IMPACT OF INTERCROPPING OF SOYBEAN (*Glycine max* L.) – MAIZE (*Zea mays* L.) ON SOIL LOSS AND CROP PERFORMANCE IN FOOTHILL REGIONS OF DIMAPUR DISTRICT

Thesis

Submitted to

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of

DOCTOR OF PHILOSOPHY

in

SOIL AND WATER CONSERVATION

By

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2021

AFFECTIONATELY
DEDICATED TO MY
FAMILY MEMBERS
& LATE MOTHER

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CERTIFICATE - I

This is to certify that the thesis entitled "**Impact of intercropping of soybean (*Glycine max* L.) – maize (*Zea mays* L.) on soil loss and crop performance in foothill regions of Dimapur District**" submitted to Nagaland University in partial fulfillment of the requirements for the award of degree of Doctor of Philosophy (Agriculture) in the discipline of Soil and Water Conservation, is the record of research work carried out by **Mr. Vizokhonyü Yhome**, Registration No.**776/2017**, under my personal supervision and guidance.

The result of the investigation reported in the thesis have not been submitted for any other degree or diploma. The assistance of all kinds received by the student has been duly acknowledged.

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CERTIFICATE – II

VIVA VOCE ON THESIS OF DOCTOR OF PHILOSOPHY IN SOIL AND WATER CONSERVATION

This is to certify that the thesis entitled **"Impact of intercropping of soybean (*Glycine max* L.) – maize (*Zea mays* L.) on soil loss and crop performance in foothill regions of Dimapur District"** submitted by **Mr. Vizokhonyü Yhome**, Admission No. **Ph-173/15**, Registration No.**776/2017**, to the Nagaland University in partial fulfillment of the requirements for the DOCTOR OF PHILOSOPHY (AGRICULTURE) in the discipline of Soil and Water Conservation has been examined by the Advisory Board and External Examiner on……………………….

The performance of the student has been found **Satisfactory/Unsatisfactory.**

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DECLARATION

I, Mr. Vizokhonyü Yhome, hereby declare that the subject matter of this thesis is the record of work done by me, that the contents of this thesis did not form the basis of the award of any previous Degree to me or to the best of my knowledge to anybody else, and that the thesis had not been submitted by me for any research degree to any other University/ Institute.

This is being submitted to SASRD, Nagaland University for the degree of Doctor of Philosophy in Soil and Water Conservation.

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LIST OF ABBREVIATIONS

A.O.A.C	-	Association of Official Analytical Chemists
@	-	at the rate of
BCR	-	Benefit Cost ratio
BD	-	Bulk density
CEC	-	Cation exchange capacity
cm	-	Centimetre
CD	-	Critical Difference
Cu	-	Copper
DAS	-	Days after sowing
df	-	Degree of freedom
ºC	-	Degree Celsius
et al.	-	*et allia* (and others/co-workers)
Fe	-	Iron
Fig.	-	Figure
g	-	Gram
ha	-	Hectare
i.e.	-	Id est (that is)
K	-	Potassium
kg	-	Kilogram
l	-	litre
m	-	Metre
Max.	-	Maximum
Min.	-	Minimum
mg	-	Miligram
mm	-	Milimetre
Mn	-	Manganese
m^2	-	Metre square
msl	-	Mean sea level

MSS	-	Mean sum of squares
N	-	Nitrogen/North
NEHR	-	North Eastern Hill Region
NS	-	Not significant
P	-	Phosphorous
$^{-1}$ or /	-	Per
%	-	Per cent
S	-	South
Sl. No.	-	Serial number
SMBC	-	Soil microbial biomass carbon
SEm±	-	Standard error of mean
SOV	-	Source of Variation
SS	-	Sum of square
t	-	Tonne
WHC	-	Water holding capacity
viz.	-	Videlicet (Namely)
Zn	-	Zinc

CONTENTS

ABSTRACT

A study was conducted on "Impact of intercropping of soybean (*Glycine max* L.) – maize (*Zea mays* L.) on soil loss and crop performance in foothill regions of Dimapur district" during the Kharif seasons of 2016 and 2017 on the experimental farm of the School of Agricultural Sciences and Rural Development under rainfed conditions. The experiment was laid out in Strip Plot Design comprising of eighteen different treatment combinations which was replicated thrice with three slope aspects namely, S_1(0% slope), S_2(9% slope) and S_3(20% slope) in main plots and six cropping combinations *viz*. T_1 – Control,T_2 - Sole Soybean,T_3 - Sole Maize,T_4 - Soybean +Maize (1:1), T_5 - Soybean +Maize (2:1) and T_6 - Soybean +Maize (1:2) in sub-plots. On soil loss and runoff, S_1 (0% slope) was found the least among the different slopes with (4.84 and 4.9 t $ha^{-1}yr^{-1}$), (440.46 and 495.93 ls^{-1}) and the highest was recorded in S_3 (20% slope) with (45.82 and 46.39 t $ha^{-1}yr^{-1}$) and run-off (1707.34 and 1728.57 ls^{-1}). Among the cropping treatments, T_{2}- Sole soybean recorded minimum values of soil loss (22.98 and 23.27 t $ha^{-1}yr^{-1}$) as well run off (1040.93 and 1053.87 ls^{-1}) during both the years which was followed by soybean + maize (2:1). While T_1- Control on the other hand recorded the highest values of both soil loss and run off with 27.35 and 27.69 t $ha^{-1}yr^{-1}$, 1345.93 and 1345.93 ls^{-1}, respectively during both the years. Under the different cropping systems, sole crops performed better than other cropping systems in respect of growth and yield attributing characters. And on intercropping systems i.e., paired rows, soybean + maize (1:1) ratio performed significantly better in terms of yield. Laboratory analysis on soil quality indicators revealed that available N and available K showed significant variation due to addition of various treatments, whereas available P, bulk density, soil aggregation, mean weight diameter, water holding capacity, soil microbial biomass carbon (SMBC), iron (Fe), zinc (Zn), copper (Cu) and manganese (Mn) did not show any significant variation due to addition of treatments. Among the macronutrients, available N was found high with a value varied from 574.62 to 605.14 kg ha^{-1}, available P was recorded medium with a range from 10.02 to 13.18 kg ha^{-1} while available K was found low with a value ranged from 73.4 to 99.28 kg ha^{-1}. The organic C in the soil was high with a value varied from 1.38 to 1.48 %, pH value was recorded very strongly acidic (4.60 to 5.06) and cation exchange capacity (CEC) ranged from 19.28 to 23.72 cmol (p^{+}) kg^{-1}. The bulk density, soil aggregation, mean weight diameter and water holding capacity of the soil ranged from 1.24 to 1.33 g cm^{-3}, 16.79 to 30.04 %, 1.10 to 1.84 mm and 45.89 to 60.05 %, respectively. The microbial biomass carbon ranged from 114.45 to 453.01 mg kg^{-1}. Among the micronutrients, iron, copper and manganese content in soil was sufficient whereas, the zinc content was found deficient. As for B:C ratio, S_1(0% slope) {1.22 and 1.19}and sub-treatment T_4-Soybean+Maize (1:1) {1.67 and 1.62} were found superior to all other slopes and treatments. Considering the soil quality indicators, soil loss, runoff and BC ratio, treatment T^5 Soybean +Maize (2:1) can be recommended in farmers' field.

Keywords: Intercropping, grain yield, soil quality and micronutrients.

CHAPTER I

INTRODUCTION

INTRODUCTION

Although soil and land are related, they are two different entities. The Land represents geographical area and landscape and is a two-dimensional entity, whereas, the soil is a three-dimensional body with length, breadth and depth and is hidden below the land surface. Under ideal conditions, a recognizable soil profile may develop within 200 years (Anonymous, 2002). It takes 100 to 2500 years for 2.5 cm of topsoil to form which can be lost in as little as 10 years. Generally, soil is formed at the rate of only 1cmevery 100 to 400 years. So, it will take around 3000 to 12000 years to form enough soil to be called as a productive land (Asres *et al*.,2014). Soils are formed by weathering processes of rocks which in the words of Jenny (1941) can be depicted by the equation: S=f(cl,r,p,o,t,….); where S=soil, cl=climate(rainfall, temperature, snow etc.), r=relief or topography, p=parent material (rocks, minerals and geological formation), and o=organisms-plants and animals, and t=time or age. Soils are known to be formed from hard rocks, loose and unconsolidated inorganic materials and an organic residue.

Soybean (*Glycine max* L.) is a potential oilseed crop of India native to North Eastern China and is also known as the Golden bean of the 20th century. Soybean is established as premier oilseed crop covering an area of 9.3 million ha with the production of 10.47 metric tonnes in India. In NEH Region, its productivity is 1000 kgha^{-1}, which is much higher than the national productivity level (822 kg ha^{-1}). It is cultivated as a kitchen garden crop and consumed as pulse crop by the people of this region. It is grown as a sole crop as well as intercropped with cereals, pulses, vegetables etc. The cultivated area, production and an average productivity of soybean for the year 2019-20 under Nagaland area was 25170 ha, 31770 tonnes and 1,262.22 kgha^{-1}(Anonymous, 2020). It is considered as one of the most popular food items among the Naga tribes and is taken as pulse crop as well as fermented product locally called as 'Akhuni' or 'Dacie'. It is rich in high quality protein (40-45%), edible oil (18-

20%) and other nutrients like calcium, iron and glycine. As it meets the different nutritional needs of human being, it can help to overcome the problem of malnutrition in hilly and backward areas. It is also a good source of isoflavones and therefore it helps in preventing heart diseases, cancer and HIVs (Kumar, 2007). Because of the aforementioned qualities, soybean is also termed as “miracle bean”, “poor man’s meat” and the “powerhouse of protein”. It has contributed towards supporting the national economy and meeting the edible oil requirement of the nation in the past four decades. The per capita consumption of the vegetable oil is increasing very rapidly, reaching to approximate 12.6 kg $year^{-1}$ in comparison to that of 4 kg $year^{-1}$ in 1961 and the projected demand for the year 2020 is expected to reach 16.38 kg $year^{-1}$. To meeting the need of future burgeoning population it will be requiring nearly 18.3 and 21.8 million tons of edible oil and the major share is to be meet from the soybean. It also builds up the soil fertility by fixing the atmospheric nitrogen through the root’s nodules and also through leaf litters that fall on the ground.

Maize (*Zea mays* L.) is the third most important food crop in India with the average productivity of 2.89 tha^{-1}, and contributes nearly 9% to the national food basket. There is a tremendous need to increase the acreage and productivity of this crop in near future to meet food, feed, and other demands, especially in the country (Kar *et al.,*2005).In North Eastern India the area and production of maize is 196.9 thousand ha and 1297.6 thousand MT, respectively(Anonymous, 2010).Also known as “queen of cereals” for its high yielding attribute and “poor man’s cereal” or “nutricereal” for its nutritive value, maize is an important coarse cereal crop next to rice as food crop in Nagaland. It has been valued as food, fodder, and feed and remained as a mainstay of Indian agriculture in general and Nagaland in particular with an area of 69130 ha and production of 137160 mt. In Nagaland, Tuensang is the highest maize growing district covering an area of 10154 ha with a production of 20150 mt (Directorate of Agriculture . Govt. of Nagaland 2020).Maize contains about 4% oil, 70% carbohydrates, 2.3% crude fibre, 10.4% albuminoids and the endosperm contain 9-12% protein. Besides human consumption, it is also grown as fodder and industrial crop. Maize has got wide adaptability and is grown in tropical as well as colder-zones and from sea level upto 2700m. Maize is essentially a warm season crop and can be grown when the night temperature does not go below 15.5° C. It can be grown in almost all types of soil ranging from sandy to heavy clay soils. Maize is also known to suffer from water logging, it is therefore desirable to avoid low-lying areas and fields with poor drainage

Intercropping is accepted as a beneficial system of crop production and evidences suggest that intercropping can provide substantial yield advantages as compared to sole cropping. The benefits are more profound when crops are inter cropped with legumes as leguminous crops are known to fix atmospheric nitrogen, thus helping to meet the N needs of cereals (Manna *et al.,*2003). Rao *et al.* (1982) emphasized upon crop substitution and intercropping to bring about stability in crop yields under aberrant situation with the ever-changing scenario and erratic and irregular monsoon, the concept of intercropping needs to be popularized and explored of its potentials and benefits. There are two types of intercropping, additive series is growing of intercrop between the rows of maincrop without any adjustment in the spacing of the main crop while in paired or replacement series, the spacing of the main crop is reduced and equal opportunity is given to the intercrop for better growth. The crops are grown in pair of two in case of pair series.

According to ICAR reports, the average topsoil erosion during the cropping period is 44 MT/ha/year and it could be as high as over 100 MT/ha/year. It has been estimated that about 88.3 million tonnes of soil are lost actually in the north-eastern states of India along with 10.7, 0.4 and 6.0

thousand tonnes of N, P and K, respectively (Sharma and Prasad, 1995). However, wide variations in soil and nutrients losses are found depending on the slope gradient, nature of the soil, crop canopy, agricultural activities, etc. Improper land management in hills can cause annual soil loss of about 80 tonnes per hectare as compared to the national average of 16.35 tonnes/ha/yr. The permissible soil loss limit is from 4.5 to 11.2 tonnes/ha/yr under different soil types. About 5334 million tonnes of soil is being eroded annually due to agricultural and associated activities in the country and 29% of eroded material is permanently lost into the sea (Dhruvanarayana, 1993). The loss of soil nutrients through water erosion is estimated to be 5.4 to 8.4 million tonnes.In India 6000 MT of soil is being lost every year resulting in Rs.6000 crore worth loss in food production annually (Anonymous, 1993). Agriculture in India depends largely on rainfall where over 80% occurs during the monsoon period i.e., June to September. Nagaland is a hilly state with a total geographical area of 1.6579 m ha sharing its border with Assam to the north and west, Manipur to the south, Arunachal Pradesh and the international boundary with Myanmar to the east. The rainy season is generally from April to September, with an average annual rainfall of about 1943 mm received in Kohima (Anonymous, 2014). In Nagaland, about 90% of the *jhum* fields are cultivated up to 60^0 of slope. However, most of the fertile topsoil are washed down during rainy season i.e., about 450qtl of soil/ha (Anonymous, 2012). Soil erosion constitutes the most serious problem of agricultural lands as it renders the land very unproductive due to depletion of soil fertility. And as it takes hundreds of years to form just a centimeter of soil from solid rock, so the health of Mother Nature should be considered as paramount importance as one's health.

Hence, keeping in view the importance of soil loss and runoff from the fields, and the high scope as well as importance of maize and soybean, the present research work entitled **"Impact of intercropping of soybean (*Glycine***

***Max* L.) – maize (*Zea mays* L.) on soil loss and crop performance in foothill regions of Dimapur district**" is undertaken with the following objectives:

1. To study the soil loss from soybean and maize intercropping treatments
2. To evaluate the growth, yield and quality of soybean and maize
3. To study the effect of soybean and maize intercropping on some important soil quality indicators
4. To evaluate the benefit cost ratio of different treatment combinations.

CHAPTER II

REVIEW OF LITERATURE

REVIEW OF LITERATURE

The literature pertaining to the present investigation entitled "Impact of intercropping of soybean (*Glycine max* L.) – maize (*Zea mays* L.) on soil loss and crop performance in foothill regions of Dimapur district" has been reviewed in this chapter. The findings have been reviewed under the following heads.

1. Physiography
2. Soils of Nagaland
3. Concept of intercropping
4. Soil loss and intercropping system
5. Intercropping impact on crop performance
6. Economic Analyses

2.1. Physiography

Maji *et al.* (2000) reported that the state of Nagaland represents hilly terrain comprising closely spaced elevated ridges with alternate "V" shape intermountain valleys. Topographically, the landscape can be grouped into three major divisions *viz.,* (i) high hills and mountainous region, (ii) the lower ranges and the mid slopes (1000m and above) and (iii) the foothills. The hilly terrains are highly dissected with occasional formation of narrow strip of valleys where the major rivers and their tributaries pass through. There are several high mountainous peaks, among which, mount Saramati, (3840 m) is the highest situated in the eastern part of the state. The foot hills were formed in western part of the state with undulated to rolling topography below 1000 m altitude facing the Assam plains in the north and west (Anonymous, 2014).

2. 2. Soils of Nagaland

Maji *et al.*, 2000 reported that as per Soil Resource Mapping of Nagaland State, 72 soil families were identified and these were mapped into 36 soil units in the entire state. The soils of Nagaland belong to 4 orders, 7 sub orders, 10 great groups and 14 subgroups. It is also observed that Inceptisols are the dominant soils followed by Ultisols, Entisols and Alfisols. The Alfisols cover 2.88 per cent, Entisols 7.32 per cent and Inceptisols, 66.03 per cent and the Ultisols 23.77 per cent of the total geographical area. The major soil problems of the area are strong acidity, high leaching of bases resulting to low base saturation status, low exchange capacity, limiting soil depth in steep hill slopes, erosion and landslides as a result of weak geological formations of Himalayan origin and humid climatic with high rainfall.

The soils of Nagaland can be broadly classified into 3 (three) major soil orders i.e. Entisols, Inceptisols and Ultisols. Recently occurrence of 'Alfisols' also identified by NBSS & LUP, Nagpur in the foot hill areas of the State. Details enclosed in the table. Above soil orders have been further classified into sub-group referring to prevailing soil temperature regime, soil moisture regime of the State. Further classification of sub-group into soil families have been made considering details about occurrence, range in physical and chemical characteristics; crop suitability and evaluation to assess their production capacity. There are 42 soil series identified till date in the State. They are widely occurring in the 12 (twelve) districts of the state. The natural topography, hill slopes of state which is once disturbed, affect soils, causing lot of soil hazards. Slope factor takes major role in the land use planning. The range of slope varies from 0% to >100% in the state (Anonymous, 2014).

Soils of Nagaland are derived from shales and sandstones of Miocene age. Although the total geographical area of the state is very small, a great variation in soil type has occurred due to the variation in topography and climate. The foot hill areas with hot and monsoon climate are characterized by occurrence of laterite soils whereas the hilly areas having cool and temperate climate with coniferous vegetation have given rise to podzolic soils. Soils of the hilly areas having cool, mountain climate and with broad leaved deciduous natural vegetation are termed as brown earth. The transported soils occurring over the foothills and valley, usually known as alluvial soils, comprise the most fertile and productive soils of the state. In general, the soils of Nagaland are acidic in reaction with a pH range from 4.5 -6.5 (Ovung, 2012).

2.3. Concept of intercropping

Intercropping can be defined as the agricultural practice of growing two or more crops in the same space at the same time (Andrews and Kassam, 1976).The main concept of intercropping is to get increased total productivity per unit area and time, besides equitable and judicious utilization of land resources and farming inputs including labour. One of the main reasons for higher yields in intercropping is that the component crops are able to use growth resources differently and make better overall use of growth resources than grown separately (Willey, 1979). The basic idea of intercropping is not only that two or more crops' species grown together can exploit the resources than either of them grown separately but also when two or more crops occupied the same field, the inherent risk in agriculture and more so, under dryland conditions are buffered to some extent, called as 'biological insurance' (Ayyangar and Ayyar, 1942; Ayaar, 1963). Several workers have reported that the hedgerow intercropping is potentially useful system for the humid and sub-humid tropics (Kang *et al*., 1984; Lal, 1989).

Intercropping is a way to increase diversity in an agricultural ecosystem. The most benefit of intercropping is optimum utilization of plant resources such as nitrogen in Gramineae (or Poaceae)/Legumes (or Fabaceae) intercropping (Nasri *et al*., 2014).Intercropping can be defined as a multiple cropping system that two or more crops planted in a field during a growing season (Yong *et al*., 2015). As known, Legume crop is used as soil N supply. When the crop with large canopy intercropped with the small crops, such as maize and soybean intercropping, soybean yield could decrease due to interspecific light competition (Liu *et al*., 2017). Thus, different intercropping designs such as alternate rows and intra rows were studied in many types of research (Ijoyah and Fanen, 2012; Mandal *et al.,* 2014). The optimum inter-row and intra-row distances are the most important to produce a high yield in maize/soybean intercropping (Kim*et al*., 2018). The LER has been recommended to evaluate the yield advantage of intercropping compared to monocropping (Mahallati *et al*., 2014). It was reported that the LER values above 1 determined in maize/soybean intercropping (Dolijanvic *et al*., 2009; Tsujimoto *et al*., 2015; Kamara *et al*., 2017).

Inclusion or replacement of either of cereal components with suitable pulse in an exhaustive cereal-cereal production system may have advantages beyond N addition through biological nitrogen fixation which includes recycling from deeper layers, minimizing soil compaction, protection of soil from erosion, increasing soil organic matter through root biomass and leaf fall, breaking the weed and pest cycles and minimizing any allelopathic effects (Yadav *et al*., 2003).Yavas and Unay (2016) reported poor nodulation of soybean and cowpea with maize intercropping and attributed it to soil compaction , flooding, and high pH levels.

2.4. Erosion and slope gradients

Soil erosion, defined as the detachment and displacement of soil particles from the surface to another location (Flanagan, 2002), is associated with about 85% of land degradation in the world, causing up to 17% reduction in crop productivity (Nyakatawa *et al*., 2006; Ran *et al*., 2018). Its impacts are more on the hilly terrains, which are very much prone to soil erosion due to steep slope, fragile geology, and intense rainfall storms. The soil erosion in hilly Himalayan regions was observed much more than the permissible limits (Mandal and Sharda, 2011; Mahapatra *et al*., 2018).High erosion rates from agriculture land are usually due to lack of vegetation cover, which is a key factor to understand in soil erosion (Ola *et al*., 2015; Zhao *et al*., 2016). The structure of soil without vegetation is easily broken by the impact of raindrops, increasing runoff and soil erosion rates (Cerda, 2000).Slope gradient is a driving factor affecting slope runoff and erosion, and the runoff velocity is determined by the slope gradient (Yao and Tang, 2001). Studies of the effects of slope gradient on soil erosion have mainly focused on gentle slopes (<10°) (Fox and Bryan, 2000; Valmis *et al*., 2005; Assouline and Ben-Hur, 2006). Within a certain range, the larger the slope gradient, the greater will be the slope runoff rate and the amount of soil loss (Foster and Martin, 1969; Wei and Zhu, 2002; Li *et al*., 2008; Geng *et al*., 2010; García-Ruiz *et al*., 2015; Zhao *et al*., 2015). However, soil erosion on slopes does not increase continually with increases in slope gradient, and there is a critical grade where runoff and erosion behaviour changes. According to simulated rainfall experiments and field observations, when the slope gradient reaches a certain limit, soil erosion decreased as slope gradient increased, meaning that a critical erosion gradient exists (Yair and Klein, 1973; McCool *et al*., 1987; Liu *et al*., 1994; Jin, 1995; Kapolka and Dollhopf, 2001). Most researchers attributed it to an increase in slope, the increase in the area of rainfall collection, the precipitation, runoff rate and sediment yield per unit area would be reduced accordingly (Jin, 1995; Wang *et al*., 2004; Li *et al*., 2016).

