155		
Total	402.458	90			
Corrected Total	102.828	89			

a. R Squared = .023 (Adjusted R Squared = .001)

N3: Analysis of sediment difference due to topographic locations

Between-Subjects Factors

		Value Label	N
Location	1	DownSlope	54
	2	UpSlope	36

Dependent Variable: Sed_Transformed

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	.030a	1	.030	.025	.874
Intercept	288.815	1	288.815	247.239	.000
Location	.030	1	.030	.025	.874
Error	102.798	88	1.168		
Total	402.458	90			
Corrected Total	102.828	89			

a. R Squared = .000 (Adjusted R Squared = -.011)

N4: Analysis of soil loss difference between the various plots

Between-Subjects Factors

Plot Code		Value Label	N
Plot	1	Plot1	18
	2	Plot2	18
	3	Plot3	18
	4	Plot4	18
	5	Plot5	18

Descriptive Statistics

Dependent Variable:Sed_Transformed

Plot code	Mean	Std. Deviation	N
Plot1	.3643	.72513	18
Plot2	2.6276	.62854	18
Plot3	2.4375	.47524	18
Plot4	2.3618	.40283	18
Plot5	1.3319	.91572	18
Total	1.8246	1.07488	90

Tests of Between-Subjects Effects

Dependent Variable: Sed_Transformed

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	66.320a	4	16.580	38.602	.000
Intercept	299.630	1	299.630	697.608	.000
Plot	66.320	4	16.580	38.602	.000
Error	36.508	85	.430		
Total	402.458	90			
Corrected Total	102.828	89			

a. R Squared = .645 (Adjusted R Squared = .628)

Multiple Comparisons

Sed_Transformed

LSD

(I) Plot	(J) Plot	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Plot1	Plot2	-2.2634*	.21846	.000	-2.6977	-1.8290
	Plot3	-2.0732*	.21846	.000	-2.5075	-1.6388
	Plot4	-1.9976*	.21846	.000	-2.4319	-1.5632
	Plot5	-.9676*	.21846	.000	-1.4020	-.5333
Plot2	Plot1	2.2634*	.21846	.000	1.8290	2.6977
	Plot3	.1902	.21846	.387	-.2442	.6245
	Plot4	.2658	.21846	.227	-.1686	.7001
	Plot5	1.2957*	.21846	.000	.8614	1.7301
Plot3	Plot1	2.0732*	.21846	.000	1.6388	2.5075
	Plot3	-.1902	.21846	.387	-.6245	.2442
	Plot4	.0756	.21846	.730	-.3587	.5100
	Plot5	1.1056*	.21846	.000	.6712	1.5399
Plot4	Plot1	1.9976*	.21846	.000	1.5632	2.4319
	Plot3	-.2658	.21846	.227	-.7001	.1686
	Plot4	-.0756	.21846	.730	-.5100	.3587
	Plot5	1.0300*	.21846	.000	.5956	1.4643
Plot5	Plot1	.9676*	.21846	.000	.5333	1.4020
	Plot3	-1.2957*	.21846	.000	-1.7301	-.8614
	Plot4	-1.1056*	.21846	.000	-1.5399	-.6712
	Plot5	-1.0300*	.21846	.000	-1.4643	-.5956

Based on observed means.

The error term is Mean Square(Error) = .430.

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

Appendix O: Runoff water quality analysis

Between-Subjects Factors

		Value Label	N
Tillagetreament	1	DT	33
	2	CT	33
	3	NT	33

Tests of Between-Subjects Effects

Dependent Variable: K

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	60.060a	2	30.030	3.499	.034
Intercept	2304.251	1	2304.251	268.519	.000
Tillagetreament	60.060	2	30.030	3.499	.034
Error	823.808	96	8.581		
Total	3188.119	99			
Corrected Total	883.868	98			

a. R Squared = .068 (Adjusted R Squared = .049)

Multiple Comparisons

K

LSD

(I) Tillagetreament	(J) Tillagetreament	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
DT	CT	-1.4505*	.72117	.047	-2.8820	-.0190
	NT	-1.7986*	.72117	.014	-3.2301	-.3671
CT	DT	1.4505*	.72117	.047	.0190	2.8820
	NT	-.3481	.72117	.630	-1.7796	1.0834
NT	DT	1.7986*	.72117	.014	.3671	3.2301
	CT	.3481	.72117	.630	-1.0834	1.7796

Based on observed means.

The error term is Mean Square (Error) = 8.581.

*. The mean difference is significant at the 0.05 level.

Tests of Between-Subjects Effects

Dependent Variable: P

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	.002a	2	.001	.538	.585
Intercept	.320	1	.320	160.559	.000
Tillagetreament	.002	2	.001	.538	.585
Error	.191	96	.002		
Total	.513	99			
Corrected Total	.193	98			

a. R Squared = .011 (Adjusted R Squared = -.010)

Multiple Comparisons

P

LSD

(I) Tillagetreament	(J) Tillagetreament	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
DT	CT	-.0060	.01098	.588	-.0278	.0158
	NT	-.0114	.01098	.302	-.0332	.0104
CT	DT	.0060	.01098	.588	-.0158	.0278
	NT	-.0054	.01098	.623	-.0272	.0164
NT	DT	.0114	.01098	.302	-.0104	.0332
	CT	.0054	.01098	.623	-.0164	.0272

Based on observed means.