According to the research on the erosion process of vineyards, the slope is one of the important causes of soil erosion, and high soil erosion occurs on steep slopes with low coverage (Comino *et al*., 2016). Some degree of crop coverage can greatly reduce soil erosion when the slope gradient is less than 5 degrees and soil erosion is produced mainly by rainfall. However, when the slope gradient is greater than 9 degrees, soil erosion increases due to runoff scouring (Woodruff, 1947). As for sloping farmland with crops, under the same coverage and rainfall, the larger the slope gradient, the higher will be the slope runoff rate, but the law producing sediment yields is not obvious (Song *et al*., 2000). Turunen *et al*. (2017) indicated that, more erosion occurred in the steep slope than in the flat slope, some studies on Chinese loess and purple soil regions have also obtained similar results (Huang *et al*., 2005; Wang *et al*., 2011; Zhong and Zhang, 2011). Compared with bare land, crop coverage can effectively reduce runoff rates and sediment yields. However, such reducing effects differ among crop types and vary with slope gradients. For instance, Wang *et al*. (2011) reported that on slopes of 5° and 15°, maize reduced the runoff rates by 29.2% and 12.2% compared to bare land, whereas the decrement of runoff rates under alfalfa (*Medicago sativa* L.) cultivation changed from 78.5% to 75.0% when slope gradient increased from 5° to 15°.

2.5. Intercropping on soil loss

Crops had positive effects on reducing slope runoff rate and sediment yield (Song *et al*., 1998; Sun *et al*., 2005; Singh *et al*., 2011; Wang *et al*., 2011).At a microscale, the splash effect of raindrop causes peeling of aggregates resulting in the disproportionate distribution of soil aggregates. Thus, when runoff occurs, the finer and lighter soil materials enriched with nutrients are preferentially entrained (Lal, 2001) and mobilized in the eroded sediment (Quinton *et al*., 2001; Six *et al*., 2015). The intercropping system can ensure continuity of protective cover and protect the soil against raindrop impact (Nyawade *et al*., 2018). It also provides a good canopy cover, which reduces the raindrop impacts and reduces soil erosion. Willey (1979) suggested that providing insurance against climatic aberration, intercropping ensures better utilization of natural resources like land, water and sunlight. During one cropping phase, agricultural systems in North East India may lose about 600kg N/ha and half of this amount is recovered during the subsequent five years fallow period (Mishra and Ramakrishnan, 1984). However, an accelerated and directed succession through the introduction of a variety of legumes and non-leguminous nitrogen fixers during the cropping and fallow phase could restore soil fertility over a five-year cycle period (Ramakrishnan, 1992).Prasad *et al*., (1987) found that observations in NEH Region shows soil loss under a traditional farming system *of jhuming* to be around 49.40 t/ha/yr, whereas mixed land uses such as agrihortisilvipasture on watershed based with soil conservation measures like bench terracing and half-moon terracing system, showed the soil loss only by 1.80 t/ha/yr. Thus, agroforestry intervention with adequate soil and moisture conservation measures could reduce the soil loss by > 90% compared to the traditional method of cultivation.

Lesoing *et al.* (1999) reported that higher maize density in border rows may further exploit a competitive advantage with soybeans in the reproductive period, perhaps increasing system productivity. It is suggested that where there is a need to control soil erosion, strip intercropping can be equally profitable to monoculture if production costs are similar. Boardman *et al.* (2001) reported that erosion during the 21^{st} century will be influenced both by land-use change and by anthropogenically-induced climate change. In strongly acid soils, complexing of Al^{3+} by humus also reduces the soil acidity (Young, 1997)

Kariaga (2004) reported better protection of the soil against erosion from intercropping of maize and cowpea. Other studies show that intercropping reduces the hazard coming from climate change through increasing production and productivity (Inns, 1997).Water erosion is a serious problem in India. The main factor directly or indirectly responsible for soil and land degradation process is water erosion (Spaan, 2005). It degrades the top productive layer of soil through huge losses of nutrients alongwith runoff and suspended sediments and results in declining productivity of land in the long run. Decline in land quality is attributed to various land degradation processes and amongst them the water induced erosion is single most destructive one (Lal, 2001). Sehgal and Abrol (1994) reported that out of 329 m ha total geographical area in the country, about 57% land (187.7 mha) is under various forms of degradation in which the dominant form is water erosion (148.9 m ha; 45%). However, according to a latest estimate, the land degradation due to water is reported to the 120.72mha area (68.4%) in the country (Maji, 2007).

Dhruvanarayana and Babu (1983) estimated that about 5334 m tonnes (16.35 t ha^{-1}) soil is detached annually due to water erosion. The loss of plant nutrients with eroded soil is said to be 8.4m tonnes including 2.5 m tonnes N, 3.3 m tonnes P and 2.6 m tonnes K in a year. The loss of any amount of soil by erosion is generally not considered beneficial but field experience as well as scientific research has indicated that some soil loss can be tolerated without affecting the crop production significantly (Schertz, 1983).Land restoration strategies are mostly based on a single generalized permissible erosion loss limit of 11.2Mg ha^{-1} yr^{-1}.This value is considered on the basic assumption that this rate of soil erosion equals to rate of soil formation (Mannering, 1981; McCormack *et al.* 1982). According to soil erosion status report of Chhattisgarh soil erosion is characterized as very slight (<5 Mg ha yr), slight (5-10Mg ha^{-1} yr^{-1}), moderate (10 -15Mg ha^{-1} yr^{-1}), moderately severe

(15-20Mg ha^{-1} yr^{-1}), severe (20-40 Mg ha^{-1} yr^{-1}), very severe (40-80 Mg ha^{-1} yr^{-1}) and extremely severe (>80 Mg ha^{-1} yr^{-1}) erosion, respectively (Tamgade*et al.*, 2003).

Soil erosion and land degradation are severe problems in India. Severe surface erosion is linked with intensive rainstorms, high detachability of surface soil materials and reduced infiltration. This is induced by poor and weak soil structure and by poor cover of vegetation or plant residue in critical periods (Pla, 1997). The vegetative covers provided through agronomic measures on soil surface proved effective in conserving the runoff water and decrease the erosivity of rainfall and erodibility of soil (Samra and Sharma, 2002). It was estimated that about 16 and 30 t ha soil get eroded annually at 2% and 3% slope, respectively from cultivated fallow plot in deep alluvial soil in absence of any canopy cover on the soil surface (Narayan and Bhusan, 2000). Vegetation covers protects the soil from intense rain and reduce the detachability of surface materials. It reduces runoff, conserves moisture and retains sediment and organic debris. It also allows drainage of excess water due to their semi-permeable nature (Kiepe, 1995). Different agroforestry systems showed large variations in soil organic carbon (Panwar *et al.,* 2013). Soil erosion affects physical, chemical and biological makeup of the soil and thus results in low crop productivity (Bhardwaj and Sindhwal, 1998).

The intrinsic soil properties and land use/land cover are important factors which govern sediment production (Wood, 1987). About 73 m ha of land in India is under vertisols spread across Madhya Pradesh, Maharashtra, Andhra Pradesh, Tamil Nadu, Gujarat, Rajasthan and parts of Karnataka, mostly confined to the semi-arid region. These soils being rich in clay content when subject to erosive storms under sloppy and topography are undulated characteristically prone to run off and eventually results in greater soil and nutrient losses. By and large, the rate and extent of runoff, soil loss and nutrient losses are primarily influenced by the type of vegetative cover on the soil surface, slope of land and rainfall characteristics (Singh*et al.,* 1997).Therefore, in order to sustain productivity of this valuable resource, it becomes necessary to reduce runoff, soil and nutrient losses by water erosion. The maintenance of vegetative cover is of great significance to dissipate the erosive energy of heavy rains. The effectiveness depends upon the percent coverage and height and thickness of the canopy.

On arable lands canopy cover can be managed through selection of cropping systems, crop rotations, planting techniques and vegetative barriers (Narain*et al.,*1994). Khisa (2002) observed the lowest soil losses under highest plant cover of intercropping. Jat (2008) reported that maize+black gram system was found effective in controlling runoff and soil loss as compared to sole maize. Singh *et al.,* (2007) observed that the improved management on soil and water conservation of the vertic Inceptisol decreased surface runoff by 24.27%and soil loss by 44.47% as compared to traditional management.

Satapathy (2003) opined that effective planning, development and utilization of all the natural resources in hills towards sustainable production are possible on the basis of watershed programmes, mainly to aim to check soil erosion, improve fertility and productivity. Practice of slash-and burn agriculture on steep slopes and expansion of agriculture to erosion-prone land results in as much as 76.6 Mg ha^{-1} yr^{-1} of soil loss (Satapathy, 1996). Consequently, 80 percent of the cultivated area is under threat of moderate to severe erosion. About 42.3 to 59.5 Mg ha-1 of soil is lost from *bun* field with ginger plantation and 21.4 to 37.1 Mg ha^{-1} yr^{-1} and 69.2 to 88.6 Mg $ha^{-1}yr^{-1}$ from fallow fields and paddy fields respectively in which bun cultivation is practiced in previous year (Singh *et al*., 2011). Saha *et al*., (2012) reported that excessive deforestation coupled with shifting cultivation practices in tremendous soil loss (200t/ha/yr), poor soil physical health in North East region of India .Studies on soil erodibility characteristics under various land use system in North Eastern Hill (NEH) region depicted that shifting cultivation had the highest erosion ratio (12.46) and soil loss (30.2-170.2 t/ha/yr),followed by conventional agriculture system (10.42 and5.10-68.20 t/ha/yr, respectively).

About 90% of the jhum fields in Nagaland are cultivated up to 60% of slope. However, most of the fertile top soils are washed down during rainy season (about 450 q of soil/ha). This soil loss is also due to excessive biotic interference in the hilly slopes by the unscientific way of cultivations (Anonymous, 2012).

Cereal – grain legume intercropping has potential to address the soil nutrient depletion on smallholder farms (Sanginga and Woomer, 2009). The legumes play an important role in nitrogen fixation (Peoples and Craswell, 1992), and are important source of nutrition for both humans and livestock Nandwa *et al.*, 2011). In the central highlands of Kenya, cereal – legume intercropping is already being widely practiced by the smallholder famers. According to Sanginga and Woomer (2009) intercropping cereal and grain legume crops helps maintain and improve soil fertility, because crops such as cowpea, mung bean, soybean and groundnuts accumulate from 80 to 350 kg nitrogen (N) ha^{-1} (Peoples and Craswell, 1992). For instance, soybean can positively contribute to soil health, human nutrition and health, livestock nutrition, household income, poverty reduction and overall improvements in livelihoods and ecosystem services, than many others leguminous grain crops (Rakasi, 2011;Raji, 2007).

Singh (2010) reported that soil loss from different land uses such as maize grown along the slope, maize grown across the slope, maize intercropped with soybean, upland paddy, strip cropping and mixed cropping may result in soil loss of 36.41, 26,91, 19.33, 42.66, 22.85 and 29.35 $ha^{-1}yr^{-1}$, respectively.

Izumi *et al.* (2004) found that soybean root growth at surface level was markedly reduced by no- tillage and slightly improved by mulching. Rusu *et al.* (2009) suggested that the minimum tillage systems ensure an adequate aerial-hydrical regime for the biological activity intensity and for the nutrients solubility equilibrium. The plant material remaining at the soil surface or superficially incorporated has its contribution to intensifying the biological activity, being an important resource of organic matter. The minimum tillage systems rebuild the soil structure, improving the global drainage of soil which allows a rapid infiltration of water in soil. Basic *et al.* (2004) found that with no-tillage, soil erosion from the maize and soybean crops was reduced 40 and 65% compared to plowing up and down slope, even though the planting direction was still up and down the slope.

Kisic *et al.* (2010) found that much higher soil losses were recorded in spring growing seasons (row crops, maize and soybean) than in winter seasons (wheat, barley and oilseed rape). Marioti *et al.* (2013) reported that soybean along the contour lines was more effective in controlling soil loss than soybean perpendicular to the contour. Maize was more effective in controlling soil loss than soybean, regardless of the form of seeding, and both were more effective than the control.

Zhang *et al.* (2011) study the plot experiments to compare runoff, soil loss, crop growth, crop yield and economic margins for soybeans and corn under conventional management (CVM), deep-till management (DTM) and conservation management (CSM). It is apparent that conservation management can reduce soil loss, increase soybean yield and improve its profit margin on sloping fields in the black soil landscape of northeastern China.

2.6. Intercropping on productivity and quality

Intercropping maize (*Zea mays* L.) and soybean (*Glycine max* (L.) Merril) reduces soybean yield considerably, but has little influence on maize yield (Hiebsch, 1980; Ahmed and Rao, 1982; Chui and Shibbles, 1984).Common characteristics of different forms of intercropping are that they have the advantage of exploiting environmental resources more efficiently (Francis, 1989; Li *et al*., 2003; Zhang and Li, 2003, improving soil fertility (Shen and Chu, 2004; Dahmardeh *et al*., 2010) and increasing crop yield and quality (Javanmard *et al*., 2009; Dahmardeh *et al*., 2010). Intercropping legumes and non- legumes are an important feature of many cropping systems in the tropics (Willey, 1979; CIAT, 1986). It is said to be a principal means of intensifying crop production and improving returns from small land holdings (Storck *et al*., 1991). Olufajo and Singh (2002) reported that the productivity of legumes in legume-cereal intercropping is low, mainly due to competition. Ennin *et al*. (2002) have attributed this low productivity to both interspecific and intraspecific competition for limited resources. A number of measures have been recommended for achieving increase in legume productivity in intercropping among which are, identifying the best suitable time of sowing the component crops in the intercropping (Singh and Ajeigbe, 2002),and choice of suitable companion crop in the intercropping (Olufajo, 1995).Previous work on soybean/maize have addressed various factors that influence the performance of crops under varying population densities, varietal suitability, cultivar and plant arrangement amongst others (Tayo,1977; Olufajo,1986; Olufajo, 1995).

Increasing productivity of intercropped soybean and maize over the sole crop has been attributed to better use of solar radiation (Keating and Carberry, 1993), nutrients (Willey, 1990) and water (Morris and Garrity, 1993). Under soybean/maize intercropping systems, soybean yield tends to be lower and maize yield tends to be higher (West and Griffith, 1992; Ghaffarzaeh *et al*., 1994). Soybean/maize intercropping could be a way of irrigation water saving, especially in situations of limited water resources (Tsubo *et al*., 2005). Intercrops have been known to conserve water, largely due to early high leaf area index and higher leaf area (Ogindo and Walker, 2005). Morris and Garrity (1993) stated that water capture by intercrops is higher by about 7% compared by sole crop. Furthermore, water use efficiency was the highest under soybean/maize intercropping, compared with sole maize and sole soybean (Barhom, 2001). Similarly, Morris and Garrity (1993) indicated that water utilization efficiency of intercrops was higher by about 18% compared by sole crop. Water stress during maize growing season resulted in reduction of plant height, leaf area index (Cassel *et al*., 1985) and total leaf area reduction (El-Shenawy, 1990). In addition, number of ovules that fertilized and developed into grains decreased rapidly when drought occurred during flowering (Gomma, 1981). Moreover, both final maize yield and kernel number were reduced as a result of water stress during grain filling period (Ritchie *et al*., 1993). The most important times for soybean plants to have adequate water are during pod development and seed fill (Kranz *et al*., 1998). These are the stages when water stress can lead to a significant decrease in yield. Stressful conditions, such as moisture deficiency reduces soybean yield. As the soybean plant ages from R1(beginning bloom) through R5 (seed enlargement), its ability to compensate under stressful conditions decreases and yield losses could increase (Foroud *et al*., 1993).

Intercropping systems have several advantages in increasing yield, land use efficiency, efficiency in utilization of natural resources including light, water and nutrients, and in controlling pests and diseases. Location specific intercropping systems shown high resilience and adaptability. As soybean is cultivated in rain fed conditions in India, the degree of its susceptibility to moisture stresses can be overcome by adopting suitable intercropping systems. Several factors can affect growth of the species used in intercropping including cultivar selection, seeding ratios, and competition between components (Carr *et al*., 2004). Intercropping of soybean with cereals like maize (*Zea mays* L.), sorghum (*Sorghum bicolor* (L.) Moench.), pearl millet (*Pennisetum glaucum*L.) etc. offers great scope for minimizing the adverse impact of moisture stress in lean rainfall years as well as excess moisture during high rainfall years (Layek *et al*., 2012).Besides, these crops with their varied morphology are able to exploit the soil and climatic conditions efficiently as compared to their cultivation as sole crops (Mohta and De, 1980).The soybean being legume and maize, sorghum and pearl millet being cereals complement each other in intercropping systems and minimize the competition for growth factors (Layek *et al*., 2014). However, the soybean being short statured crop as compared to cereals in intercropping system is likely to suffer shading effects of cereals. Under such conditions, soybean growth is likely to be hampered resulting in reduced productivity, impaired quality (Maurya and Rathi, 2000).

As cereals like maize, sorghum, pearl millet etc. exhibit varied growth pattern, morphology, requirement of growth factors etc., their impact on the base crop soybean in intercropping is also likely to be different (Carr*et al*., 2004). The extent of variability of these crops on soybean will be an important indicator in the selection of suitable cereal intercrop in soybean based intercropping system. Further, as cereals require a large amount of N, it is likely that they may draw some quantity of N fixed by the component crop soybean through biological N fixation (BNF) (Senaratne *et al*., 1993). Legumes, with their adaptability to different climatic conditions, cropping patterns and their ability to fix N, may offer opportunities to sustain productivity (Jeyabal and Kuppuswamy, 2001).Li Long *et al*. (2001) conducted a field experiment to study the yield advantage of intercropping systems and compared N,P and K uptake by wheat, maize and soybean. The results revealed that yields and nutrients acquisitions by intercropped wheat, maize and soybean were all significantly greater than for sole wheat, maize and soybean with the exception of K acquisition by maize.

Intercropping, which is one of the systems is the growth of two or more crop species simultaneously in the same field during a growing season (Carruthers *et al*., 2000; Onuh *et al*., 2011). It is also seen as a method of sustainable agriculture, where two or more crops are grown simultaneously during the same season, on the same area and are believed to utilize common limiting resources better than the species grown separately (Ghosh *et al*., 2006). It is a cropping system that has long been used in tropical areas because of its established advantages which include greater yield stability (Jensen, 1996), greater land-use efficiency (Zhang and Li, 2003), increased competitive ability towards weeds (Hauggaard-Nielsen *et al*., 2001), improvement of soil fertility (Shen and Chu, 2004; Dahmardeh *et al*., 2010), increase crop yield and quality (Dahmardeh *et al*., 2010), provision of security of returns and higher profitability due to higher combined returns per unit area of land (Javanmard *et al*., 2009). In the study off Javanmard *et al*. (2009), the dry matter yield for maize in intercrop with legumes ranged from 1044 to 1514 g/m^2, which were higher than 1002 g/m^2 obtained for maize as a sole crop.

Layek *et al*. (2015) carried out a field experiment to study the effect of nitrogen levels on yield, competition and produce quality of soybean [*Glycine max*(L.)Merril and intercrops. The sole crop of soybean recorded higher seed yield as compared to intercropping. Among the intercropping systems, soybean+ maize (*Zea mays* L) recorded the highest yield of soybean. Intercropping can be defined as a multiple cropping system that two or more crops planted in a field during a growing season (Yong *et al*., 2015).

Crop species in intercropping pattern must be carefully chosen to minimize competition and enhance the efficient use of water, light and nutrients (Sayed Galal *et al*., 1983).Abdel-Galil *et al*. (2014) concluded that soybean *cv*. Giza 22 was most compatible with growing three com plants per hill under intercropping pattern. Singh and Rana (2006) reported that adoption of suitable intercropping systems might increase the total production through efficient utilization of production factors like space, water, nutrients etc., and stability of crop yield in rainfed situation can be achieved with crop substitution and intercropping. Herberts *et al*. (1984) reported that all the intercropping patterns of corn and soybean produced more dry matter than would be obtained from monoculture at the same row ratios as in the intercrop. Phan *et al.* (2000)found that soybean is seen as an important component of a sustainable mixed cropping system, principally in rotation with maize. Singh and Singh (2000) conducted a field experiment to study the effects of early and late summer sowing on Maize leaf rolling, leaf water potential, plant growth, foliage, cob development and grain yield. Crops were sown on 6 February for early summer Maize and on 25 April for later summer Maize. Normally cobs were shorter and grain weight was lower in late summer crop compared to early summer crop. The overall performance and yield in early summer crop was much better (4452 kgha^{-1}) than that of late summer crop (2981 kg ha^{-1}).

Adoption of suitable intercropping systems might increase the total production through efficient utilization of production factors like space, water, nutrients etc., and stability of crop yield in rainfed situation can be achieved with crop substitution and intercropping (Singh and Rana, 2006).

Singh and Singh (2001) suggested that high yield of soybean and maize can be obtained with less inter/intra specific competition for space, natural resources and production inputs. Khokhar *et al.* (2002) found that a decrease in seed yield of soybean with increase in N level may be on account of smothering and shading effect of maize due to its vigorous growth with higher rates of N application. While higher grain yield of maize is the result of adequate supply of N to maize with increasing fertilizer levels as well as due to supply of symbiotically fixed N by soybean. Kitchen *et al.* (2005) reported that because erosion has degraded the topsoil on shoulder and side slope positions of major portions of this field, corn-soybean management practices have rarely been profitable in these shallow topsoil areas

In the study off Javanmard *et al.* (2009), the dry matter yield for maize in intercrop with legumes ranged from 1044 to 1514 g/m^2, which were higher than 1002 g/m2 obtained for maize as a sole crop. Cereal-legume intercropping plays an important role in subsistence food production in both developed and developing countries, especially in situations of limited water resources and low fertility conditions, as it helps to maintain and improve soil fertility. The legumes fix atmospheric nitrogen, which may be utilized by the host plant or may be excreted from the nodules into the soil and used by other plants growing nearby. They can also transfer fixed N to intercropped cereals during their joint growing period and this N is an important resource for the cereals (Chen *et al*., 2010). Important factors affecting competition between the intercrop components for water, sunlight, space and nutrients and hence input use efficiency, are crop density, relative proportion of component crops, spatial arrangement (Baumann *et al*., 2001) and time of intercropping. Plant density is an important crop management practice and is accorded a high priority (Sangoi *et al*., 2002). This was demonstrated in the study by Abuzar *et al.* (2011). They grew maize at six different plant population densities of 40,000, 60,000, 80,000, 100,000, 120,000 and 140,000 plantsha^{-1}. They observed a maximum number of grains per row (32.33) and grains per ear (4473) with the plant population of 40,000 plantsha^{-1}.

Corn N status improved with intercropping probably due to enhanced growth of plants and their roots, but soybean chlorophyll content was decreased by intercropping treatments. Yield and growth of corn were stimulated by intercropping systems, but this system depressed soybean growth, particularly at 1:1 corn-soybean ratio. Based on the remarkable dominance of corn crop observed at this arrangement, it can be concluded that a 1:2 corn-soybean ratio could be more beneficial in terms of more symmetric ecological interactions (Esteban *et al*., 2013). Intercropping treatments have significant effects on maize grain yield, mean number ear/plant, mean number of seed/ear and mean weight of maize. Furthermore, intercropping treatments showed a significant effect on grain yield, mean no of pod/plant, mean no of seed/pod and seed weight of soybean (Robab *et al*., 2013).

Mandal *et al*. (2014) conducted a field experiment on the productivity of maize (*Zea mays* L.) based intercropping system during kharif season under red and lateritic tracts of West Bengal and concluded that the grain yield and stover yield of maize were significantly higher in case of pure stand of maize than either of its intercropping systems with legumes while the cob yield was highest in the maize with soybean (1:2) intercropping systems and it was statistically at par with the yield obtained in sole maize. Paudel *et al*. (2015) conducted a study to determine the most profitable crop arrangements for maize and soybean intercropping system. The result revealed that crop arrangements significantly affect yield component and yield of both maize and soybean. Sole crop of maize and soybean recorded significantly higher grain yield than corresponding yields under intercropping systems. Planting maize+ soybean at 1:1 ratio recorded highest maize grain yield (4.58 Mg ha^{-1}) and 2:2 ratio recorded the highest soybean yield (1.70Mg ha^{-1}).

Abdel-Galil *et al.* (2014) observed that maize + soybean intercropping decreased seed yields per plant and per ha by 5.48 and 23.94 percent, respectively, as compared to solid culture of soybean. Islam *et al.* (2014) reported that sweet potato vines provide a mulch cover for maize which preserve soil moisture and reduce weed infestation producing higher yield and yield components of maize. Intercropping maize and soybean showed that intercropping system reduced use of N fertilizer per unit land area and increase relative biomass of intercropped maize due to promoted photosynthetic efficiency of border rows and N utilization during symbiotic period. Intercropping advantage began to emerge at tasseling stage after N topdressing for maize (Zhang *et al.*, 2015).

2.7. Intercropping on soil quality indicators

In agriculture, there are three primary components to soil quality, including physical, chemical, and biological characteristics (Lal, 2003). Various fractions of organic matter are used most frequently as indicators of soil quality, and soil microbial biomass carbon (SMB-C) is the most common of these (Bastida *et al.*, 2008; Gil-Sotres *et al.*, 2005; Lal, 2003). Additional indicators of physical, chemical, and biological soil characteristics are also required (Gil-Sotres *et al.*, 2005), as SMB-C may vary among soils of similar quality (Bastida *et al.*, 2008).

Conventional agriculture generally reduces soil quality (Lal, 2003). In these systems, organic matter (OM) inputs are low because much of the crop biomass is removed and tillage practices increase OM decomposition due to higher soil temperatures and increased aeration (Berhongaray *et al.*, 2013; Costantini *et al.*, 2006). This can result in losses of 30-50% of soil organic carbon (SOC) from the upper 20-30 cm of soil, whether in temperate or tropical ecosystems (Berhongaray *et al.*, 2013). Agriculture also reduces the microbial biomass due to smaller carbon inputs and SOC content (Kallenbach and Grandy, 2011).

Agricultural soil quality can be improved, primarily through two mechanisms, as outlined by Lal (2003). Firstly, the degraded soil can be converted to a non-agricultural land use, such as forestry. Secondly, crop management practices, particularly those impacting the soil organic matter (SOM), can be improved to reduce erosion, improve the soil structure, increase SOC retention, and enhance nutrient cycling. Soil organic matter is one of the most important components of soil due to its many varying roles. Soil organic matter provides nutrients for plants and soil organisms, promotes nutrient sorption, increases soil structural stability, buffers the soil from environmental pollution, and sequesters atmospheric CO2 (Gosling *et al*., 2013). Organic matter inputs to the soil determine the makeup of the SOM (Ryan *et al*., 2009) which can include soil organisms, plant residues, animal fragments, and soluble compounds formed from microbially-mediated decay processes (Gosling *et al*., 2013).

Soil microbial biomass (SMB) is another component of the active SOM which is highly sensitive to changes in soil management (Granatstein *et al*. 1987; Kallenbach and Grandy, 2011). Both a source and a sink for labile nutrients (Leite *et al*., 2010), SMB has a short turnover time (Kallenbach and Grandy, 2011) which therefore promotes a fast response to changes in soil quality. Soil microbial biomass is particularly important in its central role in the decomposition of OM, as it regulates nutrient cycling by immobilizing and then releasing labile nutrients, making them available to other soil biota (Wardle, 1998). Biomass residue returned to the soil is the primary factor impacting the levels of SOC, and thus soil quality (Studdert and Echeverría, 2000).

Fertility of Indian soils is generally poor exacerbated with progressively emerging micronutrient deficiencies due to their catalyzed removal under agricultural intensification. According to latest estimates, out of about 188.4 thousand tonnes (Tt) of micronutrients removed by 263 Mt of food grains produced, individual nutrient-wise removal is Zn - 23.9Tt, Fe -110.6 Tt, Cu - 37.4 Tt, Mn -63.3 Tt, B - 9.2 Tt and Mo - 0.99 Tt (Takkar and Shukla, 2015). Enhanced removal has resulted in 36.5, 12.8, 7.1, 4.2 and 23.4% of more than 2 lakh soil samples measuring deficient in Zn, Fe, Mn, Cu and B, respectively (Shukla and Behera, 2017).

Micronutrient content in soil is dependent on several factors such as geochemical composition (total micronutrient contents of the soil parent material); soil type (clay mineralogy, particle size distribution, soil horizon, soil age, soil formation processes); intrinsic soil properties like pH, redox potential (Eh), soluble salt concentration (EC); quality and quantity of soil organic matter and calcium carbonate content); inputs of trace elements (supplied through atmospheric deposition, pesticides, manures, fertilizers); available content of macronutrients; micronutrient interactions; and vegetation (Fageria *et al.*, 2002; Alloway 2008; Shukla *et al.*, 2016).

Total soil micronutrient content is a complex function of parent material and pedogenic processes. Indian soils are fairly satisfactory with respect to total micronutrient content. But in spite of the relatively high total contents, micronutrient deficiencies have been frequently reported in many crops due low levels of available micronutrients in soils (Singh, 2008; Behera and Shukla, 2014; Shukla and Tiwari, 2016). Legumes and other non-poaceae plants excrete organic acids to lower soil solution pH for absorbing Fe (Marschner, 1974; Schmidt, 2006). On the other hand, roots of poaceae plants produce phytosiderophores (Bowen, 1981; Romheld, 1991), such as, avenic acid (Fushiya et al., 1982) mugineic acid (Kawai *et al.*, 1988) to chelate and absorb Fe.

Legumes are known to increase soil N levels (National Academy of Science, 1979; Ladd *et al.*, 1981; Reddy *et al.*, 1986). Lantham (1940) concluded that A horizon was more than three times as productive as B horizon and even eleven times as productive as C horizon. This exposed subsoil has been found to be deficient of N and P in particular (Reuss and Campbell, 1961). They also reported that low yields are more often due to lack of phosphoric acid than any other nutrients. A number of investigators have reported that major factor involved in limiting plant growth on subsoil is deficiency of N, P and K (Hays *et al.*, 1948; Smith and Pohlman, 1951; Whitney *et al.*, 1950). Lalmuanpuia (1992) observed that on complete removal of top soil (0 - 15 cm), organic C content decreased from 2.6% to 1.5%, and available N, P and K decreased from 516.0 kg ha^{-1} to 430.0 kg ha^{-1}, 28.8 kg ha^{-1} to 11.2 kg ha^{-1} and 363.0 kg ha^{-1} to 231.0 kg ha^{-1}, respectively.

The role of organic matter in improving the fertility status and physical properties of the soil is an established fact (Ghosh *et al.*, 1968; Biswas and Ali, 1969). Crop residues and manures are well known excellent materials for improving physical condition of soil and are considered the basis of re-establishment of soil fertility after humification (Rauhe, 1987). Raghavulu and Rama Rao (1994) found that nitrogen uptake was higher in intercropping system than in sole crop. Maximum nitrogen uptake was observed when the cereal and pulse crops (Setaria + pigeon pea) were intercropped in 5:1 (192 kg ha^{-1}). Potassium uptake was similar to that of nitrogen, and it was maximum in 5:1 cereal + pulse intercropping system. The intercropping of maize and legumes is widespread among small holder farmers due to the ability of the legume to cope with soil erosion and with declining levels of soil fertility. The principal reasons for smallholder farmers to intercrop are flexibility, profit maximization, risk minimization against total crop failure, soil conservation and improvement of soil fertility, weed control and balanced nutrition (Shetty *et al*., 1995).

Kitchen *et al.* (2000) reported that generally, sub-soil P and K were negatively correlated with topsoil thickness, an explanation for why we observed a recurring crop response to surface soil-test P and K in areas with greater topsoil thickness. Clay *et al.* (2005) found that the corn - soybean rotation may not return enough biomass-C to maintain soil organic C levels at all landscape positions. Legumes with their adaptability to different cropping patterns and their ability to fix N_2 may offer opportunities to sustain productivity (Jeyabal and Kuppuswamy, 2001).Soybean is a multiuse crop which is grown for oil, human nourishment, livestock feedstuff, industrial purposes and recently for bio-energy furthermore, the crop adds to increase cereal crop yield and enhance soil fertility through biological nitrogen fixation (Singh *et al*., 2007). Cereal-legume intercropping plays an important role in subsistence food production in both developed and developing countries, especially in situations of limited water resources and low fertility conditions, as it helps to maintain and improve soil fertility. The legumes fix atmospheric nitrogen, which may be utilized by the host plant or may be excreted from the nodules into the soil and used by other plants growing nearby. They can also transfer fixed N to intercropped cereals during their joint growing period and this N is an important resource for the cereals (Chen *et al.,* 2010).

2.8. Economics

Intercropping often provides higher cash return than growing one crop alone (Grimes *et al*., 1983; Kurata, 1986). Intercropping occupies greater land use and thereby provides higher net returns (Seran and Brintha, 2009). Kalra and Gangwar (1980) reported that intercropping helps in increasing farm income on sustained basis. Intercropping commonly gave combined yields and monetary returns than obtained from either crop grown alone (Ahmad and Rao, 1982). According to Seran and Brintha (2010) the intercropping system provides higher cash return to smallholder farmers than growing the monocrops. Gunasena *et al.* (1978) studying maize-soybean intercropping system, found that the gross economic returns were increased by the intercropping.

Mucheru-Muna *et al.* (2010), using benefit cost ratio, found that the MBILI system with beans as the intercrop resulted in 40 per cent higher net benefits relative to the conventional system with beans, and 50–70 per cent higher benefits, relative to the MBILI system with cowpea or groundnut. Using the same BCR, Segun-Olasanmi, and Bamire (2010) reported that maize-cowpea intercropping was found to be profitable than their sole crops.

Intercropping of oil seeds with major crops could be an acceptable approach. Poly-Culture or Multi-Cropping (developing year) especially inter-cropping has been demonstrated extremely gainful agro-technique in tropical and subtropical areas of the world. It provides farmers with more benefits and yield stability (Lithourgidis *et al.,* 2011). Although, component crop yield decreases in intercropping but system efficiency increases in terms of benefit cost ratio (BCR), net income and land equivalent ratio (LER) Bainik *et al.* (2006) because intercropping increases farm income by using land resources efficiently.

The present system of sole cropping has failed to meet the basic needs of the small farmers. So, there is a need to shift from mono-cropping to multiple cropping which is being considered as an excellent strategy for intensifying land use, increasing income and production per unit area and time (Marer *et al.*, 2007). Maximum net return can be achieved with the choice of appropriate crops combination in intercropping, population density and geometric arrangements of the component crops. The agronomic importance of soybean is connected to its cheap, economical and high value of protein content (40%) and oil content (20%) (Popovic *et al*., 2013).

Hayder *et al.* (2003) found that intercropped maize and soybean resulted in greater LER and higher economic returns as compared to monoculture at all seed rates of soybean. Intercropping of maize with legumes is more productive and remunerative (Pandey *et al*., 2003; Kumar *et al.,* 2005) compared with their sole crops. Saleem Rashid *et al*. (2011) on crop productivity of maize-legume intercropping system for yield and yield attributes reported that maize + mash intercropping accrued the highest net benefit of ` 93546.52 $ha^{-1}$, while minimum net benefit of ` 23121.80 ha^{-1} was obtained in sole maize.

CHAPTER III

MATERIALS AND METHODS

MATERIALS AND METHODS

This chapter describes the details of the experiment, the procedures, materials and methods followed to study the "Impact of intercropping of soybean (*Glycine max* L.) – maize (*Zea mays* L.) on soil loss and crop performance in foothill regions of Dimapur district" which was carried out in the experimental research farm of the School of Agricultural Sciences and Rural Development (SASRD), Medziphema campus, Nagaland University.

3.1 General information

3.1.1Locationof experimental site

The research site is located at 25˚45'43" North latitude and 93˚53'04" East longitude with an altitude of 310 meters.

3.1.2 Weather and Climatic condition

The climate of the experimental site is sub-humid tropical with high humidity, moderate temperature and receives medium to high rainfall. Monsoon starts from the first week of June and extends to September and the rains gradually decrease from October. The dry period occurs from November to March. The average rainfall ranges between 2000-2500 mm. The mean temperature ranges from 21˚ to 32˚ C during summer and rarely goes below 8˚C in the winter season. The rainfall data recorded during the period of experimentation from the time of field preparation till the final harvest of the crops for two successive years have been presented in Fig. 3.1 and Appendix I and Appendix II.

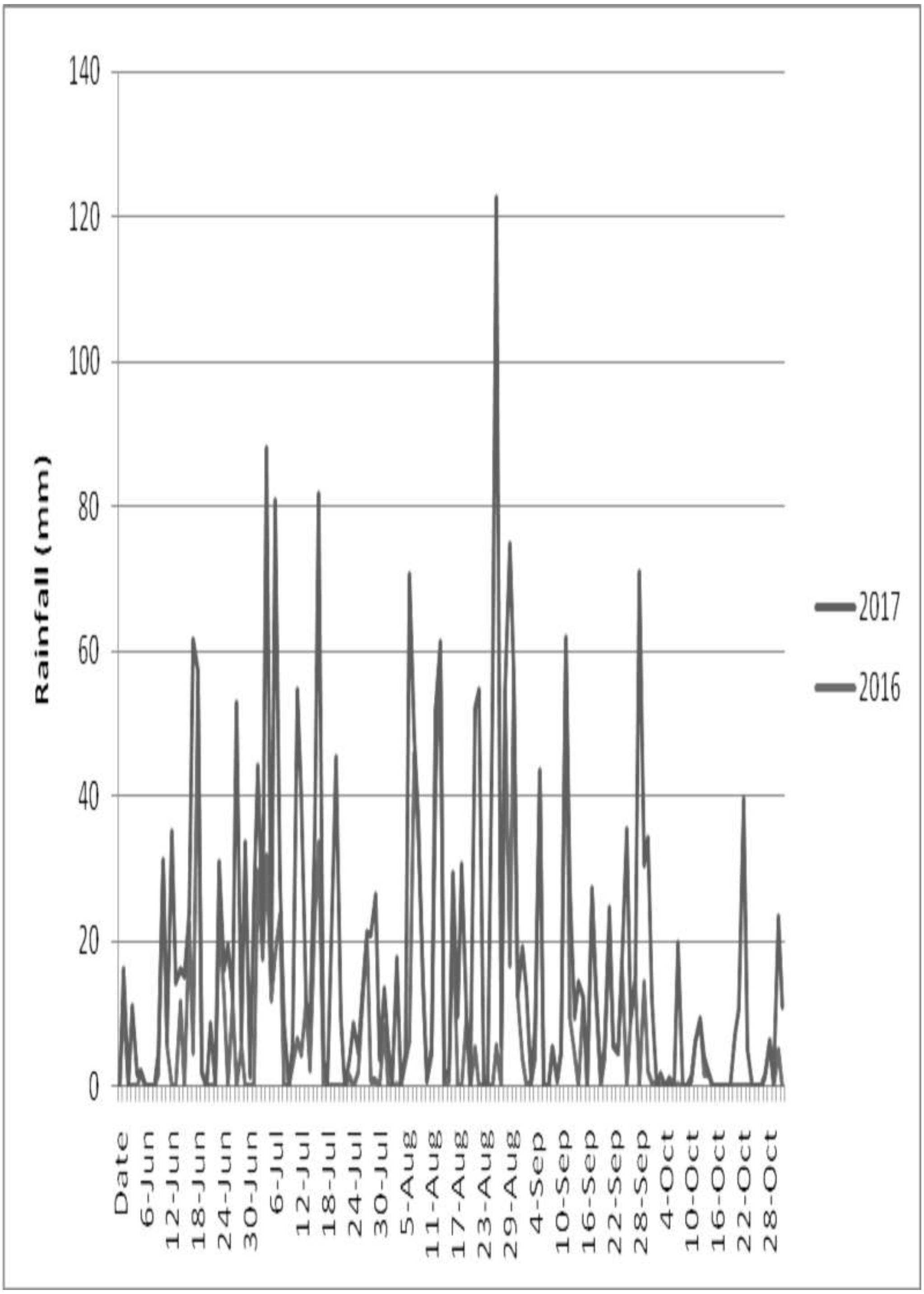

Fig. 3.1 Rainfall data during the cropping season

3.2 Experimental details

3.2.1 Design and Layout

The experiment which was conducted consisted of the following components:

a)	Crops	: Soybean (*Glycine max* L.) and Maize (*Zea mays* L.)
b)	Experimental design	: Strip plot design
c)	Plot size	: 3 m x 2 m
d)	Spacing	: Soybean-45cm x 10cm and Maize – 60 cm x 25 cm
e)	Number of mainfactors	: 3
f)	Number of sub plot	: 6
g)	Total number of combinations:	: 18
h)	Total number of replications	: 3
i)	Total number of plots	: 54
j)	Method of sowing	: Line sowing
k)	Varieties	: Soybean – JS-9752 Maize- RCM 76

3.2.2 Treatments details

Main factors: 3

Slope percent: 3

Symbol used	Slope (%)
S_1	0
S_2	9
S_3	20

Sub plot factors:

Intercropping treatment: 6

Symbol used	Treatments
T_1	Control
T_2	Sole Soybean
T_3	Sole Maize
T_4	Soybean + Maize (1:1)
T_5	Soybean + Maize (2:1)
T_6	Soybean + Maize (1:2)

3.2.3 Treatment Combinations

There were a total of 18 treatment combinations as obtained from the multiplication of three main factors and six sub factors.

S_1T_1	S_1T_2	S_1T_3	S_1T_4	S_1T_5	S_1T_6
S_2T_1	S_2T_2	S_2T_3	S_2T_4	S_2T_5	S_2T_6
S_3T_1	S_3T_2	S_3T_3	S_3T_4	S_3T_5	S_3T_6

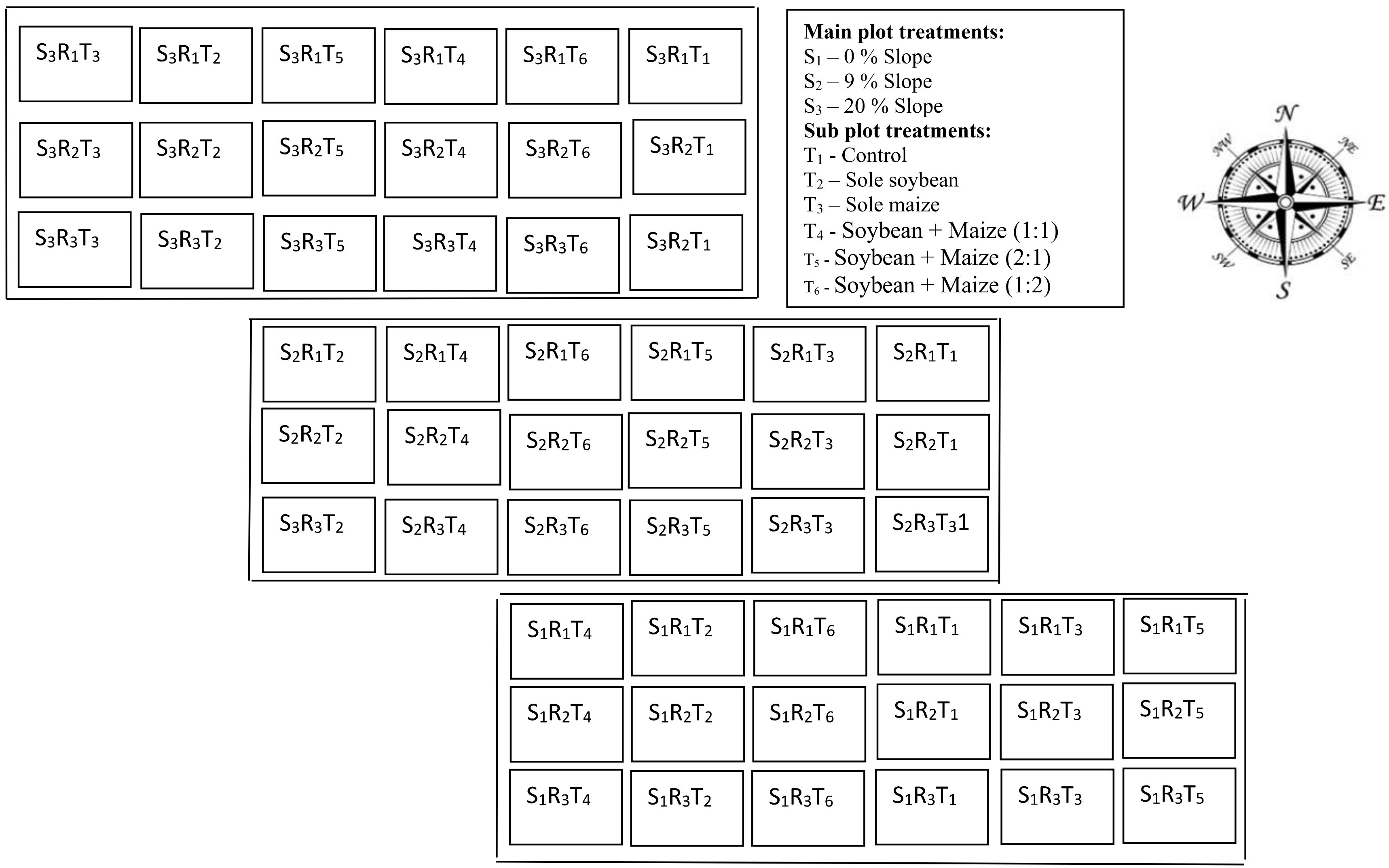

Fig. 3.2 Layout of experimental field

3.3 Soil analysis

Initial soil samples (one sample from each strip) and the soil samples collected from individual plots after harvest of crops were analysed for the following properties

- pH
- Organic carbon
- Cation exchange capacity
- Water holding capacity
- Bulk density
- Soil aggregation
- Mean weight diameter
- Available N, P, K

Soil samples from individual plots were collected after the harvest of the crop and air-dried. Five soil samples from each plot were collected, mixed thoroughly and composited using quadrate method to retain about 500 g representative soil. Two third of each sample were ground to pass through 2 mm sieve and kept in polythene bags for laboratory analysis. The remaining portion of soil samples was preserved for analysis of mean weight diameter and percent aggregation.