The error term is Mean Square (Error) = .002.

Tests of Between-Subjects Effects

Dependent Variable:N

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	.180a	2	.090	1.531	.222
Intercept	8.337	1	8.337	142.100	.000
Tillagetreament	.180	2	.090	1.531	.222
Error	5.632	96	.059		
Total	14.149	99			
Corrected Total	5.812	98			

a. R Squared = .031 (Adjusted R Squared = .011)

Multiple Comparisons

N

LSD

(I) Tillagetreament	(J) Tillagetreament	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
DT	CT	-.0737	.05963	.219	-.1921	.0446
	NT	-.1008	.05963	.094	-.2192	.0176
CT	DT	.0737	.05963	.219	-.0446	.1921
	NT	-.0271	.05963	.651	-.1455	.0913
NT	DT	.1008	.05963	.094	-.0176	.2192
	CT	.0271	.05963	.651	-.0913	.1455

Based on observed means.

The error term is Mean Square (Error) = .059.

Appendix P: Analysis of maize plant height at various growth stages

Between-Subjects Factors

		Value Label	N
Tillage	1	DT	5
	2	CT	5
	3	NT	5

Tests of Between-Subjects Effects

Dependent Variable:Plant height:
DAP=30

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	24.033a	2	12.017	11.950	.001
Intercept	20461.067	1	20461.067	20348.022	.000
Tillage	24.033	2	12.017	11.950	.001
Error	12.067	12	1.006		
Total	20497.167	15			
Corrected Total	36.100	14			

a. R Squared = .666 (Adjusted R Squared = .610)

Multiple Comparisons

Plant height:
DAP=30
LSD

(I) Tillage	(J) Tillage	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
DT	CT	-3.1000*	.63421	.000	-4.4818	-1.7182
	NT	-1.6000*	.63421	.027	-2.9818	-.2182
CT	DT	3.1000*	.63421	.000	1.7182	4.4818
	NT	1.5000*	.63421	.036	.1182	2.8818
NT	DT	1.6000*	.63421	.027	.2182	2.9818
	CT	-1.5000*	.63421	.036	-2.8818	-.1182

Based on observed means.

The error term is Mean Square(Error) = 1.006.

*. The mean difference is significant at the 0.05 level.

Tests of Between-Subjects Effects

Dependent Variable: Plant height

: DAP= 73

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	424.900a	2	212.450	2.938	.092
Intercept	76398.017	1	76398.017	1056.397	.000
Tillage	424.900	2	212.450	2.938	.092
Error	867.833	12	72.319		
Total	77690.750	15			
Corrected Total	1292.733	14			

a. R Squared = .329 (Adjusted R Squared = .217)

Multiple Comparisons

Plant height

LSD

(I) Tillage	(J) Tillage	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
DT	CT	-3.8000	5.37845	.493	-15.5186	7.9186
	NT	8.9000	5.37845	.124	-2.8186	20.6186
CT	DT	3.8000	5.37845	.493	-7.9186	15.5186
	NT	12.7000*	5.37845	.036	.9814	24.4186
NT	DT	-8.9000	5.37845	.124	-20.6186	2.8186
	CT	-12.7000*	5.37845	.036	-24.4186	-.9814

Based on observed means.

The error term is Mean Square (Error) = 72.319.

*. The mean difference is significant at the 0.05 level.

Tests of Between-Subjects Effects

Dependent Variable :Plant height:
DAP=120

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	344.104a	2	172.052	7.586	.007
Intercept	436622.268	1	436622.268	19251.737	.000
Tillage	344.104	2	172.052	7.586	.007
Error	272.156	12	22.680		
Total	437238.528	15			
Corrected Total	616.259	14			

a. R Squared = .558 (Adjusted R Squared = .485)

Multiple Comparisons

Plant height
LSD

(I) Tillage	(J) Tillage	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
DT	CT	2.8000	3.01195	.371	-3.7625	9.3625
	NT	11.2667*	3.01195	.003	4.7042	17.8291
CT	DT	-2.8000	3.01195	.371	-9.3625	3.7625
	NT	8.4667*	3.01195	.016	1.9042	15.0291
NT	DT	-11.2667*	3.01195	.003	-17.8291	-4.7042
	CT	-8.4667*	3.01195	.016	-15.0291	-1.9042

Based on observed means.
The error term is Mean Square (Error) = 22.680.

*. The mean difference is significant at the 0.05 level.