3.3.1 Soil sample collection and preparation for analysis

The soil samples were collected in a random zig zag manner from the surface of the plough upto 0-15 cm (generally expressed as plough layer).The collected soil samples were quartered until 250-500 g composite samples was obtained. The air-dry soil samples were then passed through 2mm sieve for analysis. For certain type of soil analysis (organic carbon) it becomes necessary to grind the soil further. So, the soil samples were passed through finer mesh sieve (size 0.2-0.5 mm).

3.3.2 Soil analysis methods

The available N in the soil was determined by using the method of alkaline permanganate as suggested by Subbiah and Asija (1956). The P extract of the soil was obtained by Bray's method No. 1 (Brays and Kurtz, 1945). The P content of the extract was estimated colorimetrically (Dickman and Bray, 1940). The available K was determined by Ammonium Acetate Extraction method (Hanway and Heidel, 1952).

Soil pH was determined by Potentiometric method as described by Baruah and Borthakur (1999). Organic carbon was determined by using Walkley-Black procedure with wet digestion method as outlined by Jackson (1973). The Cation exchange capacity (CEC) of the soil was determined by NH_3 distillation method (Jackson, 1973). Water holding capacity was obtained as per the procedure described by Piper (1966).Bulk Density of soil was determined by following the procedure as described by Baruah and Borthakur (1999). Micronutrients viz. iron, zinc, copper and manganese were extracted from soil by DTPA method as outlined by Lindsay and Norvell (1978). Soil microbial biomass carbon (SMBC) was obtained from soil by 0.5 M K_2SO_4 as per fumigation and extraction method by Vance *et al*. (1987).

Soil loss and runoff Volume was estimated by Direct method using procedure for slot (plot) devices sampling as follows:

Drums (Brite) were placed in the field for collecting data (runoff samples containing silt). These Runoff samples were collected from individual rainfall events throughout the year during and after the rainfall on a daily basis. The runoff water inside the drums, preferably measured in litres was churned out thoroughly to have a uniform mixture solution of it. Samples were taken out and filtered properly through separate filter papers. Silt settled on the filter paper were then properly dried and weighted in grams. This dried soil was the amount of soil loss taken place from the experimental plot. The rate of soil loss was thus calculated as the weight of soil/silt divided by the volume of runoff expressed as gm per litres per square meter of the plot area, which later was converted to tonnes/cubic meter of runoff produced and also in terms of tonnes per hectare of land of the watershed. In this process, all the runoff samples were measured and calculated to arrive at the average soil loss per hectare of the area for the given year.

For determination of Mean weight diameter (MWD), air-dried natural clod samples were broken with gentle pressure and passed through 8 mm mesh sieve and retained on 5 mm sieve. Fifty grams of soil retained on 5 mm mesh sieve were transferred to the topmost sieve of the nest of the sieves arranged in the order of 5 mm, 2mm, 1mm, 0.5mm and 0.25mm. The arranged sieves were then emerged under water for 30 minutes and shaken in Yoder's apparatus for 30 minutes. Fractions retained in each sieve was collected, oven dried at equilibrium temperature for 24 hours, weighed and percent aggregation (of various sizes) was calculated. MWD was then calculated from the equation given by Van Bavel (1949) as follows:

$$MWD = \sum_{i=1}^{N} x_i d_i$$

Where, x_i = Mean diameter of each size fraction, and

d_i = Proportion by weight of each size fraction

Summation of all the fractions > 0.25 mm in wet sieving gave percent macro-aggregates.

Plate 1. Research Plots before field activities

Plate 2: Soil sample collection

Plate 3: Field clearing

Plate 4: Field measurement and preparation

Plate 5: Pipe fixation (Arrangement)

Plate 6: Crop varieties used for sowing

Plate 7: Sowing of crops

Plate 8: Crops at germination stage

Plate 9: Standing crops in the field

3.4 Observations on crops

The experiment was conducted for two consecutive years and the following observations were recorded each year.

3.4.1 Soybean

3.4.1.1 Plant height (cm)

The plant height was measured from the base of the plant to the tip of the shoot apex at an interval of 30, 60, 90 days till harvest in centimeters from each plot and average was recorded.

3.4.1.2 Leaves plant^{-1}

The number of leaves plant^{-1} was counted from 5 randomly tagged plants from each plot at 30 days interval throughout the crop growing season. The values were average for each plot.

3.4.1.3 Dry weight of plants (After harvest)

The plants were carefully removed with the help of spade. Uprooted plants from each plot were washed in running water, oven dried and weighed.

3.4.1.4 Pods plant^{-1}

The number of pods plant^{-1} was recorded from 5 (five) selected plants at random from each plot and the average was taken to get the pods plant^{-1}.

3.4.1.5 Filled pods plant^{-1}

Number of filled pods plant^{-1} was recorded from 5(five) tagged plants and the values were averaged to get the filled pods per plant.

3.4.1.6 Number of seeds pod^{-1}

The number of pods plant $^{-1}$was counted from 5 (five) selected plants at random from each plot and the average was taken to obtain the number of seeds pod^{-1}.

3.4.1.7 Test Weight (100 grain weight)

100 seeds were counted from the samples collected from each plot and their weight was recorded.

3.4.1.8 Grain yield (kg ha^{-1})

After proper sun drying of the grains, the grain yield of net area of each plot was taken on treatment basis and the yield per plot of each treatment was expressed in kg ha^{-1}. The grain yield obtain from each plot was recorded and converted into kg ha^{-1} using the formula.

$$\text{Seed yield (kg ha}^{-1}\text{)} = \frac{\text{Weight of the seed per plot}}{\text{Size of the plot}} \times 10000$$

3.4.1.9 Stover yield (kg ha^{-1})

The plant (Stover) harvested from net area of each plot was sun dried for about a week and their weight was taken and recorded separately and thereafter Stover yield per plot was converted into kg ha^{-1} using the formula.

$$\text{Stover yield (kg ha}^{-1}\text{)} = \frac{\text{Weight of the Stover per plot}}{\text{Size of the plot}} \times 10000$$

3.4.1.10 Harvest index (%)

Harvest index (HI) was calculated by using the formula given by Donald (1962).

$$HI = \frac{\text{Economic yield (Seed yield)}}{\text{Biological yield (Seed yield + Straw yield)}} \times 100$$

3.4.2 Maize

3.4.2.1 Plant height

The plant height was taken from five tagged plants from each plot at 30 days interval throughout the crop growing season. The height was measured from the base of the plant to the tip of the upper most leaf initially but after tasseling,the height was measured up to the top of the tassel and averaged in centimetre for statistical analysis.

3.4.2.2 Leaves per plant

The number of leaves plant^{-1} was counted from 5 randomly tagged plants from each plot at 30 days interval throughout the crop growing season. The values were averaged for each plot.

3.4.2.3 Dry weight of plants (After harvest)

The plants were carefully removed with the help of spade. Uprooted plants from each plot were dried and measured.

3.4.2.4 Cobs per plant

Number of cobs plant^{-1} was recorded from the selected 5 plants. The values were averaged for each plot.

Plate 10: Soil sample run-off collection

Plate 11: Collection of crop growth parameters

Plate 12: Field inspection with advisor

Plate 13: Soil sample processing

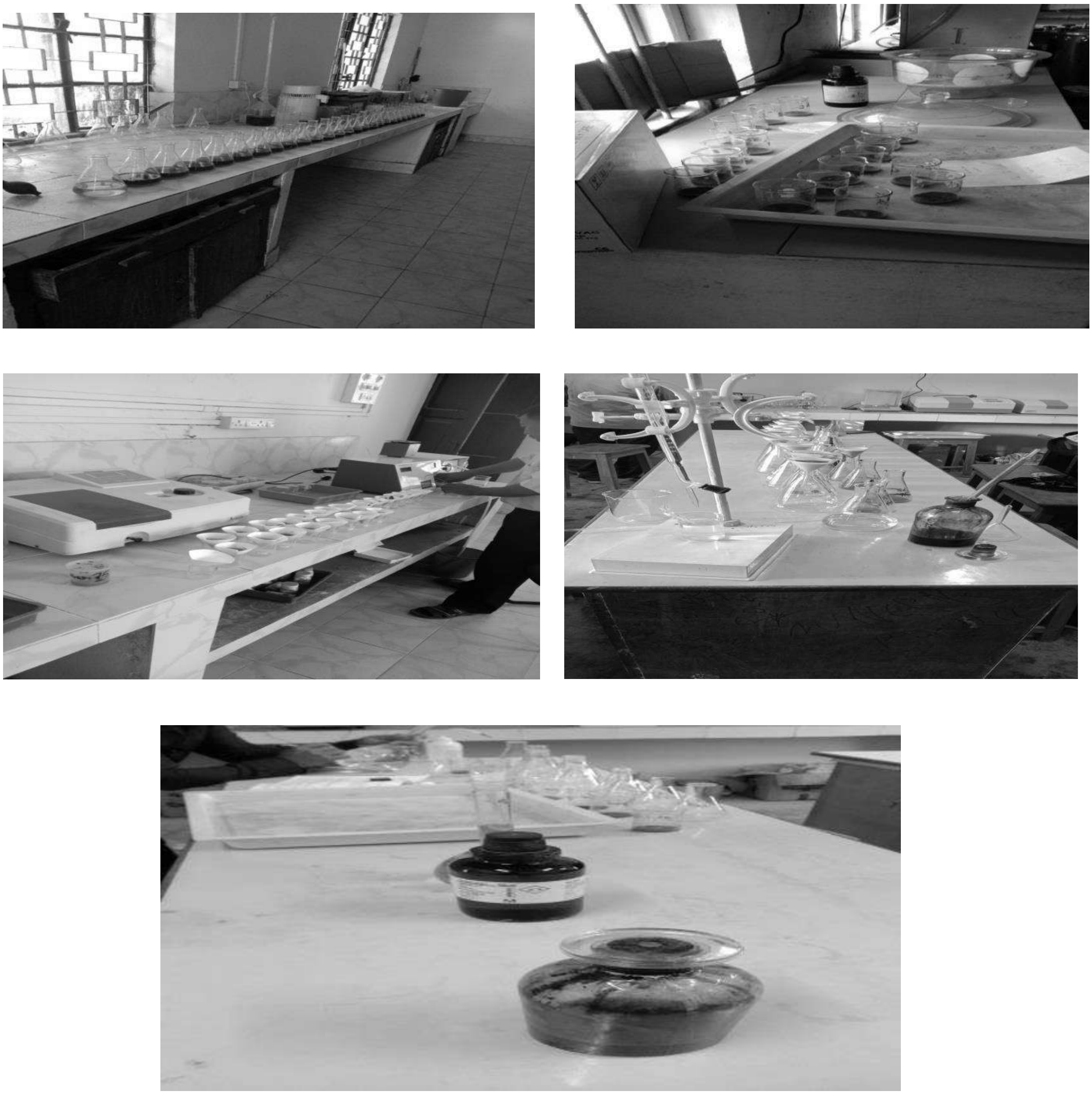

Plate 14: Soil sample analysis in laboratory

3.4.2.5 Grains per plant

Grains from the 5 (five) randomly selected cobs of each plot were counted and their average taken as number of grains cob^{-1}.

3.4.2.6 Test Weight (100 grain weight)

100 seeds were counted from the samples collected from each plot and their weight was recorded.

3.4.2.7 Grain yield (kg ha^{-1})

After proper sun drying of the grains, the grain yield of net area of each plot was taken on treatment basis and the yield per plot of each treatment was expressed in kg ha^{-1}. The grain yield obtain from each plot was recorded and converted into kg ha^{-1} using the formula.

$$\text{Seed yield (kg ha}^{-1}) = \frac{\text{Weight of the seed per plot}}{\text{Size of the plot}} \times 10000$$

3.4.2.8 Stover yield (kg ha^{-1})

The plant (Stover) harvested from net area of each plot was sun dried for about a week and their weight was taken and recorded separately and thereafter Stover yield per plot was converted into kg ha^{-1} using the formula.

$$\text{Stover yield (kg ha}^{-1}) = \frac{\text{Weight of the Stover per plot}}{\text{Size of the plot}} \times 10000$$

3.4.2.9 Harvest index (%)

Harvest index (HI) was calculated by using the formula given by Donald (1962).

$$HI = \frac{\text{Economic yield (Seed yield)}}{\text{Biological yield (Seed yield + Straw yield)}} \times 100$$

3.5 Plant analysis

3.5.1 Estimation of protein and oil content percentage in seeds

Protein content in the seeds was estimated for each treatment by multiplying the seed N by factor 6.25.

Seed sample of 5 g each from all the treatment (plot wise) was taken for oil extraction. The grinded seed were sited in a thimble and extracted with light petroleum Ether for 6 hours in a Soxhlet Extraction method as suggested by the Association of Official Analytical Chemists (AOAC,1980). Thereafter the extract was transferred to weight flask,the solvent distilled of and the last traces of solvent and moisture being removed by treating the flask at 100-150° C. Next, the flask was cooled and reweighted, thus the oil content percentage in the seed was calculated as given below:

$$\text{Per cent oil} = \frac{(W_2 - W_1) \times 100}{X}$$

Where,

W_2 = Weight of empty flask (g)

W_1= Weight of empty flask + Weight of oil (g)

X = Weight of seed sample used for oil extraction (g)

3.6 N, P and K content and uptake

Randomly selected plant samples were collected treatment wise for chemical estimation. Seed and grains were segregated, air-dried and lastly oven dried at a temperature of 65°C and grounded in Wiley Mill to pass through a

30-mesh sieve. Seed and straw samples were analyzed for nitrogen by modified Kjeldahl's method (Jackson, 1973), phosphorus by di-acid digestion and yellow colour development method (Jackson, 1973) and potassium by flame photometric method (Jackson, 1973). The uptake was further calculated by the below formula

Nutrient uptake (kg ha^{-1}) =

$$\frac{\text{Nutrient (\%) in grain or straw x grain or straw yield (kg ha}^{-1})}{100}$$

3.7 Economic studies

Total cost for the system was calculated separately by taking into account all investments (labour and inputs) at prevailing market prices. The value of the main products and by-products in terms of monetary value was calculated separately based on prevailing market price and was recorded on unit area basis. Net return was worked out by subtracting the cost of cultivation from the corresponding gross returns and expressed as Rsha^{-1}. The benefit cost ratio (BCR) was calculated by using the following formula

$$\text{B: C ratio} = \frac{\text{Net returns}}{\text{Cost of cultivation}} \times 100$$

3.8Statistical analysis

The data recorded during the course of experimentation were analysed and computed. Critical Difference (CD) means at 5% probability level of significance was worked out for comparison and statistical interpretation of treatments. The statistical analysis of the data was done as per procedure outlined by Gomez and Gomez (2010).

CHAPTER IV

RESULTS AND DISCUSSION

RESULTS AND DISCUSSION

This chapter makes an attempt to discuss in brief the variations of crop growth due to intercropping and varying slopes and soil loss due to slope gradient under different treatments. Generalized and classified results are presented here along with tables and graphs. The results obtained through the experiment is also discussed along with suitable evidences based on experiments carried out elsewhere to draw valid conclusions for scientific and practical utility. Interaction effects of treatments on observed parameters are presented only wherever found significant.

4.1. Effect of rainfall on Soil loss and Crop:

Weather parameters play a key role on the performance of soil loss as well as crop during field experimentation. Rainfall data during the period of investigation i.e. *kharif* seasons of 2016 and 2017 has been presented in Fig. 3.1 and appendix I and II.

Weather during both the years was congenial and favourable and there were no drastic changes which resulted in crop loss. Crop performance and yield was also observed to be comparable to each other during both the years. Due to high rainfall pattern in the state, it was extremely difficult to collect all the run-off as the buckets overflew resulting in loss of run-off (mixture of soil and rain water) during certain times. However, to the maximum extent possible, the run-off was collected by transferring to secondary buckets manually during rains for siltation and collection of soil. Crop growth on the other hand was not affected due to weather conditions and no visible trend was observed during the two years of experimentation.

4.1.1. Slope gradient and intercropping effect on soil loss and run off:

The data on soil loss and runoff pertaining to the effect of slope gradient and intercropping were presented in Table 4.1. The variations were very wide with each increase in slope both for soil loss as well as run off. S_1 recorded minimum soil loss (4.84 and 4.9 t ha^{-1} yr^{-1}) as well as run off (440.46 and 495.93 ls^{-1}) while S_3 recorded the maximum values of both soil loss (45.82 and 46.39 t ha^{-1} yr^{-1}) and run-off (1707.34 and 1728.57 ls^{-1}). The differences were significant among the treatments. With the increase in slope gradient, there is an increase in the velocity of run off depending on the steepness. In our present case too, with the increase of slope, at same or different level of rainfall intensities the rate of runoff velocity must have increased manifold which resulted in more soil loss as the scouring capacity of the soil also increased proportionately. The same trend was also observed in the case of runoff. This finding is in agreement with several others (Defersha and Melesse, 2012; Sajjadi and Mahmoodabadi, 2015; Mahmoodabadi and Sajjadi, 2016) who reported that slope is positively correlated with soil erosion. At 0 % slope, the rain drops falling on the soil received more time duration for infiltration thus resulting in lesser amount of runoff. Bo *et al.* (2019) also reported that runoff rate and sediment yield increased with slope gradient while decreasing with the presence of crops, a phenomenon which played an important role in soil and water loss on sloping farmland. However, with the increase in slope gradient, the time window available for infiltration or seepage was reduced resulting in higher runoff irrespective of the intensity as rainfall intensity factor could not be taken into account in the present study.

Among the intercropping treatments, sole soybean recorded minimum values of soil loss (22.98 and 23.27 t ha^{-1} yr^{-1}) as well as run off (1040.93 and 1053.87 ls^{-1}) during both the years which was followed by and comparable to soybean + maize (2:1). Sole maize on the other hand recorded highest values of both soil loss and run off during both years. This finding is in conformity with Jinhua *et a.* (2020) who found that the runoff and soil loss from uncultivated land were much higher than from cultivated plots, and soybeans gave better protection from runoff and soil loss than maize on the same slopes. As soybean is a short statured plant and is bushy in nature, it acted as an erosion resistant crop by way of reducing the velocity of rain drops hitting the ground thus reducing splash erosion ultimately leading to low soil loss. The velocity of run off also may have been reduced due to the leafy nature and more ground cover as compared to maize. Soybean + maize in the ratio of 2:1 recorded least soil loss and run off among the intercropping ratios. On an average, the practice of sole soybean and soybean + maize (2:1) caused a reduction of 15.97and 12.13% soil loss, respectively as compared to control.

The interaction effect of intercropping and slope on soil loss was found significant and the data has been presented in Table 4.1a. In the first year, control treatment at 20 % slope recorded highest soil loss followed by sole maize at the same degree of slope. 0 % slope on the other hand suffered minimal soil loss with sole soybean recording the least values of 3.62 t ha^{-1} yr^{-1}. Similar trend was also observed in the second year of experimentation. By and large, 0 % slope recorded lesser soil loss irrespective of intercrop. Soybean being low statured covered the ground better compared to maize thus resulting in lesser soil loss.

Interaction effect of intercropping and slope was also found significant for run-off. Sole soybean in combination with 0 % slope recorded least run-off. This was followed by soybean + maize (1:2) which was at par with the rest of the treatments under 0 % slope. Run-off was found to be affected more by slope percentage though the intercropping treatments had varying effects on run – off. Control treatment at 20 % slope recorded the maximum run-off during both the years of field experimentation. Apart from 0 % slope, combination of control treatment and slope recorded significantly higher values than its counterparts.

Table 4.1: Effect of intercropping and slope on soil loss and run-off

Treatments	Soil loss (t $ha^{-1}yr^{-1}$)		Run off (ls^{-1})	
Slope	**2016**	**2017**	**2016**	**2017**
S_1 (0)	4.84	4.90	440.46	445.93
S_2 (9)	24.87	25.18	1421.81	1439.48
S_3 (20)	45.82	46.39	1707.34	1728.57
SEm±	0.60	0.60	56.76	57.46
CD at 5%	2.34	2.34	222.87	225.64
Crop				
T_1 - Control	27.35	27.69	1345.93	1362.66
T_2 - Sole Soybean	22.98	23.27	1040.93	1053.87
T_3 - Sole Maize	26.51	26.84	1272.50	1288.32
T_4 - Soybean +Maize (1:1)	24.93	25.24	1266.81	1169.17
T_5 - Soybean +Maize (2:1)	24.03	24.33	1058.23	1071.39
T_6 - Soybean +Maize (1:2)	25.27	25.58	1154.81	1282.56
SEm±	1.02	1.02	113.79	115.2
CD at 5%	3.20	3.23	358.57	363.03

Table 4.1a Interaction effect of intercropping and slope on soil loss (t ha^{-1} yr^{-1})

Treatments	**Slope**					
Crop	**2016**			**2017**		
	S_1	**S_2**	**S_3**	**S_1**	**S_2**	**S_3**
T_1 - Control	6.18	27.47	48.40	6.26	27.81	49.00
T_2 - Sole Soybean	3.62	22.23	43.10	3.66	22.51	43.64
T_3 - Sole Maize	5.66	26.50	47.37	5.73	26.83	47.96
T_4 - Soybean +Maize (1:1)	4.51	24.63	45.63	4.57	24.94	46.20
T_5 - Soybean +Maize (2:1)	4.16	23.13	44.80	4.21	23.42	45.36
T_6 - Soybean +Maize (1:2)	4.94	25.27	45.60	5.00	25.58	46.17
		SEm±	**CD (*P*=0.05)**		**SEm±**	**CD (*P*=0.05)**
For comparison between intercropping treatments at same level of slope		2.04	6.02		2.03	6.00
For comparison between slopes at same or different intercropping treatments		2.34	3.20		2.34	3.23

Table 4.1b Interaction effect of intercropping and slope on run-off (l s^{-1})

Treatments	Slope					
Crop	2016			2017		
	S_1	S_2	S_3	S_1	S_2	S_3
T_1 - Control	463.71	1579.23	1994.84	469.47	1598.86	2019.64
T_2 - Sole Soybean	371.45	1257.49	1835.50	376.06	1273.12	1858.33
T_3 - Sole Maize	454.96	1357.82	1361.92	460.62	1374.71	1378.85
T_4 - Soybean +Maize (1:1)	455.66	1466.61	1878.16	461.32	1484.85	1901.51
T_5 - Soybean +Maize (2:1)	448.61	1376.41	1297.77	454.18	1393.53	1313.90
T_6 - Soybean +Maize (1:2)	448.36	1493.26	1875.87	453.93	1511.83	1899.19
		SEm±	**CD (*P*=0.05)**		**SEm±**	**CD (*P*=0.05)**
For comparison between intercropping treatments at same level of slope		199.24	587.76		201.72	595.06
For comparison between slopes at same or different intercropping treatments		56.76	222.87		57.47	225.64

4.1.2. Crop parameters:

4.1.2.1. Plant height of soybean:

The data on plant height recorded at 30, 60 and 90 DAS are presented in Table 4.2. The difference in plant height among the different slope gradients was found to be significant at all stages of crop growth. 0 % slope recorded significantly higher plant height followed by 9 % and 20 %. The variations were observed to be significant at all stages and it followed a similar trend throughout. The differences in height may be attributed to slope gradient as crop on higher degrees of slope faced greater amount of soil loss and more stress as compared to those on 0 % slope.

Data recorded also revealed that intercropping had significant effect on plant height. The variations in this case were however not very prominent among all the treatments at all stages. Proper observation of data showed that sole soybean and soybean intercropped with maize in 1:1 ratio had better height as compared to the rest. The better height in these cases may be due to lesser competition and more availability of nutrients for plant growth. The better plant height observed in sole soybean than the various intercropping treatments at different successive growth stages may be due to the absence of intercrop competition. This result corresponds with those of Kithan (2012), Aye (2013) and Yhokha (2015). Poor soybean growth due to intercropping in additive series was also reported by Maurya and Rathi (2000) and Layek *et al*. (2015).

Table 4.2: Effect of intercropping and slope on plant height of soybean at 30, 60 and 90 DAS

Treatments	Plant height (cm)					
	30 DAS		60 DAS		90 DAS	
Slope	**2016**	**2017**	**2016**	**2017**	**2016**	**2017**
S_1 (0)	15.99	16.15	34.20	30.58	36.64	32.92
S_2 (9)	13.23	13.28	31.11	21.93	32.78	23.33
S_3 (20)	10.73	10.70	27.65	17.86	30.94	20.20
SEm±	0.42	0.36	0.57	0.60	0.64	0.62
CD at 5%	1.66	1.42	2.22	2.35	2.50	2.44
Crop						
T_1 - Control	0.00	0.00	0.00	0.00	0.00	0.00
T_2 - Sole Soybean	21.89	21.22	47.26	37.43	50.52	41.15
T_3 - Sole Maize	0.00	0.00	0.00	0.00	0.00	0.00
T_4 - Soybean +Maize (1:1)	19.22	21.28	48.63	36.33	52.49	38.00
T_5 - Soybean +Maize (2:1)	19.52	20.70	46.26	33.52	50.35	36.08
T_6 - Soybean +Maize (1:2)	19.28	17.06	43.79	33.46	47.36	37.69
SEm±	0.62	0.35	1.35	0.72	1.19	1.71
CD at 5%	1.96	1.11	4.26	2.26	3.74	5.38

Note: No crops grown in T_1 – Control. No soybean grown in T_3 – Sole Maize

4.1.2.2. No. of leaves and biomass per plant of soybean at harvest:

The data on plant dry weight recorded at 30, 60 and 90 DAS are presented in Table 4.3. Among the different slopes, 0 % slope was observed to record the highest number of leaves per plant during both years at all stages of crop growth. The higher values here may be attributed to the plant growing in stress free condition of leveled land and having better nutrient as the loss of top soil due to erosion was negligible. This was followed by 9 % and 20 % at all stages during both years. The higher slope gradient of 20 % recorded the least biomass among the three different slopes. The variations were observed to be significant and of similar trend during both years. Dry weight of plant of soybean at harvest was also significantly higher in S_1 during both the years of experimentation. The variations were however not significant.

Among the different intercropping methods, no regular trend could be observed for the number of leaves per plant. However, for dry weight of plant at harvest, sole soybean recorded higher biomass compared to the rest of the treatments which may be attributed to less competition. It was however observed to be at par with the other intercropping ratios except sole maize.

Table 4.3: Effect of intercropping and slope on no. of leaves of soybean at 30, 60 and 90 DAS and dry weight/plant at harvest

Treatments	No. of leaves/plant						Dry weight (g/plant)	
	30 DAS		60 DAS		90 DAS			
Slope	**2016**	**2017**	**2016**	**2017**	**2016**	**2017**	**2016**	**2017**
S_1 (0)	3.20	3.76	8.03	9.22	8.84	11.98	18.19	18.06
S_2 (9)	2.85	3.69	4.8	5.72	5.70	7.20	18.03	17.89
S_3 (20)	1.80	3.11	3.76	4.04	4.47	4.85	17.98	17.84
SEm±	0.08	0.16	0.15	0.23	0.15	0.21	0.56	0.59
CD at 5%	0.32	0.65	0.61	0.91	0.57	0.82	NS	NS
Crop								
T_1 - Control	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T_2 - Sole Soybean	4.07	5.34	8.71	10.37	10.01	12.93	27.27	27.09
T_3 - Sole Maize	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T_4 - Soybean +Maize (1:1)	4.00	5.85	7.78	11.22	8.80	14.41	27.04	26.89
T_5 - Soybean +Maize (2:1)	3.63	5.41	7.06	8.41	8.28	10.59	27.10	26.94
T_6 - Soybean +Maize (1:2)	4.00	4.52	9.63	7.96	10.93	10.15	26.98	26.64
SEm±	0.10	0.15	0.33	0.32	0.27	0.32	0.79	0.77
CD at 5%	0.33	0.46	1.04	1.02	0.87	1.00	2.49	2.44

***Note*:** No crops grown in T_1 – Control. No soybean grown in T_3 – Sole Maize

4.1.2.3. Yield attributes of soybean:

The effect of slope on yield attributes as is evident from Table 4.4 was observed to be higher at 0 % slope. The number of pods/plant though higher at 0 % slope was comparable to the rest of the main treatments. The same was observed in the case of number of filled pods/plant for both the years. The number of seeds/pod was also not significantly affected by the varying degrees of slope. Test weight was also not affected significantly by slope.

Except for the control plots and sole cropped plots where soybean was not planted, neither of the yield attributes was affected significantly by the intercropping treatments. The lower number of soybean pods/plant obtained in intercrop could be due to shading and competitive effect by the taller maize as reported by Dalai (1977). Yield reduction in intercrop was related to reduce number of pods/plant because number of pods significantly influences yield. (Akanda and Quayyaum, 1982).

Table 4.4: Effect of intercropping and slope on number of pods/plant, filled pods/plant, seeds/pod and test weight of soybean

Treatments	Pods/plan (No.)		Filled pods/plant (No.)		Seeds/pod (No.)		Test weight (g)	
Slope	**2016**	**2017**	**2016**	**2017**	**2016**	**2017**	**2016**	**2017**
S_1 (0)	58.29	56.87	57.07	55.53	2.00	1.98	55.52	55.40
S_2 (9)	54.23	52.82	52.95	51.48	2.00	1.98	55.45	55.38
S_3 (20)	52.79	51.46	51.52	49.57	2.04	2.00	54.78	54.71
SEm±	1.85	1.63	1.67	1.62	0.02	0.02	1.11	1.08
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS
Crop								
T_1 - Control	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T_2 - Sole Soybean	85.35	83.11	84.69	80.78	3.11	3.00	82.95	82.85
T_3 - Sole Maize	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T_4 - Soybean +Maize (1:1)	83.77	81.64	81.44	79.42	3.00	3.00	82.90	82.69
T_5 - Soybean +Maize (2:1)	81.59	79.90	79.25	77.57	3.00	3.00	82.85	82.75
T_6 - Soybean +Maize (1:2)	79.92	77.63	77.70	75.41	2.96	2.93	82.80	82.70
SEm±	1.82	2.51	1.96	2.04	0.03	0.06	1.57	1.53
CD at 5%	5.72	7.91	6.73	7.31	0.09	0.18	4.95	4.83

***Note*:** No crops grown in T_1 – Control. No soybean grown in T_3 – Sole Maize.

4.1.2.4. Yield and harvest index of soybean:

Data pertaining to yield and harvest index as presented in Table 4.5 showed better yields and harvest index at 0 % slope compared to the rest. Treatments at 0 % slope gave higher yields as well as harvest index during both years. The higher yield can be attributed to better growing conditions as compared to steeper gradients and more nutrients as there was minimal loss of top soil and equal distribution of sunlight. The harvest index was however not affected by the differences in slope.

Among the various intercropping ratios followed, sole soybean gave the highest yield for both years irrespective of slope. Sole soybean recorded the highest seed yield since it suffered from inter specific competition in the intercropping treatment. Similar results were reported by Sawargi and Tripathi (1999) in rice and soybean intercropping system, Kithan (2012) in maize and soybean intercropping system, Aye (2013) in sunflower and soybean and Yhokha (2015) in soybean-based intercropping. Mouneke *et al*. (2007) also reported higher seed yield of soybean in sole cropping than intercropping with cereals. This can be attributed to lesser competition. In the case of intercropping the growth as well as yield attributes may have been reduced due to competition from maize, as maize is a tall plant which may have induced shading effect on soybean plants resulting in lesser productivity. When the crop with large canopy intercropped with the small crops, such as maize and soybean intercropping, soybean yield could decrease due to interspecific light competition (Liu *et al*., 2017). Reduction in yield of soybean due to competition when intercropped with maize where there were negligible effects on maize yield has also been reported by several other authors (Hiebsch, 1980; Ahmed and Rao, 1982; Chui and Shibbles, 1984; Singh, 2002). Olufajo and Singh (2002) also reported lower productivity of legumes in legume-cereal intercropping mainly due to competition. In the present study too, soybean being short statured compared to maize recorded lower yields when intercropped with maize than when grown alone and is in corroboration with the findings of Maurya and Rathi (2000). In addition, the availability of nutrients may also have been higher as there was less crowding in the case of mono cropped soybean.

Intercropping and slope interaction was observed to be significant and the data is presented in Table 4.5a. sole soybean at 0 % slope recorded higher values while soybean +maize (1:2) at 20 % slope recorded the least values. Higher yield in sole soybean might be attributed to higher plant population as compared to the intercropping treatments. Similar trend was observed during both the years. Another reason of having higher yields could be the better soil fertility owing to fixation of nitrogen and lesser washing away of top soil due to the soybean plants covering the soil and reducing splash erosion compared to maize.

Interaction effect of intercropping and slope was found significant in the case of stover yield of soybean as can be seen from table 4.5b. Combination of 0 % slope and sole soybean recorded higher values as compared to the rest for both the years. The higher biomass might be due to higher plant population in the case of sole soybean. Also, lesser loss of nutrient rich top soil in the case of lesser slope helped the plant in growing better as can be seen from the data where higher degrees of slope recorded lesser stover yields. Soybean +maize (1:2) recorded the minimum stover yields irrespective of slope due to lesser population of soybean as compared to the other intercropping treatments.

Table 4.5: Effect of intercropping and slope on grain yield, stover yield and harvest index of soybean

Treatments	Grain yield (kg ha^{-1})		Stover yield (kg ha^{-1})		Harvest index (%)	
Slope	**2016**	**2017**	**2016**	**2017**	**2016**	**2017**
S_1 (0)	1078.6	1060.0	1863.9	1832.8	24.56	24.35
S_2 (9)	960.0	926.7	1761.7	1729.4	23.48	23.23
S_3 (20)	925.5	892.2	1648.9	1621.1	23.94	23.63
SEm±	29.86	34.5	55.5	56.02	0.71	0.74
CD at 5%	117.2	135.6	216.4	219.9	NS	NS
Crop						
T_1 - Control	0.00	0.00	0.00	0.00	0.00	0.00
T_2 - Sole Soybean	1610.0	1560.0	2758.9	2720.0	37.10	36.78
T_3 - Sole Maize	0.00	0.00	0.00	0.00	0.00	0.00
T_4 - Soybean +Maize (1:1)	1476.6	1426.7	2653.3	2607.8	35.74	35.35
T_5 - Soybean +Maize (2:1)	1492.2	1440.0	2624.4	2575.6	36.24	35.85
T_6 - Soybean +Maize (1:2)	1349.4	1297.8	2512.2	2463.3	34.88	34.44
SEm±	40.5	36.75	75.61	77.67	1.06	0.97
CD at 5%	127.8	115.8	238.6	244.7	NS	NS

***Note*:** No crops grown in T_1 – Control. No soybean grown in T_3 – Sole Maize

Table 4.5a: Interaction effect of intercropping and slope on grain yield of soybean (kg ha^{-1})

Treatments	Slope					
Crop	2016			2017		
	S_1	S_2	S_3	S_1	S_2	S_3
T_1 - Control	0.00	0.00	0.00	0.00	0.00	0.00
T_2 - Sole Soybean	1726.67	1566.67	1536.67	1676.67	1516.67	1486.67
T_3 - Sole Maize	0.00	0.00	0.00	0.00	0.00	0.00
T_4 - Soybean +Maize (1:1)	1610.00	1436.67	1383.33	1560.00	1386.67	1333.33
T_5 - Soybean +Maize (2:1)	1623.33	1470.00	1383.33	1566.67	1420.00	1333.33
T_6 - Soybean +Maize (1:2)	1511.67	1286.67	1250.00	1456.67	1236.67	1200.00
		SEm±	**CD (*P*=0.05)**		**SEm±**	**CD (*P*=0.05)**
For comparison between intercropping treatments at same level of slope		68.60	202.36		29.86	117.24
For comparison between slopes at same or different intercropping treatments		70.72	208.61		36.75	115.80

Table 4.5b: Interaction effect of intercropping and slope on stover yield of soybean (kg ha^{-1})

Treatments	Slope					
Crop	2016			2017		
	S_1	S_2	S_3	S_1	S_2	S_3
T_1 - Control	0.00	0.00	0.00	0.00	0.00	0.00
T_2 - Sole Soybean	2983.33	2726.67	2566.67	2933.33	2676.67	2550.00
T_3 - Sole Maize	0.00	0.00	0.00	0.00	0.00	0.00
T_4 - Soybean +Maize (1:1)	2796.67	2696.67	2466.67	2760.00	2646.67	2416.67
T_5 - Soybean +Maize (2:1)	2816.67	2623.33	2433.33	2766.67	2576.67	2383.33
T_6 - Soybean +Maize (1:2)	2586.67	2523.33	2426.67	2536.67	2476.67	2376.67
		SEm±	**CD (*P*=0.05)**		**SEm±**	**CD (*P*=0.05)**
For comparison between intercropping treatments at same level of slope		136.83	403.64		137.65	406.06
For comparison between slopes at same or different intercropping treatments		75.61	238.26		77.67	244.73

4.1.2.5. Oil, protein and nutrient content:

Data pertaining to the oil, protein and nutrient content of soybean is presented in Table 4.6. The variations were not found to vary much due to slope. Oil and protein content as well as P and K content were not affected significantly due to variations in slope. The variation was found to be significant in the case of N with 0% slope recording higher concentrations as compared to the rest of the slopes. The slightly higher content in this case may be attributed to higher availability in the soil which could be easily absorbed from the soil and thus transferred to the sink. Soybean being a legume may have also aided in the abundant availability of N thus leading to more uptake. Also, minimal stress under plain conditions may have helped the plant in easy partitioning of resources to the economic part.

Among the different intercropping methods, sole soybean was observed to record higher values than the rest of the treatments. The variations were however not wide in all the cases. The higher values can be attributed to lesser competition as compared to the other intercropped treatments where maize plant and its roots may have reduced the availability for uptake. Keeping aside the control treatment and sole maize treatment, the content of protein, oil, N, P and K were comparable to each other. Protein synthesis in soybean is reported to be highly influenced by minerals such as phosphorous, potassium, nitrogen and sulphur (Utsumi *et al*., 2002; Mahmoodi *et al*., 2013). Various other nutrients such as sodium and potassium (Kaviani *et al*., 2011), sulphur and nitrogen have been reported to influence protein composition in soybean as well as improve plant growth and yield (Marshner, 2005; Kopriva *et al.,* 2002; Zhao *et al*., 1999). However, in this case, apart from sole maize and control plot where no crop was sown, the difference in the content of oil or protein among the treatments was comparable to each other.

Table 4.6: Effect of intercropping and slope on oil, protein, N, P and K Content of soybean

Treatments	Oil (%)		Protein (%)		N (%)		P (%)		K (%)	
Slope	**2016**	**2017**	**2016**	**2017**	**2016**	**2017**	**2016**	**2017**	**2016**	**2017**
S_1 (0)	11.28	11.17	23.83	24.00	2.31	2.31	0.22	0.22	1.42	1.43
S_2 (9)	11.50	11.78	23.94	23.94	2.22	2.22	0.22	0.22	1.44	1.43
S_3 (20)	11.39	11.61	23.83	23.83	2.24	2.23	0.22	0.22	1.43	1.42
SEm±	0.29	0.16	0.13	0.15	0.01	0.01	0.00	0.00	0.01	0.00
CD at 5%	NS	NS	NS	NS	0.04	0.04	NS	NS	NS	NS
Crop										
T_1 - Control	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T_2 - Sole Soybean	17.33	17.67	36.11	36.11	3.51	3.49	0.34	0.33	2.19	2.17
T_3 - Sole Maize	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T_4 - Soybean +Maize (1:1)	16.89	17.22	35.33	35.56	3.41	3.41	0.33	0.32	2.14	2.16
T_5 - Soybean +Maize (2:1)	17.11	17.11	35.78	35.89	3.32	3.32	0.33	0.33	2.13	2.13
T_6 - Soybean +Maize (1:2)	17.00	17.11	36.00	36.00	3.30	3.30	0.32	0.32	2.11	2.11
SEm±	0.31	0.22	0.13	0.24	0.02	0.02	0.00	0.00	0.01	0.01
CD at 5%	0.98	0.70	0.41	0.75	0.05	0.08	0.01	0.01	0.04	0.04

***Note*:** No crops grown in T_1 – Control. No soybean grown in T_3 – Sole Maize

4.1.2.6. N, P and K uptake by soybean:

The data on N uptake under different slopes varied from 31.18 kg ha^{-1} to 36.18 kg ha^{-1} in the year 2016 and 29.90 kg ha^{-1} to 34.96 kg ha^{-1} in the year 2017. The highest N uptake was recorded in 0% slope (S_1) in both the years recording 36.18 and 34.96 kg ha^{-1} followed by 9% slope (S_2) during 2016 and 2017, respectively. The lowest N uptake was recorded in 20% slope (S_3) with a value of 31.18 and 29.90 kg ha^{-1} during 2016 and 2017, respectively.

The effect of different slope percentage on P uptake of soil presented in Table 4.7 revealed that the highest P uptake i.e. 3.50 and 3.31 kg ha^{-1} were recorded in 0% slope (S_1) in 2016 and 2017, respectively. And the lowest P uptake (3.05 and 2.88 kg ha^{-1}) were found in 20% (S_3) during 2016 and 2017.While the data pertaining to the K uptake presented in Table 4.6 under different slope percentage pointed that the highest K uptake was noted in 0% slope (S_1) with a value of 22.30 and 21.61 kg ha^{-1} in both the experimental years. The lowest was recorded in 20% slope (S_3) with a value of 19.83 and19.04 kg ha^{-1}. Perusal of Table 4.7 revealed that variations in slope had significant effect on the uptake of nutrients. 0 % slope recorded significantly higher values of N, P and K uptake followed by 9 % and 20 % slope respectively. The uptake of nutrients had a negative correlation with the degree of slope. Though there were slight variations in the nutrient content, the significant differences in uptake were a result of the differences in biomass and not because of the concentration.

Among the various intercropping systems, the highest N uptake i.e. 52.51 and 50.43 kg ha^{-1} were recorded in sole soybean treatment in 2016 and 2017, respectively followed by soybean + maize (1:1) (T_4). The lowest N uptake were found in soybean + maize (1:2) (T_6) during 2016 and 2017, respectively. The P uptake in the soil after various cropping pattern ranged from 4.63 to 5.10 kg ha^{-1} and 4.44 to 4.79 kg ha^{-1} in 2016 and 2017, respectively (Table 4.7). In both the years of the experiment the highest P uptake was found in sole soybean (T_2) followed by soybean + maize (2:1) (T_5) and the lowest was observed in soybean + maize (1:2) (T_6) sole maize. Data on different intercropping system on K uptake revealed that, the maximum value was found under sole soybean (T_2) during 2016 and 2017 respectively, with a value of 32.68 and 31.21 kg ha^{-1}, which was followed by control (T_5) treatment during both the experimental years. However, the minimum K uptake of 30.25 and 29.15 kg ha^{-1} was recorded under soybean + maize (1:2) (T_6) and soybean + maize (T_4) during 2016 and 2017, respectively.

Among the sub-treatments, sole soybean recorded higher values of N, P and K uptake compared to the intercropped treatments. Long *et al*. (2001) also reported that nutrient acquisitions by intercrops were significantly greater when intercropped than when grown as sole crops. The variations in this regard can also be attributed to the differences in biomass production and not in the variations in nutrient concentration.

Table 4.7: Effect of intercropping and slope on uptake of N, P and K by soybean

Treatments	N uptake (kg ha^{1})		P uptake (kg ha^{1})		K uptake (kg ha^{1})	
Slope	**2016**	**2017**	**2016**	**2017**	**2016**	**2017**
S_1 (0)	36.18	34.96	3.50	3.31	22.30	21.61
S_2 (9)	32.03	30.92	3.19	3.03	20.73	19.93
S_3 (20)	31.18	29.90	3.05	2.88	19.83	19.04
SEm±	1.17	1.27	0.11	0.11	0.67	0.76
CD at 5%	4.61	4.98	0.45	0.44	2.64	2.98
Crop						
T_1 - Control	0.00	0.00	0.00	0.00	0.00	0.00
T_2 - Sole Soybean	52.51	50.43	5.10	4.79	32.68	31.21
T_3 - Sole Maize	0.00	0.00	0.00	0.00	0.00	0.00
T_4 - Soybean +Maize (1:1)	49.83	48.12	4.81	4.56	31.29	30.39
T_5 - Soybean +Maize (2:1)	49.03	47.29	4.92	4.65	31.50	30.39
T_6 - Soybean +Maize (1:2)	47.41	45.72	4.63	4.44	30.25	29.15
SEm±	1.48	1.59	0.15	0.13	0.95	0.82
CD at 5%	4.66	5.01	0.47	0.41	3.01	2.59

***Note*:** No crops grown in T_1 – Control. No soybean grown in T_3 – Sole Maize

4.1.2.7 : Plant height of maize:

Table 4.8 depicts the plant height of maize (cm) at various stages of crop growth. Plant height increased as the stage of crop growth progressed. At all the stages, 0 % slope recorded higher plant height followed by 9 % and 20 % slope, respectively. The variations were however not significant at 30 DAS. At 60 DAS the variations were significant while at 90 DAS S_1 and S_2 were comparable to each other and significant over S_3. The variations in height could be due to stress factor of crop plants at steeper slopes as compared to the plains (0 % slope).

Among the sub-treatments, soybean + maize (1:2) recorded higher values at 30 and 60 DAS during both the years.Similar results were also reported by Kithan (2017). At 60 DAS the values were significantly higher than sole maize and at par with soybean + maize (1:1) and soybean + maize (2:1). At 90 DAS, soybean + maize (1:1) recorded higher values than the rest of the treatments.