Tests of Between-Subjects Effects

Dependent Variable: Plant height:
DAP=150

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	3061.336a	2	1530.668	24.208	.000
Intercept	901387.951	1	901387.951	14255.884	.000
Tillage	3061.336	2	1530.668	24.208	.000
Error	758.750	12	63.229		
Total	905208.038	15			
Corrected Total	3820.086	14			

a. R Squared = .801 (Adjusted R Squared = .768)

Multiple Comparisons

Plantheight
LSD

(I) Tillage	(J) Tillage	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
DT	CT	6.9200	5.02908	.194	-4.0374	17.8774
	NT	33.1667*	5.02908	.000	22.2092	44.1241
CT	DT	-6.9200	5.02908	.194	-17.8774	4.0374
	NT	26.2467*	5.02908	.000	15.2892	37.2041
NT	DT	-33.1667*	5.02908	.000	-44.1241	-22.2092
	CT	-26.2467*	5.02908	.000	-37.2041	-15.2892

Based on observed means.
The error term is Mean Square(Error) = 63.229.

*. The mean difference is significant at the 0.05 level.

Appendix Q: Analysis of yield

Q1: Analysis of interaction of tillage and location on yield

Tests of Between-Subjects Effects

Dependent Variable:Yeild

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	3.642E7a	5	7284722.223	4.486	.025
Intercept	2.131E8	1	2.131E8	131.265	.000
Tillage	5169907.408	2	2584953.704	1.592	.256
Location	3.063E7	1	3.063E7	18.861	.002
Tillage * Location	542129.630	2	271064.815	.167	.849
Error	1.461E7	9	1623713.991		
Total	3.080E8	15			
Corrected Total	5.104E7	14			

a. R Squared = .714 (Adjusted R Squared = .555)

Q2: Analysis of yield difference due to topographic locations

Univariate Analysis of Variance

Between-Subjects Factors

		Value Label	N
Location	1	Down Slope	9
	2	Up slope	6

Tests of Between-Subjects Effects

Dependent Variable:Yeild

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	3.063E7a	1	3.063E7	19.504	.001
Intercept	2.131E8	1	2.131E8	135.742	.000
Location	3.063E7	1	3.063E7	19.504	.001
Error	2.041E7	13	1570156.695		
Total	3.080E8	15			
Corrected Total	5.104E7	14			

a. R Squared = .600 (Adjusted R Squared = .569)

Appendix R: Analysis of biomass

R1: Analysis of effect of tillage on biomass

Between-Subjects Factors

		Value Label	N
Tillage	1	Deep Till	5
	2	Conventional Till	5
	3	No Till	5

Tests of Between-Subjects Effects

Dependent Variable: Biomass

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	2.039E7a	2	1.019E7	2.141	.160
Intercept	3.473E8	1	3.473E8	72.930	.000
Tillage	2.039E7	2	1.019E7	2.141	.160
Error	5.714E7	12	4761518.009		
Total	4.248E8	15			
Corrected Total	7.752E7	14			

a. R Squared = .263 (Adjusted R Squared = .140)

R2: Analysis of effect of location on Biomass

Between-Subjects Factors

		Value Label	N
Location	1	DownSlope	9
	2	UpSlope	6

Tests of Between-Subjects Effects

Dependent Variable: Biomass

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	3.671E7a	1	3.671E7	11.692	.005
Intercept	2.906E8	1	2.906E8	92.552	.000
Location	3.671E7	1	3.671E7	11.692	.005
Error	4.082E7	13	3139710.981		
Total	4.248E8	15			
Corrected Total	7.752E7	14			

a. R Squared = .474 (Adjusted R Squared = .433)

R3: Analysis of interaction of tillage and location on biomass

Between-Subjects Factors

		Value Label	N
Tillage	1	Deep Till	5
	2	Conventional Till	5
	3	No Till	5
Location	1	DownSlope	9
	2	UpSlope	6

Tests of Between-Subjects Effects

Dependent Variable: Biomass

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	5.742E7[a]	5	1.148E7	5.142	.017
Intercept	2.906E8	1	2.906E8	130.109	.000
Tillage	1.952E7	2	9760345.286	4.370	.047
Location	3.671E7	1	3.671E7	16.436	.003
Tillage * Location	329039.830	2	164519.915	.074	.930
Error	2.010E7	9	2233416.127		
Total	4.248E8	15			
Corrected Total	7.752E7	14			

a. R Squared = .741 (Adjusted R Squared = .597)

b.

Appendix S: Some important pictures

Picture S1: Measuring pre treatment left and post treatment right steady state infiltration rate

Picture S2: Pit excavated for bulk density analysis for various depths


Picture S3: Perforated pipe for ground water recharge monitoring (left) and collector channel to drain event runoff from plots to runoff tank (right)


Picture S4: Conducting deep tillage by manually digging (Left) and Conventional till by ox (right)

Picture S5: Soil profile during deep tillage left and sub plots for the three different treatments right

Picture S6: Tank for runoff collection (runoff barrel)

Picture S7: Corrugated iron sheet roof for barrel cover

Picture S8: Trench for sheet metal and plot delineation by sheet metal


Picture S9: Plantation for zero tillage and weed removal by manually pulling


Picture S10: Plant height at various stages

Picture S11: Up slope plants hit by heavy storm with hailstones

PictureS12: Measuring biomass