Table 4.8: Effect of intercropping and slope on plant heightof maize at 30, 60 and 90 DAS

	Plant height (cm)					
Treatments	**30 DAS**		**60 DAS**		**90 DAS**	
Slope	**2016**	**2017**	**2016**	**2017**	**2016**	**2017**
S_1 (0)	32.12	32.79	80.82	92.59	114.94	111.03
S_2 (9)	31.99	31.74	79.52	84.59	112.89	100.87
S_3 (20)	30.79	30.24	66.92	61.52	96.78	88.26
SEm±	1.51	1.17	1.45	1.70	3.46	3.45
CD at 5%	NS	NS	5.71	6.69	13.57	13.57
Crop						
T_1 - Control	0.00	0.00	0.00	0.00	0.00	0.00
T_2 - Sole Soybean	0.00	0.00	0.00	0.00	0.00	0.00
T_3 - Sole Maize	46.48	41.74	108.65	91.24	151.81	136.07
T_4 - Soybean +Maize (1:1)	46.98	47.35	114.48	120.13	168.54	169.26
T_5 - Soybean +Maize (2:1)	45.87	50.00	112.61	130.21	165.16	155.52
T_6 - Soybean +Maize (1:2)	50.46	50.45	118.77	135.83	163.72	139.46
SEm±	1.70	1.67	2.32	3.65	5.02	3.69
CD at 5%	5.36	5.25	7.31	11.51	15.82	11.61

***Note*:** No crops grown in T_1 – Control. No maize grown in T_2 – Sole Soybean.

4.1.2.8 : No. of leaves and dry weight/plant of maize

Perusal of data presented in Table 4.9 revealed that 0% and 9 % slope recorded higher number of leaves at all stages of crop growth for both the years of experimentation and was comparable to each other. The values were however significantly higher than 20 % slope. With increase in slope gradient, the growth of plant may have been affected to due to lower fertility status as well as stress. Plant biomass at harvest was higher in the case of plain as compared to steeper slopes. The values were however at par with each other.

Among the intercropped treatments, soybean + maize (1:2) recorded higher number of leaves as compared to the others during the entire crop growth period. As far as dry weight of sole plants is concerned, the intercropping treatments were not found to have any significant effect.

Table 4.9: Effect of intercropping and slope on no. of leaves of maize at 30, 60 and 90 DAS and dry weight/plant at harvest

Treatments	No. of leaves/plant						Dry weight (g/plant)	
	30 DAS		60 DAS		90 DAS			
Slope	**2016**	**2017**	**2016**	**2017**	**2016**	**2017**	**2016**	**2017**
S_1 (0)	3.70	3.83	5.15	4.93	4.93	5.75	889.94	889.17
S_2 (9)	3.72	3.61	4.76	4.76	4.76	5.80	886.78	884.67
S_3 (20)	3.20	3.57	4.67	4.67	4.67	5.37	886.11	884.33
SEm±	0.13	0.07	0.05	0.11	0.11	0.05	22.24	22.47
CD at 5%	0.49	0.27	0.18	0.41	0.41	0.21	87.33	88.23
Crop								
T_1 – Control	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T_2 - Sole Soybean	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T_3 - Sole Maize	4.96	4.70	6.71	6.26	6.26	7.70	1334.22	1329.44
T_4 - Soybean +Maize (1:1)	5.42	5.87	7.59	7.59	7.59	8.45	1330.89	1327.78
T_5 - Soybean +Maize (2:1)	4.92	5.41	7.11	7.11	7.11	8.50	1333.11	1331.56
T_6 - Soybean +Maize (1:2)	5.94	6.04	7.74	7.74	7.74	9.19	1327.44	1327.56
SEm±	0.20	0.19	0.08	0.18	0.18	0.15	31.19	31.30
CD at 5%	0.62	0.59	0.26	0.57	0.57	0.46	98.29	98.62

***Note*:** No crops grown in T_1 – Control. No maize grown in T_2 – Sole Soybean

4.1.2.9. Yield attributes of maize:

Table 4.10 depicts the effect of intercropping and slope aspect on the yield attributes of maize. Attributes such as cobs per plant and test weight were not affected by variations in slope aspect. However, differences were found significant in the number of seeds per cob where 0 % slope recorded higher numbers which was comparable to 9 % slope and significant over 20 %. Ideal conditions of levelled land may have reduced stress as well as nutrient availability thus resulting in proper development of reproductive/economic parts. The resources from source could be well transferred to the sink in lieu of the crop growing under better conditions of less stress compared to 20 % slope.

Similar observations were observed among the sub treatments also where variations were significant only in the case of seeds per cob. Soybean + maize in the ratio of 2:1 was observed to record highest number of seeds per cob for both the years. The presence of soybean in two rows may have helped in availability of more nitrogen to the maize plants through fixing which in turn helped in better transportation and assimilation of nutrients to the economic part. In a study by Javanmard *et al*. (2009), the dry matter yield of maize in intercrop with legumes was recorded to be higher as compared to sole crop of maize. The present results obtained were however the opposite of this, which could be due to increase in availability of soil nitrogen for succeeding maize crop.

Table 4.10: Effect of intercropping and slope on no. of cobs/plant, filled cobs/plant, seeds/cob and test weight of maize

Treatments	Cobs/plant (No.)		Filled cobs/plant (No.)		Seeds/cob (No.)		Test weight(g) 100 grains	
Slope	**2016**	**2017**	**2016**	**2017**	**2016**	**2017**	**2016**	**2017**
S_1 (0)	0.67	0.69	0.67	0.67	124.1	115.4	171.14	171.07
S_2 (9)	0.67	0.70	0.67	0.67	118.3	106.2	171.06	171.02
S_3 (20)	0.67	0.69	0.67	0.67	103.49	93.22	171.17	171.03
SEm±	0.00	0.01	0.00	0.00	2.61	2.59	2.78	2.78
CD at 5%	NS	NS	NS	NS	10.24	10.15	NS	NS
Crop								
T_1 - Control	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T_2 - Sole Soybean	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T_3 - Sole Maize	1.00	1.04	1.00	1.00	162.42	148.41	256.84	256.63
T_4 - Soybean +Maize (1:1)	1.00	1.00	1.00	1.00	177.47	161.91	256.78	256.68
T_5 - Soybean +Maize (2:1)	1.00	1.04	1.00	1.00	203.01	185.79	256.57	256.47
T_6 - Soybean +Maize (1:2)	1.00	1.07	1.00	1.00	149.02	133.79	256.55	256.45
SEm±	0.00	0.03	0.00	0.00	3.08	3.45	3.93	3.93
CD at 5%	0.00	0.09	0.00	0.00	9.71	10.86	12.38	12.38

***Note*: No crops grown in T_1 – Control. No maize grown in T_2 – Sole Soybean

4.1.2.10. Maize yield

The data on yield of maize as affected by slope and intercropping (Table 4.11) revealed that grain yield as well as stover yield of maize was significantly higher with 0 % slope. It was followed by 9 % slope while 20 % slope recorded least yields of both grain and stover. Harvest index was however not affected significantly by slope during both the years of experimentation. The absence of significant differences in harvest index of maize agrees with results by Haseeb- ur-Rehman *et al.* (2010) and Egbe *et al.* (2011) in maize-cowpea intercropping; Saleem *et al*. (2011) in maize –legumes intercropping systems; and Carruthers *et al*. (2000) in maize-soybean intercropping who reported that the intercropping systems did not affect the harvest index of maize component. Amede (1995) stated that one of the factors that reduces grain yield is dry conditions that occur specially during the flowering period. Higher populations under intercrops as compared to monocrop under stress conditions might result in intercrop yields being lower than sole crop yields due to increased competition for moisture (Natarajan and Willey, 1986). The higher yield and better crop performance at lesser slope are due to better soil quality and lesser loss of top soil through erosion. Under better conditions of leveled land and lesser loss of nutrients through erosion, the crop may have performed better.

Among the intercropped treatments, sole maize gave higher grain as well as stover yields compared to the rest of the treatments. This can be attributed to the higher population in case of sole maize and not due to increase or higher values of yield attributes. This was followed by soybean + maize (1:2) while soybean + maize (2:1) recorded the least values of both grain and stover yield during both years. Intercropping significantly affected grain yield of maize crop. Intercropped maize provided slightly lower grain yield than sole cropping on mean basis. This decline in the grain yield despite similar plant population in sole and intercropped stand may be attributed to change in the planting pattern, which induced more inter-species and intra-species competition in the intercropped stand, both underground and above-ground (Jain *et al*., 2015). A substantial reduction in grain yield of associated maize crop was observed as compared to maize alone. Khalil (1990) and Himayatullah (1992) also reported reduction in grain yield of maize due to intercropping. The reduction in the grain yield might be due to spatial and temporal competition for growth factors for a prolonged period and their susceptibility shading effect of maize crop. The results confirm the findings of Padhi and Panigrahi (2006) and Kaushal *et al*. (2015) who did on maize (*Zea mays* L.)- based intercropping systems. Crop intensification with intercropping reduced the yield of main crop due to more interspecific competition (Singh *et al*. 2008) and disturbance of the habitat (Banik *et al*. 2000). This was also in conformity with the finding by Singh *et al.* (2015). In maize-soybean intercropping systems, maize plant belonging C4 carbon assimilation pathway being dominant is usually much more competitive than legumes, first of all due to rapid initial growth (Kitonyo *et al*., 2013). As stated earlier, the decrease in values maybe due to population and not lesser values of yield attributes. Harvest index in this case was also comparable among the treatments. Intercropping system caused reduction in maize yield compared with sole stand in maize and soybean intercropping because of the reason that in sole stand there was less competition for light, nutrients and water and the resources were utilized in a proper manner for better growth and yield (Singh and Singh, 2001).

Table 4.11: Effect of intercropping and slope on grain yield, stover yield and harvest index of maize

Treatments	Grain yield (kg ha^{-1})		Stover yield (kg ha^{-1})		Harvest index (%)	
Slope	**2016**	**2017**	**2016**	**2017**	**2016**	**2017**
S_1 (0)	2322.22	2304.89	4908.33	4893.33	21.43	21.37
S_2 (9)	2186.22	2195.22	4760.00	4752.50	20.95	21.03
S_3 (20)	2081.89	2070.89	4636.67	4639.17	20.63	20.54
SEm±	51.17	54.49	53.31	59.04	0.38	0.42
CD at 5%	200.92	213.97	209.32	231.82	1.49	1.65
Crop						
T_1 - Control	0.00	0.00	0.00	0.00	0.00	0.00
T_2 - Sole Soybean	0.00	0.00	0.00	0.00	0.00	0.00
T_3 - Sole Maize	3558.67	3537.33	7270.00	7250.00	32.83	32.76
T_4 - Soybean +Maize (1:1)	3212.00	3204.00	7160.00	7140.00	30.96	30.96
T_5 - Soybean +Maize (2:1)	3132.00	3129.33	7050.00	7040.00	30.74	30.75
T_6 - Soybean +Maize (1:2)	3278.00	3271.33	7130.00	7140.00	31.48	31.41
SEm±	73.93	72.37	82.49	81.86	0.69	0.63
CD at 5%	232.96	228.05	259.92	257.95	2.18	1.98

4.1.2.11. Protein, N, P and K content of maize:

The content of N P K and protein as presented in Table 4.12 revealed that 0% slope recorded significantly higher values of N and protein which was comparable to 9 % slope and significantly higher over 20 % slope. P and K content were not affected significantly due to slope. N which is easily leached down by water may have been higher in slopes while it could have been slower in leveled plots due to which the uptake as well as content may have been higher in S_1. The results followed similar trend for both the years.

The content of protein, N, P as well as K were observed to vary significantly during both the years of experimentation. Sole maize recorded higher values during both the years for all the four nutrient constituents. The absence of competition from the other inter crop may have led to sole crop having higher contents as the inter crop was done in additive series for all the ratios

Table 4.12.Effect of intercropping and slope on protein, N, P and K content of maize

Treatments	Protein (%)		N (%)		P (%)		K (%)	
Slope	**2016**	**2017**	**2016**	**2017**	**2016**	**2017**	**2016**	**2017**
S_1 (0)	8.30	8.23	1.33	1.32	0.42	0.41	0.93	0.93
S_2 (9)	8.30	8.33	1.33	1.33	0.43	0.42	0.85	0.85
S_3 (20)	7.60	7.74	1.22	1.24	0.41	0.42	1.01	1.02
SEm±	0.08	0.09	0.01	0.02	0.01	0.01	0.01	0.02
CD at 5%	0.30	0.37	0.05	0.06	NS	NS	NS	NS
Crop								
T_1 - Control	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T_2 - Sole Soybean	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T_3 - Sole Maize	12.29	12.29	2.32	2.36	0.81	0.80	1.67	1.69
T_4 - Soybean +Maize (1:1)	10.63	10.63	1.70	1.70	0.51	0.51	1.31	1.31
T_5 - Soybean +Maize (2:1)	10.97	10.97	1.97	1.97	0.69	0.69	1.47	1.47
T_6 - Soybean +Maize (1:2)	0.00	0.00	1.76	1.76	0.50	0.50	1.14	1.14
SEm±	0.18	0.14	0.03	0.02	0.03	0.03	0.04	0.03
CD at 5%	0.56	0.45	0.09	0.07	0.08	0.09	0.11	0.10

***Note*:** No crops grown in T_1 – Control. No maize grown in T_2 – Sole Soybean

4.1.2.12. Protein, N, P and K uptake by maize:

The data obtained on N uptake of the maize under different slope percentage as depicted in Table 4.13revealed that, 0% slope (S_3) showed the highest N uptake in both the experiment years. Whereas, the lowest was recorded in 20% slope (S_1) with the percentage of 38.05 and 38.61 kg ha^{-1}, respectively. While in the case of P uptake, the examination of the data showed that, under different slope percentage, the highest P uptake was found in 0% slope (S_1) with a value 14.54 kg ha^{-1} and 14.31 kg ha^{-1} in both the years of experiment. The lowest P uptake was noted from 20% slope (S_3) with 12.88 kg ha^{-1} and 13.02 kg ha^{-1} during 2016 and 2017, respectively. The experimental results relating to K uptake under different slope condition revealed that the 0% slope (S_1) resulted in highest K uptake with a value of 32.40 and 32.48 kg ha^{-1}, in both the years of experiment. And the subsequent highest was obtained from 20% slope (S_3) with 28.09 and 28.09 kg ha^{-1} during the study period.

Data pertaining to uptake of protein and NPK is presented in Table 4.13. Perusal of data revealed that 0 % slope recorded maximum uptake of all the three nutrients and was followed by 9 % slope while 20 % slope recorded the least uptake. The uptake of K was however not significant among the slopes. S_1 and S_2 were observed to be at par with each other while being significant over S_3. The differences in the uptake can be attributed to the differences in the biomass yield of the crop as the variation in content were not much. The better growth and yield of the crop at lesser slopes led to the higher differences in the uptake of nutrients.

In the study, the results obtained on N uptake under different cropping pattern of maize and soybean revealed varying results in all the cropping system. It was clear from the results presented in Table 4.13 that sole maize (T_3) resulted in highest N uptake with values of 82.76 and 83.41 kg ha^{-1} during

2016 and 2017, respectively. The lowest uptake was recorded in soybean + maize (1:1) (T_4) reporting 54.71 and 54.58 kg ha^{-1} during 2016 and 2017, respectively. It is apparent from the table that P uptake on different cropping system showed that during 2016 and 2017, the P uptake was highest in sole maize (T_3) with a P uptake of 16.35 kg ha^{-1} and 16.30 kg ha^{-1}, while the lowest was recorded in soybean + maize (1:1) (T_4). The result on varied cropping system recorded during 2016 and 2017 showed that the highest K uptake was found in sole maize (T_3) with 58.89 and 59.51 kg ha^{-1}, which was followed by soybean + maize(2:1) (T_5)with 45.87 and 45.86 kg ha^{-1}. However, the lowest K uptake was found in soybean + maize (1:1) (T_4) followed by soybean + maize(1:2) (T_6) with a value of 37.38 and 37.27 kg ha^{-1}, respectively.

Among the intercropping treatments, sole maize recorded higher nutrient uptake for both the years of experimentation. A proper trend could however be not observed among the intercropping treatments. Soybean + maize (1:1) recorded minimum uptakes of N and P and were at par with soybean + maize (1:2) and vice versa in the case of K uptake for both the years. The higher uptake in sole maize could be due to higher biomass as there was no competition as compared to the interspecific competition in the case of intercropping.

Table 4.13: Effect of intercropping and slope on N, P and K uptake by maize

Treatments	N uptake (kg ha^{1})		P uptake (kg ha^{1})		K uptake (kg ha^{1})	
Slope	**2016**	**2017**	**2016**	**2017**	**2016**	**2017**
S_1 (0)	46.46	45.81	14.54	14.31	32.40	32.48
S_2 (9)	43.86	44.12	14.18	13.96	31.57	31.67
S_3 (20)	38.05	38.61	12.88	13.02	28.09	28.09
SEm±	1.34	1.29	0.41	0.48	0.78	0.91
CD at 5%	5.27	5.06	1.60	NS	NS	NS
Crop						
T_1 - Control	0.00	0.00	0.00	0.00	0.00	0.00
T_2 - Sole Soybean	0.00	0.00	0.00	0.00	0.00	0.00
T_3 - Sole Maize	82.76	83.41	28.77	28.27	58.89	59.51
T_4 - Soybean +Maize (1:1)	54.71	54.58	16.35	16.30	41.98	41.86
T_5 - Soybean +Maize (2:1)	61.60	61.55	21.66	21.65	45.87	45.83
T_6 - Soybean +Maize (1:2)	57.66	57.54	16.42	16.37	37.38	37.27
SEm±	1.79	2.05	0.98	1.28	1.29	1.83
CD at 5%	5.64	6.45	3.08	4.04	4.08	5.76

***Note*:** No crops grown in T_1 – Control. No maize grown in T_2 – Sole Soybean

4.1.3. Effect of soybean-maize intercropping on soil properties under different slope percentages:

The results of the important soil physico-chemical properties as influenced by intercropping under different slope percentage *viz.*,available N, P, K, organic carbon, soil pH, cation exchange capacity (CEC), bulk density, percent aggregates >0.25mm, mean weight diameter, water holding capacity (WHC), Iron (Fe), Zinc (Zn), copper (Cu), manganese (Mn) and soil microbial biomass carbon (SMBC) are discussed and presented under the following headings.

4.1.3.1. Effect on available nitrogen (N):

The data pertaining to the effect of intercropping on available N in soil is presented in Table 4.14. The available nitrogen of the soil under different slopes percentage varied from 575.01 kg ha^{-1} to 603.62 kg ha^{-1} in the year 2016 and 574.62 kg ha^{-1} to 605.14 kg ha^{-1} in the year 2017. The highest available nitrogen value was recorded in 0% slope (S_1) in both the years followed by 9% slope (S_2) recording 584.07 and 582.10 kg ha^{-1} during 2016 and 2017, respectively. The lowest available nitrogen was recorded in 20% slope (S_3) with a value of 575.01 and 574.62 kg ha^{-1} during 2016 and 2017, respectively. The higher available N value in 0% slope may be due to less erosion whereas the lowest available N value in S_3 i.e.,20% may be due to the steepness of slope which in this case is steeper than S_1 thus resulting in loss of topsoil.

Among the different sub-treatments, the highest available nitrogen i.e., 600.82 and 606.26 kg ha^{-1} were recorded in soybean + maize (1:2) (T_6) and control treatment (T_1) in 2016 and 2017, respectively followed by soybean + maize (2:1) (T_5). Garg (2004) reported that, legumes in good conditions must use a lot of amount of carbohydrate to produce more nodules, hence, nitrogen fixation. The lowest available nitrogen (568.24 and 569.43 kg ha^{-1}) were found in sole maize (T_3) during 2016 and 2017, respectively .The higher available N value in control (T_1) must be due to vegetation cover which reduces the erosivity of runoff. While the lower value in T_3 i.e., Sole maize may be due to the loss of nutrients as maize is an erosion permitting crop.

Interaction effect of slope and intercropping was found to be significant, data of which is presented in Table 4.14a. Combination of 0% slope with sole soybean recorded higher values in the first year and was at par with the rest of the treatments except sole maize. The available N was found to be negatively correlated with the increasing slope degrees. The variation in control plot was not much as no treatments or cropping was done in the same. The trend was observed to be almost similar in both years. Sole maize was observed to exhaust N although nutrition through fertilizers was provided. The differences were however not much in all the cases. The presence of legume crop in the intercrop was observed to maintain the soil available N through fixation.

4.1.3.2. Effect on available phosphorus (P):

The data on the effect of intercropping on available P in soil is presented in Table 4.14. The available P content in soil ranged from 10.69 to 13.18 kg ha^{-1}. The data showed that intercropping of soybean and maize caused a significant increase in available P in all the treatments. Among the slopes, the highest available P was recorded in S_1 (Pre-sowing) and lowest available P was recorded in S_3 (2nd year). The highest available phosphorus i.e. 12.94 and 11.64 kg ha^{-1}were recorded in 9% slope (S_1) in 2016 and 2017, respectively. And the lowest available phosphorus (11.65 and 10.02 kg ha^{-1}) was found in 20% slope (S_3) during 2016 and 2017. The lowest available P in slope 20%(S_3) among the three slopes viz. S_1, S_2 and S_3 may be due to the more erosion in S_3 as it was steeper than the other two slopes i.e., S_1& S_2. Low to medium range concentration of available phosphorus in the soils might be due to its fixation in soil colloid under strongly acidic soil reaction.

Among the different sub-treatments, the available phosphorus in the soil after various cropping pattern ranged from 10.69 to 11.78 kg ha^{-1} and 10.23 to 11.29 kg ha^{-1} in 2016 and 2017, respectively (Table 4.14). In both the years of the experiment the highest available phosphorus was found in soybean + maize (1:2)(T_6) followed by soybean + maize(2:1)(T_5)and the lowest was observed in sole maize (T_3). The lower available P value in T_3 i.e., Sole Maize may be due to the loss of nutrients as Maize is a voracious feeder and also an erosion permitting crop. This agrees with the results found by Phiri *et al*., (2013) who reported that, some legumes have the capacity to enhance the availability and efficient utilization of residual phosphorus which is otherwise not available to cereals. Bandyopadhyay *et al*. (2007), found that, legumes help in solubilizing insoluble phosphorus in soil, enhancing the soil physical area, improving soil microbial activity and restoring organic matter. Ghosh *et al*. (2009) concluded that soybean in advanced stages, with a developed root system, can increase the availability of native and fixed P for intercrops. The critical analysis of the data clearly revealed that there was no significant variation in both the years. This agrees with Matusso (2014), who reported that, the available phosphorus values did not show any significant differences among treatments. Zhi- Gang *et al*. (2014) also reported that there were no significant differences in soil Olsen P between intercropping.

4.1.3.3. Effect on available potassium (K):

The data on the available potassium are presented in Table 4.14. Perusal of the data under different slope percentage revealed that the highest available potassium was noted in 20% slope (S_3) with a value of 99.28 and 92.57 kg ha^{-1} in both the experimental years. The lowest was recorded in 9% slope (S_1) with a value of 81.07 and 73.4 kg ha^{-1}.Under the different cropping patterns, the maximum available K was found in sole soybean (T_2) with a value of 89.80 and 86.25 kg ha^{-1} in 2016 and 2017, respectively. However, the minimum available K of 81.12 kg ha^{-1} was observed in soybean + maize (1:1) (T_4) in 2016 and 75.14 kg ha^{-1} in sole maize (T_3) in 2017. The less available potassium in soybean and maize intercropping in 2016 is in conformity with the findings of Zhi- Gang *et al*. (2014) who reported that only maize/soybean intercropping decreased soil exchangeable K by 17.3% compared to the corresponding monocrops. The medium concentration of available potassium found in the soils during the research years may be due to the result of constant dynamics of potassium exchange in the soils.

Soil available K was observed to be significantly affected through the interaction of slope and intercropping as presented in table 4.14b. control and sole soybean recorded higher values irrespective of slope. The lesser values of available K was observed where maize crop was grown either solely or as intercropping, the reason being loss of top soil through run-off as maize is a tall growing crop with lesser soil cover as compared to soybean.

Table 4.14: Effect of intercropping and slope on soil available N, P and K

Treatments	Available N (kg ha$^{-1)}$			Available P (kg ha$^{-1)}$			Available K (kg ha$^{-1)}$		
Slope	**Pre sowing**	**2016**	**2017**	**Pre sowing**	**2016**	**2017**	**Pre sowing**	**2016**	**2017**
S_1 (0)	595.98	603.62	605.14	13.18	11.71	10.65	83.48	84.67	84
S_2 (9)	597.04	584.07	582.10	13.11	12.94	11.64	88.08	81.07	73.4
S_3 (20)	605.09	575.01	574.62	12.10	11.65	10.02	103.19	99.28	92.57
SEm±	2.42	2.71	5.23	0.55	0.48	0.38	2.47	1.86	2.38
CD at 5%	9.68	10.65	20.55	NS	NS	NS	9.69	7.29	9.36
Crop									
T_1 - Control	599.69	600.41	606.26	11.76	11.35	10.23	100.95	86.93	78.7
T_2 - Sole Soybean	599.55	582.18	595.46	10.97	11.33	11.07	100.1	89.8	86.25
T_3 - Sole Maize	599.22	568.24	569.43	11.55	10.69	10.68	87.65	83.28	75.14
T_4 - Soybean +Maize (1:1)	598.36	573.94	581.80	11.49	11.48	11.14	86.02	81.12	76.63
T_5 - Soybean +Maize (2:1)	598.86	599.81	590.54	11.87	11.74	11.21	83.97	85.72	78.88
T_6 - Soybean +Maize (1:2)	600.54	600.82	580.21	11.79	11.78	11.29	90.81	83.2	76.33
SEm±	0.57	7.39	7.26	0.30	0.49	0.33	2.71	1.82	3.11
CD at 5%	1.78	23.28	22.87	NS	NS	NS	8.53	5.75	9.79

***Note**:* NS = Non- significant at 5% level of significance

Table 4.14a: Interaction effect of intercropping and slope on soil available N (kg ha^{-1})

Treatments	Slope					
Crop	2016			2017		
	S_1	S_2	S_3	S_1	S_2	S_3
T_1 - Control	607.57	598.37	595.30	621.00	602.80	594.97
T_2 - Sole Soybean	609.57	586.50	592.47	609.77	592.58	584.03
T_3 - Sole Maize	585.37	564.00	555.37	579.10	575.80	553.40
T_4 - Soybean +Maize (1:1)	607.40	557.57	556.87	610.93	572.03	562.43
T_5 - Soybean +Maize (2:1)	606.97	597.13	590.33	603.03	585.60	583.00
T_6 - Soybean +Maize (1:2)	606.87	600.87	591.73	607.00	563.77	569.87
		SEm±	**CD (*P*=0.05)**		**SEm±**	**CD (*P*=0.05)**
For comparison between intercropping treatments at same level of slope		6.80	20.05		8.31	24.51
For comparison between slopes at same or different intercropping treatments		3.72	10.97		3.63	10.71

Table 4.14b: Interaction effect of intercropping and slope on soil available K (kg ha^{-1})

Treatments	Slope					
Crop	2016			2017		
	S_1	S_2	S_3	S_1	S_2	S_3
T_1 - Control	54.71	70.95	135.12	49.95	62.81	123.33
T_2 - Sole Soybean	135.08	61.84	72.48	127.91	53.70	77.14
T_3 - Sole Maize	85.27	87.63	76.94	78.13	79.49	67.80
T_4 - Soybean +Maize (1:1)	70.11	87.22	86.03	70.70	80.44	78.75
T_5 - Soybean +Maize (2:1)	36.76	106.44	113.96	32.00	98.30	106.34
T_6 - Soybean +Maize (1:2)	66.05	72.36	111.18	61.29	65.67	102.04
		SEm±	CD (P=0.05)		SEm±	CD (P=0.05)
For comparison between intercropping treatments at same level of slope		4.15	12.25		4.98	14.68
For comparison between slopes at same or different intercropping treatments		3.65	10.44		3.11	9.79

4.1.3.4. Effect on organic carbon (%):

The data obtained on organic carbon of the soil under different slope percentage as depicted in Table 4.15 revealed that, 20% slope (S_3) showed the maximum organic carbon content in the first year of the experiment. However, in the succeeding year the organic carbon content was found to be highest in 9% slope (S_2) with a value of 1.40%. In both the experimental years the organic carbon content was lowest in 0% slope (S_1) with a value of 1.42 and 1.39%, respectively.

In the investigation, the results obtained on organic carbon content under different cropping pattern of maize and soybean revealed varying results in all the cropping system. It was clear from the results presented in Table 4.15 that sole soybean (T_2)resulted in highest organic carbon content with values of 1.43 and 1.43 % during 2016 and 2017, respectively. The control (T_1) closely followed with value of 1.42 and 1.42 %, respectively in the two years of experiment. The lowest organic carbon content was recorded in soybean + maize (1:2) (T_6) reporting 1.38 and 1.38 % during 2016 and 2017, respectively. However, Habineza *et al*. (2018) reported that intercropping reduced slightly organic carbon compared to sole crop. This could be due to competition among component crops which did not allow high biomass production which could result to high organic carbon production. This was not in agreement with Akinnifesi *et al*. (2007); Sebetha (2015); Nagar *et al*. (2016) who reported that, the soil organic carbon increase in the legume-cereal intercropping, while in monocropping cereal there was a small decrease. Differences in organic carbon could also be depended on varietal genetic make ups. Matusso *et al*. (2012) observed higher soil organic carbon in intercropping than in sole crop. Naresh *et al*. (2014) reported that, sole maize-wheat rotation showed a decline in soil organic carbon by 3.7%, while black gram and cowpea intercropping with corn followed by wheat increased organic carbon. Organic C did not show significant difference in both the years.

4.1.3.5. Effect on soil pH:

The perusal of the data revealed that, in both the years of experiment of different slope percentage, the highest soil pH was found in 20% slope (S_3) with a soil pH of 4.96 and 4.81. The lowest soil pH was noted from 9% slope (S_2) with a value of 4.76 and 4.58 during 2016 and 2017, respectively.

It is apparent from the Table 4.15 that soil pH on different cropping system showed that during 2016 and 2017, the soil pH was highest in sole soybean (T_2) with a soil pH of 4.96 and 4.86, while the lowest was recorded in control (T_1).Nagar *et al.*, (2016) reported that, the enhanced organic production in green manure amended soils buffers the soil against pH changes. In addition, Matusso *et al*. (2012); Owusu and Sadick (2016) argued that increasing soil pH values in intercropping compared to sole crop, means that intercropping led to decrease in soil acidity compared to monocropping, due to higher organic material production. An inquisition of the data showed that there was no significant variation in both the years. This result is in conformity with Song *et al*. (2007) who reported that soil pH was almost constant during the crop cycle, being unaffected by treatments.

4.1.3.6. Effect on cation exchange capacity (CEC):

The experimental results relating to Cation Exchange Capacity under different slope conditionis revealed in Table 4.15 where the 9% slope (S_2) resulted in highest Cation Exchange Capacity with a value of 23.72 and 22.95 [cmol(p^+) kg^{-1}], in both the years of experiment. And the subsequent highest was obtained from 20% slope (S_3) with 21.81 and 21.10 [cmol(p^+) kg^{-1}] during the study period.

The result on varied cropping system recorded during 2016 showed that highest cation exchange capacity was found in soybean + maize (2:1)(T_5)[22.36cmol(p^+) kg^{-1}], which was followed by sole maize (T_3) [21.87cmol(p^+) kg^{-1}] and the lowest was recorded in sole soybean (T_2) [21.44 cmol(p^+) kg^{-1}]. In 2017 also, the highest cation exchange capacity was found in soybean + maize (2:1) (T_5) with a value of 21.59 [cmol(p^+) kg^{-1}] followed by sole maize (T_3) with a value of 21.27 [cmol(p^+) kg^{-1}], respectively and the minimum was recorded 20.86 [cmol(p^+) kg^{-1}] in soybean + maize (1:2) (T_6).The CEC values did not show significant differences in both the years.

Table 4.15: Effect of intercropping and slope on chemical properties of soil; Organic carbon, pH and cation exchange capacity (CEC)

Treatments	**Organic carbon (%)**			**pH**			**CEC [cmol(p^+) kg^{-1}]**		
Slope	**Pre sowing**	**2016**	**2017**	**Pre sowing**	**2016**	**2017**	**Pre sowing**	**2016**	**2017**
S_1 0)	1.44	1.42	1.39	4.97	4.87	4.76	20.31	19.89	19.28
S_2 (9)	1.43	1.43	1.44	4.86	4.76	4.58	23.41	23.72	22.95
S_3 (20)	1.44	1.48	1.40	5.06	4.96	4.81	23.09	21.81	21.10
SEm±	0.03	0.03	0.03	0.13	0.12	0.13	0.75	0.51	0.60
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS
Crop									
T_1 - Control	1.42	1.42	1.42	4.96	4.86	4.60	23.06	21.91	20.94
T_2 - Sole Soybean	1.39	1.43	1.43	5.06	4.96	4.86	22.06	21.44	21.00
T_3 - Sole Maize	1.42	1.40	1.39	4.88	4.78	4.67	22.89	21.87	21.27
T_4 - Soybean +Maize (1:1)	1.40	1.39	1.39	4.97	4.87	4.77	20.19	21.66	21.00
T_5 - Soybean +Maize (2:1)	1.41	1.39	1.38	4.97	4.87	4.77	23.12	22.36	21.59
T_6 - Soybean +Maize (1:2)	1.39	1.38	1.38	4.94	4.84	4.64	22.30	21.60	20.86
SEm±	0.03	0.03	0.03	0.10	0.09	0.10	0.97	0.81	0.73
CD at 5%	NS	NS	NS	0.31	0.29	0.31	NS	NS	NS

Note: NS = Non- significant at 5% level of significance

4.1.3.7. Effect on bulk density:

The data on bulk density of the soil of different slope percentage is presented in Table 4.16. The highest bulk density was recorded in 0% slope (S_1) recording 1.31 and 1.32 g cm^{-3} in the first and second year of the work, followed by 9% slope (S_2) recording 1.28 and 1.30 g cm^{-3} during 2016 and 2017, respectively. The lowest bulk density was recorded in 20% slope (S_3) with a value of 1.26 and 1.29 g cm^{-3} during 2016 and 2017, respectively.

The bulk density of the soil of intercropping varied from 1.26 g cm^{-3} to 1.31 g cm^{-3} in the year 2016 and 1.28 g cm^{-3} to 1.33 g cm^{-3} in the year 2017. Among the cropping system studied, the highest bulk density was recorded in control (T_1) and the lowest bulk density was recorded under soybean + maize (1:1) (T_4) i.e. 1.26 and 1.28 g cm^{-3} in both the years, respectively. This might be due to variation of organic residue added in various treatments. The data revealed that different intercropping treatments did not cause any significant variation in bulk density of the soil.

4.1.3.8. Effect on soil aggregation >0.25mm (%):

The data pertaining on percent aggregates > 0.25 mm of soil under varying slopes is presented in Table 4.16. The highest percent aggregates > 0.25 mm i.e. 29.09and 28.24% were recorded in 20% slope (S_3) in 2016 and 2017, respectively followed by 9% slope (S_2) treatment. The lowest percent aggregates > 0.25 mm (18.62and 18.99 %) were found in no 0% slope (S_1) during 2016 and 2017, respectively. The data revealed that soil aggregation value decreases under different slopes with the passage of time as there is no additional organic matter content that favors particle aggregation.

The percent aggregates > 0.25 mm of the soil among the various intercropping ratios, sole maize (T_3) gave the highest percentage during the first experimental year, which was followed by control (T_1). However, during the succeeding year the highest percentage was found in control (T_1) with a value of 23.59%.

4.1.3.9. Effect on mean weight diameter:

The data on mean weight diameter of the soil under different slope percentage is shown in Table 4.16. The highest mean weight diameter was recorded in 20% slope (S_3) recording 1.44 mm in the first and 1.79 mm recorded in 0% slope (S_1) in the second year of experiment, followed by 9% slope (S_2) recording 1.42 and 1.71mm during 2016 and 2017, respectively. The lowest mean weight diameter was recorded in 0% slope (S_3) and 9% slope (S_2) with a value of 1.35mm and 1.71mm during 2016 and 2017, respectively.

The mean weight diameter of the soil under different sub-treatments varied from 1.34mm to 1.47mm in the year 2016 and 1.68mm to 1.84 mm in the year 2017. Among the cropping system studied, the highest mean weight diameter was recorded in control (T_1) in the year 2016 and in the sole maize (T_3) during 2017 and the lowest mean weight diameter was recorded under soybean + maize (1:2) (T_6)*i.e.* 1.34 and 1.68 mm in 2016 and 2017, respectively. However, the mean weight diameter did not show any significant variation in both the years.

4.1.3.10. Effect on water holding capacity (%):

The data on the maximum water holding capacity (WHC) in soil of different slope is depicted in Table 4.16. The maximum WHC was recorded in 0% slope (S_1) and minimum was recorded in 9% slope (S_2) in both the years of experiment. The higher WHC value in 0%may be due to high biomass content.

The maximum water holding capacity of the soil under various inter cropping treatments varied from 52.14 to 55.21 % and 45.93 to 51.16 % during

2016 and 2017, respectively. The highest percentage of water holding capacity (WHC) was noted in sole soybean (T_2) and the lowest was found in sole maize (T_3) in the first year. Similarly, during the second experimental year, the highest percentage of WHC was documented in sole soybean (T_2) which was followed by control (T_1).The higher WHC value in sole soybean plot may be due to high biomass content as there was less erosion. Laxminarayana (2006) also reported that the application of organic manures either alone or in combinations with inorganic fertilizers progressively improved the water holding capacity of the soil. The data pointed out that there were no significant differences in WHC in both the years.

Table 4.16: Effect of intercropping and slope on bulk density, soil aggregation, mean weight diameter and water holding capacity

Treatments	Bulk density (g cm^{-3})			Soil aggregation>0.25mm (%)			Mean weight diameter (mm)			Water holding capacity (%)		
Slope	**Pre sowing**	**2016**	**2017**	**Pre sowing**	**2016**	**2017**	**Pre sowing**	**2016**	**2017**	**Pre sowing**	**2016**	**2017**
S_1 0)	1.28	1.31	1.32	22.79	22.82	22.99	1.12	1.35	1.79	59.62	54.72	50.10
S_2 (9)	1.26	1.28	1.30	24.13	23.46	22.77	1.13	1.42	1.71	55.67	51.32	45.89
S_3 (20)	1.24	1.26	1.29	27.04	26.09	25.24	1.16	1.44	1.74	59.90	54.64	49.63
SEm±	0.03	0.03	0.04	1.19	0.82	0.67	0.05	0.05	0.06	1.17	1.14	1.83
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Crop												
T_1 - Control	1.29	1.31	1.33	24.10	23.77	23.59	1.18	1.47	1.76	58.64	53.47	45.93
T_2 - Sole Soybean	1.26	1.29	1.31	22.67	23.57	23.38	1.12	1.36	1.78	60.05	55.21	51.16
T_3 - Sole Maize	1.26	1.28	1.32	23.49	24.21	23.00	1.15	1.44	1.84	56.98	52.14	47.44
T_4 - Soybean +Maize (1:1)	1.24	1.26	1.28	24.13	23.43	23.39	1.12	1.41	1.70	58.42	53.35	48.32
T_5 - Soybean +Maize (2:1)	1.26	1.28	1.30	23.67	23.67	23.39	1.13	1.42	1.71	56.62	52.60	49.04
T_6 - Soybean +Maize (1:2)	1.24	1.27	1.29	23.88	23.69	23.24	1.10	1.34	1.68	59.64	54.57	49.36
SEm±	0.04	0.05	0.08	0.94	0.61	0.48	0.06	0.06	0.05	1.90	1.00	2.58
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Note: NS = Non- significant at 5% level of significance

4.1.3.11. Effect on soil microbial biomass carbon (SMBC):

The perusal of the data reported that, in the first year of experiment of different slope percentage, the highest SMBC was found in 0% slope (S_1) with a value of 287.86 and 230.27 mg kg^{-1} in both the years of experiment. However, the lowest SMBC was noted from 20% slope (S_3) with a value of 180.06 and 114.45 mg kg^{-1} during 2016 and 2017, respectively. Similar finding was also reported by Alvarez *et al*. (1998) who reported that SMBC values decreases with depth of the soil.

It is obvious from the Table 4.17 that SMBC on different cropping system showed that during 2016 and 2017, the SMBC was highest in sole soybean (T_2) with 231.33 and 179.09 mg kg^{-1}while the lowest was recorded in soybean + maize (2:1) [T_5] and sole maize (T_3).An investigation of the data showed that there was no significant variation in both the years. This finding agrees with Balota *et al*. (2003) and Alison (2014) who reported that, there were no significant differences in SMBC between the sole soybean, sole maize and the intercropping.

Table 4.17: Effect of intercropping and slope on soil microbial biomass carbon

Treatments	Soil microbial biomass carbon - SMBC (mg kg^{-1})		
Slope	**Pre-Sowing**	**2016**	**2017**
S_1 ($_0$)	453.01	287.86	230.27
S_2 (9)	323.47	183.18	130.46
S_3 (20)	379.87	180.06	114.45
SEm±	6.17	4.08	5.45
CD at 5%	NS	NS	NS
Crop			
T_1 (Control)	359.66	207.11	152.51
T_2 (Sole Soybean)	405.16	231.33	179.09
T_3 (Sole Maize)	380.16	206.85	144.06
T_4 (Soybean +Maize (1:1))	394.02	230.78	167.04
T_5(Soybean +Maize (2:1))	387.3	203.31	146.12
T_6(Soybean +Maize (1:2))	386.39	222.82	161.56
SEm±	9.39	3.45	6.40
CD at 5%	NS	NS	NS

***Note*: NS = Non- significant at 5% level of significance**

4.1.3.12. Effect on Iron (Fe):

Data obtained on iron of the soil under different slope percentage as depicted in Table 4.18revealed that, 9% slope (S_2) showed the maximum iron content in the first year of the experiment. On the contrary, in the succeeding year the iron was found to be highest in 0% slope (S_1) with a value of 22.92 mg kg^{-1}. In both the experimental years the iron was observed lowest in 20% slope (S_3) and 9% slope (S_2) with a value of 25.93 and 20.02 mg kg^{-1} in 2016 and 2017, respectively. The reason may be due to loss of iron in soil erosion.

In the study, the results obtained on iron under different cropping patterns of maize and soybean revealed varying results in all the cropping system. The sole soybean (T_2) resulted in highest iron with values of 31.92 and 28.54 mg kg^{-1} during 2016 and 2017, respectively. The soybean + maize (1:2) [T_6] closely followed with value of 27.85 and 24.49mg kg^{-1}, respectively in the two years of experiment. The lowest iron was recorded in sole maize (T_3) reporting 24.59 and 18.69 mg kg^{-1} during 2016 and 2017, respectively. The sufficient concentration of Fe in the soil might be due to the result of occurrence of soils from parent materials with high degree of weathering. The data revealed that different intercropping treatments did not cause any significant variation in Fe of the soil.

4.1.3.13. Effect on Zinc (Zn):

The data on the Zinc are presented in Table 4.18. Perusal of the data under different slope percentage revealed that the highest Zinc was noted in 0% slope (S1) with a value of 0.54 and 0.48 mg kg^{-1} in both the experimental years. While, the lowest was recorded in 9% slope (S2) with a value of 0.29 and 0.26 mg kg^{-1}.

Furthermore, under the different cropping pattern on Zinc revealed that, maximum was found under sole soybean (T_2) during 2016 and 2017 respectively, with a value of 0.55 and 0.56 mg kg^{-1} and the minimum Zinc of 24.59 and 18.69 mg kg^{-1} was recorded under sole maize (T_3) during 2016 and 2017, respectively. However, the Zn did not show any significant variation in both the years.

4.1.3.14. Effect on Copper (Cu):

The copper of the soil under different slope percentage varied from 2.29 mg $kg^{-1}$to 2.69 mg kg^{-1}in the year 2016 and 2.09 mg $kg^{-1}$to 2.58 mg kg^{-1}in the year 2017 (Table 4.18). The highest copper was recorded in 0% slope (S_1) in both the years followed by 20% slope (S_2) recording 2.29 and 2.13 mg kg^{-1}during 2016 and 2017, respectively. The lowest copper was recorded in 9% slope (S_3) with a value of 2.29 and 2.09 mg kg^{-1}kg ha^{-1} during 2016 and 2017, respectively.

The data on the effect of intercropping of soybean-maize on copper of the soil is presented in Table 4.5 The highest copper i.e. 2.95 and 2.80 mg kg^{-1}were recorded in soybean + maize(1:1) [T_4] treatment in 2016 and 2017, respectively followed by sole soybean [T_2]. The lowest copper (2.13 and 1.94 mg kg^{-1}) were found in sole maize (T_3) during 2016 and 2017, respectively.

4.1.3.15. Effect on Manganese (Mn):

The effect of different slope percentage on manganese of soil is presented in Table 4.18. The highest manganese i.e. 8.94 and 4.87 mg kg^{-1}were recorded in 20% slope (S_2) in 2016 and 2017, respectively. Whereas, the lowest manganese (4.59 and 2.61 mg kg^{-1}) were found in 9% (S_2) during 2016 and 2017.

The manganese in the soil in various cropping pattern ranged from 5.42 to 6.91 mg kg^{-1} and 2.98 to 4.03mg kg^{-1} in 2016 and 2017, respectively. In both the years of the experiment the highest manganese was found in soybean + maize (1:2) [T_6] and sole soybean [T_2] and the lowest was observed in control (T_1). The data pointed out that there were no significant differences in Mg in both the years.

Table 4.18: Effect of intercropping and slope on soil micronutrients

Treatments	Iron (mg kg^{-1})			Zinc (mg kg^{-1})			Copper (mg kg^{-1})			Manganese (mg kg^{-1})		
Slope	**Pre-Sowing**	**2016**	**2017**	**Pre-Sowing**	**2016**	**2017**	**Pre-Sowing**	**2016**	**2017**	**Pre-Sowing**	**2016**	**2017**
S_1 (0)	32.8	26.06	22.92	0.54	0.54	0.48	2.92	2.69	2.58	7.61	4.91	3.26
S_2 (9)	33.45	28.97	20.02	0.31	0.29	0.26	2.45	2.29	2.09	8.44	4.59	2.61
S_3 (20)	32.55	25.93	22.49	0.44	0.37	0.31	2.5	2.29	2.13	13.76	8.94	4.87
SEm±	0.96	0.99	0.99	0.01	0.02	0.02	0.03	0.09	0.09	0.18	0.09	0.05
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Crop												
T_1 (Control)	33.13	25.42	20.16	0.40	0.35	0.26	2.37	2.17	1.95	9.24	5.42	2.98
T_2 (Sole Soybean)	37.71	31.92	28.54	0.56	0.55	0.56	3.11	2.76	2.62	10.06	6.36	4.03
T_3 (Sole Maize)	28.81	24.59	18.69	0.40	0.38	0.28	2.34	2.13	1.94	9.86	5.98	3.17
T_4 (Soybean +Maize (1:1))	37.95	26.47	19.97	0.44	0.38	0.33	3.10	2.95	*2.80*	10.00	6.35	3.78
T_5(Soybean +Maize (2:1))	33.08	25.68	19.02	0.39	0.36	0.31	2.39	2.23	2.13	10.05	5.86	3.56
T_6(Soybean +Maize (1:2))	26.9	27.85	24.49	0.38	0.37	0.38	2.42	2.32	2.13	10.42	6.91	3.96
SEm±	1.92	1.52	0.83	0.01	0.02	0.02	0.04	0.08	0.08	0.19	0.2	0.07
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Note: NS = Non- significant at 5% level of significance

4.1.4. Economics of treatments:

Economics of the different treatments have been presented in Table 4.19. The grain and straw/stover yield obtained in respective years was used for profitability calculation. Appraisal of the table revealed that S_3 recorded maximum cost of cultivations during both the years. Gross and net returns were however higher in S_1 and was followed by S_2. S_3 recorded the minimum net returns during both the years. The BC ratio was also higher for S_1 for both years and followed by S_2 while S_3 recorded the least BC ratio among the different slopes.

Among the inter-cropped treatments, soybean + maize (1:1) recorded highest gross as well as net returns. Apart from control where no returns could be obtained, sole soybean obtained least returns as well as BC ratio. The trend was observed to be the same during both the years. Soybean + maize (1:1) recorded the maximum BC ratio during both the years and were followed by soybean + maize (2:1) and can be attributed to higher yield of both intercrops.

Cost of cultivation was highest under S_3due to the higher labour requirement followed by S_2 as steepness created hurdles and thus requiring more effort and man days. The costs involved among the intercropping treatments did not vary much and were comparable to each other. The variations in returns can be attributed to yield of the crops and complementary effect among the intercrops.

Table 4.19: Economics of various treatments

Treatments	Cost of cultivation (` ha^{-1})		Gross returns (` ha^{-1})		Net returns (` ha^{-1})		BC ratio	
Slope	**2016**	**2017**	**2016**	**2017**	**2016**	**2017**	**2016**	**2017**
S_1 (0)	59980	59980	121590	119460	66854	64723	1.22	1.19
S_2 (9)	63627	63627	112048	110798	56394	55144	0.84	0.82
S_3 (20)	67397	67397	107249	105407	50496	48653	0.73	0.69
Crop								
T_1 - Control	7260	7260	0	0	-7260	-7260	-0.67	-0.67
T_2 - Sole Soybean	76607	76607	73829	71560	15036	12767	0.27	0.23
T_3 - Sole Maize	75853	75853	110395	109745	55202	54552	1.04	1.03
T_4 - Soybean +Maize (1:1)	76453	76453	167717	165194	96423	93901	1.67	1.62
T_5 - Soybean +Maize (2:1)	76627	76627	165947	163488	94854	92394	1.64	1.60
T_6 - Soybean +Maize (1:2)	76467	76467	163886	161342	93233	90688	1.63	1.58

CHAPTER V

SUMMARY AND CONCLUSION

SUMMARY AND CONCLUSION

The present study entitled "Impact of intercropping of soybean (*Glycine max* L.) – maize (*Zea mays* L.) on soil loss and crop performance in foothill regions of Dimapur district" was conducted during the monsoon seasons of 2016 and 2017 in the experimental farm of School of Agricultural Sciences and Rural Development, Nagaland University, Medziphema with the following objectives:

1. To study the soil loss from soybean and maize intercropping treatments
2. To evaluate the growth, yield and quality of soybean and maize
3. To study the effect of soybean and maize intercropping on some important soil quality indicators
4. To evaluate the benefit cost ratio of different treatment combinations

The experiment comprising of eighteen different treatment combinations was replicated thrice in strip plot design with three slope aspects and cropping combinations, *viz*. S_1 (0 % slope), S_2 (9 % slope) and S_3 (20 % slope) in main plots and six intercropping combinations *viz*. T_1 – Control, T_2 - Sole Soybean, T_3 - Sole Maize, T_4 - Soybean +Maize (1:1), T_5 - Soybean +Maize (2:1) and T_6 - Soybean +Maize (1:2) in sub-plots. The soil of the experimental site was acidic with had high soil organic carbon, available N and low content of available P and K. Recommended package of practices were followed for the cultivation of crop while soil and run off from the treatments were collected through slots provided at the bottom of each treatment.

The salient findings of the investigation have been summarized as follows:

5.1. Effect on soil loss and runoff:

1. The Soil loss and run off were minimum in sole soybean irrespective of slope aspect.

2. The treatments T_5-Soybean + Maize (2:1),T_4-Soybean + Maize (1:1) andT_6-Soybean + Maize 1:2) were the best in controlling the soil loss. Among these treatmentsT_5-Soybean + Maize (2:1) was found to be the best in controlling soil loss and runoff .

5.2. Effect on soybean:

1. Plant height, number of leaves and plant dry weight was significant among the slope gradients throughout the entire crop growth stage with 0 % slope giving higher values. Sole soybean and soybean intercropped with maize (1:1) gained better height and dry matter than the rest while no regular trend could be observed for number of leaves.

2. Yield attributes such as number of pods plant^{-1}, seeds pod^{-1}and test weight though higher at 0 % slope was not found significant. Neither slope gradient nor intercropping had significant effect on yield attributes. Seed and stover yield were observed to be highest in 0 % slope and sole soybean. Harvest index was however not affected significantly either due to slope or intercropping during both years. The number of seeds pod^{-1} was found to be highest in T_2 - sole soybean (3.11).

3. Oil, protein and NPK content were found higher with 0 % slope but significant only in the case of N. Sole soybean recorded higher values of nutrient content among the inter cropping treatments. S_1 also recorded

higher uptakes of NPK among the slopes while among the intercropping treatments, sole soybean recorded higher uptakes.

5.3. Effect on maize:

1. Plant height was highest 0 % slope among all growth stages. Among sub treatments, soybean + maize (1:2) performed better. Similar trend was observed in the case of number of leaves plant^{-1} and dry weight of plant at harvest during both years.

2. Among yield attributes, seeds cob^{-1} was found to be higher with 0 % slope while the rest of the attributes were at par. Soybean + maize (2:1) recorded significantly higher values of seed cob^{-1} among the sub treatments while the rest were comparable. The number of seeds cob^{-1} was found to be highest in T_5-soybean + maize (2:1) with 203.01.

3. 0 % slope among the different slope aspects and sole maize among the intercropping treatments recorded higher grain yield as well as stover yield for both the years. Concentration of NPK and protein was also higher with 0 % slope where P and K were not affected significantly. Sole maize was observed to record higher values among the sub treatments. Uptake of nutrients also followed similar trend as that of content.

5.4. Effect on soil properties:

1. Among the macronutrients, the available N was found high with a value varied from 574.62 to 605.14 kg ha^{-1}, available P was recorded medium with a range from 10.02 to 13.18 kg ha^{-1} and available K was found low with a range from 73.4 to 99.28 kg ha^{-1}.

2. Although available P was not significant, available N and K were significant with 0 % slope recording higher values among the slopes while no regular

trend could be observed among the intercropping treatments except for available N where sole soybean left higher amounts of available N in the soil.

3. Under the chemical properties of soil organic C was found high with a value varied from 1.38 to 1.48 %, pH of soil was very strongly acidic with a range from 4.60 to 5.06 and CEC was found in the range from 19.28 to 23.72 cmol (p^+) kg^{-1}

4. Among physical properties of soil, bulk density, soil aggregation, mean weight diameter and water holding capacity ranged from 1.24 to 1.33 g cm^{-3}, 16.79 to 30.04 %, 1.10 to 1.84 mm and 45.89 to 60.05 %, respectively.

5. The microbial biomass carbon was varied from 114.45 to 453.01 mg kg^{-1}.Among the micronutrients, iron, copper and manganese content in soil was found sufficient with a value varied from 20.02 to 37.95, 2.09 to 2.95 and 2.61 to 13.76 mg kg^{-1}, respectively. The zinc content in soil was deficient with a value ranged from 0.26 to 0.56 mg kg^{-1}.

6. Bulk density, soil aggregation and mean weight diameter values increased in both the experimental years irrespective of different slopes and cropping patterns. While other soil properties decreased with passage of time due to the water erosion.

7. Organic carbon, pH, cation exchange capacity, bulk density, soil aggregation, mean weight diameter, water holding capacity, soil microbial biomass carbon, iron, zinc, copper and manganese were not affected significantly either due to slope or intercropping.

5.5. Economic analyses:

S_1 recorded maximum gross and net returns during both the years as well as higher B:C ratio followed by S_2 and S_3. Among intercropping treatments, higher returns were recorded in soybean + maize (1:1) with ` 96423and ` 93901 ha^{-1}. Same highest values were also observed in soybean + maize (1:1) for BC ratio followed by soybean + maize (2:1) and soybean + maize (1:2).

Conclusions:

On the basis of the findings from two years of experimentation, the study can be concluded that among the treatments, T_5-Soybean + Maize(2:1) was found to be the best in controlling soil loss and runoff during both the research years. While crop growth and yield attributes as well as yield was higher under Soybean + Maize (1:1). Whereas, grain yield, stover yield and harvest index of maize was found to be the best in these three treatments namely, T_5-Soybean + Maize (2:1), T_4-Soybean + Maize (1:1) and T_6-Soybean + Maize (1:2). In soil properties, bulk density, soil aggregation and mean weight diameter increases in T_5-Soybean + Maize (2:1) and T_6-Soybean + Maize (1:2). While, water holding capacity decreased in both T_5-Soybean + Maize (2:1) and T_6-Soybean + Maize (1:2).

On the economics aspect namely, cost of cultivation, gross returns, net returns and BC ratio were found to be better in T_4-Soybean + Maize (1:1) and T_5-Soybean + Maize (2:1). While Maximum net returns and BC ratio were obtained in S_1 in combination with soybean + maize in the ratio of 1:1 or 2:1.

Recommendation:

It is recommended from two years of experimental research that soybean + maize (2:1) is the best option for earning good revenue while at the same time reducing soil loss as well as run-off at different slope gradients.

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APPENDICES

Appendix – I

Meteorological data recorded at during the experimental period (2016, *kharif* season)

Standard Week No.	Date	Rainfall
	1-Jun-16	12.1
	2-Jun-16	0.0
	3-Jun-16	0.0
	4-Jun-16	0.0
22	5-Jun-16	2.1
	6-Jun-16	0.0
	7-Jun-16	0.0
	8-Jun-16	0.0
	9-Jun-16	1.8
	10-Jun-16	31.1
	11-Jun-16	5.8
23	12-Jun-16	0.0
	13-Jun-16	0.0
	14-Jun-16	11.8
	15-Jun-16	0.0
	16-Jun-16	22.6
	17-Jun-16	4.8
	18-Jun-16	55.5
24	19-Jun-16	2.0
	20-Jun-16	0.0
	21-Jun-16	0.0
	22-Jun-16	0.4
	23-Jun-16	22.8
	24-Jun-16	12.6
	25-Jun-16	0.0
25	26-Jun-16	12.0

	27-Jun-16	0.0
	28-Jun-16	5.6
	29-Jun-16	0.0
	30-Jun-16	0.0
	1-Jul-16	0.0
	2-Jul-16	29.6
26	3-Jul-16	17.8
	4-Jul-16	31.8
	5-Jul-16	12.0
	6-Jul-16	18.4
	7-Jul-16	23.6
	8-Jul-16	0.0
	9-Jul-16	0.0
27	10-Jul-16	3.0
	11-Jul-16	6.5
	12-Jul-16	4.4
	13-Jul-16	11.7
	14-Jul-16	2.5
	15-Jul-16	23.5
	16-Jul-16	33.6
28	17-Jul-16	0.0
	18-Jul-16	0.0
	19-Jul-16	0.0
	20-Jul-16	0.0
	21-Jul-16	0.0
	22-Jul-16	0.0
	23-Jul-16	1.6
29	24-Jul-16	0.0
	25-Jul-16	2.2
	26-Jul-16	10.7
	27-Jul-16	21.2

	28-Jul-16	0.9
	29-Jul-16	0.8
	30-Jul-16	0.0
30	31-Jul-16	8.4
	1-Aug-16	0.0
	2-Aug-16	0.0
	3-Aug-16	0.4
	4-Aug-16	0.0
	5-Aug-16	3.6
	6-Aug-16	6.4
31	7-Aug-16	45.8
	8-Aug-16	35.2
	9-Aug-16	14.4
	10-Aug-16	0.9
	11-Aug-16	4.6
	12-Aug-16	41.2
	13-Aug-16	60.4
32	14-Aug-16	0.0
	15-Aug-16	1.0
	16-Aug-16	23.8
	17-Aug-16	0.0
	18-Aug-16	0.0
	19-Aug-16	9.6
	20-Aug-16	0.0
33	21-Aug-16	5.4
	22-Aug-16	0.0
	23-Aug-16	0.2
	24-Aug-16	0.0
	25-Aug-16	0.0
	26-Aug-16	5.7
	27-Aug-16	0.0

34	28-Aug-16	54.2
	29-Aug-16	16.8
	30-Aug-16	56.8
	31-Aug-16	12.5
	1-Sep-16	3.9
	2-Sep-16	0.4
	3-Sep-16	0.6
35	4-Sep-16	3.8
	5-Sep-16	43.4
	6-Sep-16	0.0
	7-Sep-16	0.0
	8-Sep-16	5.4
	9-Sep-16	1.0
	10-Sep-16	4.6
36	11-Sep-16	61.8
	12-Sep-16	9.7
	13-Sep-16	4.6
	14-Sep-16	0.0
	15-Sep-16	12.4
	16-Sep-16	0.0
	17-Sep-16	26.4
37	18-Sep-16	12.7
	19-Sep-16	0.0
	20-Sep-16	3.8
	21-Sep-16	21.2
	22-Sep-16	5.8
	23-Sep-16	4.8
	24-Sep-16	17.2
38	25-Sep-16	0.0
	26-Sep-16	9.2
	27-Sep-16	14.4

	28-Sep-16	0.0
	29-Sep-16	14.4
	30-Sep-16	2.2
	1-Oct-16	0.6
39	2-Oct-16	0.0
	3-Oct-16	0.0
	4-Oct-16	0.0
	5-Oct-16	0.0
	6-Oct-16	0.0
	7-Oct-16	0.4
	8-Oct-16	0.0
40	9-Oct-16	0.0
	10-Oct-16	0.8
	11-Oct-16	6.2
	12-Oct-16	9.2
	13-Oct-16	1.7
	14-Oct-16	1.8
	15-Oct-16	0.0
41	16-Oct-16	0.0
	17-Oct-16	0.0
	18-Oct-16	0.0
	19-Oct-16	0.0
	20-Oct-16	0.0
	21-Oct-16	0.0
	22-Oct-16	0.0
42	23-Oct-16	0.0
	24-Oct-16	0.0
	25-Oct-16	0.0
	26-Oct-16	0.0
	27-Oct-16	1.5
	28-Oct-16	6.2

	29-Oct-16	0.0
43	30-Oct-16	5.2
	31-Oct-16	0.0

Appendix – II

Meteorological data recorded at during the experimental period (2017, *kharif* season)

Standard Week No.	Date	Rainfall (mm)
	1-Jun-17	4.0
	2-Jun-17	0.0
	3-Jun-17	11.1
23	4-Jun-17	1.8
	5-Jun-17	0.0
	6-Jun-17	0.0
	7-Jun-17	0.0
	8-Jun-17	0.0
	9-Jun-17	3.0
	10-Jun-17	0.0
24	11-Jun-17	0.6
	12-Jun-17	35.1
	13-Jun-17	14.4
	14-Jun-17	4.4
	15-Jun-17	15.2
	16-Jun-17	1.4
	17-Jun-17	56.8
25	18-Jun-17	2.0
	19-Jun-17	0.0
	20-Jun-17	0.0
	21-Jun-17	8.8
	22-Jun-17	0.0
	23-Jun-17	8.2
	24-Jun-17	3.5
26	25-Jun-17	19.4
	26-Jun-17	0.2

	27-Jun-17	52.8
	28-Jun-17	0.8
	29-Jun-17	33.8
	30-Jun-17	1.4
	1-Jul-17	26.0
27	2-Jul-17	14.5
	3-Jul-17	2.8
	4-Jul-17	56.2
	5-Jul-17	2.7
	6-Jul-17	62.6
	7-Jul-17	4.8
	8-Jul-17	9.4
28	9-Jul-17	0.1
	10-Jul-17	2.7
	11-Jul-17	48.2
	12-Jul-17	35.7
	13-Jul-17	0.0
	14-Jul-17	6.2
	15-Jul-17	11.6
29	16-Jul-17	48.2
	17-Jul-17	3.8
	18-Jul-17	0.0
	19-Jul-17	25.0
	20-Jul-17	45.3
	21-Jul-17	9.5
	22-Jul-17	0.0
30	23-Jul-17	2.4
	24-Jul-17	8.8
	25-Jul-17	2.5
	26-Jul-17	1.8
	27-Jul-17	0.0

	28-Jul-17	20.2
	29-Jul-17	25.8
31	30-Jul-17	3.8
	31-Jul-17	5.0
	1-Aug-17	5.8
	2-Aug-17	0.0
	3-Aug-17	17.2
	4-Aug-17	0.4
	5-Aug-17	1.3
32	6-Aug-17	64.4
	7-Aug-17	2.4
	8-Aug-17	2.4
	9-Aug-17	0.0
	10-Aug-17	0.0
	11-Aug-17	1.2
	12-Aug-17	10.8
33	13-Aug-17	0.9
	14-Aug-17	1.2
	15-Aug-17	1.4
	16-Aug-17	5.6
	17-Aug-17	9.9
	18-Aug-17	30.6
	19-Aug-17	0.7
34	20-Aug-17	0.0
	21-Aug-17	46.8
	22-Aug-17	54.6
	23-Aug-17	0.0
	24-Aug-17	0.5
	25-Aug-17	53.0
	26-Aug-17	117.0
35	27-Aug-17	5.7

	28-Aug-17	0.5
	29-Aug-17	58.2
	30-Aug-17	0.0
	31-Aug-17	0.0
	1-Sep-17	15.2
	2-Sep-17	13.2
36	3-Sep-17	0.0
	4-Sep-17	4.5
	5-Sep-17	0.0
	6-Sep-17	0.0
	7-Sep-17	0.0
	8-Sep-17	0.0
	9-Sep-17	0.0
37	10-Sep-17	0.6
	11-Sep-17	0.0
	12-Sep-17	18.4
	13-Sep-17	5.0
	14-Sep-17	14.3
	15-Sep-17	0.0
	16-Sep-17	0.0
38	17-Sep-17	0.9
	18-Sep-17	1.4
	19-Sep-17	1.1
	20-Sep-17	2.0
	21-Sep-17	3.4
	22-Sep-17	0.0
	23-Sep-17	0.0
39	24-Sep-17	0.0
	25-Sep-17	35.5
	26-Sep-17	0.0
	27-Sep-17	1.0

	28-Sep-17	71.0
	29-Sep-17	16.4
	30-Sep-17	32.0
40	1-Oct-17	11.4
	2-Oct-17	0.0
	3-Oct-17	1.8
	4-Oct-17	0.0
	5-Oct-17	1.2
	6-Oct-17	0.0
	7-Oct-17	19.5
41	8-Oct-17	0.0
	9-Oct-17	0.0
	10-Oct-17	0.7
	11-Oct-17	0.0
	12-Oct-17	0.0
	13-Oct-17	2.4
	14-Oct-17	0.0
42	15-Oct-17	0.0
	16-Oct-17	0.0
	17-Oct-17	0.0
	18-Oct-17	0.0
	19-Oct-17	0.0
	20-Oct-17	7.1
	21-Oct-17	10.8
43	22-Oct-17	39.6
	23-Oct-17	5.0
	24-Oct-17	0.1
	25-Oct-17	0.0
	26-Oct-17	0.0
	27-Oct-17	0.0
	28-Oct-17	0.0

44	29-Oct-17	1.0
	30-Oct-17	18.4
	31-Oct-17	11.0

Appendix - III

Cost of cultivation for different slopes

Slope	Particulars	Unit (man days)	Rate (``)	Cost (``)	Total (``)
S_1	Jungle Clearing	34	220	7480	24420
	Field Preparation & Layout	8	220	1760	
	Primary Tillage	37	220	8140	
	Secondary Tillage	32	220	7040	
S_2	Jungle Clearing	35	220	7700	25520
	Field Preparation & Layout	8	220	1760	
	Primary Tillage	39	220	8580	
	Secondary Tillage	34	220	7480	
S_3	Jungle Clearing	37	220	8140	26840
	Field Preparation & Layout	8	220	1760	
	Primary Tillage	41	220	9020	
	Secondary Tillage	36	220	7920	

Appendix - IV

Cultivation cost for different sub treatments

Cost for different cropping patterns (Operation)		Unit	Rate (`)	Cost (`)	Total (`)
T_2	Seed cost	60	80	4800	33200
	Sowing	25	220	5500	
	1st Weeding	25	220	5500	
	2nd Weeding	20	220	4400	
	Harvesting	10	220	2200	
	Threshing & Winnowing	10	220	2200	
	Drying and bagging	5	220	1100	
	Soil loss & run off collection	3	2500	7500	
T_3	Seed cost	20	60	1200	29600
	Sowing	25	220	5500	
	1st Weeding	25	220	5500	
	2nd Weeding	20	220	4400	
	Harvesting	10	220	2200	
	Threshing & winnowing	10	220	2200	
	Drying and bagging	5	220	1100	
	Soil loss & run off collection	3	2500	7500	
T_4	Seed cost	30	80	2400	45700
		10	60	600	
	Sowing	50	220	11000	
	1st Weeding	40	220	8800	
	2nd Weeding	30	220	6600	
	Harvesting	15	220	3300	
	Threshing & winnowing	15	220	3300	
	Drying and bagging	10	220	2200	
	Soil loss & run off collection	3	2500	7500	
T_5	Seed cost	40	60	2400	45500
		5	80	400	
	Sowing	50	220	11000	

	1st Weeding	40	220	8800	
	2nd Weeding	30	220	6600	
	Harvesting	15	220	3300	
	Threshing & winnowing	15	220	3300	
	Drying and bagging	10	220	2200	
	Soil loss & run off collection	3	2500	7500	
T_6	Seed cost	30	60	1800	45060
		7	80	560	
	Sowing	50	220	11000	
	1st Weeding	40	220	8800	
	2nd Weeding	30	220	6600	
	Harvesting	15	220	3300	
	Threshing & winnowing	15	220	3300	
	Drying and bagging	10	220	2200	
	Soil loss & run off collection	3	2500	7500	

Maize grain price – ` 30

Stover price – ` 1

Soybean grain – ` 45

Stover – ` 0